ABSTRACT VOLUME
TROPMET 2024
NATIONAL SYMPOSIUM

on

Recent Advances and Challenges in Understanding and Predicting High-impact Weather and Climate Extremes over Indian Subcontinent in the Climate Change Context

JOINTLY HOSTED BY

Indian Meteorological Society (IMS) Rourkela Chapter

&

National Institute of Technology, Rourkela

ORGANISED BY
Indian Meteorological Society

10-12 December 2024

SPONSERED BY

PUBLISHED BY:
NATIONAL ORGANIZING COMMIITEE, TROPMET 2024, &
LOCAL ORGANIZING COMMITTEE, TROPMET 2024

TROPMET 2024

Recent Advances and Challenges in Understanding and Predicting High-impact Weather and Climate Extremes over Indian Subcontinent in the Climate Change Context

JOINTLY HOSTED BY

Indian Meteorological Society (IMS)
Rourkela Chapter

&

National Institute of Technology, Rourkela

ORGANISED BY
Indian Meteorological Society

PATRONS

Dr. M. Ravichandran, Secretary, MoES, New Delhi
Prof. K. Umamaheshwar Rao, Director, NIT Rourkela
Shri S. Somanath, Chairman ISRO, Secretary DOS
Prof. Abhay Karandikar , CEO, ANRF, Govt of India

ADVISORY BOARD

Dr. M. Mohapatra, DGM, IMD, New Delhi
Dr. Shailesh Nayak, Director, NIAS, Bangalore
Dr. R. Krishnan, Director, IITM, Pune
Dr. J. V. Thomas, ISRO
Dr. Parvinder Maini, Scientific Secretary, Office of PSA
Dr. V.S. Prasad, Head, NCMRWF
Dr Mrs Anita Gupta, DST
Prof. Sandeep Verma, Secretary, SERB
Prof. U. C. Mohanty, Siksha 'O' Anusandhan
Dr. R. K. Datta, Patron IMS
Prof. D. V. Bhaskar Rao, Hon. Prof., Andhra University
Prof. S. Gadgil, IISc Bangalore
Prof. S. K. Dash, Past President, IMS
Dr. Dr. Thamban Meloth, Director, NCPOR, Goa
Prof. Sunil Kumar Singh, Director, NIO, Goa
Dr. Balakrishnan Nair T.M., Director, INCOIS
Shri Nilesh M. Desai, Director, SAC, Ahmedabad
Dr. Prakash Chauhan, Director, NRSC, Hyderabad
Prof. A. D. Rao, Eme. Prof., IIT Delhi
Prof. G. Beig, NIAS, IISc Bangalore
Prof. G. S. Bhat, IISc Bangalore
Prof. N.V.Chalapathi Rao, Director, NCESS
Dr. G.V.M. Gupta, Director, CMLRE
Dr. Kurian N. P., President, OSI
Dr. Amit Kumar Patra, Director, NARL
Prof. S. N. Tripathi, IIT Kanpur
Dr. Duvvuri Seshagiri, Director, NPOL
Prof. A. P. Dimri, Director IIG, Mumbai
Dr. R.P. Singh, Director, IIRS
Dr. Anil Bhardwaj, Director, PRL
Dr. M.K. Goel, Director, National Institute of Hydrology

NATIONAL ORGANIZING COMMITTEE (NOC)

Chairman: Mr. Anand Kumar Sharma, President, IMS
Co-Chairman: Dr. N. Subash, Vice-President, IMS
Co-Chairman: Ms. Samanti Sarkar, Vice-President, IMS

CONVENER

Dr. S. I. Laskar, IMD, New Delhi (Secretary, IMS)

Co-CONVENER

Mr. Sanjay Bist, IMD, Joint Secretary, IMS

MEMBERS

Dr. Kamaljit Ray, MoES, New Delhi
Dr. Jagvir Singh, MoES, New Delhi
Dr. R. S. Maheskumar, MoES, New Delhi
Dr. Ananda Kumar Das, IMD, Treasurer, IMS NC
Dr. M. R. Ramesh Kumar, NIO Goa, IMS NC
Dr. Pradeep Kumar Thapliyal, SAC-ISRO, IMS NC
Dr. Kaustav Charavarty, IITM Pune, IMS NC
Dr. Atul Kumar Shrivastava, IITM Pune, IMS NC
Dr. M. T. Bushair, IMD, IMS NC
Dr. Suresh Ram, MoES, IMD NC

Dr. Amit Bhardwaj, IMD, IMS NC
Ms. Laxmi Pathak, IMD, IMS NC
Dr. T.V.S. Udaya Bhaskar, INCOIS
Dr. C. Gnanaseelan, IITM Pune
Dr Milind Mujumdar, IITM Pune
Dr. Arun Bhardwaj, ISRO, New Delhi
Dr. Suryachandra A. Rao, IITM Pune
Dr. V. K. Soni, IMD, New Delhi
Prof. P. K. Bhaskaran, IIT Kharagpur
Prof. A.N. V. Satyanarayana, IIT Kharagpur
Prof. C. V. Naidu, Andhra University
Prof. Vimal Mishra, IIT Gandinagar
Dr. Rashmi Sharma, SAC Ahmedabad
Dr. Thara Prabhakaran, IITM Pune
Dr. Sachin Ghude, IITM Pune
Prof. Somnath Baidya Roy, IIT Delhi
Prof. M. D. Behera, IIT Kharagpur
Prof. Sumit Sen, IIT Roorkee
Prof. Ashish Pandey, IIT Roorkee
Prof. K. Satheesan, CUSAT
Prof. P. Pradeep Kumar, Hon. Prof., S. P. Pune University
Dr. K. Rajeev, VSSC Trivandrum
Dr. S. Suresh Babu, VSSC Trivandrum
Prof. A. Chandrasekar, IIST Trivandrum
Prof. Pentakota Sreenivas, University of Hyderabad
Prof. Vimlesh Pant, IIT Delhi
Shri Gopal Iyengar, MoES, New Delhi
Dr. K. K. Singh, IMD, New Delhi
Dr. Amit Kesarkar, NARL
Dr. M. Rajasekhar, SHAR

SCIENTIFIC PROGRAMME COMMITTEE (SPC)

Chairman: Dr. Swati Basu, Former Special Secretary, MoES, Former Secretary, PSA Office

MEMBERS

Dr. D. R. Pattanaik, IMD, New Delhi
Dr. Roxy Mathew Koll, IITM Pune
Prof. Arindam Chakraborty, IISc Bangalore
Dr. R. Ashrit, NCMRWF
Prof. P. Sunitha, Andhra University
Dr. Sanjib Deb, SAC, Ahmedabad
Prof. C. Shaji, IIT Kharagpur
Prof. Sourav Sil, IIT Bhubaneswar
Prof. Vinoj V., IIT Bhubaneswar
Prof. Pranab Deb, IIT Kharagpur
Dr. Anant B. Parekh, IITM Pune
Dr. Yogesh K. Tiwari, IITM Pune
Dr. Ramesh Kumar Yadav, IITM Pune
Dr. Jasti S. Chowdary, IITM Pune
Dr. S. K. Sahu, Berhampur University
Dr. V. Yesubabu, NARL
Dr. Raju Attada, IISER Mohali
Prof. Ravi Kumar Kunchala, IIT Delhi
Prof. T.V. Lakshmi Kumar, JNU, Delhi
Prof. Chandan Sarangi, IIT Madras
Prof. Govindan Kutty M., IIST Trivandrum
Convener: Dr. Naresh Krishna Vissa, Member Secretary

LOCAL ORGANIZING COMMITTEE (LOC)

CHAIRMAN: Prof. Sk. Md. Equeenuddin, NIT Rourkela
Organizing Convener: Dr. Naresh Krishna Vissa, NIT Rourkela
Organizing Secretary: Dr. Bhishma Tyagi, NIT Rourkela
Organizing Co-Convener: Dr. Nagaraju Chilukoti, NIT Rourkela

MEMBERS

Prof. Jagabandhu Panda, NIT Rourkela
Prof. K. K. Osuri, NIT Rourkela
Prof. Bhaskar Kundu, NIT Rourkela
Prof. Rekha S., NIT Rourkela
Prof. Thungyani N. Ovung, NIT Rourkela
Prof. Sushant Das, NIT Rourkela
Prof. Vikas Das, NIT Rourkela
Prof. Amit Kumar Gorai, NIT Rourkela
Prof. Surajit Das, NIT Rourkela
Prof. Bala Chakravarthy, NIT Rourkela
Prof. Santosh Kumar Sahoo, NIT Rourkela
Prof. Anil Kumar Singh, NIT Rourkela
Prof. Ananta Charan Pradhan, NIT Rourkela
Prof. Bukke Kiran Naik, NIT Rourkela
Prof. Koteswara Rao K, NIT Rourkela
Prof. Binit Kumar, NIT Rourkela

VENUE: National Institute of Technology Rourkela, Rourkela, Odisha, India
https://www.nitrkl.ac.in/

Contact Us

Dr. Naresh Krishna Vissa
Convenor, TROPMET 2024,
Chairman, IMS Rourkela Chapter,
Department of Earth and Atmospheric Sciences,
National Institute of Technology Rourkela,
Rourkela 769008, Odisha, India.
Email: tropmet24@gmail.com

TROPMET 2024

National Symposium

on

Recent Advances and Challenges in Understanding and Predicting High-impact Weather and Climate Extremes over Indian Subcontinent in the Climate Change Context

10th - 12th December 2024
National Institute of Technology Rourkela, Rourkela, Odisha

Organised by
Indian Meteorological Society

Jointly hosted by
Department of Earth and Atmospheric Sciences, National Institute of Technology Rourkela, Rourkela
&
Indian Meteorological Society Rourkela Chapter

TROPMET is a series of national conferences organized annually by the Indian Meteorological Society (IMS). This year TROPMET will be jointly hosted by the National Institute of Technology (NIT) Rourkela, and IMS Rourkela chapter, at Rourkela, Odisha, from 10-12 December 2024. TROPMET series have received generous support from several government and private agencies in the past, and efforts are underway to seek their sponsorship this year. The TROPMET-2024 focuses on High Impact Weather and Climate Extremes over the Indian Subcontinent. Extreme weather and climate events have increased in frequency and severity due to human-caused climate change. Such extremes have far-reaching effects on many areas, including ecosystem damage, human health, and biodiversity. These extreme weather events affect both social and economic sectors, and society needs better risk assessments and earlier alerts for these high-impact weather extremes. TROPMET-2024 will provide an opportunity to exchange the ideas among various stakeholders. Keeping this in view, TROPMET-2024 deliberates on the following subthemes:

- In-situ and space-based observational and monitoring aspects of extreme weather and climate events
- Diagnostics and numerical modelling of extreme weather events over the Indian subcontinent
- Impact of land use and land cover changes on extreme weather and climate events
- Impact of large-scale climate modes on weather extremes (e.g., ENSO, IOD, MJO, etc.)
- Climate data analysis, assessments and projections
- Analysis and prediction of weather and climate extremes using AI/ML/DL techniques etc.
- Early warning systems, mitigation, preparedness and response actions for weather and climate extremes in disaster risk reduction
- Air Pollution Interactions with weather extremes
- Impact of weather extremes on Agriculture, livestock, fisheries including climate change and climate variability
- Attribution of weather extremes to climate change aspects
- Developments of innovative and indigenous met-sensors and ocean technologies
- OSI Special Session on Role of oceanic and atmospheric processes in the development of weather and climate extremes

REGISTRATION FEES

CATEGORY	BY 18th November 24	ON SPOT
IMS/OSI Members	₹ 3000/-	₹ 4000/-
Non-IMS/OSI Members	₹ 4000/-	₹ 5000/-
Scholars/Students	₹ 1000/-	₹ 1500/-
Post-Doctoral Researchers	₹ 2500/-	₹ 3000/-
Industry Exhibitions	₹ 100000/- onwards	
Associated Persons	₹ 4000/-	₹ 4500/-

The Registration Fee can be paid through multiple payment options such as net banking or UPI/bank drafts. There is no registration fee for Honorary Fellows and Fellows of the IMS/OSI.

TRANSPORT AND ACCOMMODATION

TROPMET-2024 has limited resources for offering travel and accommodation support, and all participants are expected to secure support from their own sources. However, some support may be extended to a few case-to-case basis subject to the availability of resources, with priority given to IMS members with no affiliations and students without financial support.

Industry Presentation & Exhibition Special sessions are planned to provide a platform for industry/entrepreneurs. A presentation slot of 15 to 20 minutes duration will be allowed for selected industry/entrepreneurs. Provision is also made for vendors to exhibit their products and services.

Best Paper Award

The best paper award in the student category (lead author of the paper/poster must be a student) will be given to the selected papers presented.

More Details about TROPMET 2024 can be found at https://www.tropmet2024.in/

Scan Me

ABSTRACTS

Advancing Understanding of Space Weather Phenomena and role in weather hazards

Neeti Singh, Gajendra Kumar

India Meteorological Department

ABSTRACT

This study delves into the augmenting our comprehension of space weather phenomena. With India's burgeoning scientific community dedicated to solar studies, including solar storms, coronal mass ejections, and heliospheric activities, there is a pressing need for sophisticated instrumentation to deepen our understanding of these phenomena. Many researchers have posited a correlation between long-term secular changes in sunspot numbers and alterations in solar irradiance, potentially influencing Earth's long-term climate. To address these inquiries, the Indian Space Research Organization (ISRO) and affiliated research institutes developed the Aditya-L1 satellite specifically tailored to explore the solar atmosphere. Launched on September 2, 2023, Aditya-L1 is equipped with Supra Thermal Energetic Particle Spectrometer(STEPS), a state-of-the-art instrument designed to monitor energetic particles within the solarwind.

This study elucidates the aviation applications of STEPS, distinguishingbetween proton and alpha particle fluxes, thus enriching our understanding of space weather variations. Emphasizing Aditya-L1's primary objectives, such as observing solar coronadynamics, flare events, and coronal mass ejections, the research underscores the critical role played by the mission in deciphering solar wind dynamics and their implications for satellite operations, communication networks, navigation systems, and human space exploration endeavors. Notably, the study highlights the significance of Aditya-L1's observations during asevere geomagnetic storm in May 2024, showcasing the mission's capacity to provide vital datafor space weather prediction and mitigation strategies. By leveraging Meteorological Service for International Air Navigation (Annex 3) guidelines issued by the International Civil Aviation Organization (ICAO) for issuing space weather advisories, this research underscores different case study and the importance of integrating space weather monitoring into global aviation protocols, ensuring the safety and functionality of both space and Earth-based technological infrastructures.

Predicting Pigeonpea Yield Using Machine Learning Approaches Under Changing Climatic Scenarios in the Eastern Dry Zone of Karnataka

Jashwanth, C.[a], Manjunatha, M. H., [b], and Lingaraj Huggi. [c], Pooja, R. S., [d]

[a] *Department of Agricultural Meteorology, College of Agriculture,*
University of Agricultural Sciences,
GKVK, Bengaluru-560 065 Karnataka
[b,c&d] *AICRP on Agrometeorology CoA, UAS, GKVK Bengaluru -65*
E-Mail: Jashwanthc312@gmail.com

ABSTRACT

The crop-weather relationship field experiment on pigeonpea is being conducted at AICRPAM field unit, DLAP, UAS, Bangalore, during the 2024 kharif season. This study involves three pigeonpea varieties (BRG 1, BRG 5, PRG 176) and three sowing dates, using a factorial RCBD design. Phenological stages are recorded to evaluate the impact of weather parameters (solar radiation, minimum and maximum temperature, relative humidity, growing degree days) on pigeonpea yield in the Eastern dry zone of Karnataka. This research assesses machine learning approaches for yield prediction, including stepwise linear regression, random forest (RF), shrinkage regression methods (LASSO, elastic net), and artificial neural networks (ANN). Correlation and regression analyses will be conducted to determine the impact of weather factors on pigeonpea performance. The models will be evaluated based on the coefficient of determination, model efficiency, and normalized root mean square error (nRMSE), using 80% of the data for calibration and 20% for validation. The best-performing model will be used to predict yield under future climatic scenarios (2040-2099) for SSP 2.0-4.5 and SSP 5.0-8.5 pathways. Preliminary results suggest that temperature, alone or in interaction with other weather parameters, significantly influences pigeonpea yield in the study area. Yield predictions indicate a decreasing trend from 2040 to 2099, with the SSP 5.0-8.5 scenario projecting a substantial reduction in crop productivity. This weather parameter-based yield prediction equation can effectively assess the impact of climate change on agriculture. The study also emphasizes adopting climate-resilient models, such as suitable agronomic practices and genetically improved varieties, to maintain yield under changing climatic conditions.

This research aims to provide precise yield predictions for pigeonpea across different districts in the Eastern dry zone of Karnataka, ensuring food security through informed climate-resilient strategies.

Keywords: Crop-weather relationship**,** Pigeonpea**,** Climate change**,** Yield prediction**,** Machine learning

The Role of Patents in Fostering Climate Resilience:A Case Study of the Indian Subcontinent

Kumari Lipi

Akhildev IPR and Research Services,Corporate Park, Tower 1, 907, Sector 142, Noida-20130
E-Mail:lipi.kaundilya@gmail.com

ABSTRACT

Climate change poses a critical threat to sustainable development. Intellectual Property Rights (IPR), particularly patents, are often seen as a catalyst for innovation, which is crucial for addressing environmental challenges. This study aims to explore the role of patents in building climate resilience, specifically focusing on the Indian subcontinent. By examining relevant databases, we investigate the relationship between innovation, research, and climate change. The study analyzes the Indian patent landscape to understand how patents contribute to the development and dissemination of climate-friendly technologies. Furthermore, we assess the effectiveness of the international IPR framework in facilitating the transfer and adoption of these technologies in the region.The findings of this research contribute to the broader discourse on therole of patents in climate action and provide insights for policymakers to enhance patent systems for promoting climate resilience in the Indian subcontinent.

Keywords:Intellectual Property Rights, Patents, Innovation, Climate resilience, Sustainable development.

The recent trends in the Indian summer monsoon rainfall

Ramesh Kumar Yadav
Indian Institute of Tropical Meteorology, Pashan, Pune 411008, India
Email: yadav@tropmet.res.in

Abstract

India gets maximum rain during the summer months of June through September, called Indian summer monsoon rainfall (ISMR). The increasing/decreasing trend of ISMR affects millions of agriculture-dependent people in India. The spatial deviation of long-term ISMR trends indicates the monsoon circulation shift and should be minutely observed. The current study has observed that the ISMR has statistically significantly increased/decreased in western/eastern India in the last four decades. The significance of these trends is checked by evaluating the incomplete beta function used as a *p*-Value calculator for the Student *t*-test. In the meantime, the Indian Ocean has become more active due to its recent warming. The warming of the equatorial Indian Ocean has increased the in-situ convection south of the equatorial Indian Ocean, whose subsidising Hadley's branches has increased the upper- tropospheric geopotential height (GPH) in northern Europe and southern Africa. The north Europe GPH is associated with the Eurasian wave having massive ridges over eastern Europe and east Asia sandwiched with a trough east of the Caspian Sea. The penetration of this trough towards the Indian landmass has created favourable conditions for deep convection. Besides, the southern African GPH increases the cross-equatorial flow, which interacts with the mid-tropospheric trough over the Arabian Sea, increasing the moisture flow/convergence over western India. The interaction of the cross-equatorial flow with the upper-tropospheric penetrated trough through the Indian landmass increases the moist static energy, which results in heavy rainfall over west India and causes a shift of monsoon westward. This teleconnection could further be examined in the seasonal forecast models.

Keywords: Indian summer rainfall · Eurasian wave · Mid-tropospheric trough · Upper-troposphere trough · Cross- equatorial flow · Trend analysis · Equatorial convection

Recent Extreme Weather events of Punjab & Haryana

Vikrant Nimesh,
Meteorologist-A and A,K
Singh, Scientist-E

Meteorological Centre (I.M.D), Chandigarh

E-Mail: vikrant.nimesh@gmail.com

ABSTRACT

The states of Punjab & Haryana, are witnessing extreme weather events very frequently. Whether we talk about recent Extreme Heat Wave conditions of May-June 2024, Extreme Cold Wave & Foggy conditions during January 2024, Extreme rainfall activity during 8-10th July 2023, Two consecutive Tornados during February 2023 & February 2024, Frequent cases of cloud bursts in the nearby north-west regions or irregular arrival pattern of the Western disturbance in the region, it is clearly showing that very frequently weather events are taking place, which is defying climatology of the entire region. The irregular variation & spatial distribution of the Rainfall pattern / Maximum & Minimum Temperature profile, Thunderstorm activities, clearly indicate that the climatology of the region has changed a lot. In some of the cases, a maximum temperature of 50^{o}C has also been recorded in the region. Some regions of the Punjab which are very close to the foothills of Himalayas, have also reported maximum temperature of the order 47-48^{o}C during this summer season. Some of the regions of Punjab (e.g Bhatinda, Fazilka, Muktsar etc of Malwa region) & Haryana (Hissar, Sirsa, Gurgaon, Mahendragarh etc) are frequently recording extreme temperature profiles. Based on the Extreme events of Rainfall / Maximum & Minimum Temperature, Thunderstorm activities during last 50 years, a case study has been done for Punjab & Haryana to establish the fact that the climatology of the region is changing in an uneven manner causing serious concern to the environment, flora & fauna of the region & ultimately affecting the civilization in a very rough manner. An early preventive action for the safeguard of the region, is must in this regard.

Keywords:Extreme Weather events,Climate change

A Teleconnection Between Tropical Cyclones and Fog: A Case Study Over the Indo- Gangetic Basin, India

Rizwan Ahmed[a] and Sashi Kant[b]

[a]*India Meteorological Department, Nagpur*
[b]*India Meteorological Department, New Delhi*
E-Mail:rizwan.ahmed@imd.gov.in

ABSTRACT

Widespread catastrophic fog episodes in the heavily polluted northern regions of India have been associated with tropical cyclone activity originating in the Bay of Bengal and the Arabian Sea. Despite this, research on the impact of tropical cyclone intensity on various fog characteristics within the Indo-Gangetic Basin has been limited. This study investigates the effects of tropical cyclones on fog persistence, intensity, and areal extension in the Indo-Gangetic Basin over a ten- year period from 2013 to 2023.

Our analysis indicates that high-intensity tropical cyclones significantly increase fog persistence, intensity, and areal extension by inducing strong subsidence in the region. These findings are essential for enhancing short-term fog forecasting capabilities and will provide valuable insights for government agencies to develop timely preventive safety measures and strategic planning by government agencies to mitigate the impacts of fog-related disruptions.

Keywords: Subsidence, Tropical Cyclone, Fog, Indo Gangetic Basin

IMPACT OF URBANIZATION ON CLIMATIC CHANGE OF ODISHA

Kshirod Bal[a], Saratchandra Sahu[b], Manorama Mohanty[a], Shreerup Goswami[d], Umashankar Das[a], Sanjeev Dwivedi[a]

[a]MetCentre,Bhubaneswar(BBSR),
[b] ITER,SOA University(BBSR)
[c]Utkal University, (BBSR)
*E-mail:*kkbalimd@gmail.com

ABSTRACT

The Odisha experiences severe meteorological disaster like flood, cyclone,tornado and drought due to erratic behavior of rainfall, temperature, relative humidity, change of pressure and so on. Especially, rapid urbanization of major urban areas namely Bhubaneswar, Cuttack, Angul, Jharsuguda, Balasore, Berhampur, Paradip, Rourkela and Puri etc. causes acute environmental pollutions. Therefore, there is serious ecological imbalance resulting adverse climatic change. So,the rigorous heat waves, super cyclone, flood, drought and irregular onset of monsoon have devastated Odisha. Hence urbanization effect for climatic change over Odisha has significant impact on urban economy. In reality a comprehensive and exhaustive study on the same has beentaken. The following 7 tests has been done to analyze the trend of climatic change of study. 1. The mean annual temperatures :The inter-annual variations of the yearly averages of the temperature, 2. Histogram analysis, 3.Normality test, 4. Homogeneity test, 5. Kruskal-Wallis non-parametric test, 6. t test and 7.Mann Kendle test. 1.The mean annual temperatures are obtained from the mean daily values of maximum and minimum temperatures.The mean annual temperaturefor the period from 1969 to 2018 is 27.68^0C in Bhubaneswar and it is 27.390C for Cuttack duringthe same period whereas at Ranital, it is 26.850C for the period 1992 to 2018. It may be here mentioned that Bhubaneswar and Cuttack are urban areas whereas Ranital is a rural area. 2. Histogram analysis: The max, min and mean annual temperature of season wise (4 seasons) of above three stations has been clearly analysed. 3.Normality test: Graphical representation of normal probability and detrended normal probability plots are made for assessing departures from normality. 4. Homogeneity test: Homogeneity test for both parametric and non-parametric have been made. Then, the hypothesis is accepted. These values are obtained for maximum, minimum and mean temperature with its mean rank statistics. 5. Kruskal-Wallis: In Kruskal-Wallis non- parametric test, there is not statistically significant among the mean, as chi-square statistic value with p value. The p value is more than 0.05 (5%). So, the hypothesis is accepted. 6. t test and 7.Mann Kendle test :These values are obtained for maximum, minimum and mean temperature with its mean rank statistics.

Keywords: Climatic Change;Normality test; Homogeneity test; Kruskal-Wallis non-parametric test;Mann Kendle test.

Assessment of Observed and Projected Weather Parameters in Dapoli, Maharashtra for Observing Climate Change Scenarios

Shahenaz Mulla[1,2]*, Sudhir K. Singh[2,] Mamta Rana[3]

[1]India Meteorological Department, Ministry of Earth Sciences,
Pune, Maharashtra, India.

[2] K Banerjee Centre of Atmospheric & Oceanic Studies (KBCAOS),
Nehru Science Centre,IIDS, University of Allahabad-Allahabad UP, India –211002.

[3]Satyawati College, Delhi University, New Delhi, India.

**E-Mail:shahenaz11@gmail.com*

ABSTRACT

A study was conducted to compare climate change scenarios using two different models, the Institute Pierre-Simon Laplace (IPSL) and the Geophysical Fluid Dynamics Laboratory Earth System (GFDL), particularly maximum temperature (Tmax), minimum temperature (Tmin) and rainfall trends in Dapoli, Maharashtra. The research evaluates historical climate patterns from 1983–2023 and projects future trends from 2024–2099 for representative concentration pathways(RCP) 4.5 and 8.5 scenarios. Non-parametric tests and statistical analyses were performed on the observed and projected Tmax & Tmin, as well as rainfall, to identify significant trends and variations. The findings revealed a consistent increase in both Tmax and Tmin across all scenarios,with RCP8.5 showing a more pronounced rise compared to RCP4.5. The GFDL model aligns withhistorical temperature trends, while the IPSL model overestimates temperature and rainfallvariability. Rainfall projections under RCP8.5 indicate a significant increase, suggesting wetter future conditions, while RCP4.5 presents a mixed pattern, with the GFDL model predicting a decline and the IPSL model indicating a slight increase in rainfall. In the RCP4.5 scenario, the GFDL model shows a significant decline in rainfall, whereas the IPSL model indicates a minor increase. Future predictions from both models indicate similar warming trends, with significant increases in temperature and unpredictable rainfall patterns. Uncertainty in model projections persists despite thorough climate change analysis, especially rainfall pattern variations under RCPscenarios. This gap can be fulfilled with improved forecast and adaptive strategies to mitigate theadverse effects on agriculture and water resources using a variety of climate models is required.

Keywords**:** Climate change, RCP, IPSL, GFDL.

Precipitation Extremes over India's High Mountain Region

Raju Attada [a] **and Rohtash Saini** [a]

[a] Department of Earth and Environmental Sciences

Indian Institute of Science Education and Research
Mohali, Punjab-140306

E-Mail:rajuattada@iisermohali.ac.in

This study investigates the physical processes behind extreme precipitation events (EPEs) in the Himalayas, notorious for causing frequent floods and significant loss of life and property. Here, we decipher the precipitation characteristics and their driving factors responsible for the occurrence of EPEs in the western Himalayas (WH) for the period 1979 to 2020. EPEs are definedas events exceeding the 99th percentile threshold. The extreme precipitation in the WH is contributed by both large-scale precipitation (accounting for 61%) and convective precipitation (39%). Moreover, 25.49% of EPEs in this region are directly associated with monsoon depressions. An omega-type blocking pattern emerges four days before EPEs, facilitating the intrusion of an extratropical cyclonic circulation. This circulation, characterized by its slow eastward and equatorward movement, leads to low-level moisture flux convergence and ascending motions, which in turn trigger the EPEs. This highlights the crucial role of extratropical signals in driving EPEs and implies that tropical-extratropical interactions play an important role in these EPEs. Furthermore, the shifting of the Intertropical Convergence Zone is strongly linked to the enhancement of the intensity of EPEs. Moreover, moisture budget analysis shows that EPEs overthe WH are primarily driven by vertical advection, with the dynamic (thermodynamic) terms explaining 92% (8%) contribution. Lastly, our study demonstrated that most intensified and persistent EPEs over the Himalayas are found to be linked with Quasi-Resonance Amplification

Keywords: Western Himalayas, Extreme Precipitation, Physical drivers, Tropical –Extratropicalinteraction

Runoff reconstruction for western Himalaya in India duringthe last two centuries inferred from tree ring-width records

Dr. Somaru Ram[1,*], Prof. Manoj K. Srivastava[2]

[1]Indian Institute of Tropical Meteorology, Pune-411008, India
[2] Department of Geophysics, Banaras Hindu University, Varanasi-221005, India
Email: somaru@tropmet.res.in*

ABSTRACT

High-resolution proxy records of tree ring chronologies from different sites of the western Himalayas are used to study climatic variation. The 1st principal component performed based on the multi-species chronologies shows that increases in runoff water over the region are found to have a positive impact in favoring of tree growth process during the winter and summer months. While the role of vapor pressure on tree growth during the summer is not found conducive. The Correlation coefficients (CCs) of tree growth with regional runoff and vapor pressure during summer season (April-June) are 0.46 and -0.50 respectively, showing statistically significant at 0.1% level. The significant positive relationship of tree growth with runoff indicates that the increasing runoff water may be useful for the tree growth. Based on the significant relationship, the regional runoff water has been extended back to A.D. 1779.

Keywords: Western Himalayas, Tree ring-width index chronologies, Runoff, Vapor pressure

Indigenous Filter for ElectromagneticInterference Elimination in DWR

Prabhdeep Singh[a], Brajesh Kumar Kanaujiya[b],Rakesh Kumar[c] and Siddhartha Singh[d]

India Meteorological Department

E-Mail:officialpds@gmail.com

ABSTRACT

Doppler Weather Radar being used by IMD operating at S-Band performs its functions with peakpower of 800KW and high sensitivity of receiver of to detect echo reflected from rain drops (typically 0.5–5 mm in diameter) while navigating for the target in the dynamically changing electromagnetic environment. Interferences are observed when Microwaves are emitted by any other devices within the similar frequency range as weather radars or when RF signal is reflectedby some building. These interferences produce characteristic interference patterns such as spokes, dots and stripes in the output images which disrupt the radar's measurement capabilities. The attenuation from other sources working within same frequency band and reflected echo by some building were captured by the radar system. In a Radio communication, filters play a vital role for selecting specific frequency bands. The bandpass filters allow signals with only specific frequencies to go through improving the quality of signals by reducing interferences. Band pass filers block those frequencies which are outside the pass-band. The designed filter frequency response has centre frequency of 2.81 GHz and a small size of (30x25 mm^2). The structure of this filter uses the Rogers substrate. The proposed BPF is intended for Doppler Weather Radar operating at 2.825GHz. Simulation and optimizationof the proposed design are conducted utilizing the HFSS software. The filter offers a bandwidth of 400 MHz from 2.58GHz to 2.98 GHz with centre frequency at 2.81 GHz and having a low insertion loss of -0.36 dB and return loss of -25dB. The designing stage of BPF is completed and upon hardware fabrication of the PCB, the impact of the filter will be identified when it will be integrated with the Radar receiver system and observed for several periods of different weather phenomenon.

Keywords: Electromagnetic Interference, DWR, Band Pass Filter, HFSS.

Quantum Computer, the future requirement for Weather Services

Ajay Kumar Singh, Scientist-E
Meteorological Centre (IMD), Chandigarh
E-Mail: aksingin@gmail.com

ABSTRACT

During last few years, India is witnessing frequent extreme weather evetns causing enormous damage to the country. Whether it is Extreme Hot / Cold / Foggy weather conditions, Extreme rainfall activity, Extreme Weather events e.g Tornados / Cyclone , Strong Western disturbances or Frequent cases of Cloud bursts, everytime we need to have an advanced system to analyze the various type of weather data & issue Early Warning to take the preventive measures. The weather data (Surface, Upper Air, Satellite, Weather Radars, Radiometers, Wind profiliers etc) is complex / voluminous & dynamic in nature. In case of extrem weather events, it changes with a extremely high speed. Very-very fast system is needed to analyze these data & issue early warning. With the development of the new tools such as AI/ML/DL,ChatGPT, it is possible to analyze these data resulting various probablistics output. But, even the best available Super-computers, have got its own inherent limitations, to analyze these data with a extremely high speed, as it also stores & process the data on the basic concepts of BITs. To have a presise & timely analysis of this data, we need such device which can do parallel multi-processing of different sets of the data. Quantum Computer can fulfil this purpose as it works on the principle of QUBITs i.e the result is a probabilistic output of the classical Binary BITs. As such, the quantum algorithms have to be designed in the form of time complexity, rather than computability. Hence,with with tools like AI/ML/DL, it can be utilized to issue early warning for the Extreme weather events in a more effective manner. However, the complex, costly & highly noise sensitive architecture of the Quantum Computer, restricts its use for general purpose of computing.

Keywords: Extreme Weather events, Early Warning, Quantum Computer, AI/ML/DL, ChatGPT

Interrelationship between Evapotranspiration and Indian Summer MonsoonRainfall across Homogenous Regions of India

Vinaya A. J.[1], Thanushree B. S.[2*], Patil R. H.[3]

Department of Agricultural Meteorology, College of Agriculture, University of AgriculturalSciences (UAS), Dharwad, Karnataka, Pin: 580 005, India

* Email ID: thanushreebs64@gmail.com

Mob: 8867229400

ABSTRACT

Indian Summer Monsoon Rainfall (ISMR) is one of the most prominent events of the world's monsoon systems. ISMR spans over a period from June to September (JJAS) every year. Interrelationship between evapotranspiration and ISMR by analysing spatial and temporal correlation across homogenous regions of India for both historical and projected period was taken up. The monthly data for this study (historical and projected) was downloaded from Copernicus website (CMIP6) with a resolution of 0.5° X 0.5°. The data were processed using FERRET and CDO program. The analysis revealed that there was a strong correlation between evapotranspiration and ISMR, but negative correlations were observed in Central, Eastern, and Northeastern India. Spatial correlations revealed that both rainfall and evapotranspiration exhibited a high degree of positive correlation across the entire India, with the exception of Himalayan regionsof Northeastern India where moderate degree of negative correlation was found. A notably high degree of negative correlation was recorded during the 2006-2015, followed by a moderate degree of positive correlation is observed in some parts of Central and Eastern India. This study reveals thatsimilar kind of analysis can be done to study inter-annual and intra-seasonal variations of ISMR to use it as a potential predictor for ISMR.

Keywords: Coupled Model Inter Comparison Project Phase-6, Evapotranspiration, Homogeneous regions, Indian Summer Monsoon Rainfall.

Assessment of Agricultural Drought Based on Various Drought Indices by Using RSand GIS Approach for Beed District of Maharashtra (India).

Pralhad Jaybhaye [a], Mahesh Palve [a], Madhukar Jadhav[a]and Dhavan Karnraj [a]

[a]*Department of Agricultural Meteorology,VNMKV, Parbhani*
E-Mail: drpralhadjaybhaye@gmail.com

ABSTRACT

Drought, a climatic phenomenon resulting from below-average precipitation, compounds water scarcity issues. Its impacts are far-reaching, affecting agriculture, food security, and social stability. Henceforth, meteorological droughts over different tahsils (bloks) of Beed district during monsoon season for the period 31 year (1992 to 2022) were identified by using Standardized Precipitation Index (SPI) through SPI computing software. Spatio-temporal maps of NDVI, VCI and NDWI for *kharif* as well as *rabi* season were developed based on vegetation and water indicesfor the selected years. NDVI values intelligibly showed maximum vegetation growth during the year 2010 and 2021, compared to other years of study period. Maximum area under drought condition was observed in the month of June and July during the years 2008, 2012, 2014, 2015 and 2018. Wet conditions were conquered in September month as indicated from the vegetation condition during all selected years in the study area. The computed values and prepared maps of VCI and NDWI were coincided with the results of NDVI. These findings validated to the meteorological index (SPI). The vegetation indices are found complementary to meteorological index for detecting drought related stresses to vegetation, which are useful to monitoring the intensity and severity of drought affecting agriculture. The such type of hybrid drought indices aremore effective to represent drought conditions, and useful to preparation AAB by which reduces intensity of agricultural drought by adapting different agro-techniques. It also proved valuable information for policy makers, government administrators, agro base industries, crop insurance companies for settling insurance claims, providing a robust framework for assessing agricultural losses due to drought conditions for different types of compensations.

Key words: Beed, drought indices, GIS and RS.

VALIDATION OF TEMPERATURE PREDICTIONS FROM IMD-GFS MODEL ACROSS INDIA FOR THEYEAR 2023

Abhishek Jayant, M. T. Bushair, C. J. Johny

and D. R. Pattanaik

Numerical Weather Prediction

Division, India MeteorologicalDepartment,

Musam Bhawan,

New Delhi 110003

E-Mail: abhishekjayant10@gmail.com

ABSTRACT

Validation of temperature forecasts is paramount in the context of daily weather forecasting. Accurate temperature predictions are essential for a myriad of societal activities, from planning outdoor events to managing energy consumption and agricultural practices. Validation ensures that forecast models are reliable and trustworthy, bolstering public confidence in weather forecasting agencies. By analyzing the performance of forecast models through validation metrics, meteorologists can identify areas for improvement and refine their techniques, ultimately enhancing the quality of forecasts. Continuous validation fosters a cycle of improvement, allowing forecasters to learn from past errors and make adjustments to optimize future predictions. This study validates temperature forecasts from different Numerical Weather Prediction models such as Global Forecasting System (GFS) from India Meteorological Department (IMD) and National Centers for Environmental, and Unified model from National Centre for Medium Range Weather Forecasting (NCMRWF). Validation is conducted both at individual stations throughout the year and country as a whole, spanning up to 120 hours of forecast. Various statistical measures, including correlation coefficients, root mean square errors,and bias, are computed across different regions and temporal scales. Results indicate that the GFS model's temperature forecasts shows a consistent bias, which varies both spatially and temporally. Understanding this bias can aid forecasters in issuing more accurate operational forecasts.

Keywords: Temperature forecast, Verification, Numerical Weather Prediction.

DIFFERENCES IN LAND-ATMOSPHERE FEEDBACK PROCESSES DURING EARLY AND LATE MONSOON ONSET YEARS

Shubhi Agrawal[a], Nilanjan Debsharma[a],

and Suparya Sonalika Raj[a]

[a] *Earth and Environmental Sciences Department,*
Indian Institute of Science Education andResearch, Bhopal
E-Mail:sagrawal@iiserb.ac.in

ABSTRACT

In this study, we examine how land-surface heat and moisture fluxes, planetary boundary layer and regional convective activities evolve over Central India (CI; 16°N–26°N and 76°E–86°E) during the Indian Summer Monsoon onset phase using ERA-Interim reanalysis dataset and precipitation data from India Meteorological Department. We identify 11 early and 12 late onsetyears during the period 1979-2014, using the classification by Chakraborty and Agrawal, 2017, and we use these composited years to understand the differences in land-atmosphere feedback processes in early and late onset years. The composite precipitation difference between early minuslate onset years show significant positive anomalies over CI in June. We observe that mid-May onwards, the vertically integrated water vapor increases considerably over CI and a significant reduction in boundary layer height is noted in the early onset years as compared to the late onset years. The decrease in the boundary layer height is accompanied by increased surface upward latent heat flux and decreased surface upward sensible heat flux over CI. As a result, the 850 hPamoist static energy is increased significantly during the early onset years, which is strongly associated with increased local convective activities that supports an early monsoon onset and higher precipitation over CI in June. The observed long term mean onset date over CI is 14th June,whereas, the mean onset date for early (late) years is 6th June(21th June) for our analysis period.As moisture entraps in the lower atmosphere due to a reduction in the boundary layer height duringearly onset years, leading to an increase in the convective instability, an associated higher frequency of mesoscale convective systems has also been noted in June in the early onset years, highlighting the role of regional land-surface processes in supporting the northward progression of monsoon onset.

Keywords: Indian Monsoon onset; Land-atmosphere coupling; Surface fluxes; Boundary layer height; Mesoscale systems.

Unveiling the Response of Chlorophyll in Connection to the Interaction of Marine Heat Wave and Intrinsic Climate Modes over Seychelles

Harikrishnan R[a], and Tanuja Nigam[a],

[a] *Physical Oceanography Division,*
CSIR-National Institute of Oceanography,
Dona Paula, Goa,403004, India
E-Mail:harikrishnanmaniyur@gmail.com

ABSTRACT

The Seychelles-Chagos Thermocline Ridge (SCTR) in the southwestern tropical Indian Ocean is a crucial region characterized by wide-open ocean upwelling. The Asian monsoonal winds play asignificant role as drivers of this upwelling during the boreal summer (June-September). This upwelling zone greatly supports marine primary productivity in the southern Indian Ocean, a topic extensively studied by many researchers in terms of seasonal, inter-annual, and climatic variability. However, less attention has been paid to studying variations in upwelling intensity and its biogeochemical features in connection with extreme ocean warming episodes under the recent changing climate scenario. Therefore, detailed investigations were conducted to examine how extreme upper ocean warming episodes modify the physical and biogeochemical characteristics of the SCTR upwelling region.Dominant intrinsic climate modes such as ENSO, IOD, and IOBM can significantly influence upwelling intensity and resulting biological productivity. To clearly delineate the relative roles of different contributors to these extreme warm events and their impact on biogeochemical responses, efforts have been made. The analysis reveals two major extreme warming events during the study period (1998-2020): one in 2015-2016 and another in 2019-2020. The investigation shows that chlorophyll suppression was more intense during the 2019-2020 event compared to the 2015-2016 event. Furthermore, it was found that marine heatwaves, in conjunction with various climatic modes, were responsible for these extreme warmings in the SCTR, and their respective contributions were estimated.

Keywords: Upwelling, Chlorophyll, Marine Heat Wave, Extreme Intrinsic Climatic Modes, El- Nino, Indian Ocean Dipole

Modeling and simulation of Hailstorm events over Karnataka during pre-monsoon season using high resolution Mesoscale model

G N Mohapatra and Rakesh V

Interdisciplinary Data Research Division(IDRD)
CSIR-Fourth Paradigm Institute, Wind tunnel Road,
Belur Campus, Bengaluru-37
E-Mail:gnm@csir4pi.in

ABSTRACT

Hailstorms are convective storms that produce a large number of hailstones that can cause damage to crops, life and property. Important characteristics associated with the thunderstorms that support the formation of hailstones are strong updrafts, high cloud tops and regions of temperature below the freezing point. The formation of such convective storms is influenced by parameters such as the development of convective instability, high surface temperatures and moisture incursion. Hence, it is important to identify methods for better simulation and prediction well in advance using state of the art mesoscale model at high resolution. The aim here is to examine the categorical skill of the mesoscale model in simulating hailstorm eventsand identification of a single or a set of parameters as predictors/precursors using a high-resolution numerical model. In this study, we simulated five different hailstorm events over different parts of Karnataka state during the pre-monsoon season of 2018 with very high resolution mesoscale model. There are four nested model domains set over the state of Karnataka, having horizontal resolutions 36 km, 12 km, 4 km and 1.3 km respectively. In all these cases,the model is initialized at 00:00 UTC and 06:00 UTC, one day prior to the hailstorm event, witha 36-hour period of integration. The simulations are performed using the New Kain–Fritsch scheme for cumulus parameterization, and the WSM6 cloud microphysics scheme. The model capability is examined by comparing it with reanalysis datasets ERA5 and NGFS Data from NCMRWF for parameters influencing hailstorm development, such as the surface temperature, surface relative humidity, Convective Available Potential Energy (CAPE), Convective Inhibition(CIN), and cloud properties like cloud ice mixing ratio and cloud liquid water content. MODIS satellite dataset (MOD06L2 product) is also used to examine the model capability in simulating the cloud properties like cloud-top temperature, cloud-top height and cloud fraction, which will provide better prediction of Hailstom magnitude and intensity.

Keywords: Hailstorm; Mesoscale model; Microphysics scheme; Cloud Microphysics; Cloud Toptemperature.

PREDICTING CLIMATOLOGICAL DROUGHT FOR THE WEST COASTOF INDIA USING scPDSI DERIVED FROM CMIP6 DATA

Sreekumar Haridas [a], M.G. Manoj[a],
Ashish Shaji[a], and Angel Anita Christy[a]
[a] *Advanced Centre for Atmospheric Radar Research,Cochin University of Science and Technology, Cochin-682022, Kerala, India*
E-Mail: sreekuttanarackal@gmail.com.

ABSTRACT

In recent years, the Indian sub-continent has witnessed an increase in the frequency and intensity of extreme weather events associated with global climate change. Due to the high population density and multiple climate hotspots, the west coast of India (WCI) deserves special attention forstudying extreme climate events such as droughts and floods. This study used bias-corrected, downscaled climate variables from multiple global climatic models available in the coupled model intercomparison project - phase 6 (CMIP6) under diverse shared socio-economic pathway (SSP) scenarios (SSP2-4.5, SSP3-7.0, and SSP5-8.5) for the period 2024–2050. The present work examines the intensity and duration of droughts utilizing the self-calibrating Palmer drought severity index (scPDSI), considering the region's projected temperature and potential evapotranspiration. It is noted that the WCI, particularly the Kerala region, will experience significant temperature rises of more than 2 °C under all SSPs by 2050, with SSP3-7.0 having highprominence, indicating frequent extreme weather events. While central Kerala is projected to experience a statistically significant increase of 225 mm in mean monsoon rainfall under SSP3- 7.0, with substantial post-monsoon increase of up to 250 mm (at 90% confidence level), pre- monsoon rainfall in northern Kerala may rise by an insignificant amount of 5–25 mm and south- central Kerala may witness a 5–10 mm decrease. While the mean itself shows an increase, the standard deviation may attain even higher values resulting in manyfold increase in the intensity ofthe extreme events. The projected scPDSI reveals that severe and extreme droughts will increase,with regions like central Kerala facing prolonged (> 90 months) extreme droughts. According to climate change projections, the WCI will be exposed to an increased risk of extreme weather eventswhich requires comprehensive strategies to address the multifaceted impacts.

Keywords: Climate Projections; CMIP6; MME mean; SSP; scPDSI

Impact of extreme weather event on black gram production in Central India

A.K.Srivastava*

College of Agriculture, Jawaharlal Nehru Agriculture University, Tikamgarh - 472001, Madhya Pradesh

ABSTRACT

Weather plays a crucial role in crop management and changes in weather patterns during the crop period have a significant impact on crop yields. Black gram is an important pulse crops grown throughout Madhya Pradesh and share highest area (18.6 %) in the India. Bundelkhand Agro climatic Zone (BAZ) of Madhya Pradesh has contributed to around thirty per cent black area gram in Madhya Pradesh. Bundelkhand Agro climatic Zone (BAZ) of Madhya Pradesh has been affected by extreme weather events and their frequency impacting the pulse production in general and black gram in particular. The heavy and continuous rainfall, which was received during the flowering and grain-filling stages of the crop, is found to be most critical for yield sustainability of black gram. The farmers of this region start sowing of black gram just after the onset of monsoon during 3 to 4th week of June. During recent decade it is noted that the period of wet spell s and heavy rainfall received during flowering and grain filling stages has destroyed the crop yield. To make adjustmentin sowing date to escape the heavy rainfall events and wet sells coincide with flowering and grain filling stage to avoid total loss of the crop yield. Long term rainfall (1980-2020) and temperature data of three districts(Tikamgarh, Chhatarpur ,Datia) were analyzed and it is found that thefrequency of heavy rainfall and rainy days events have increased over the time during August. The changes in thermal environment due to adjustment of sowing date were also analyzed and reportedin this paper. It is noted that the date of sowing may be shifted to second week of July to minimize the negative impact of heavy rainfall and rainy days on black gram yield in BAZ. It was noted that shift in sowing date to 2nd week of July may be able to escape heavy rainfall events during flowering /grain filling duration. Thus it is infer that the change in cultural practices will able to minimize the total loss of black gram production in BAZ.

CHARACTERISTICS OF THE MAXIMUM DURATION AND MAXIMUM INTENSITY MHWS OVER THE BAY OF BENGAL IN RECENT PERIOD

Rama Kanta Nayak, Biplab Sadhukhan,
Rashmi Rekha Nayak and Arun
Chakraborty

Centre for Ocean, River, Atmosphere and Land Sciences
Indian Institute of Technology Kharagpur,
West Bengal, 721302, India

E-Mail: ramakant29@gmail.com

ABSTRACT

Global warming has made Marine heatwaves (MHWs) a serious environmental hazard on account of their catastrophic effects on marine ecosystems, fisheries, and coastal communities. As global warming continues, the frequency of MHWs is expected to rise in the future. This emphasizes the significance of continued monitoring and research efforts to improve our understanding of MHWs and the consequences they have for society and the environment. Our study investigates some of the critical aspects of recent MHWs that eventuated over the Bay of Bengal (BoB), their characteristics, and their impacts on atmospheric, oceanic, and biogeochemistry variables. In this study, we have identified two major MHWs that eventuated over the BoB region (89°E-95°E, 16°N-22°N) during the recent years. These two major MHW events are characterized based on maximum duration and maximum intensity. We found that the maximum duration MHW event that occurred in 2020, continued for 117 days and had a maximum intensity of 1.73 °C. Meanwhile, the maximum intensity MHW event that occurred in 2022, lasted for 18 days and had an intensity of 3.07 °C. During the maximum duration (maximum intensity) MHW event the average values of latent heat flux, shortwave radiation, and net heat flux are found to be about -90 (-75) W/m^2, 190 (250) W/m^2, and 50 (125) W/m^2 respectively. The variation in biogeochemistry variables namely chlorophyll, net primary production, phosphate, dissolved oxygen, silicate, and nitrate during the maximum duration (maximum intensity) MHW event are found to be -15.789 (-25) %, -20 (-25.714) %, -16.667 (+20) %, -2.884 (-0.99) %, +2.04 (-12.5) % and -78.571 (-7.692) % respectively.

Keywords: Marine Heat Wave, Chlorophyll, Biogeochemistry, Marine Environment, Net Heat Flux

Cloud Seeding, a technique to mitigate the effects of Extreme Weather

Ajay Kumar Singh[a] & Kanwar Ajay Singh[b] [a]Scientist-E, M.C. Chandigarh, [b]Meteorologist-A, I.M.D, New Delhi

E-Mail: kajaysingh74@gmail.com

ABSTRACT

India is facing extreme weather conditions very frequently. Whether it is Extreme Heat Wave conditions / Cold Wave conditions / Foggy Weather / Rainfall activities / Draught like conditions / Dust-storms / Thunder-storms or Extreme Weather events (e.g Tornados, Cyclones, Cloud-bursts etc), it is affecting the entire civilization in a very bad manner causing enormous damage to mankind & other resources. Cloud seeding is a type of weather modification that aims to change the amount or typeof precipitation, mitigate hail or disperse fog. It is undertaken by dispersing some chemicals into the atmosphere that serve as cloud condensation or ice nuclei e.g Dry CO_2, AgI, KI,Common salt etc. using Aircrafts, Missiles, Ground based generators or Drones. Now a days, thenewer approaches, involving drones delivering electric charges to stimulate rainfall, or infrared laser pulses aimed at inducing particle formation, have also been introduced. Many of the countries, have used this technique successfully e.g Dubai is utilizing it to introduce artificial rain; in 2008 Olympics, China used it to protect the Olympic Games sites from extreme rainfall activity; in Vietnam War, USA used it to restrict the movements of troops;in India, Tamilnadu & Karnataka governments, have utilized it to mitigate the effect of Droughts etc. During recent years, it has become a tool for event planning as well. Despite decades of research and application, cloud seeding's effectiveness remains a subject of debate among scientists. Concerns persist over the potential accumulation of seeding agents in sensitive ecosystems causing irreversible damage to the flora & fauna. The technique isquite costly as well. If the technique is used, but goes out of control, may cause a havoc to the environment. Some of the countries, may utilize it, to have a military gain. It can be utilized by the opponent to destroy the eco-system & hence the entire economy of a rival country. Cloud seeding on a very large scale or system, may have a disastrous impact on the climatology of the whole world. As such, Cloud seeding is an old technique, it still needs thorough deliberations.

Keywords: Extreme Weather, Cloud seeding, Flora & fauna

Evaluation of Tropical Cyclone's Track using machinelearning technique over the North Indian Ocean

Monu Yadav[a], Laxminarayan Das[a],

[a] *Department of Applied Mathematics, Delhitechnological University,*

New Delhi, India

E-Mail: yadavm012@gmail.com

ABSTRACT

Accurately estimating the track of tropical cyclones (TCs) is crucial for comprehending their evolution throughout their life cycle and plays a pivotal role in mitigating the impact of TCs. Thereare a number of track estimation techniques in the literature, however their accuracy is not very excellent. A single change in the position of track of TCs can lead to even more disaster. To addressthese challenges, we present a novel neural network-based model. This model incorporates inputs derived from three traditional methods: the automated rotational center hurricane eye retrieval algorithm, the advanced Dvorak technique, and the satellite Consensus technique. The model's training uses 57 cases from the North Indian Ocean, with an additional 5 cases utilized for testing from 2014 to 2024}. The results indicate a \hl{root mean square error of 0.14 knots and an error percentage of 0.41$\%$, lower than those of alternative methods. Consequently, our proposed neural network-based model demonstrates significant potential for accurate TC track estimation, showcasing its effectiveness in overcoming prevalent challenges in existing methodologies.

Keywords: Tropical Cyclone; Track; Machine learning technique; North Indian Ocean

DECADAL GLACIER RESPONSE TO CHANGING CLIMATE OVER LAHAUL AND SPITI REGION, INDIAN HIMALAYA.

Shubhendu Karmakar[a,b], Ankita Paul[b], Julekha Khatun[b], Atanu Bhattacharya[b,c]

[a]Regional Meteorological Centre Kolkata, Alipore, Kolkata
[b] Department of Earth Sciences & Remote Sensing, JIS University, Kolkata
[c] Centre for Data Science, JIS Institute of Advanced Studies & Research, JIS University, Kolkata

E-Mail: shubhendu.karmakar1997@gmail.com

ABSTRACT

The significant concentration of the glaciers in the High Mountain Asia are experiencing constant mass loss due to ongoing climate change, yet, significant spatio-temporal heterogeneities are also evident. However, due to insufficient ground observation, glacierclimate interactions in decadal scale are still poorly understood.

Rising temperatures and increased precipitation, coupled with decreased snowfall, making Himalayan glaciers more prone to melting. Thus, glacier mass budget is a key indicator of a no- delayed response to climate change in high altitudes. To address these issues, we study a long- term, multi-temporal geodetic mass balance study focusing on glaciers in the Lahaul-Spiti region, Himachal Pradesh. We generated precise surface elevation grids using photogrammetry- based techniques with declassified and optical stereo images. A multitemporal geodetic glacier mass balance during 1971-2022 has been assessed for 348 glaciers in the study area, revealing an average glacier mass budget of -0.25±0.11 m w.e. a−1 with decrease in area by 32.78 km^2. From 2002 to 2022, there has been a significant glacier mass loss, averaging -0.47±0.12 m w.e. a−1.The mass budget observations for the small glaciers (<0.5 km^2) revealed ~5.8% of the overall volume change in regional glaciers, which represented around 6.1% of the total glacier- covered area in the region. During the monitoring period, the ERA5 Land Reanalysis climate data highlighted a marked increase in summertime temperatures after 1981. Annual precipitation decreased by roughly 34.4%, dropping from about 103 mm in 1972 to around 67.6 mm in 2022.In the studied area, the slope and the glacier median elevation establish a high relevance. Considering this sensitivity, accelerated melting is expected due to increasing temperatures and shifting precipitation patterns.

Keywords: Climate change, Glacier mass balance, ERA5 land reanalysis data, Optical stereo satellite images.

Uncertainty Estimation and Reduction of Satellite Rainfall using a Non-Stationary Blending Algorithm over North East Region of India

Aniket Chakravorty[a], Shyam Sundar Kundu[a], and Shiv Prasad Aggarwal[a]

[a]*North Eastern Space Applications Centre, Department of Space, Government of India, Umiam, Meghalaya, India, 793103*

E-Mail: aniket.chakravorty@nesac.gov.in

ABSTRACT

The changing climate has altered both the mean and variability of rainfall across India, especially of extreme rainfall events in regions with complex terrain like the North East Region of India (NER). However, limited weather stations and uncertainty in satellite and reanalysis products make rainfall monitoring challenging in such regions. While frameworks for blending multiple rainfall products can generate low uncertainty rainfall products, their consideration of stationary blending weights can cause a misrepresentation of temporal variability of uncertainty. In this study the efficacy of a new non-stationary blending approach based on Triple Collocation (TC) is examined over NER. TC considers a triplet of rainfall products to estimate the correlation between the rainfall product and an unknown truth, which represents the uncertainty of the corresponding rainfall product. The non-stationary approach merges the spatially-varying and temporally-varying uncertainty estimates to generate weights that vary both in space as well as in time. This study considers a two-fold analysis, first is the examination of the uncertainty present in contemporary rainfall products over NER, second is the comparison between stationary and non-stationary TC- based blending frameworks. Four satellite rainfall products, namely, IMERG, INSAT-3D IMR, SM2RAIN-ASCAT and CHIRPS, and a reanalysis rainfall from IMDAA are used in this study. The uncertainty analysis showed, that IMERG, SM2RAIN-ASCAT and IMDAA showed relatively lower uncertainty over NER, whereas CHIRPS and INSAT-3D showed relatively high uncertainty. Considering this, three blended rainfall products are generated by blending SM2RAIN-ASACT and IMDAA with each from the set, IMERG, CHIRPS, and INSAT-3D IMR. The efficacy of the non-stationary blending framework is evaluated by comparing the TC-based uncertainties of the blended products against that from the stationary blending framework. The error in the blended product is also examined using the available ground station rainfall data as reference in a dual comparison framework.

Keywords: Satellite Rainfall, Data Blending, Uncertainty Estimation

Integrating 3C and 3M Models with AI-Driven Early Warning Systems for Disaster Resilience in South Asia

Poulomi Chakravarty[a] and Urjani Chakravarty[b]

[a] Global Climate Association, *India*
[b] *Department of Business Communication, Indian Institute of Management, Bodh Gaya*

E-Mail: *poulomi@globalclimateassociation.org*

ABSTRACT

South Asia, a region frequently besieged by climate extremes such as floods, cyclones, heatwaves, cloudbursts, and thunderstorms, faces significant challenges in Disaster Risk Reduction (DRR). The region's diverse cultural landscape, with its myriad languages and indigenous practices, presents both a challenge and an opportunity for enhancing disaster resilience. This research proposes a holistic framework that integrates the Climate Communication Channels© Model (3C) with the 3M (Mistake, Manage, Mitigate) Crisis Communication Model within AI-driven Early Warning Systems (EWS). A key focus is on incorporating local vernacular languages and Indigenous knowledges to improve the effectiveness of disaster preparedness and response acrossSouth Asia. The 3C© Model — comprising Communication, Coordination, and Collaboration criteria—ensures that critical information are effectively disseminated, understood, and acted uponvia AI-driven warnings by incorporation of local vernacular languages and culturally relevant messaging. It integrates governmental agencies, local communities, and indigenous practices withmodern technology, fostering a comprehensive and inclusive approach to disaster management across South Asia.The 3M Model—centered on Mistake identification, risk Management, and impact Mitigation—enhances the framework by ensuring continuous monitoring and culturally sensitive strategies. It quickly addresses communication errors, incorporates Indigenous insights into decision-making, and blends traditional knowledge with AI-driven data for effective disasterresponses.This integrated 3C-3M framework, customized for South Asia, acknowledges the vital role of local vernaculars and indigenous knowledge in enhancing the region's disaster resilience. This approach not only improves the accuracy and relevance of disaster communications but alsoempowers communities by respecting and leveraging their cultural heritage, ensuring a more inclusive and effective response to the growing threats posed by climate extremes. The paper alsodiscusses the challenges of implementing this framework, including the need for comprehensive language coverage and scientific accuracy in AI systems and the respectful integration of Indigenous practices into formal disaster management protocols.

Keywords: climate extremes; crisis communication; climate resilience; Disaster Risk Reduction (DRR); Early Warning Systems (EWS)

Relationship between Atmospheric Aerosols and Surface Temperature over the Indian Region

Sarin. T. S, V. Vinoj

School of Earth, Ocean, and Climate Sciences

Indian Institute of Technology Bhubaneswar, Arugul, Odisha, India.

E-mail: a21es09007@iitbbs.ac.in

ABSTRACT

Atmospheric aerosols play a crucial role in Earth's climate system through their interactions with solar radiation through direct, indirect and semi-direct effects. Multiple studies have explored the impact of aerosols on surface-reaching solar radiation, which indicates an overall negative radiative forcing due to aerosols globally. It is also well known that aerosol-induced radiation changes have a corresponding effect on surface air temperature, an essential meteorological parameter. However, few studies have explored this issue on regional scales, especially using observational data. This study attempts to quantify the effect of aerosols on the maximum surface air temperature using long-term daily satellite observations and reanalysis data (2002-2019) over the Indian region—the aerosol effects calculated exhibit sizeable spatial variability. Aerosols reduce the daytime surface temperature over India by an average of -0.26°C during the winter (Dec-Jan-Feb, DJF) and -0.03°C post-monsoon season (Sep-Oct-Nov, SON). Surprisingly, during the pre-monsoon season (March to May, MAM), aerosols induce an average warming of up to 0.18°C over India. The timing and spatial distribution of the warming signature point to the possibility of aerosol absorption-induced changes in cloud properties and radiative heating by predominantly dust aerosols as the plausible cause. The results obtained using the MERRA2 reanalysis datasets (-0.51°C in DJF, 0.02°C in MAM and -0.15°C in SON) match spatiotemporally with satellite observation results with the reanalysis maximum surface air temperature having a slightly higher sensitivity to reanalysis AOD than that observed using satellite aerosol information (MODIS). Modelling studies conducted using RegCM 4.7 further corroborate the results obtained using observational studies. These findings highlight the complex interplay between aerosols, clouds on surface air temperature, particularly in regions such as India, where aerosols loading is one of the highest in the world.

Keywords: Atmospheric aerosols; Surface temperature; MERRA2; MODIS; India

STUDIES OF AEROSOL OPTICAL AND RADIATIVEPROPERTIES USING GROUND-BASED SKY RADIOMETER INSTRUMENTS FROM HIGH-ALTITUDE SITES AT LADAKH IN THE HINDU KUSH HIMALAYAN REGION

Swagata Mukhopadhyay1[a],-Shantikumar S. Ningombam2[a]
A. K. Srivastava3[b], B. L. Madhavan4[c], Sonam Jorphail5[d],
Dorje Angchuk6[d]

[a]Indian Institute of Astrophysics, Bengaluru, India;
[b]Indian Institute of Tropical Meteorology,
Ministry of Earth Sciences, New Delhi, India;
[c]National Atmospheric Research Laboratory, Gadanki, India;
[d]Indian Astronomical Observatory, Indian Institute of Astrophysics, Leh, India
- *E-Mali: swagata.mukhopadhyay@iiap.res.in*

ABSTRACT

The study investigated aerosol optical and radiative properties using multi-wavelength sun-sky radiometer instruments (Prede, P0M-01) at four high-altitude sites in Ladakh, namely Hanle, Merak, Nyoma, and Leh, located in the Hindu Kush Himalayan (HKH) region. The instrument works in a robotic mode: a spectral scanning radiometer, an automatic sun tracker and a rain sensor. The instrument measures direct irradiance and diffuse sky radiance at different scattering angles at seven discrete wavelengths, namely 315, 400, 500, 675, 870, 940, and 1020 nm and for aerosol studies, we excluded the data obtained at 315 nm and 940 nm. The raw data collected by these instruments is processed using SKYRAD.Pack (version 4.2). This software tool is writtenin Fortran and is specifically designed to analyse the radiometer data. These high-altitude locations, situated over 3000 meters above mean sea level, are excellent for studying backgroundaerosols and the impacts of regional and global climate change. Their elevation also provides a unique advantage in characterizing or classifying the background aerosols and their sources, whether from natural dust from the local surroundings or anthropogenic sources from industrial emissions or transported from distant areas. The paper will describe aerosols' optical and microphysical properties derived from SKYRAD.Pack with fine and coarse mode aerosols estimated using the Mie scattering algorithm. Observational data was collected over this extended period in different periods at each site. Still, the total duration of long-term data (2008 to 2024) in the HKH region allows for examining temporal trends and variability in aerosol properties. Such a study of long-term datasets is crucial for identifying patterns and understanding the effects of seasonal and inter-annual changes.

Keywords: Aerosols, sun-sky radiometer, Skyrad.pack, Mie scattering

Identification of Extreme rainfall hotspots overrainfall homogeneous regions in India

Ipsita P.[a], Rakesh V.[a, b]

[a] CSIR Fourth Paradigm Institute, Bangalore

[b] Academy of Scientific and Innovative Research (AcSIR), Ghaziabad

E-Mail:ipsita.putatunda@gmail.com

ABSTRACT

Frequency and intensity of extreme rainfall events (EREs) has been increased globally including India in past few decades. Increasing temperature can increase the atmospheric water holding capacity according to Clausius-Clapeyron relationship, which along with other factors can leadto further increase in EREs. Keeping in mind the socio-economic impacts of EREs; understanding on the distribution and frequency of EREs is critical for preparing management strategies in various sectors like disaster preparedness, smart city planning, water quality, public health, agriculture planning, etc. In this backdrop, this study aimed to identify the EREs hotspots in India. Rainfall pattern over India has tremendous spatio-temporal variability across different homogeneous regions. This study aim to examine the spatio-temporal rainfall variability of EREsidentified based on objective criteria over homogeneous regions in India defined by IMD for pre- monsoon, monsoon and post-monsoon season. Suitable rainfall threshold values for defining EREs are identified for each homogeneous region and season based on frequency distribution of daily accumulated rainfall. Machine Learning (ML) techniques enable machines using algorithms to analyze large amount of data and make decisions without any explicit constraints. Clustering algorithms which is popular unsupervised ML techniques used to identify groups of rainfall regions with similar spatio-temporal variability, has been used in this study. After identifying EREs over each homogeneous region, K-means clustering and DBSCAN (Density- Based Spatial Clustering of Applications with Noise) clustering algorithms are deployed for understanding the ERE distribution and identifying rainfall hotspots based on long term daily rainfall data. A comparative study between the output from K-means and DBSCAN clustering methods has also been carried out. Our study shows that ML algorithms proves to be promising techniques for analyzing spatial variability of EREs based on long term rainfall data over India.

Keywords: Extreme Rainfall Events; Homogeneous rainfall region; DBSCAN Clustering; K-means Clustering.

Integrative Modeling of Coastal Flooding in Storm Surge Events: Utilizing ADCIRC and HEC-RAS for Comprehensive Flood Risk Assessment in IndianRiver Basins

Pawan Tiwari

Indian Institute of Technology Delhi

ABSTRACT

Coastal flooding triggered by tropical cyclones is a frequent and devastating threat in low-lying coastal areas. The risk of inundation escalates when storm tides interact with river systems and arecompounded by intense rainfall during the cyclone. This vulnerability is further heightened whencyclones land near estuaries, river deltas, or adjacent rivers along the coast. Consequently, understanding these interactions and accurately quantifying their contributions to coastal inundation is crucial for effective inland flood mapping and disaster management. ADCIRC modelis one of the practical tools in computing coastal inundation, but it needs to consider precipitation,which plays a major role during flooding. The HEC-RAS model is coupled with ADCIRC to solvethis issue to provide realistic coastal flooding. Validation of inundation is a very tough task duringstorm surge events due to the unavailability of an inundation map at the time of landfall. In our experiment, we used coupled ADCIRC and HEC RAS over the significant river estuaries (Hooghly, Mahanadi, Krishna, and Godavari) along the east coast of India since these regions arevery vulnerable to storm surges. Significant cyclone landfalling over or near these river systems is selected for computing inundation. To calculate the inundation, storm tides from the ADCIRC model are used as input to the HEC-RAS model. Other parameters like river discharge and griddedprecipitation are also incorporated.

Further model capability is enhanced by adding land cover, soil, and infiltration data over these river systems. Fani cyclone is one of the devastating cyclones that significantly impacted the Mahanadi basin. Inundation from the model is validated with the satellite map, which was available two days after the landfall. Model inundation is adjusted by altering the precipitation factor depending on the observed value. The same factor is used for other river basins. Results show that the model is validated reasonably well with the observation.

Assessing the Role of Ground GNSS Observations in NCMRWF's Unified Model

Smrati Purwar[a], S Indira Rani[a]

[a] *National Centre for Medium Range Weather Forecasting (NCMRWF), Noida (U.P.)*

E-Mail: smrati.purwar@govcontractor.in, ritipurwar@gmail.com

ABSTRACT

Accurate estimation of water vapor with high spatial and temporal resolution is crucial for operational weather forecasts and climate research. Moisture representation in numerical weather prediction (NWP) models often falls short, particularly when forecasting mesoscale precipitation events. Precise data on middle and upper tropospheric moisture is essential for determining the intensity, effectiveness, and longevity of deep convective processes. The Global Navigation Satellite System (GNSS) offers a continuous, cost-effective method to measure atmospheric humidity by co-locating GNSS receivers with meteorological sensors. Studies reported that the influence of GNSS- Zenith Tropospheric Delay (ZTD) assimilation extends beyond areas with dense networks, positively affecting other regions as well. Currently, many ground-based GNSS observations are integrated into the NWP systems at the National Centre for Medium Range Weather Forecasting (NCMRWF). NCMRWF receives the GNSS-ZTD global observations from various sources like Suominet, Eumet, India meteorological Department (IMD), Global Telecommunication System, etc. A robust data quality control and monitoring system has been established at NCMRWF to evaluate the quality of data before it is assimilated into models. Recently NCMRWF started receiving the GNSS-ZTD data from Survey of India through IMD. This study investigates the impact of assimilating GNSS-ZTD data during August 2024, the peak of the monsoon season in the Indian subcontinent, using the NCMRWF Unified Model (NCUM). Observing System Experiments (OSEs) are designed to investigate the global and regional impact of GNSS-ZTD in the NWP system. It is expected that the assimilation of GNSS-ZTD will improve various meteorological parameters like temperature, humidity, wind, precipitation etc in the short and medium ranges. The main findings from the study will be presented during the conference.

Keywords: Unified Model; Monsoons; GNSS; Zenith Tropspheric Delay; Weather Prediction

WARMING OVER INDIAN CITIES: URBANIZATION OR CLIMATE CHANGE

Soumya Satyakanta Sethi and V Vinoj
School of Earth, Ocean and Climate Sciences,
Indian Institute of Technology Bhubaneswar
E-Mail: sss11@iitbbs.ac.in

ABSTRACT

Rapid urbanization is defining the future of the anthropocene driving the socio-economic growth trajectory. Nevertheless, the transformed natural landscape to urban environment with altered thermodynamic and aerodynamic properties pose risk to the urban climate. In the backdrop of climate change, the challenges confronted by cities are exacerbated by the combined effects of both urbanization and climate change. One such major challenge is urban warming. Although numerous studies have explored the urban heat island phenomenon, as cities are expected to trap more heat, less attention has been given to understanding the contribution of urbanization and climate change to the observed warming over cities. Here, we have explored the warming over 141 cities across India and have segregated the role of urbanization and climate change from the observed warming using MODIS surface temperature data during 2003-2020. Our study highlights urbanization has contributed to 60% enhancement in warming for Indian cities with the developing eastern Indian cities showing the highest urban contribution. Overall, our study calls for a differential approach in warming mitigation efforts across cities.

Keywords: Urbanization; Climate Change; Warming; Urban Sustainability

A Comparative Study of SCAT-3 and GFS Wind Datasets for the Bay of Bengal Cyclones of 2023

Ritama Das[1,3], Sumit Mondal[1,3], Anup Kumar Mandal[2], Neeru Jaiswal[2], Tushar Kanti Saha[1], Tarun Kumar De[3]

[1]*Department of Mathematics, Surendranath College, 24/2 M.G. Road, Kolkata 700 009, India*
[2]*Atmospheric and Oceanic Sciences Group, EPSA, Space Applications Centre, ISRO, Ahmedabad 380015, India*
[3]*Department of Marine Science, University of Calcutta, 35, B.C. Road, Kolkata 700 019, India*
E-mail: ritamadas1234@gmail.com

ABSTRACT

The Bay of Bengal emerges as one of the most susceptible regions in the world from tropical cyclone catastrophic viewpoint due to its intricate geographical pattern. The severity of cyclones and consequent storm surges bring loss to natural and anthropogenic assets. This study focuses on the variability and trend of u-, v- components of wind, their speeds, magnitude and directions during four cyclonic events (Mocha, Hamoon, Midhili, Michaung) that occurred in the Bay of Bengal in 2023 together with the changes in mean sea level pressures and sea surface temperatures. Six-hourly SCAT-3 (Ku-band Scatterometer aboard the Oceansat-3, Level 4- Analyzed Wind Vector) wind data from Meteorological & Oceanographic Satellite Data Archival Centre (MOSDAC) and Global Forecast System (GFS) reanalysis data from National Centers for Environmental Prediction (NCEP) are used to assess the parameters. SCAT-3 and GFS wind fields are compared using MATLAB. Both datasets generally agree at lower wind speeds and deviate to a certain extent as wind speed increases as noted from certain statistical parametric calculations. Time series analysis comparing the two datasets shows considerable similarities though GFS wind values remain slightly higher than SCAT-3 in most cases. For storm surge simulation, GFS vector wind datasets are preferred over SCAT-3 datasets since GFS datasets provide uninterrupted wind fields for water and land surface unlike SCAT-3 which is limited to oceanic regions only. SCAT-3 data may be integrated with GFS land data to resolve this issue. While working with long-duration datasets, both shows data gaps that may distort parametric results. This study reveals that Hamoon has the best agreement and Mocha, the maximum disagreement. The wind data tracks for four cyclonic events, plotted from both datasets, comply well with the Indian Meteorological Department's (IMD) best track data. SAC, ISRO, Ahmadabad, India, is acknowledged for funding the research work.

Keywords: Tropical Cyclone, Bay of Bengal, SCAT-3 & GFS winds, IMD, MATLAB

UNDERSTANDING THE BACKGROUND BLACK CARBON OVER THE INDIAN REGION

Smaran, Maji, Vinoj,V

School of Earth, Ocean and Climate Science, Indian Institute of Technology Bhubaneswar E-Mail: a22es09004@iitbbs.ac.in

ABSTRACT

Air pollution levels have been rapidly rising in the Indian region in recent years, and black carbon (BC) is a vital component affecting the health and welfare of the general population. With an emphasis on heavily polluted cities, significant efforts are being made to lower pollution levels. It is qualitatively well-established that a substantial background black carbon pollution load exists over India. However, no research has specifically addressed the scientific quantification of them. The objective of this work is to analyze and distinguish black carbon, a significant primary aerosol/air pollutant, into two distinct groups: background (the lowest concentration levels resulting from regional and long-range transport) and foreground concentrations (local emissions) using the moving average subtraction method. The method is examined for its consistency by utilizing ground-based observations collected from the Aethalometer. It is then expanded to include the entire Indian region by using chemical reanalysis datasets from MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications, version 2). Our analysis shows that the background BC over India obtains its maximum value during the winter season, at 2.32 µg m^{-3} (background BC 86%), and its minimum value during the monsoon season, at 0.60 µg m^{-3} (background BC 79%). Furthermore, irrespective of the season, the background BC level in India is consistently above 75%. An independent examination of the foreground BC after eliminating the background BC reveals significant sources of emissions that are comparable to the HTAP_v3 (Hemispheric Transport of Air Pollution) BC emission database, therefore confirming the robustness of the methodology. The significant qualitative agreement between the concentration of foreground BC and the sources of BC emissions enhances the reliability of the analysis. The results of this study will offer policymakers an important perspective, highlighting the substantial impact of background black carbon aerosol pollution in India.

Keywords: Air pollution, Background Pollution, Atmospheric aerosols, Carbonaceous aerosols, Regional air quality

Evaluation of trend analysis of drought over Odisha

Pujyasmita Nayak[a], Sanjeev Dwivedi[a] and Manorama Mohanty[a]
[a]*Meteorological Centre, Bhubaneswar,*
India Meteorological Department
E-Mail: nayaksmitapuja@gmail.com

ABSTRACT

Drought is a condition of decline in soil moisture content and water availability, and it negativelyimpacts Agriculture and Livestock. Odisha state is vulnerable to not only cyclones but also droughts. One of the most crucial parts of drought analysis is the assessment of drought characteristics. Therefore, it is necessary to study the rainfall analysis for developing farming system which may help to increase and stabilize agricultural production. This st dy envisages the spatio-temporal trend analysis of drought patterns in Odisha across 120 years (1901-2020) using data collected 215 rainfall grid. Addition to this, the Standardized Precipitation Index (SPI-3) is calculated to evaluate the drought severity as SPI-3 aims to access soil moisture and groundwater flow which leads to evaluate agricultural drought. From agricultural aspect, one of the most severe drought event occurred during 1999-2000 with SPI-3 value below -2.80 indicated a negative significant trend. Trend analysis for drought was carried out by Mann- Kendal Test withthe magnitude of the trend evaluated using Sen’s estimator with having decreas ng trend 61.40% of grid cell and 38.60% of grid cell in increasing trend in different significance levels. Particular consideration needs to be given to the analysis of short term droughts (flash droughts), as they account for 30% of the state of Odisha's NSDP (Net State Domestic Product) due to agriculture. Study also reveals that the drought characteristics having total 66 drought years found affecting the agricultural productivity mostly in western odisha contributing 35.08% of western region falls under high to very high drought vulnerability and also to flash droughts.This analysis will be helpful to mitigate drought and build resilience over the state.

Keywords: Drought, Standardized precipitation Index, Trend analysis, Agricultural productivity

THE ROLE OF DUST IN THE FORMATION ANDMAINTENANCE OF MONSOON INVERSION OVERTHE ARABIAN SEA

Sanjeev Dwivedi[a], Amit Kumar Pandit[b], and Buddhi Prakash Jangid[c]

[a]*Meteorological Centre, Bhubaneswar, India Meteorological Department (IMD), Ministry of Earth Sciences (MoES),Bhubaneswar 751 020, India*

[b]*National Institute of Aerospace, Hampton, VA 236 66, USA*

[c]*Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pashan, Pune 411 008, India*

E-Mail:Sanjeev.dwivedi@imd.gov.in

ABSTRACT

The Monsoon Inversion (MI) plays an important role and is one of the semi - permanent features of the Asian Summer Monsoon, observed over the Arabian Sea. MI is defined as a sustained temperature inversion (TI) that is observed in the lower troposphere, during the whole summer monsoon (June to September) over the Western Arabian Sea (WAS). Once the MI break up near the western coast of India, It brings sudden rainfall over the coastal areas. A comprehensive analysis is carried out to observe the formation, evolution, and dissipation of MI using long-term observations (from 2008 to 2022) of satellites and ERA - 5 reanalysis. MI is stronger over the WAS and occasionally with lesser strength over the Eastern Arabian Sea (EAS) during July – August. The reasons for the existence and strength of MI are investigated using the CALIPSO measurements of dust. There is ~ 15% difference in the occurrence of dust over the WAS comparedto the EAS. Also, MI occurrence has shown significant differences in temperature profiles duringdust and non - dust cases. The dust which is mixed up with Black Carbon (BC) emitted from Arabian refineries may be making a coating on it, i.e. dust coated with BC. The AEROGUI modelis used to obtain the optical properties of dust and dust coated with BC to infer their relative role in radiative heating. Satellite observations show that MI is stronger during the break spell as compared to the active spell of the Asian Summer Monsoon.

Keywords: Monsoon Inversion; Monsoons; CALIPSO; Black Carbon; Dust

VEGETATION PHOTOSYNTHESIS AND RESPIRATION MODEL BASED ASSESSMENT OF BIOSPHERIC CO2 FLUX FROM MAJOR ECOSYSTEMS IN INDIA

Akshay S[a,b], S Sijikumar[a] and Anjumol Raju[c].

[a] *Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram, India*
[b] *Research Centre, University of Kerala, Thiruvananthapuram, India*
[c] *Department of Meteorology and Geophysics, University of Vienna, Vienna, Austria*

E-Mail: akshaysvk0@gmail.com

ABSTRACT

In the context of rapidly increasing atmospheric concentration of Carbon dioxide (CO_2) and resulting global warming which causes frequent occurrence of extreme weather events, it is essential to quantify regional carbon fluxes for mitigation purposes. Carbon fluxes from biosphere are critical for quantifying CO_2 source-sink balance over the Indian region having distinct climate and vegetation patterns. High spatio-temporal variability in the terrestrial biospheric flux, compared to other fluxes in the carbon cycle, makes it pivotal in determining the net flux. This study aims to enhance our understanding of Net Ecosystem Exchange (NEE) of CO_2 across various ecosystems and its variability using the Vegetation Photosynthesis and Respiration Model (VPRM) simulations during 2011 to 2023. High resolution reflectivity data from MODIS satellite, land use land cover data derived from the satellite IRS-P6 AwiFS and meteorological variables from ERA5 reanalysis data are used to quantify the NEE within key ecosystems over the Indian landmass. Our primary results indicate that agricultural crops contribute the most to carbon absorption owing to their larger extent, especially during the growing seasons. Forests, however, is more efficient in terms of absorption per unit area. On average, -0.968 $PgCyear^{-1}$ absorbed by the Indian biosphere during the study period. On this, 59% of the absorption is from croplands, 48% was absorbed by forests and 7% net emission from other ecosystems. In terms of seasonal variability, cropland showed more efficient carbon absorption compared to forests in response to monsoon rainfall, both in terms of gross seasonal NEE and on a per-month basis. Significant increase in biospheric absorption is found during the monsoon season, with forests and cropland absorbing -0.211 Pg C and -0.209 PgC respectively. Cropland continued high CO_2 absorption during the post monsoon season with NEE as -0.216 PgC, whereas forests contributed -0.178 PgC.

Keywords: Climate Change; Carbon cycle; Net Ecosystem Exchange; Biospheric modelling

Assessment of diurnally evolving atmospheric boundary layer over the centralIndian region under the influence of extreme heat waves

Adarsh Jain[a] and D. Bala Subrahamanyam[a]

[a] *Space Physics Laboratory, Vikaram Sarabhai Space Centre,Department of Space, Government of India, Indian Space Research Organisation, Thiruvananthapuram, India*
E-Mail: adarshjainph@gmail.com

ABSTRACT

A heat wave is a period of unusually high temperatures, exceeding the normal summer maximum, especially in the northwestern and central parts of India. Due to climate change, extreme weather events are becoming more frequent worldwide, with heat waves increasing in intensity and frequency. It is well-known that during heat waves, air temperatures at a given location exceed the usual maximum. As a result, all meteorological parameters are affected. However, the impact of heat waves on the daily evolution of the atmospheric boundary layer (ABL) remains an area of ongoing investigation for various reasons. We present a detailed study using an atmospheric model and in situ measurements to examine the effect of extreme heat waves on the daily development of the ABL across 26 inland stations in central India. The modelsimulations were performed using the COSMO (Consortium for Small-scale Modelling), aregional numerical weather prediction model. The study focuses on May 2023 and December 2023, contrasting periods representing extreme heat waves and calm, cold winter conditions, respectively. The model simulations are validated against the concurrent in situ measurements obtained from the Indian Meteorological Department (IMD) stations. During the extreme heat waves in May 2023, the mean solar irradiance corresponding to noontime reached 700 W m^{-2}, compared to 500 W m^{-2} in December 2023. This surplus irradiance led to a peak sensible heat flux of 300 W m^{-2} in May 2023, while it was about 200 W m^{-2} in December 2023. Similar differences were also observed in the diurnal pattern of latent heat flux. The extreme heat waves also caused a significant rise in sub-soil temperatures in May 2023. Further analysis showed intensified turbulence kinetic energy (TKE) and a deepening of the ABL in May 2023, whereas ABL heights were much lower in December 2023.

Keywords: Atmospheric boundary layer; Diurnal evolution; Extreme weather events; Heat Waves; Irradiance

Nationwide Probabilistic Forecasting of Pluvial Flood Hazards across India

Ankan Chakraborty[a], Subimal Ghosh[a, b], Subhankar Karmakar[a, c]

[a] *Centre for Climate Studies, Indian Institute of Technology Bombay, Mumbai 400076, India*

[b] *Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai 400076, India*

[c] *Environmental Science and Engineering Department, Indian Institute of Technology Bombay, Mumbai 400076, India*

ABSTRACT

The increasing frequency of global extreme rainfall events highlights the urgent need for improved early warning systems to mitigate pluvial floods. Current extreme rainfall forecast systems face significant challenges, including poor skill scores (e.g., low hit rate, high false alarm) and substantial spatiotemporal biases. This study introduces a novel approach to forecast and develop pluvial flood hazard map across India using global forecasted rainfall data. Instead of predicting specific rainfall quantities, it estimates pluvial flood hazard by evaluating conditional exceedance probability of observed rainfall, based on forecasted rainfall data. The study utilizes gridded observed rainfall data from the India Meteorological Department (IMD) and gridded hindcast rainfall data from the NOAA's Global Ensemble Forecast System (GEFS), spanning 1985-2018. A non-parametric approach is employed for frequency analysis, incorporating multivariate methods to capture both marginal and joint probability density functions. Hazard values, expressed as conditional exceedance probabilities, are calculated at a $1° \times 1°$ grid resolution level across India for lead times of 1 to 15 days. The model, validated against recent extreme rainfall events in India, demonstrated strong concordance between the predicted flood hazard maps and observed rainfall patterns. The model efficiently forecasts pluvial flood hazards events up to 10 days in advance. Its skill scores, specifically in terms of hit rate and false alarm, confirm its accuracy and reliability in forecasting extreme rainfall-induced flood hazards. The proposed framework is very generic and applicable to any country (global scale) and any rainfall event using global rainfall forecast data for reliable pluvial flood hazard forecasting with sufficient lead time. The model offers stakeholders and policymakers sufficient lead time to implement effective disaster management and reduction strategies like proper evacuation and mitigation at the national level for pluvial flood events.

Keywords: Extreme rainfall; Hazard; Non-parametric; Pluvial flood; Weather forecast

TELECONNECTION AND THE ANTARCTIC RESPONSE TO THE INDIAN OCEAN DIPOLE IN CMIP5 AND CMIP6 MODELS

Arnab Sen[a] , Pranab Deb[a]

[a] *Centre for Ocean, River, Atmosphere and Land Sciences (CORAL),*
Indian Institute ofTechnology Kharagpur
E-Mail: arnab253@kgpian.iitkgp.ac.in

ABSTRACT

Tropical-Antarctic teleconnections are known to have large impacts on Antarctic climate variability at multiple timescales. Anomalous tropical convection triggers upper-level quasi-stationary Rossby waves, which propagate to high southern latitudes and impact the local environment. Here the teleconnection between the Indian Ocean Dipole (IOD) and Antarctica was examined using daily gridded reanalysis data and the linear response theory method (LRTM) during September–November of 1980–2015. The individual contribution of the IOD over the Antarctic climate is challenging to quantify, as positive IOD events often co-occur with El Niño events. However, using the LRTM, the extratropical response due to a positive IOD was successfully extracted from the combined signal in the composite map of anomalous 250-hPa geopotential height. Applying the method to a set of models from phases 5 and 6 of the Coupled Model Intercomparison Project (CMIP5 and CMIP6), significant differences were observed in theextratropical response to the IOD among the models. The LRTM was then applied to evaluate theextratropical response of the 850-hPa temperature, wind anomalies, and sea-ice concentration anomalies in observation data, as well as models that represented both the IOD precipitation and the extratropical waveguide adequately. The IOD induced cold southerly flow over the west of theRoss Sea, Weddell Sea, and Antarctic Peninsula, causing cold surface-temperature anomalies andthe increase of sea ice, and warm northerly flow over the east of the Ross Sea and Amundsen Sea,causing warm surface-temperature anomalies and the decrease of sea ice. We recommend the LRTM as a complementary method to standard analysis of climate variability from observations and global climate models.

Keywords: CMIP5; CMIP6; IOD; Rossby waves; Tropical-Antarctic teleconnections

IDENTIFYING THE SUITABLE THERMODYNAMIC INDICES FOR LIGHTNING FORECAST IN INDIA

Junaid Bin Yousuf P[a,b], Sudeep Kumar B.L[b] and K S Hosalikar[b]

[a] *Department of Physical Oceanography, Kerala University of Fisheries and Ocean Studies, Kochi, India*

[b] India Meteorological Department, Ministry of Earth Sciences,

Pune, India

junaidbinyousufp@gmail.com

ABSTRACT

Lightning is one of the major natural disasters that caused many casualties in India. This study evaluates the spatiotemporal variation of lightning activity over India and identifies suitable thermodynamic indices for lightning forecasts across different regions. Daily thermodynamic indices such as SWEAT, SHOW, LI, KI, CTI, VTI, TTI, and CAPE at 00 UTC and ground based lightning observations data from 21 meteorological stations for the period 2019-2022 have been utilised. The study employs a skill score method to evaluate the predictive capabilities of various thermodynamic indices and also delineates the seasonal and regional variations in lightning activity over the country. Our findings reveal significant variations in lightning occurrences, with the highest lightning days observed in the Northeast and Southern regions of India and the minimum over the northern and northwest regions. The monsoon season accounts for the maximum lightning days, followed by the pre-monsoon, post-monsoon, and winter seasons. Monthly analysis indicates a peak in lightning days during September. The study further identifies that the SWEAT, K, and CTI indices exhibit strong predictive skills for over 14 stations, while LI, SHOW, TTI, and CAPE indices perform well for fewer stations. The VTI index did not demonstrate suitable predictive capability for any station. Optimal threshold values for these indices, derived from the normalized skill score, have been validated and can be effectively used for operational lightning forecast.

Keywords: Lightning; Thermodynamic Indices; Forecast; Skill Score; Threshold Value

Investigation of Atmospheric Conditions Driving Lightning Disasters:Case Studies Using Space-Borne and Ground-Based Sensors in Land-Sea Boundary Regions of Eastern and Western India

Gargi Rakshit[a], Ashim Kumar Mitra[a],and K. C. Sai Krishnan[a],

[a]*India Meteorological Department, Ministry of Earth Sciences, Government of India, New Delhi,India*
E-Mail:gargirksht@gmail.com, gargi.rakshit@imd.gov.in

ABSTRACT

Lightning is a striking and perilous natural phenomenon, posing significant risks to human life andproperty. Globally, it is responsible for approximately 24,000 fatalities and 240,000 injuries eachyear (Holle, 2008). In India, lightning is most prevalent during the pre-monsoon and monsoon seasons, when conditions favour the formation of deep convective clouds. This study examines two contrasting lightning disasters: one in Odisha during the monsoon (September 2023), where lightning is a state-declared disaster, and another in Gujarat during winter (November 2023), whenlightning is less frequent. Severe lightning hours are identified using real-time data from the Indian Institute of Tropical Meteorology (IITM) lightning sensor network, available internally at the India Meteorological Department (IMD), Satellite Meteorology Division, New Delhi. Observations from the INSAT 3D satellite showed that in the regions affected by lightning, cloud top brightness temperature (CTBT) and cloud top pressure (CTP) plummeted to -89°C and 100 hPa, respectively. Additionally, ERA5 data indicated a significant intensification in cloud ice water content during intense lightning discharges, highlighting the critical role of cloud microphysical parameters in lightning disasters. The study also found that elevated convective available potential energy (CAPE) signaled an impending lightning threat. This research provides important insights into the physical processes that cause lightning disasters. It highlights the importance of incorporating cloud properties and atmospheric instability parameters into predictive models, which can improve lightning forecasting and early warning systems in India. This is crucial for strengthening operational meteorological services and enhancing the country's weather forecasting infrastructure.

Keywords: Extreme weather events; Lightning; Cloud Top Brightness Temperature (CTBT); INSAT 3D/DR; Cloud Ice Water Content

Evaluation of CMIP6 GCM Simulations of Surface Air Temperature over India

A Sabarinath[1,2], T. Kesavavarthini[1,2], Meera M. Nair[1,2], A. Naga Rajesh[*1,2]

[1]Department of Physics and Nanotechnology, Faculty of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu-603203, India.

[2]Centre for Atmospheric Sciences and Climate Studies (TROPIC), Faculty of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu 603203,

ABSTRACT

Surface air temperature (SAT) plays a critical role in both natural systems and human activities, influencing health, agriculture, and energy demand. To effectively study SAT in a specific region, selecting appropriate climate models is essential. This study began by evaluating simulations of SAT from 42 Coupled Model Intercomparison Project Phase 6 (CMIP6) models over India for the annual and all four seasons (summer, southwest monsoon, northeast monsoon, and winter) during the historical period from 1985 to 2014, using gridded SAT datasets from the India Meteorological Department (IMD) as a reference. The Multi-Model Mean (MMM) of the 42 models was included in the analysis. The evaluation employed various statistical metrics such as root mean squared error (RMSE), mean bias error (MBE), correlation coefficient (R), mean absolute error (MAE), Taylor skill score (TSS), Brier skill score (BSS), and Interannual variability skill score (IVSS). Through the estimation of the Comprehensive Rating Index (CRI), the top-performing models were identified: CMCC-CM2-SR5 for the annual and summer seasons, MIROC6 for winter, ACCESS-ESM1-5 for the southwest monsoon, and NorESM2-LM for the northeast monsoon. The study's innovation lies in its approach to developing the best ensemble. For each season, the top- ranked models based on individual statistical metrics were selected to form the best ensemble. The overall ranking of the models and the best ensemble for each season were determined by calculating the CRI. The findings revealed that, for all seasons, the best ensemble ranked within the top three models. Future SAT projections under four Shared Socioeconomic Pathways (SSP- 2.6, 4.5, 7.0, and 8.5) were also analyzed using the best ensemble for each season. The results indicate that under the SSP5-8.5 scenario, India is expected to experience a significant rise in mean SAT during the summer season, with increases of 1.160°C, 1.288°C, and 2.368°C between the historical period (1985-2014) and the near future (2021-2040), mid-future (2041-2060), and far future (2081-2100), respectively.

Keywords: CMIP6, Surface air temperature, statistical metrics, comprehensive rating index.

Assessing the relationship between Climate Indices and Extreme Precipitationduring the Indian Summer Monsoon using CMIP6 simulations

Meera M Nair[1,2], T. Kesavavarthini[1,2], A. Sabarinath[1,2], A. Naga Rajesh[1,2*]

[1]Atmospheric Science Research Laboratory, Department of Physics and Nanotechnology,College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu 603203, India.

[2]Centre for Atmospheric Sciences and Climate Studies (TROPIC), College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu 603203, India.mn5998@srmist.edu.in

ABSTRACT

The Indian summer monsoon rainfall is associated with convective systems generated over warmoceans surrounding the Indian subcontinent, which propagate into the landmass. During the SW monsoon season, arid northwest regions typically experience positive or minimally negative vertically integrated moisture flux divergence (VIMD) values, while the Northeast region often sees high negative values indicating significant moisture convergence corresponding to intensifying precipitation. Various factors influence the Indian summer monsoon, such as the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). This study aims to providea significant breakthrough for Coupled Model Intercomparison Project – phase 6(CMIP6) GCMsto understand and simulate climatic phenomena and their impact on extreme precipitation during the Indian summer monsoon. The discrepancies between observations and CMIP6 outcomes underscore the need for continuous refinement of models and validation against observational datato improve the reliability and accuracy of climate projections. The uncertainties in Sea surface temperature are quantified using the square root error variance (SREV) method, a standard error metric regarded as the conditional total standard deviation of the variable of interest. According tothis study, model uncertainty is the largest contributor to uncertainty when it comes to long-term sea surface temperature (SST) projections, followed by scenario and ensemble uncertainties.

Keywords: CMIP6, Extreme Precipitation, ENSO, IOD, Uncertainty

Understanding rapid intensification of tropical cyclones in the Bay of Bengal through Energetics

Gokul Suresh[1], Sarvesh Dubey[2*], Nirupam Karmakar[3]

[1]Indian Institute of Science Education and Research (IISER) Tirupati, Andra Pradesh, India

[2]Centre for Atmospheric Sciences (CAS), Indian Institute of Technology (IIT) Delhi, New Delhi, 110016, India

[3]School of Earth, Ocean, and Climate Sciences, Indian Institute of Technology (IIT) Bhubaneswar, India

ABSTRACT

Rapid intensification (RI) of tropical cyclones (TCs) is challenging to understand and predict. RI TCs often result in extreme natural hazards in coast regions. Understanding the associated energetics in RI TCs and differentiating it from non-RI cases provides insight in these extreme events. This study investigates the dynamics and energetics of TCs that underwent RI and non-RI TCs between 2005 and 2023 in the Bay of Bengal (BoB). Leveraging IMD Best track and ERA5 reanalysis data, Eulerian and quasi-Lagrangian frameworks were employed to study the energetics of TCs. Results shows that the quasi- Lagrangian energetics framework demonstrates a more pronounced representation of RI intensity, particularly highlighting the rapid increase in EKE, which significantly differs from the Eulerian method. Therefore, we advocate use of quasi- Lagrangian framework for detecting RI using energetics. Results also reveal that warm ocean regions serve as primary energy sources for RI, with the baroclinic conversion term emerging as the dominant driver of Eddy Kinetic Energy (EKE) during intensification phases. The study delineates distinct RI and non-RI TC trajectories, with RI TCs showing poleward movement and non-RI TCs predominantly moving westward. Analysis of composite sea surface temperature (SST) anomalies reveals correlations with RI TC tracks, indicating a positive anomaly during RI phases. This distinction underscores the relevance of RI and its intricate energy dynamics, emphasizing the importance of baroclinic conversion in driving cyclone intensification. This comparative analysis between these frameworks sheds light on the complexities of cyclonic energy cycles and underscores the quasi-Lagrangian framework's efficacy in capturing subtle yet critical variations in RI dynamics.

ASSESSING THE PERFORMANCE OF WRF MODEL IN SIMULATINGSEVERE HAILSTORM EVENTS OVER ASSAM AND BIHAR, INDIA

Bhavyasree[a], S. K. Panda[a],

Gitesh Wasson[a,b], Unashish Mondal[a], Anish Kumar[a,c], Devesh Sharma[a]

[a] *Department of Atmospheric Science, School of Earth Sciences, Central University of Rajasthan, Bandar Sindri, Kishangarh, District: Ajmer, State: Rajasthan, India (305817)*

[b] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*

[c] *Institute of Meteorology, Leipzig, Germany*

E-Mail: bhavyasree012016@gmail.com

ABSTRACT

This study investigates the performance of the Advanced Research Weather Research and Forecasting (WRF-ARW) model in simulating two severe hailstorm events. The simulation period covers the post-monsoon and pre-monsoon hailstorm events of 26 December 2022 in Assam and 19 May 2022 in Bihar, respectively, with a continuous model integration of 48 h. The WRF modelis integrated on a double nested domain of 9 and 3 km horizontal resolutions using the Milbrandt 2-moment microphysical and Kain Fritsch cumulus schemes. Critical analyses include the mixing ratio of hydrometeors, maximum reflectivity, wind magnitude and direction, temperature contours,and relative humidity. The results were validated using ERA-5 reanalysis data. Instability indices such as Convective Available Potential Energy (CAPE), Total Totals Index (TTI), and Significant Hail Parameter (SHIP) are evaluated to assess the hailstorm environment. The hail mixing ratio peak between altitudes 600–700 hPa suggests a significant presence of hail in the mid-troposphere.A high-level jet was observed during the Assam event. The SHIP value calculated from the model output for the Assam event was 0.1, indicating a non-significant hail environment. In contrast, for Bihar, the SHIP value was 2.0, suggesting a significant hail environment. Despite a CAPE valueof approximately 500 J/kg for the Assam event, typically not indicative of severe thunderstorms, hail occurred. The CAPE value of around 3000 J/kg in Bihar indicated severe thunderstorm conditions. The WRF could reasonably simulate both hailstorm events with the selected configuration.

Keywords: Hailstorm, Hailstorm indices, WRF-ARW model, Model skill score

Imrpoving Convective Afternoon Rainfall Prediction using 4D-Var Assimilation over a Region with Dense Ground-Based Observations

Francis Babu[1], Govindan Kutty[1] and and V. Rakesh [2]

[1]*Department of Earth System Science, Indian Institute of Space Science and Technology*
[2] *Council of Scientific and Industrial Research, Fourth paradigm Institute (CSIR-4PI)*

E-Mail : francisbmadassery@gmail.com

ABSTRACT

Predicting convective afternoon rainfall is challenging due to its short-lived nature and small spatial extent. Previous studies have shown that forecasted rainfall is often overestimated, largely because of insufficient high-resolution surface observations. In this study, we focus on Karnataka as the domain, where over 6,000 telemetric weather stations are deployed to collect a dense network of surface observations, including 2-m temperature, 2-m relative humidity, wind speed, and wind direction. Using the advanced 4D-Var assimilation method, we incorporate this data, resulting in reduced rainfall bias and improved accuracy in forecasting 2-m temperature and surface humidity. However, despite these improvements, the root mean square error (RMSE) for temperature and humidity profiles did not show a significant reduction, likely due to the lack of upper-air observations. To address this gap, satellite-derived temperature and humidity profiles of INSAT-3DR were assimilated along with surface observations, leading to a substantial reduction in errors for predicted temperature and humidity profiles. This integration also enhanced the skill of forecasting afternoon thunderstorms. Overall, the assimilation of both surface and upper-air observations significantly improves the accuracy of convective rainfall predictions, offering promising results for short-term weather forecasting in the region.

Keywords: Convective rainfall, 4D-Var assimilation, surface observations, satellite-derived profiles

Interannual Variation of summer Heat Content of the Tropical Indian Ocean during 1872-2010

Amit Sharma [a,b], Anant Parekh[a], Rahul U. Pai[a], Jasti Chowdary[a]
and

C. Gnanaseelan[a]

[a]Indian Institute of Tropical Meteorology, Pune-411008, India

[b] Academy of Scientific and Innovative Research (AcSIR),
Ghaziabad- 201002, India

E-Mail: amit.sharma@tropmet.res.in

ABSTRACT

Ocean Heat Content (OHC) plays a crucial role in influencing weather patterns and climate. Despite its significance, the interannual variation of OHC in the Tropical Indian Ocean for longertime period remains underexplored. This study investigates the temporal variability of OHC usingthe SODA dataset, spanning from 1871 to 2010. To ensure the reliability of the dataset, we compared it with various analysis and reanalysis products, including EN4, ISHI, and ORSS5 for the common period, with respective correlation of 0.63, 0.77, and 0.66. The analysis revealed thatthe standard deviation of OHC is highest during the summer season, with a value of 7×10^{22} J. Based on this standard deviation criterion, years with OHC anomalies greater than 1 standard deviation were classified as positive years, while those with anomalies less than 1 standard deviation were identified as negative years. We identified 25 positive years and 21 negative years within the study period. The significant (at 95% confidence level) anomalies are predominantly located in the southwest tropical Indian Ocean. The 20°C isotherm depth (D20) for positive and negative composite years reflected similar variations to OHC, with D20 being deeper in positive years and shallower in negative years. Additionally, sea level anomalies showed consistent patterns with higher sea levels in positive years and lower sea levels in negative years. Furthermore, heat flux anomalies indicated no significant changes among positive and negative years, suggesting that over the Tropical Indian Ocean, heat flux plays a minimal role in OHC variability. We also conducted model experiments using MOM5, which showed similar OHC variations across the Tropical Indian Ocean and similar standard deviation patterns, consistent withthe results obtained from the SODA, EN4, ISHI, and ORSS5 datasets. The composite analysis of the model fields yielded conclusions similar to different analysis and reanalysis datasets. Detailedinvestigation provides more insights into the underlying mechanisms responsible for these variabilities.

Keywords: Oceanic Heat Content; Monsoons; Climate Variability; Reanalysis; Tropical Indian Ocean

Temporal and Intensity Dynamics of Fog across the Indo-Gangetic Plain: A Multi-Decadal Analysis from 1991 to 2024

Prathima Deevi [a], ANV Satyanarayana [a],
[a] Centre for Ocean River Atmosphere and Landsciences,
Indian Institute of Technology, Kharagpur
E-Mail:prathimadeevi55@kgpian.iitkgp.ac.in

ABSTRACT

This study presents a comprehensive analysis of fog trends over the Indo-Gangetic Plain region, focusing on five key airport stations: Amritsar, Delhi, Lucknow, Patna, and Gaya. Employing hourly visibility data from METAR reports and the modified Mann-Kendall test, we analyzed fog duration and frequency across the Indo-Gangetic Plain from 1991 to 2024, with a particular emphasis on different categories of fog intensity (shallow, moderate, dense, and very dense) and seasonal variations (November to February). Our findings reveal significant increases in fog occurrences, particularly in Delhi and Amritsar. The analysis shows that January experiences the most substantial rise in fog hours and days across all intensities, making it the most affected month. Shallow and moderate fog trends are prominent in the early winter months, whereas dense and very dense fog peaks in January and February. Delhi emerges as the most fog-prone city, with notable increases in fog intensity and duration. The results indicate a discernible shift in fog hours, with some regions experiencing an increase in fog days while others show a decrease. Amritsar and Delhi exhibit a significant reduction in very dense fog days, suggesting a potential impact of urbanization and pollution control measures. Conversely, regions like Gaya show a notable increase in dense fog days, highlighting the influence of local climatic factors. Temperature trends associated with fog intensity reveal complex patterns. The data and trends identified in this study are crucial for policymakers and urban planners, particularly in designing strategies to combat visibility-related disruptions in the Indo-Gangetic Plain.The study provides valuable insights for policymakers and meteorologists to understand the evolving nature of fog and its implications on transportation, agriculture, and public health in India.

Keywords : Fog, Indo-Gangetic Plain, METAR, Mann-Kendall test.

Projection of tropical cyclone frequency over the Bay of Bengal in the near future

Biswajit Jena*, Vineet Kumar Singh, Anant Parekh, and C. Gnanaseelan
Climate Variability and Prediction,
Indian Institute of Tropical Meteorology,
Ministry of Earth Sciences, Pune 411008, India
**E-Mail: biswajit.jena@tropmet.res.in*

ABSTRACT

The Bay of Bengal hosts 4% of the global cyclone activity, despite the low frequency of cyclones they pose a significant threat to the densely populated coastlines of Bay of Bengal rim countries. In the satellite era (since the 1980s), cyclone activity in the basin during the premonsoon season (April-June) and the post-monsoon season (October-December) is nearly constant. However, the future projection of cyclones in the near future (2015-2050) using a highresolution CMIP6 model reveals a contrasting difference between the pre-monsoon and the postmonsoon seasons. The frequency of cyclones during the post-monsoon season is projected to increase by ~13%, whereas in the pre-monsoon season, it is projected to decrease by ~22%. The projected increase in the TC frequency in the basin during the post-monsoon is attributed to the increase in low-level relative vorticity, mid-tropospheric relative humidity, and upper ocean heat content throughout the basin. However, the projected decrease in cyclone activity during the premonsoon season is mainly due to the atmosphere's unfavorable dynamic and thermodynamic conditions. These seasonal contrasts in the projected changes in cyclone frequency highlight the contrasting influence of global warming on cyclone activity in this basin. This study may assist with the adaptation pathways and implications for the regional scale climate change in the basin.

Keywords: Bay of Bengal, cyclone frequency, future projection, CMIP6

.

Deciphering Urbanization and Climate Change led Thermal Signatures over the Smart City Bhubaneswar using Urban Scale Model Simulations

Nandini Gopinath[a] & V Vinoj[a],

[a] *School of Earth Ocean and Climate Sciences, IIT Bhubaneswar*

E-Mail:ng18@iitbbs.ac.in

ABSTRACT

Urban areas experience heightened climate change effects due to dense infrastructure, heat-retaining surfaces like concrete and asphalt, and high population density. Alongside infrastructure and connectivity, it is essential to prioritize climate resilience when developing smart cities. A key initial step in this process is to separate and quantify the effects of climate change and urbanization on changes in the urban microclimate. Smart city Bhubaneswar is a rapidly urbanizing tier-II city which is one among the first in the list of smart cities to be developed under the smart cities mission program. Previous studies have confirmed a discernible urban heat island over the city of Bhubaneswar getting amplified with the expansion of the city. Model simulations, conducted across all seasons for the years 2004 and 2015, show nighttime warming of approximately (1.02±0.8)°C over the city. The high standard deviation suggests that this warming is uneven, with the most significant increases occurring in the city's rapidly growing peripheral areas. When the overall warming was broken down into regional climate change effects and local urbanization impacts, it was found that regional effects caused a spatially uniform cooling of about (-0.13±0.09)°C. This cooling was countered by urban-induced warming of approximately (1.16±0.8)°C, with the most significant warming observed at the urban peripheries. Regional cooling was observed during the months of January and March-June, while urbanization consistently contributed to warming throughout the year. During dry periods (winter and pre-monsoon), regional and urban effects counteracted each other, moderating the warming. However, during wet periods (monsoon and post-monsoon), both regional and urban effects contributed to the temperature rise. The regional cooling can be attributed to the strengthening of the low-level zonal winds from the ocean during nighttime.

Keywords: Urbanization; Climate change; Temperature Changes

Mercury Emissions from Industrial Processes and Other Unattended Sectors in India: A Quantitative Study

Ashirbad Mishra[a], Saroj Kumar Sahu[a], Poonam Mangaraj[b]

[a] Dept. of Environmental Science, Berhampur University, India

[b] Research Institute for Humanity and Nature (RIHN), Kyoto, Japan

E-Mail: ashirbadmishra10@gmail.com

ABSTRACT

Hazardous pollutants like Mercury (Hg) have emerged as a pressing challenge in recent times where the expanding industrial sector is regarded as the major source in developing countries like India. In this study, we are trying to identify all possible industrial sectors to quantify the Hg emission load across India for the year 2019 using IPCC methodology where the country-specific technological emission factors are used. We have included 5 major sectors out of which emission from coal combustion in thermal power plants accounts for 186.5 t/yr of Hg emission followed by non-ferrous metal production (88.3 t/yr), captive power plants (65.5 t/yr) and fly ash generation from various manufacturing industries (45.9 t/yr). A total of 459.4 t/yr of Hg was released to the atmosphere in 2019 with an uncertainty of ± 48 %. This study also estimated that about 233 million people living in the 10 km periphery of major industrial zones and as many as 17 million people residing near the 10 major hotspots are susceptible to hazardous Hg emissions directly or indirectly. This information will be quite useful in formulating future Hg emission control strategies in India.

Keywords: Mercury emission, fossil fuel, industrial sources, solid waste, crop residue burning.

Climatology of Rapid Intensification of Tropical Cyclones over North Indian Ocean during 1990-2019

Krishna Mishra[a], Mrutyunjay Mohapatra[b]
[a,b] India Meteorological Department
krishhindustan@gmail.com

ABSTRACT

A Tropical Cyclone (TC) is said to undergo Rapid Intensification (RI) if its maximum sustained surface wind speed increases by 30 knots or more during past 24 hours. This exponentially enhances damage causing capacity of a TC. The prediction of RI of TC is still challenging by the numerical weather prediction model. This is why RI of TCs over the North Indian Ocean (NIO) has been major cause of concern for Weather Forecasters as well as for Disaster Managers. In this study, an attempt has been made to study the RI of TCs over the NIO based upon the best track data for the period 1970-2019. We have attempted to demarcate the climatological area of RI over both the basins namely Bay of Bengal and Arabian Sea. T No., Maximum Sustained Surface Wind, Estimated Central Pressure and Central Pressure drop for Rapidly intensifying TCs over both the basins have been calculated and analyzed. The above characteristics of RI have further been analyzed for two different cyclone seasons viz., Post monsoon (OND) and Pre monsoon (MAM) Seasons. The dynamical parameters of all the RI TCs for both the basins and both the seasons have also been calculated for the period 2000-2019 using CIMSS data. For the Pre monsoon Season, the RI region over Arabian Sea shifts northwards by about 2° latitude as compared to that in the Post-monsoon Season. For the Bay of Bengal the reverse is true, i.e. in the Pre monsoon season, the RI region shifts southwards by about 2° latitude and also westwards by about 1.5° longitude. The spread of RI location from the mean center of the RI over the Bay of Bengal is almost halved during the Pre monsoon season as compared to that in the Post monsoon season whereas for the Arabian Sea it remains almost same for both the seasons. The RI region over Bay of Bengal is smaller during the Pre monsoon season. This study can provide climatological guidance to predict RI of TC and help in interpreting the numerical guidance from models for prediction of TC.

Keywords: Tropical Cyclone, Rapid Intensification, North Indian Ocean.

Performance evaluation of different PBL and microphysics parameterizations in WRF for simulating pre-monsoon thunderstorms over Delhi-NCR

Debjyoti Roy[a] and Jagabandhu Panda[a]

[a] Department of Earth and Atmospheric Sciences. NIT Rourkela
E-Mail:debjyotiroy8617@gmail.com / jagabandhu@gmail.com

ABSTRACT

The present study evaluates the performance of three different planetary boundary layer (PBL) schemes, i.e., Mollar-Yamada-Jenjic (MYJ), Yonsei University (YSU), and the Asymmetric Convective Model version 2 (ACM2) and four microphysics (MP) schemes, i.e., Lin, WRF Single Moment (WSM6), WRF double moment (WDM6) and Thomson over Delhi National Capital Region (NCR). For this purpose, a composite analysis of 10 different thunderstorm cases occured during 2008 to 2020, has been considered. ECMWF 5th generation reanalysis (ERA5) highresolution initial and boundary conditions have been provided to the WRF model for this purpose. Global Precipitation Measurement (GPM) and IMDAA reanalysis datasets have been used for validation purposes. The study highlights that for the simulation of precipitation and 10 m wind speed, YSU scheme performs better than the other two. For temperature and relative humidity prediction, the performance of ACM2 and MYJ, respectively, is found to be better. Accordingly, YSU PBL is considered for carrying out the MP sensitivity, and the results indicate that the Lin scheme could capture the temporal variability and intensity of precipitation better than the other three schemes. WSM6 also performs considerably well. However, all the simulations exhibited poor spatial distribution of rainfall pattern. Thus, the study infers that a combination of YSU PBL and Lin MP schemes could be used in the further studies for thunderstorm simulations over Delhi NCR and its neighborhood.

Keywords: Thunderstorm, PBL, Micro Physics, Sensitivity

Evaluation of total column ozone measurements from INSAT-3D/3DR with satellite-based AIRS and CAMS reanalysis data

P. Sangeetha [1,2], G. S. Gopikrishnan[1], J. Kuttippurath[1*], P. K. Thapliyal[3]
[1] *CORAL, Indian Institute of Technology Kharagpur, Kharagpur–721302, India.*
[2]*Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi – 682508, kerala, India.*
[3]*Space Applications Centre (SAC), Indian Space Research Organisation (ISRO), Ahmedabad, India*
** To whom correspondence should be addressed.*
Email: jayan@coral.iitkgp.ac.in

ABSTRACT

Total column ozone (TCO) has been monitored for nearly a century, with recent research focusing on ozone depletion and recovery. Validation of satellite measurements is essential for ensuring accuracy and reliability of the data to be used for scientific studies and thus, to understand the atmospheric processes and to make policy decisions aimed at environmental protection and public health. This study validates TCO measurements from the Indian geostationary satellites INSAT- 3D (2017–2019) and INSAT-3DR (2019–2023) by comparing them with Atmospheric Infrared Sounder (AIRS) satellite measurements and the Copernicus Atmosphere Monitoring Service (CAMS) reanalysis data. INSAT-3D data have a homogenised distribution, with values generally between 265 and 270 DU, which peaks at 275 DU in the northern India. Seasonal analysis indicates the highest TCO during premonsoon (MAM-March, April, May) around 280 DU and the lowest during the monsoon (JJA-June, July, August) around 220 DU. The INSAT-3DR data show consistent TCO of around 240 DU over the southern peninsular regions, which increases to 270– 280 DU in the northernmost India. Comparison with AIRS and CAMS data show that INSAT-3D overestimates TCO (5–15 DU), particularly in the northwestern and central India, whereas INSAT- 3DR shows a negative bias by about 5–20 DU. Furthermore, INSAT-3DR also shows improved correlation in comparison with AIRS and CAMS. For instance, in peninsular India, it is about 70% and 66% for CAMS and AIRS, respectively. Therefore, in general, the INSAT measurements are accurate within ±15–20 DU or 5% when compared to AIRS and CAMS data, and are comparable to other satellite and ground-based instruments.

Keywords: Total Column Ozone; India; INSAT; Validation; AIRS; CAMS

Trends in extreme precipitation indices over the mountainous regions of northwest Himalaya

Kritika Nag[a], Vartika Sharma[a], Veluswamy Venkatramanan[a] , M.S. Shekhar[b]

[a]*School of Interdisciplinary and Transdisciplinary Studies, Indira Gandhi National Open University, Maidan Garhi, New Delhi*

[b]*Defence Geoinformatics Research Establishment, Defence Research and Development Organisation, Sector 37A, Chandigarh*

E-Mail: kritikanag21@gmail.com

ABSTRACT

The Northwest Himalaya are particularly vulnerable to excess rainfall due to their steep topography and complex climatic variations. Significant hydro meteorological hazards such as heavy snowfall, hailstorms, floods and droughts are triggered by erratic precipitation both on long and short-term basis. Climate change with an increase in frequency and intensity of these extreme weather events is making the areas increasingly vulnerable and creating significant challenges for infrastructure, agriculture and disaster management. HAR v2 dataset, which is a model output dataset of WRF model, is used for the period of 1981-2020, at a resolution of 10 km has been used in the present study to examine the trends in precipitation over the region in the context of present climate change and global warming. All the extreme precipitation indices as defined by Expert Team on Climate Change Detection and Indices (ETCCDI) have been used for the study. Co-relation coefficient between IMD 4 and HARv2 datasets was found to be 0.92, which establishes the reliability of the HAR v2 dataset for further study over these mountainous regions of Northwest Himalaya. Mixed trends are observed for different indices over the regions and have been discussed in the study. Consecutive wet and consecutive dry days (CWD & CDD) show slightly increasing trends over the period, while R95p & Rx5day show slightly decreasing trends, though the results are not statistically significant. Increasing trend of CDD and CWD suggests the need to manage and regulate water resource, pointing towards increased likelihood of floods and droughts. The study brings light to the urgency of protecting the fragile region from the effects of climate change, and also paying attention towards resource allocation and more region specific analysis.

Keywords: Extreme precipitation, ETCCDI, trend analysis, climate change.

FUTURE-READY CLIMATE INTELLIGENECE: INTEGRATING 4D-Var WITH ARTIFICIAL INTELLIGENECE FOR NEXT-LEVEL FORCASTING IN THE INDIAN SUBCONTINENT

Shanthababu Pandian 1[a], Shanthakumar Pandian 2[b],
[a] *Director (Data and AI), [a]Rolan Software and Consultancy solutions, London, England, United Kingdom.*
[b]*S-Square dot AI Engineering and Technologies, Chennai, Tamil Nadu, India.*
E-Mail: 1 pandian.shanthababu@gmail.com

ABSTRACT

The Indian subcontinent faces increasing threats from severe climate extremes driven by global climate change, including intensified floods, cyclones, and heatwaves. To effectively address these challenges, advanced forecasting and mitigation strategies are essential. This study explores how integrating 4D-Variational Data Assimilation (4D-Var) with Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) technologies can revolutionize real-time climate forecasting and disaster management. The 4D-Var enhances weather models by incorporating time-series observational data, but traditional methods struggle with the complexity of evolving climate systems. By integrating AI and ML techniques, which analyses extensive real-time data from Internet of Things (IoT) sensors—such as ground stations and drones—the accuracy of forecasts is significantly improved. For instance, during some southern States's floods, the integration of real-time data with deep learning models could have provided more accurate flood predictions. Similarly, cyclones can benefit from AI/ML-enhanced 4D-Var for precise storm tracking and effective evacuation planning.

This approach can improve predictions of extreme weather events and inform precautionary measures. DL models can improve forecasts of heatwaves and monsoon patterns, thereby enhancing disaster preparedness and risk mitigation strategies. Comparing with global climate data, while international models face similar challenges, regional adaptations like those proposed for the Indian subcontinent offer tailored solutions. Integrating 4D-Var with AI, ML, and DL provides a more detailed and responsive approach to climate prediction, aligning with global advancements. This integration offers a robust framework for improving climate resilience in the Indian subcontinent, providing enhanced forecasting accuracy and disaster preparedness in the face of growing climate impacts.

k**eywords:** 4D-Var; Artificial Intelligence; Climate Extremes; Weather Forecasting; Disaster Management.

Mapping of particle pollution and analysis of different atmospheric constituents

Adarsh Kumar Sharma[a], Siddhartha Singh[b] And Chirashree Ghosh[a]

[a]*Department of Environmental Studies, University of Delhi, Mall Road, Delhi-110007*

[b]*India Meteorological Department, Mausam Bhawan, Lodhi Road, New Delhi-110003*

Corresponding author: chirashreeghosh.63@gmail.com *Presenting author:* adarshs040@gmail.com

ABSTRACT

The spatio-temporal variations of Particulate Matter (PM_{10} and $PM_{2.5}$) and Black Carbon (BC) were studied for the eight SAFAR monitoring sites based on the observations of Ministry of Earth Sciences sponsored SAFAR programme over a period of nine year (2014-2022) and five year (2014-2018) respectively. Further, the relation between radiative forcing and optical properties of Aerosol Optical Depth (AOD) with Black Carbon (BC), Total Columnar Ozone (TCO), Incident Solar Radiation (ISR) were investigated under pre-monsoon and post-monsoon conditions based on the observations of the MERRA-2 model for two SAFAR monitoring sites in Delhi over a period of thirteen year (2005-2018). The results show that the concentrations of particulate matter (PM_{10} and $PM_{2.5}$) are found to have highest values at North Delhi sites (CV RAMAN and DU) and minimum at South West Delhi (IGI Airport) and South Delhi (IMD Aya Nagar) sites. Temporal variation of PM_{10} has showed that out of the nine studied years (2014-2022), most polluted year was 2016. Unlike the spatial trend reported for the PM pollution, BC concentration showed opposite trend with high concentration at South Delhi site (IMD Aya Nagar) compared to North Delhi (CV RAMAN) during a five year monitoring period (2014 to 2018). The study also reported that AOD over Delhi was high during pre-monsoon season as compared to post-monsoon season during a thirteen year period (2005-2018). It was also observed that AOD over Delhi has positive correlation with BC because BC aerosols warm the Earth by “positive forcing” but negative correlation with ISR and TCO confirms that BC aerosols reduce the albedo through “negative forcing” and produce cooling effect on the surface by decreasing ISR; in effect, reduce TCO which immensely affect the atmospheric physical and chemical processes.

Keywords: Aerosol Optical Depth, Incident Solar Radiation, Monsoon, Particulate Matter, Total Columnar Ozone

Solar influence on Climate change over Indian subcontinent: Analysis and impacts

Vijai Kumar [a,b], Abhishek Singh [a], Somnath Mahato [a], Anjit Anjan [a], Lakshi Prosad Roy [b], and S. M. Hiremath [b]
[a] *India Meteorological Department, Pune*
[b] *Department of ECE, NIT Rourkela*
E-Mail: vijai.imd@gmail.com

ABSTRACT

Analysis of long-term solar radiation data reveals significant impacts of climate change, including severe weather events such as heat waves, cloud bursts, and altered rainfall patterns. These changes are evident through variations in diurnal temperature ranges, shrinking Himalayan glaciers, and increased uncertainty in rainfall, leading to floods and droughts in various regions. This also affects agriculture and biological systems. The Central Radiation Laboratory (CRL) in Pune, under the India Meteorological Department (IMD), manages a network of 47 radiation measuring stations accredited by the World Meteorological Organization (WMO). These stations track critical parameters such as global, diffuse, direct, and terrestrial radiation, as well as UV A and UV B irradiation. Recently, CRL has enhanced its monitoring to include continuous assessment of terrestrial radiant energy and biologically significant UV levels.

In the Indo-Gangetic Plain (IGP), high levels of air pollution from sources like biomass burning, waste disposal, and automobile emissions exacerbate the impacts of climate change. Monitoring solar radiation across India is crucial for various applications, including solar energy utilization, photovoltaic systems, meteorology, and climate research. This data supports advancements in solar energy applications and helps address health issues linked to pollution, such as gastrointestinal diseases and respiratory infections.Climate change is not gender-neutral and has profound cultural implications, affecting societal structures at local levels. While climate change is a global issue driven largely by human activities, mitigating its impacts requires localized actions. Addressing these challenges involves a concerted effort to slow the pace of climate change and adapt to its effects on communities and ecosystems.

Keywords: Solar radiation; Ultraviolet ; Climate change; Weather Prediction;

Role of Tropical Subseasonal Variability on Future Projection of Frequency and Intensity of Indian Heatwaves

Tukaram Zore, Ankita Singh, Kiranmayi Landu
School of Earth Ocean and Climate Sciences,
Indian Institute of Technology Bhubaneswar

Email: **ztc10@iitbbs.ac.in**

ABSTRACT

Heatwaves are among the most severe weather extremes in India, posing significant risks to public health, agriculture, water resources, and energy supply. In recent decades, the frequency, duration, and intensity of heatwaves in India have increased due to both anthropogenic climate change and natural variability. As global temperatures continue to rise, understanding future heatwave characteristics is crucial for developing effective adaptation and mitigation strategies. In addition to global warming influence, the characteristics of heatwaves are also influenced by other large scale climate variability. While much research has focused on the role of tropical subseasonal variability in modulating weather extremes such as rainfall and cyclones, the impact of these subseasonal oscillations on heatwaves remains underexplored. This study examines how these tropical subseasonal variability, including the Boreal Summer Intraseasonal Oscillation (BSISO), Equatorial Rossby (ER) waves, Equatorial Kelvin waves, Mixed Rossby-Gravity waves, and Tropical Depressions (collectively termed "MT waves") will influence future Indian heatwaves using 15 CMIP6 models. The future projections span the period from 2019 to 2099, which is divided into three epochs: near-future (2019-2045), mid-future (2046-2072), and far-future (2073-2099), under three different CMIP6 scenarios (SSP126, SSP245, and SSP585). Our results show that the Equatorial Rossby wave has the most significant influence on heatwave frequency. The dry phase of the ER wave increases the probability of heatwave events across all three epochs, with a more pronounced impact on eastern India. This influence is especially enhanced under the SSP585 scenario and far future. Other tropical subseasonal variability also shows increased heatwave frequency in the future compared to climatology. Further the presence of the dry phase of waves leads to an increase in heatwave intensity compared to climatology. These findings suggest that, alongside global warming, large-scale climate variability will play a crucial role in intensifying both the frequency and intensity of future heatwaves, highlighting the importance of natural drivers in future heatwaves modulation.

Keywords: Extreme weather events; Heatwave; Intraseasonal Oscillation; CMIP6

Numerical modelling of extreme waves in one dimension along coastal Bay of Bengal

Sohaniya Mandal[a], T.K. Saha[b], and T.K. De[a]
[a] *Department of Marine Science, University of Calcutta, 35, B.C. Road, Kolkata-700019, India*
[b] *Department of Mathematics, Surendranath College, 24/2 M.G. Road, Kolkata 700009, India*
E-Mail: sohaniyamandal@gmail.com

ABSTRACT

An extreme wave is a rare natural phenomenon resulting from extreme weather events. Tsunamis and cyclones are such events that generate extreme waves in coastal regions. These extraordinary extreme waves pose significant threats to coastal communities, maritime operations, and offshore structures, highlighting the need for advanced monitoring techniques to understand their propagation nature better.

Extreme waves can be modelled appropriately using Shallow Water Equations (SWE's). Here we have tried to develop a numerical model to simulate the propagation of extreme waves in one dimension numerically. These equations have been discretized using the Crank-Nicolson scheme of Finite Difference Method (FDM) for the spatial domain and the forward difference method for the temporal domain. A basic sample model with five grid points is demonstrated to explain model development. MATLAB code has been generated using both linear and nonlinear (considering friction and convection) shallow water models with appropriate initial and boundary conditions for obtaining results for some representative bathymetry. The effect of these extreme waves is visible along shallow water region where depth is less than wave length of water near coast. Computational results successfully show that the wave height increases with time as the wave approaches the shore.

To obtain the wave propagation results along real bathymetry profile of off-coast of Puri, Odisha, bathymetry data is obtained from GEBCO data source. Comparative results of wave height and speed obtained with both linear and non-linear models are presented.

Keywords: Shallow Water Equation, Finite Difference Method, MATLAB, GEBCO, Extreme Weather Events.

Particulate Matter Shifts in India’s Expanding Urban Areas Over the Last Two Decades (2000-2020)

Rohan Anand[a*], Amarendra Singh[a] and Sagnik Dey[a]
[a]*Centre for Atmospheric Sciences, Indian Institute of Technology, Delhi-110016*
E-Mail: anand00rohan@gmail.com

ABSTRACT

Human settlements are rapidly changing due to factors like population and economic growth, urban transformation, and rural-urban migration. Urbanization drives rapid growth in both large and smaller cities, leading to challenges like air pollution, unplanned development, and increased demand for transport and energy. In middle-income countries like India, with limited land and a large population, spatial growth driven by demand for services is a key factor in the recent rise in $PM_{2.5}$ levels. Present study assesses the change in human settlement during 2000-2020 using global human settlement layer (GHSL) data and corresponding change in satellite derived $PM_{2.5}$ concentration during the period. GHSL data is available for every 5 years, therefore the analysis is done for years 2000, 2005, 2010, 2015 and 2020. In 20 years (2000-2020), the $PM_{2.5}$ concentration increased by nearly 47.17% across the country. GHSL has divided human settlement into eight categories based on human presence. We found that ‘very low density rural’ areas, which covered 61% of total geographical area in 2000, declined to 52.29% in 2020, and there is an increase of 11.65 µg/m^3 in $PM_{2.5}$ concentration. The ‘urban centre’ became double in area within that time frame that led to an increase in $PM_{2.5}$ concentration from 36.12 to 56.13 µg/m^3. Even though ‘low density rural’ areas, which covers most geographical areas after ‘very low density rural’, did not change much (grew by ~ 1%) in 20 years, the $PM_{2.5}$ concentration increased drastically from 30.87 to 45.64 µg/m^3. Similarly, the waterbody was almost unchanged (decreased by 0.013%) during the time frame but $PM_{2.5}$ levels increased 33.54 to 51.71 µg/m^3. This shows that even areas with minimal population growth or spatial expansion experienced significant increases in air pollution, likely due to factors such as industrialization, increased vehicular emissions, and agricultural activities. These findings highlight those not only urban areas, but also rural regions are contributing to the rise in $PM_{2.5}$ levels during last two Decades.

Keywords: Particulate Matter, Human Settlement, Urbanization, Air Pollution.

Machine Learning-Based Identification of Convective Clouds Using INSAT-3DR Data and Lightning Detection

Amee Chhatbar[a], Abhishek Chhari[b]

[a]*Computer Science, Indus University,*

[b]*SAC, ISRO*
E-Mail: chhatbaramee3@gmail.com

ABSTRACT

Convective clouds, which are closely linked to severe weather events such as thunderstorms, heavy rainfall, and lightning, play a critical role in the atmospheric system. Accurate identification and monitoring of these clouds are essential for improving weather prediction models and mitigating the impacts of extreme weather. In this study, we developed a machine learning model to identify convective clouds using data from the INSAT-3DR satellite, aiming to enhance real-time weather monitoring and forecasting capabilities.

We trained the model using ground-based lightning detection sensor data, which provided labeled data. Since lightning is strongly correlated with convective clouds, it served as an effective indicator for training the model. The input features included all available bands from the INSAT-3DR satellite, along with two Brightness Temperature Differences (BTDs): (TIR1 TIR2) and (WV - TIR1). We selected these BTDs based on their relevance in detecting cloud top temperatures and water vapor content, both of which are key indicators of convective activity.

To ensure robust training and validation, we utilized five months of lightning data, from June 2022 to October 2022. We employed feature extraction techniques to identify the most correlated parameters, bands, and BTDs with lightning activity, refining the model's predictive accuracy. Additionally, we used symbolic regression to uncover interpretable relationships between the input features and lightning density, providing deeper insights into the physical processes linking convective clouds and lightning occurrence.

Our machine learning model reliably identified convective clouds, offering a valuable tool for real-time weather forecasting and early warning systems. By integrating satellite data and lightning observations, the model shows significant potential for operational meteorology, particularly in regions prone to severe weather. This capability enhances preparedness and response efforts, ultimately reducing the risks associated with extreme weather conditions.
Special acknowledgement to Dr. Alok Tawari from NRSC and data provided through the Bhoonidhi portal of NRSC.

Keywords : Convective Cloud, Lightning, INSAT-3DR, Machine learning

Classification of aerosols using machine learning algorithm

[1]Prathamesh Sanjay Kadam, [2]Shantikumar S. Ningombam*, [2]Swagata Mukhopadhyay, [3]Amoghavarsha A. V.

[1]Sardar Vallabhbhai National Institute of Technology, Surat, India
[2]Indian Institute of Astrophysics, Bengaluru, India,
[3]Indian Institute of Science Education and Research, Pune, India
Corresponding author's email: shanti@iiap.res.in

ABSTRACT

The current work reported about a spectral clustering method using k-means and Mahalanobis distance to enhance the correlation between data points and improve clustering accuracy. By incorporating the correlation coefficient as a weight, the method achieves more accurate clustering using Laplacian matrix eigenvectors. The application of this method to aerosol classification shows improved precision and reliability, highlighting its potential in effectively distinguishing different aerosol types. In order to apply the machine learning algorithm, we used ground based 17 stations of Aerosol Robotic Network (AERONET) data from African continent. The data used in the current work is cloud-screened, quality assured AERONET data product, Version 3.0 and Level 2.0 during October, 1995 to January, 2022. The clustering algorithm utilized five aerosol optical parameters from the inversion AERONET data product: fine mode Aerosol Optical Depth (AOD), EAE (Extinction Angstrom Exponent), SSA (Single Scattering Albedo), Absorption Angstrom Exponent (AAE), and RRI (Real Refractive Index). The study found that dust aerosols were dominated in the continent followed by biomass and mixed aerosol types. Our findings from the machine learning also compared with the results obtained from the threshold-based method. However, identifying aerosols of marine or continental origin remains challenging due to low AOD values
(less than ~0.20) in AERONET data, which limits the retrieval of complete aerosol optical parameters like SSA and Absorption AOD (AAOD).

Keywords: Aerosol, Single Scattering Albedo, Absorption Angstrom Exponent

Balancing Role of the Arabian Sea Mini Warm Pool in the ENSO-Monsoon Onset Relationship

Sankar Prasad Lahiri[a], Vimlesh Pant[a], Takeshi Izumo[b,c], and K R Prakash[a,d]

[a]*Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, India*
[b]*Institut de Recherche pour le Développement (IRD), UMR241 SECOPOL (ex-EIO) Laboratory, Université de la Polynésie Française (UPF), Tahiti, French Polynesia*
[c]*Sorbonne Université–CNRS-IRD-MNHN, LOCEAN, IPSL, Paris, France*
[d]*Applied Physics Laboratory, University of Washington Seattle, WA, USA*
E-Mail:sankarprasadlahiri2@gmail.com

ABSTRACT

Before the onset of the Indian Summer Monsoon, SST in the southern region of the Arabian Sea typically exceeds 28°C, a phenomenon often referred to as the Indian Ocean Warm Pool. However, the highest temperatures are observed in the southeastern Arabian Sea (SEAS) from late April to May, just before the Monsoon Onset in Kerala (MoK). These patches of warm water in the SEAS are often referred to as the Arabian Sea Mini Warm Pool (MWP). Previous studies have speculated that the MWP could impact the Indian Summer Monsoon (ISM) onset. Moreover, El Niño Southern Oscillation (ENSO) significantly dominates the MWP's interannual variability with a positive correlation of +0.8. Besides, ENSO possesses an inverse correlation with the MoK. Thus, the present study focuses on the potential influence of the MWP on the ENSO-MoK relation using a regional coupled atmosphere-ocean numerical model. The model is configured over the Arabian Sea for the years 2013 (MWP intensity was weak), 2016 (MWP intensity was strong), and 2018 (MWP intensity was close to climatology). The model results show minimal bias in the MWP region. Further, few sensitivity experiments have shown that without the presence of the MWP, the monsoon onset following an El Niño event will be further delayed. However, MWP intensity is weak after a La Niña event, and so is its influence on the MoK.

Keywords: Coupled atmosphere-ocean numerical model; Indian Summer Monsoon Onset; Arabian Sea Mini Warm Pool; El Niño Southern Oscillation.

Satarkabarta: Detect alert message services using NavIC signals

Somnath Mahato [a], *KS Hosalikar* [a], *Mritunjay Mahapatra* [b]

[a]*India Meteorological Department, Pune*
[b] *India Meteorological Department, New Delhi*
E-Mail: somnathmahato1@gmail.com

ABSTRACT

Navigation with Indian Constellation (NavIC) satellite system plays a crucial role in providing essential communication services to remote and difficult-to-access regions within India. One of its key applications is the Short Messaging Service (SMS), which is particularly valuable where traditional communication infrastructure like cellular networks or the internet are unreliable or absent. This capability is utilized by organizations such as the Indian National Centre for Ocean Information Services (INCOIS) and Indian Meteorological Department (IMD) to broadcast critical information to users, especially fishermen operating in open seas and other remote areas. The SMS service via NavIC satellites distributes messages related to Potential Fishing Zones (PFZ), cyclone warnings, high wave alerts, and other vital notifications. These messages are allocated specific message IDs based on the type of information and the urgency of communication required. For instance, disaster warnings and distress alerts receive higher priority, ensuring they are promptly broadcasted to the intended recipients. NavIC satellites, specifically NavIC 1A and 1E, handle the distribution of messages in a time-shared mode, optimizing resource usage and ensuring efficient delivery. High-priority messages may be broadcasted by multiple satellites simultaneously to expedite their dissemination and increase reliability. The system's design includes mechanisms for message staggering and distribution across satellites to manage bandwidth effectively and enhance coverage.

The software “Satarkabarta,” developed by Climate Research Services (CRS), IMD in Pune, utilizes NavIC 1A satellites to track and disseminate crucial weather information such as cyclone warnings and tsunami alerts. Using Satarkabarta software successfully Tracked Cyclone Michaung (November 2023), Cyclone Michaung (December 2023), and Cylone Remal (May 2024) from Automatic Weather Stations (AWS), and Meteorological Training Institute (MTI), Pune.

In essence, “Satarkabarta” service is a lifeline for users in remote areas, ensuring they receive timely and vital information that can significantly impact their safety and livelihoods, especially during weather emergencies and other crises.

Keywords: NavIC, Alert message, Cyclone Tracking, High-wave Alert, Potential Fishing Zone Climate Extremes over Indian Subcontinent in the Climate Change Context

Dynamics of SSW-Induced Cold Waves Over India: Insights from the Intense Cold Wave of January 2024

[a]Athira K S and [a]Raju Attada

[a]*Department of Earth and Environmental Sciences,*

Indian Institute of Science Education and Research Mohali,
SAS Nagar, Punjab
E-Mail: ph20044@iisermohali.ac.in

ABSTRACT

The winter of 2024 was notable for a prolonged cold wave (CW) in January over north India, which occurred without the association of a western disturbance activity. In our work, we found that this CW has a potential linkage with the sudden stratospheric warming (SSW), which disrupted the polar vortex and displaced cold Arctic air to lower latitudes across North Asia and Europe. This cold air mass moved to East Asia and settled over north India, as a result of a dipole atmospheric block in the Siberian-East Asian regions, where the ridge pushed cold air southward, causing the prolonged CW conditions. From 1982 to 2020, we found that similar SSW events led to CWs in 2004 and 2019, with atmospheric blocks forming post-SSW in all three cases. These blocks are enhanced by signals propagating from the stratosphere to the troposphere, making them a key feature of these CWs. Furthermore, to assess the impact of CWs on humans, we investigated the Universal Thermal Climate Index (UTCI) and Wind Chill Index (WCI) during the 2024 cold wave. Analysis reveals that significant cold stress is observed, especially from 18:00 to 08:00 IST, with cold stress beginning in the evening, and intensifying overnight. Against the backdrop of the cold stress, the WCI further amplifies the cold stress over most parts of north India, which can have huge implications. The findings emphasize the importance of understanding the interactions between SSW and cold wave conditions.

Keywords: Cold waves, Sudden Stratospheric Warming, Polar Vortex, Cold stress

High-resolution satellite observations to understand the regional scale analysis of atmospheric CO_2 and its links with SIF and climate parameters

Aparna, Aparajita[a], Ravi Kumar Kunchala[a]
[a] *Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi, 110016*
E-Mail: asz238216@iitd.ac.in

ABSTRACT

The atmospheric carbon dioxide (CO_2) is one of the most significant greenhouse gases and impacts both global warming and climate change. Understanding the CO_2 levels at regional scales is of utmost importance because of the continuous rise of anthropogenic activities. However, understanding the process behind the regional scale variability is hindered by inadequate observations. Recent advancements in satellite remote sensing have provided an alternative way of monitoring and will help us understand the relationship between CO_2 and different climatic conditions. To examine the source-sink relationship, mainly the biosphere photosynthetic activities that act as a significant sink of atmospheric CO_2, Solar-Induced Fluorescence (SIF) datasets are used. In this study, we explore the variations of atmospheric CO_2, SIF and different climate parameters during El Nino Southern Oscillation (ENSO) events in the different homogenous˜ regions of India during the recent decade of 2010-2020. During the strong 2015-2016 El-Nino event, the growth rate of CO_2 reached a spike of 3.5 ppm/year, whereas the SIF shows a decreasing trend due to hot and dry conditions formed during this period that significantly reduces photosynthetic activity and productivity. Along with this, different climate parameters like precipitation, temperature, soil moisture and Normalised Difference Vegetation Index (NDVI) have also been evaluated, revealing the links between the increasing CO_2 levels and climate variables on a regional scale over Indian landmass.

Keywords: Carbon dioxide (CO_2); ENSO; SIF; Growth rate; Homogenous regions.

Enhancing Coastal Vulnerability Assessment: A Systematic Review of Indices and Integration of Geostatistical Tools for Improved Analysis

Manas Ranjan Singh[a], Prashanth Janardhan[b]

[a] *M.Tech Student, Department of Civil Engineering, NIT Silchar*

[b] *Assistant Professor, Department of Civil Engineering, NIT Silchar*

E-Mail: manas.00627@gmail.com

ABSTRACT

Coastal regions face growing threats from natural hazards such as sea-level rise, storm surges, and coastal erosion, endangering human settlements, infrastructure, and ecosystems. Effective coastal vulnerability assessments are crucial for guiding management and resilience strategies. While the Coastal Vulnerability Index (CVI) model is commonly used to integrate physical, socioeconomic, and environmental factors, its current predictive accuracy and spatial precision are limited. This study proposes an enhancement to the CVI model by integrating advanced geostatistical tools, including variogram models, kriging techniques, and cross-validation methods. These tools are expected to improve the model's ability to capture spatial variability and enhance predictive accuracy. Variogram models quantify spatial continuity, kriging techniques provide refined spatial predictions, and cross-validation evaluates the reliability of these predictions. Theoretical estimates suggest that this integration could potentially improve the model's predictive accuracy from around 60-70% to up to 85-90%. These tools are designed to better capture spatial variability and refine predictions, though actual improvements will be confirmed through empirical testing.

A systematic review of coastal vulnerability assessment methods published in 2023 revealed that existing models often lack novelty and do not fully address predictive limitations. This study introduces a block design that classifies variables into strictly stationary, weak stationary, and nonstationary categories. While the effectiveness of this classification in conjunction with geostatistical techniques remains to be tested, it is proposed as a method to enhance the precision of vulnerability predictions.The study concludes that integrating geostatistical tools into the CVI model represents a significant advancement in addressing current limitations in predictive accuracy and reducing subjectivity. The proposed model, with an estimated potential accuracy of 85-90%, could provide valuable insights for more effective coastal management and policymaking.

Keywords: Coastal Vulnerability Index (CVI); Geostatistical Tools; Variogram Models; Kriging Techniques; Cross-Validation

Optimizing Land Data Assimilation: Ensemble vs. simplified Extended Kalman Filter in the Diffusion-Based ISBA Land Model coupled with HARMONIE-AROME

Abhishek Lodh
Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden
E-Mail: abhishek.lodh@smhi.se

ABSTRACT

The current research in seamless numerical weather prediction (NWP) particularly in land surface processes involves accurate estimation of surface variables like soil moisture, soil temperature, 2m temperature, 2m humidity and snow. Over the Northern European region, the land surface variables like snow temperature exerts deeper impact on latent and sensible heat flux and influences weather. So, it is important to provide accurate initial condition of land surface variables to the land surface model across the different soil levels down to root zone. Both NWP and hydrology models requires proper root zone soil moisture information and microwave sensors provides soil moisture information only upto top few centimeters. Even after receiving soil moisture observations in real time, various sequential land data assimilation algorithms are being adopted to properly initialize the land surface state in NWP models with a higher spread extending down to root zone. With the HORIZON EUROPE CERISE project where SMHI, Sweden is one of contributors, we are in process of developing an Ensemble Kalman filter (EnKF) based land data assimilation in the HARMONIE-AROME limited-area system to initialize soil variables from wide range of surface observations. Ensemble Kalman filter solves the limitations of saturated soil moisture in simplified Extended Kalman filter (sEKF). The advantage for EnKF based surface assimilation is that the offline runs allow a cheaper numerical estimation of the observation operator and Kalman gain. Studies are ongoing for evaluating the spread in screen level observations and soil moisture (both surface and root zone) and to find the correlation between the screen level humidity and temperature to the soil moisture, soil temperature across the soil levels in the ISBA land surface model. Comparisons are made with respect to spatial structure and values of the Kalman gain values and increments from sEKF and EnKF. The research thus presents the highlights in the main methodologies of Ensemble and sEKF filter in realm of Land Data Assimilation and Land Surface Processes for NWP.

Keywords: Land Surface Processes, Land Data Assimilation, SYNOP, soil moisture, land surface fluxes.

MIGRATION OF THE TROPICAL CYCLONE RAPID INTENSIFICATION ZONES OVER THE NORTH INDIAN OCEAN DURING THE CURRENT CLIMATE

1[a] Kasturi Singh
[a] *Department of Mathematics and Statistics*
University of Exeter
Laver Building, North Park Road, Exeter, EX4 4QE, UK
E-Mail:kasturi.env@gmail.com

ABSTRACT

The poleward migration trend of tropical cyclones (TCs) is evident in the global historical data in both hemispheres and is statistically significant. The migration of maximum intensity is triggering a shift in the rapid intensification (RI) locations towards the coasts of ocean-rim countries. The North Indian Ocean (NIO) comprising of two sub-basins Bay of Bengal (BOB) and Arabian Sea (AS), is one of the challenging world basins as it suffers a significant number of highly intensified TCs every year despite its comparatively smaller ocean basin. Further, the highly populated coastal areas and low socio-economic conditions of the countries make it even more crucial to understand the behavior of these disturbances over the NIO basin. The percentage of annual RI TC frequency over BOB shows a stable trend with a sharp rise over AS in the recent decade. The percentage of RI TCs ranges nearly between 20 to 100% over BOB and 50-100% over AS during the last 30 years. Though the annual frequency over BOB is higher than AS in post-monsoon season, the rapidly intensifying TC frequency over AS is comparable to that of BOB, confirming that AS is more vulnerable to rapidly intensifying systems in present climate conditions. Furthermore, it is realized that with a significant increase in the percentage of RI TCs over NIO, the locations where these systems suffer rapid intensification are migrating towards the southern coastal regions of NIO. The distribution of RI TC location gradient is meridional during the pre-monsoon season and is confined zonally below 15^{o}N during the post-monsoon season over BOB. The corresponding locations over AS are confined between 10^{o}N-15^{o}N and 12^{o}N-18^{o}N latitudinal regions. An inverse relation between the rise in SST and RH550 is evident during the pre-monsoon season, while the relation fails during the post-monsoon season over BOB. While sea surface temperature and midtropospheric relative humidity play a crucial role in RI, the observed changes in tropospheric vertical wind shear patterns and upper-level divergence alignment in current climate conditions are identified as influential factors shaping the distribution of RI location over BOB and AS. The migration of the location of RI of these storms poses a severe threat to the coastal population and is a challenge for the prediction agencies as well as for the disaster management agencies.

Keywords: Tropical cyclones, Rapid intensification, North Indian Ocean, Bay of Bengal, Arabian Sea, Warming climate

Assessment of WRF model for simulation of extreme weather event in different parts of India

Lt Cdr Pratishtha Vashishtha[a], Cdr J Sundar[a]
School of Naval Oceanology and Meteorology (SNOM)
Indian Navy
E-Mail:pratishh.v@gmail.com

ABSTRACT

Extreme weather events have become increasingly frequent and severe due to global climate change, posing significant threats to life, infrastructure, and ecosystems. Accurately forecasting these events is critical for preparedness and mitigation efforts. This research assesses the performance of the Weather Research and Forecasting (WRF) model in simulating extreme weather events across various regions in India. The study focuses on specific case studies, including the record-breaking heatwave in Delhi on 29 May 2024, which registered an unprecedented temperature of 52°C; the Wayanad disaster on 30 July 2024, which caused devastating floods and landslides due to intense rainfall; and the Tripura flood and landslide on 21 August 2024, which saw extreme rainfall leading to severe flooding and landslides.

The WRF model's accuracy in predicting these events is evaluated using meteorological verification techniques and comparison with observed data. Model configurations and various parametrization schemes, including microphysics, boundary layer schemes, and cumulus schemes are analyzed to determine their impact on forecast performance in different climatic regions. The preliminary results indicate that, while the WRF model effectively captures mesoscale weather patterns, its performance in predicting hyper-local phenomena varies across regions and is largely influenced by local features.

The study highlights areas where the model excels and improvements are necessary, particularly in the simulation of convective activity and heat stress conditions. This research underscores the need for region-specific model tuning to improve the forecasting of extreme weather events in India, ultimately contributing to more effective disaster preparedness and response strategies. This work has broader implications for enhancing the accuracy of numerical weather prediction models in regions prone to extreme weather, aiding in better planning and risk mitigation.

Keywords: Extreme weather events; Weather Research and Forecasting (WRF); Model configuration

Simulation of tropical cyclones in Bay of Bengal & Arabian Sea for various physics schemes in WRF model

[a] Cdr Anish, Kumar, [b] Cdr J Sundar,
[a]Meteorology Dept,INS Garuda (Indian Navy)
[b]School of Naval Oceanology and Meteorology (SNOM) (Indian Navy)
E-Mail: anish1032@gmail.com

ABSTRACT

Tropical Cyclones is one of most Extreme Weather events that has devastating effect on mankind. The study aims to establish the relative performances of various parameterization and physics schemes applied to the WRF-ARW model in the simulation of three unique Tropical Cyclones formed over Bay of Bengal and Arabian sea . Cyclone Michaung originated in Bay of Bengal from 1st -6th December 2023, Cyclone Remal originated in Bay of Bengal from 24 -28 May 2024 and Cyclone Asna developed over Gujarat coast and dissipated in Arabian Sea from 28 Aug- 02 Sep 2024 have been studied in this paper and associated parameters have been simulated using WRF- ARW model. NCEP-GFS data was used as IC for simulating these cyclones. Various parameters like temperature, sea level pressure, reflectivity and surface winds were generated and validated with observed data and reanalysis data. Model generated tracks and CTT were compared/validated with actual observed data available from Satellite imagery, Radar products and data taken from RSMC, IMD. A performance matrix was developed to to evaluate the relative performance for various parameters against the actual/observed data for different parameterization scheme. Based on the outputs received from various simulations performed for these cyclones , the paper highlights the forcasting capabilities of local models based on area on genesis post tweaking with its physics schemes.

Keywords: Extreme weather events; Tropical Cyclone;WRF model

Trends in temperature extremes across Northeast India and nearby areas: A multisite analysis using IMDAA datasets

Rohit Gautam[a,b], Arup Borgohain[b], Binita Pathak[a,c], Shyam Sundar Kundu[b], Shiv Prasad Aggarwal[b]

[a] *Department of Physics, Dibrugarh University, Dibrugarh 786004, Assam, India*

[b] *North Eastern Space Applications Centre, Umiam 793103, Meghalaya, India*

[c]*Centre for Atmospheric Studies, Dibrugarh University, Dibrugarh 786004, Assam, India*

E-Mail: rohitgtm62@gmail.com

ABSTRACT

This study investigated the annual climate trends across 21 study sites in North-East India and contiguous areas between 1979 and 2020. Using reanalysis datasets from the Indian Monsoon Data Assimilation and Analysis reanalysis (IMDAA), a regional atmospheric reanalysis over the Indian subcontinent, we examined minimum (Tmin) and maximum temperatures (Tmax) related extreme events. The study employed the Expert Team on Climate Change Detection and Indices (ETCCDI) criteria, analyzing trends at 5% and 1% significance levels using the Mann-Kendall (MK) and a modified version of it. Additionally, change point analysis was carried out with Cumulative sum (CUSUM) charts to detect abrupt shifts in all time series. Results revealed greater significance for indices related to warmer nights. Indices such as summer days (SU25), tropical nights (TR20), annual maximum of daily Tmin (TNx), warm days (TX90p), warm nights (TN90p), annual minimum of daily Tmax (TXn) and Tmin (TNn) shift from negative to positive, indicating a warming scenario. Conversely, indices like annual maximum of daily Tmax (TXx), cool days (TX10p), cool nights (TN10p) and diurnal temperature range (DTR) shift from positive to negative, suggesting pronounced warming of nighttime temperatures. The rise in extreme events poses a serious threat to the region and the continuously evolving pattern of climatic variables may have significant implications on human and natural ecosystems over this area of Indian subcontinent.

Keywords: Climate extremes, ETCCDI, IMDAA, North-East India, Trend analysis

Investigating the spatiotemporal variability of atmospheric methane (CH_4) over India using TROPOMI satellite retrievals

Shalini, Yadav[a], *Ravi Kumar Kunchala*[a], *and Sajeev Phillip*[a]

[a] *Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi, 110016*

E-Mail: asz238479@iitd.ac.in

ABSTRACT

Methane (CH_4) is the second most potent greenhouse gas after carbon dioxide, accounting for a 20% increase in global climate forcing. The mitigation of CH_4 emissions can be crucial in limiting global warming, considering its short atmospheric lifetime (~10 years) and high global warming potential. India is the third largest emitter of CH_4, with emissions primarily from sectors such as livestock, intensive agricultural practices, poor solid waste management, and anthropogenic activities. Methane emissions in India have increased by more than 35% since 1990. Therefore, understanding the emissions and atmospheric concentrations of CH_4 over India is essential. Moreover, few studies have investigated the CH_4 emissions and concentrations in India. In this study, we analyze the spatiotemporal variability of CH_4 to better understand and quantify these emissions over different geographical regions of India. The high-resolution XCH_4 retrievals from the TROPOMI sensor aboard the Sentinel 5P satellite are used in this study. We find higher XCH_4 concentrations during monsoon (July-August-September: JAS) and winter season (OctoberNovember-December: OND) over India. This could be attributed to agricultural and wetland emissions during JAS and biomass burning during OND seasons. We conduct regional-scale time series analysis of the TROPOMI XCH_4 data. The Western Indo-Gangetic Plain region and eastern India experience two XCH_4 concentration peaks around the JAS and OND seasons. The peak in monsoon season could be attributed to high emissions from the wetlands due to increased microbial activity and from paddy fields. Increased biomass burning during winter could be leading to the second peak in methane concentrations.

Keywords: Methane, XCH_4, Satellite, TROPOMI

A Quantitative Tropical Cyclone Risk Assessment Study over the Eastern Coast of India

Geo Tom, and Jagabandhu Panda

Department of Earth and Atmospheric Sciences,
National Institute of Technology, Rourkela
E-Mail: geotom00@gmail.com

ABSTRACT

Tropical Cyclones (TCs) are regarded as major devastating phenomena that generate torrential rainfall, extreme winds, and severe storm surges, causing loss of lives and infrastructure and ecological-environmental damages annually. Globally, the tropical warm North Indian Ocean (NIO) basin is considered as an active breeding zone for TCs, and a higher population density over the coastal regions exacerbates the risk. The eastern coastal areas of India, which are more prone to frequent TC strikes, are considered for the study. A statistical approach is adopted in this study to project the future probabilities of risk induced by TC rainfall and extreme wind speed events. The extreme value theory technique via frequentist and Bayesian paradigms is evaluated. The frequentist statistics include generalized extreme value (GEV) and gamma, whereas the Bayesian approach is configured using a non-informative prior (NIP) method. Also, various parameter estimation schemes are incorporated with previous models, viz., maximum likelihood estimation (MLE), generalized MLE, and linear moments (L-mom), to capture the heterogeneous characteristics of the rainfall and wind extremes. The results revealed that the frequentist paradigm in GEV with L-mom configuration is robust approach to capture the reasonable outputs over most locations with lower error and the least uncertainty for wind extremes. However, the Gamma with MLE and Bayesian paradigm in NIP configuration exhibits better and optimal fitting for rainfall having heavier tails. The estimated recurrence interval shows that the coastal districts of West Bengal and Odisha, followed by Andhra Pradesh, are highly susceptible to severe cyclonic wind hazards in the near future. However, the coastal and near-coastal parts of Andhra Pradesh and Odisha, followed by the southern coastal districts of West Bengal, are exposed to TC-induced heavy rainfall events in the near future.

Keywords: Tropical Cyclone; Extreme Value Theory; Vulnerability; Coastal hazard

Regional Modeling of Aerosol-Radiation Interactions during an Unusual Dust Scenario

Ankan Sarkar[a], Jagabandhu Panda[a], and Sushant Das[a]

[a]*Department of Earth and Atmospheric Sciences, National Institute of Technology Rourkela*

E-Mail:ankan.sarkar29@gmail.com

ABSTRACT

The present study employs the RegCM model to explore the regional influences of dust-radiative impacts during an unprecedented scenario of consecutive dust storms in the 2018 pre-monsoon season. The model reproduces aerosol and meteorological variables well, strongly agreeing with observational and reanalysis datasets. The areas most impacted by dust include the major arid regions, the dust transportation pathways over the Arabian Sea, and the Indo-Gangetic Plain, with the Thar Desert receiving the maximum dust loading (1800-2200 mg.m^{-2}). In high-albedo regions, dust reversed the sign of top-of-atmosphere direct radiative forcing (DRF) from negative to positive, peaking at 25 W.m^{-2}. Despite the opposing effects of shortwave cooling and longwave heating, surface DRF remained net negative, ranging from -10 to -30 W.m^{-2}. However, the positive DRF in the atmosphere dominated, leading to notable atmospheric warming (0.2-0.6 K.day^{-1}). While dust reduced mid-tropospheric cloud cover through semi-direct effects, it triggered stronger updrafts, lifting moisture to higher altitudes. Furthermore, increased surface temperatures (0.6-1.2 °C) and decreased surface pressure (-0.6 hPa) intensified southwesterly winds and large-scale convergence. This reinforced the 'Elevated Heat Pump' mechanism, promoting substantial moisture transport (40-60 kg.m^{-1}.s^{-1}), fostering deep convective cloud formation, and enhancing convective rainfall over the ocean and nearby coastal regions.

Keywords: Dust; Direct Radiative Forcing; Semi-direct effect; Elevated Heat Pump; RegCM

Variability in regional characteristics of extreme rainfall of India

Amit Kumar[a,*], D.R. Pattanaik [a],

[a] *India Meteorological Department, New Delhi*
E-Mail: amitkriitm@gmail.com

ABSTRACT

The spatial and temporal variability of extreme rainfall during the south-west monsoon period is investigated, using the India Meteorological Department (IMD) gridded rainfall data coupled with the re-analysis and satellite observation. Extreme rainfall indices, like maximum 1-day rainfall (Rx1day), maximum 5-day rainfall (Rx5day), and heavy rainfall days (R10, R20), are analyzed to identify hotspots of extreme rainfall. Regional distribution shows significant heterogeneity, with the Western Ghats and north-east India appearing as hotspots of extreme rain events, amplified by the complex mountainous topography. This is possibly due to a rise in moist convective instability. Trend analysis reveals increasing frequency and intensity of extreme rainfall events in several regions, particularly in urbanized and orographically influenced areas. Several factors contributing to extreme rainfall variability is examined, including synoptic systems like low-pressure areas that are major drivers of extreme rain events. The linkage between large-scale climatic phenomena and how they affect India's regional rainfall pattern, intensity, and spatial distribution of severe rainfall is also examined in this study.

Keywords: Extreme rainfall; South-west monsoon; gridded data; regional variability

Enhancing Satellite Precipitation Estimates Using MUMBAI-MESONET Observations: A Random Forest Approach To Bias Correction

Deepak Singh Bisht[a], Preveen Kumar D[a]., Amarjyothi K[a]. and Upal *Saha*[a]

[a] *National Center for Medium-Range Weather Forecasting, Ministry of Earth Sciences, A-50, Sector-62, Noida 201309, India*

E-Mail:db.scienceforever@gmail.com

ABSTRACT

In the coastal areas like Mumbai, India where monsoons can cause severe floods through high intensity rains, it is essential to have accurate hourly rainfall estimations for meteorological and hydrological purposes. The Satellite Precipitation Products (SPPs), such as Integrated Multisatellite Retrievals for GPM (IMERG), provide wide coverage, though they have biases. This research uses actual high-density ground-based rain gauges over Mumbai in real-time and applies various correction methods to correct each point of satellite precipitation for a whole monsoon region on an hourly basis. The additive and multiplicative corrections in traditional parametric methods were not that effective, particularly under heavy rainfall conditions. Quantile mapping did well with negative biases but struggled with extreme rainfall events. Machine learning method called Random Forest (RF) algorithm performed best enhancing the correlation between satellite and ground-based data from 11% to 69%. The RF model successfully reduced overestimation and underestimation, and shifted towards zero bias, capturing the space and time variation of rainfall well across different stations. The study implies that machine learning can be used to enhance satellite precipitation products as an effective way to improve rainfall estimates in monsoon-prone areas. The application of the RF framework is likely to lead to more precise information for effective water resource management as well as disaster preparedness.

Keywords: Bias Correction, Machine Learning, IMERG, Rain Gauge, Quantile Mapping

Mechanistic challenges of prolonged ENSO events in CMIP6 climate models: an analysis

Anika Arora

Indian institute of tropical meteorology pune

E-Mail: anika.cat@tropmet.res.in

ABSTRACT

This study looks at the unique characteristics of prolonged El Niño (PE) and La Niña (PL) events, which last longer than typical ENSO cycles and have significant impacts on global weather and economies. By comparing observational data with climate model simulations from CMIP6, the study aims to better understand these extended events. Observations show that PE and PL events involve persistent warming or cooling in the equatorial Pacific beyond the usual timeframes of regular El Niño and La Niña events. While climate models can generally capture this trend, they often struggle with accurately simulating the intensity and timing of temperature changes, especially during the peaks of these events. The study also highlights that current models have difficulty simulating consecutive El Niño events after PE episodes and strong El Niño events before PL events. Additionally, the models show inconsistencies in representing deep ocean dynamics and wind patterns, which are important for understanding ENSO variability. Improving these models is crucial for better predicting future climate changes and planning adaptation strategies.

Netweb TECHNOLOGIES Tyrone®

https://www.netwebindia.com/

With more than 20 years of experience, Netweb has helped thousands of organisations globally by following a customer-centric approach. We are a leading provider of servers, storage, backup, and HPC solutions that customize the right technology blocks customized to your business requirements. Netweb is one of India's leading Indian origin owned and controlled OEM for HCS with integrated design and manufacturing capabilities. We have offices across 15 locations in India. We are one of the few players in India who can offer a full stack of product and solution suite with comprehensive capabilities in designing, developing, implementing and integrating high performance computing solutions. We are also an Indian origin OEM to build Supercomputing systems, private cloud and HCI, data centre servers, AI systems and enterprise workstations, and HPS solutions under the 'Make in India' initiative of the Government of India. Netweb is one of India's leading high-end computing solutions (HCS) provider, with fully integrated design and manufacturing capabilities. Our HCS offering comprises HPC, Private cloud and (HCI), AI systems and enterprise workstations, High performance storage (HPS) and Data Centre Servers with Netweb HPC Solutions, accelerate time to result and solve your most complex computing challenges at high speeds. A Turnkey HPC solution that takes the customer through all levels of HPC. Netweb has over 300 HPC installations deployed under our belt, our experienced team of experts can recommend the right hardware, design your HPC architecture with application-level support and post-cluster installation services. Our "Tyrone Cluster Management System" features the below mentioned salient points • Enterprise-class software to manage all clustered IT infrastructure • Easily turn a pile of hardware into a fully functional cluster in under an hour • Total lifecycle management • Deep health checking capabilities • Insightful metrics • Deploy and manage HPC clusters • Easily move individual resources between components as requirements change A fault-tolerant and redundant production cloud suite that offers one of the lowest turnaround time in the industry, implementable on-site with Netweb's service engineering experts. Engineered to deliver premium cloud services with exceptional security, performance, and scalability. Helping organizations meet the modern-day challenges and needs of a data center with our tailored-to-build approach. Netweb designs from the ground up for data-intensive applications with High-performance computing, analytics and AI. We have purpose-built servers and workstations that are adapted to be faster, simpler and scalable to give cutting-edge performance. Along with Unified Storage Solution delivering one of the best-in-class scalability, redundancy, performance and availability.

Contact:

25 YEARS OF TRUST AND EXCELLENCE
Netweb

Vivek Lodha
Director

+91-9900065298
vivek@netwebindia.com

www.netwebindia.com
#36, 1st Floor, Neela Nivas,
Plain Street, Shivaji Nagar,
Bangalore, - 560001

Satellite-Derived Groundwater Variability and its Link to Hydrological Processes in India during Extreme Monsoon Years

Bushra Y. Shaikh*, Anant Parekh, C. Gnanaseelan
Climate Variability and Prediction,
Indian Institute of Tropical Meteorology,
Pune, India
E-Mail:
shaikhbushraa23@gmail.com; *bushra.shaikh@tropmet.res.in*

ABSTRACT

This study focuses on understanding groundwater dynamics in India during extreme monsoon years by leveraging data from the Gravity Recovery and Climate Experiment (GRACE) satellite. GRACE provides valuable insights into groundwater variations by analyzing Terrestrial Water Storage Anomalies (TWSA), which are further complemented by hydrological data from the Global Land Data Assimilation System (GLDAS). The research investigates how groundwater levels respond to varying meteorological and hydrological conditions across different seasons. The findings reveal significant seasonal variability in both hydrological parameters and Groundwater Anomalies (GWA). During the summer monsoon months (June to September), the standard deviation of hydrological parameters is higher, indicating more significant fluctuations in factors like precipitation and soil moisture. In contrast, GWA shows greater variability during the fall (October to November), particularly in many regions of India. This suggests that seasonal changes in hydrological parameters during summer have a delayed impact on GWA, which becomes more pronounced in the following seasons. The study also identifies distinct patterns during deficit and excess monsoon years between 2002 and 2022, which include four deficit years and three excess years. Composite analysis reveals that during excess monsoon years, groundwater levels tend to increase, with this replenishment continuing into the fall and winter. Conversely, deficit monsoon years are marked by reduced groundwater recharge and a subsequent decline in GWA. A closer examination of extreme years—2002, 2009 (deficit), and 2019 (excess)—shows that the 2019 summer decline in GWA was influenced by the hydrological conditions of the preceding year. In conclusion, the study highlights the critical role of understanding the interplay between hydrological factors and groundwater dynamics, especially in the face of climate variability and water scarcity. This understanding is vital for developing sustainable water management practices and enhancing resilience to extreme climate events.

Keywords: Extreme Monsoon years, Groundwater, GRACE satellite data, Hydrological parameters, Seasonal Cycle

Lightning and LCL, EL and Relative Humidity relationship at various CAPE in India

Deen Mani Lal[1], Nandivada Umakanth[1,] Manoj Arjun Domkawale[1], Manoj Kumar Srivastava[2],*

ABSTRACT

Lightning, a mesoscale phenomenon that occurs throughout the globe, is a socio-economic risk for humans' lives and economics. Lightning frequency has been seen to change during the last few decades. The causes of lightning frequency changes, and their generation mechanism, are very complicated and pose a challenge to the scientific community. Aerosol is considered a prime cause of lightning. The study investigated lightning activity in India's Delhi NCR region (Lat: 270N -290N, Lon: 760 E-780E) using data from 2019 and 2020. It has been seen that there will be more lightning in 2020 than in 2019, even though aerosol concentration was quite uniform. Changes in lifting condensation level (LCL), equivalent level (EL) and low level (850hPa) and high level (200hPa) moisture with lightning frequency at specified CAPE has been observed. High lightning with low LCL, high relative humidity at 850mb, and high "Kx" index has been seen. Upper-level moisture at 200 mb and EL is also influencing lightning. Finding reveal that low LCL and high relative humidity at 850mb (low dew point depression) play a crucial role in the production of severe thunderstorms, resulting lightning. A significant negative relationship between LCL and Lightning, as well as LCL and the "Kx" index (a thunderstorm genesis indicator) has been found. EL and moisture at 200mb determine whether severity.

Spatial Prediction of Monthly Air Temperatures using Machine Learning Techniques

Mayank Pandey[a] , Shailendra Rai[a,b]

[a]K. Banerjee Centre of Atmospheric and Ocean Studies, University of Allahabad, Prayagraj-211002, UP, INDIA
[b]M. N. Saha Centre of Space Studies, University of Allahabad, Prayagraj-211002, UP, INDIA
E-Mail:*mayankpandey1510@gmail.com*

ABSTRACT

Predicting monthly air temperatures is a complex task due to random fluctuations and the nonlinear interactions among meteorological elements. This study employs five Machine Learning (ML) techniques – Linear Regression (LR), Gradient Boosting (GB), Decision Tree (DT), K-Nearest Neighbor (KNN), and Extreme Gradient Boosting (XGB) to enhance prediction accuracy. Training and testing dataset use meteorological data (air temperature, humidity, wind speed) from January 2000 to December 2022 at the ERA5 fifth generation of the ECMWF reanalysis dataset. Performance metrics including Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Correlation Coefficient (CC) evaluate the models. XGB and KNN yield MAE/RMSE/CC values of 0.86/1.51/0.89 and 0.89/1.62/0.87, respectively, demonstrating accurate monthly temperature predictions. This work highlights the significance of advanced ML techniques in addressing intricate meteorological prediction tasks. The consistent monthly temperature predictions from the XGB and KNN models emphasize their effectiveness in handling the nonlinear relationships inherent in meteorological data prediction. By effectively combining diverse ML approaches, this study contributes to our understanding of temperature prediction and underscores the potential of these methodologies in complex meteorological forecasting.

Keywords: Machine Learning, Temperature Prediction, XGB, DT, KNN, Analysis and Prediction of Weather and climate extreme using AI/ML/DL techniques etc

Atmospheric moisture residence time variation in Indian Summer Monsoon: How faithful is isotope based estimates?

Rajaveni S P[a], S. S. Nimya[a,b], and Saikat Sengupta[a]

[a] *Centre for Climate Change Research, Indian Institute of Tropical Meteorology, Pune, India*

[b] *Department of Earth, Atmospheric and Planetary Sciences, Purdue University, USA*

E-Mail:rajaveni.sp@tropmet.res.in

ABSTRACT

Atmospheric moisture residence time (MRT) is the duration between moisture formation from its source and its precipitation at a sink. As air temperature controls moisture-holding capacity, the MRT is considered a useful proxy to study climate change. Moisture for Indian Summer Monsoon (ISM) rainfall is derived from multiple sources and experiences different rain mechanisms across the country. Consequently, the MRT has significant spatial and interannual variation. Besides the moisture sources, local atmospheric processes such as moisture recycling, raindrop evaporation and evapotranspiration also control the MRT. The MRT can be estimated by various methods. However, a limited number of studies focused on region-specific MRT estimation during the ISM season. Towards this, the current work presents MRT during ISM over four stations: (1) Port Blair (island); (2) Mahabaleshwar (Western Ghats); (3) Kolkata (east coast); and (4) Tezpur (forest) through various methods such as water balance, rain isotopes (hydrogen and oxygen), and Lagrangian moisture tracking trajectories. Apart from estimation using meteorological parameters, MRT is also estimated from rain hydrogen and oxygen isotopes. These isotopes are considered a proxy for various hydrological processes operating in the hydrological cycle, such as evaporation, condensation, and moisture recycling. Rainwater samples were routinely collected over these locations for more than six years, and the isotopes were measured at the Indian Institute of Tropical Meteorology, Pune. Our study shows that the water balance method estimates a minimum MRT of 3 days and a maximum of 14 days across all four locations. However, the isotope-based method indicates spatial and inter-annual variations in MRT, with Mahabaleshwar and Kolkata showing the shortest MRT of 1 day and the longest between 28 and 30 days.

Keywords: Stable Isotope; Climate change; Indian summer monsoon; Moisture residence time

Tropical Cyclone Tracking Algorithms in the north Indian Ocean

Rushikesh Adsul[a], Vineet Kumar Singh[a], Anant Parekh[a],
C. Gnanaseelan[a]

[a] *Climate Variability and Prediction, Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune-411008*

E-Mail: rushikesh.adsul@tropmet.res.in

ABSTRACT

In this study, we examined the skills of different tracking algorithms in realistically capturing the TC activity in the north Indian Ocean during the post-monsoon season using the ERA5 reanalysis dataset for the period 1990–2022. The tracking algorithms considered for detailed study are TRACK, UZ, OWZ and CNRM for TC detection and tracking. In both the Arabian Sea and the Bay of Bengal, CNRM algorithm displayed the highest skill in realistic capturing of the spatial distribution of TC tracks with 80% TC detection probability score and less than 50 km track errors. Although the CNRM tracker has a higher false alarm rate compared to the UZ and OWZ trackers, it excels in accurately representing TC frequency, interannual variability, and their duration. This study highlights the critical role of tracker selection, as TC metrics in both reanalysis and climate models are highly sensitive to the choice of algorithm. The CNRM tracker, with its reliable performance, offers a robust solution for TC detection and its tracking in the north Indian Ocean.

Keywords: north Indian Ocean, cyclones, cyclone tracking algorithm, CNRM tracker

Assessing the Role of Low Level Jets on the Extreme Rainfall Events over Coastal Regions of Peninsular India

Shubham[a], M.K Verma[a], Manish Kumar Sinha[a], and Nikhil Ghodichore[a],

[a] *Environmental and Water Resources Engineering Department, University Teaching Department, Chhattisgarh Swami Vivekanand Technical (CSVTU), Bhilai, India*
E-Mail: shubhamchandrakar386@gmail.com

ABSTRACT

The peninsular coastal region of India has experienced Extreme Rainfall Events (ERE) in last two decades. Floods caused due to extreme rainfall events pose significant danger to environmental activity, life and socio-economic progress. In the recent years, researchers have focused on understanding the mechanism behind such EREs and found associated events like Kerala flood in the year 2018 with moisture transport. Low Level Jets (LLJ) are one of the major controlling factor for the movement of moisture in lower atmosphere at different pressure level. This study attempts to identify the impact of LLJ on the major flood events caused due to extreme rainfall over Peninsular India, particularly Ratnagiri, Idukki, and Chennai floods. The most vulnerable range of pressure levels that leads to development of LLJs is analyzed using Integrated Vapor Transport (IVT) computation at different pressure levels. The IVT was calculated using the specific humidity, u- and v- wind speed data from ERA- 5 reanalysis dataset. This study emphasizes on the importance of monitoring atmospheric moisture in order to identify high moisture streams, which may lead to extreme rainfall events in the coastal regions. The IVT results of this study were validated using ground-based observation data for Ratnagiri, Idukki, and Chennai regions. This analysis could also serve as IVT monitoring based an early warning system for EREs.

Keywords: Extreme Rainfall Events, Low Level Jets, Integrated Vapor Transport, peninsular India, Kerala flood.

WRF -CHEM Simulation of Transport of aerosols and trace gases in Northern India throughout summer and winter

[1] Himangi Tripathi , [2] Ujjwal Kumar and [2] Vikas Singh

[1,2] *Doon University, Dehradun, Institution*
[2] *CAMQ, Delhi,*
E-Mail:himangitripathi11@gmail.com

ABSTRACT

This study looks at how aerosols and trace gases change throughout the course of the summer and winter in Northern India's atmosphere. The purpose of the study is to comprehend the mechanisms and patterns of pollution transfer in this area. The study clarifies the impact of meteorological factors on aerosol dispersion by examining seasonal fluctuations. The research advances our knowledge of Northern India's regional atmospheric dynamics, climate impacts, and air quality. In this study we have configured WRF-CHEM (version 3.8.1) using two nested domains to simulate the regional chemical weather over the North Indian region. Aerosol concentrations are simulated using the Weather Research and Forecasting Model combined with Chemistry (WRF-Chem). WRF-Chem simulation is being run for a period of 1 year from 1st jan 2015 to 31st dec 2015. Transported aerosols, primarily from IGP, were found to be responsible for the bulk of the aerosol mass over North India of near-surface PM10 concentration, thus primarily responsible for air pollution as climatic impacts over the region during pre-monsoon season. The simulation differentiates and quantifies the impacts of aerosols emitted locally within North Indian region and those transported from outside this region to ascertain whether local or transported aerosols are more impactful in influencing this region’s atmosphere. Validation of aerosol concentrations (**PM10**) and (**PM2.5)** with available ground-based observations over the Northern Indian region has been done.

Keywords: (Climate impacts, Weather and Research Forecasting)

Climatological Analysis of Winter Storms in the National Capital Region of India Using Doppler Weather Radar

[a]Amit Kumar, [a]Mrutyunjay Mohapatra, Mohit [a]Dixit
India Meteorological Department, Ministry of Earth Sciences, New Delhi – 110003
E-Mail: *imd.amitkumar@gmail.com*

ABSTRACT

This study marks a effort in India to develop a radar-based climatology using maximum reflectivity data from the C-Band dual-polarimetric Doppler Weather Radar. It focuses on analyzing convective systems over Delhi and surrounding regions during the winter months from 2018 to 2022. By employing this radar-based approach, the study provides improved spatial and temporal resolution compared to traditional climatological methods that rely on surface observations, allowing for detecting small-scale, short-lived weather systems often missed by surface instruments. Convective systems are classified based on maximum reflectivity values, and the study identifies regions prone to frequent convective activity while examining storm intensity, movement, and spatial-temporal distribution. The analysis also explores the connection between convection and local orography. The findings from this radar-based climatology contribute to better weather forecasting, enabling more accurate nowcasting and timely alerts.

The life cycle analysis of winter storms in Delhi and nearby areas reveals distinct patterns shaped by geographical and topographical features. Storm initiation is most frequent in grids 1 and 4 due to favorable conditions in central Haryana's flat agricultural lands, while intensification peaks in grid 7 under the influence of the Aravalli Range. Storm weakening is most noticeable in grid 3 as storms shift from plains to the rugged terrain of the Himalayan foothills, and dissipation is highest in grids 3 and 5, largely due to topographical and urban disruptions. Most storms (71%) move in a northeasterly direction, following the path of western disturbances, with longer durations observed in grids 3 and 6. Smaller storms dominate grids 7 and 8, while medium and large storms are more common in grids 2, 6, and 9. Intense convection is widespread, particularly in grid 9, with extreme convection noted in grids 5 and 9.

Expanding this study to cover a broader region of India would yield vital insights into regional variations in winter storm patterns, further enhancing weather forecasting and disaster management across the country.

Keywords: Doppler Weather Radar, Climatology, Winter Storms

Effectiveness of Dual-Resolution Hybrid Ensemble Variational Data Assimilation scheme using dense network of surface weather observations for Afternoon Rainfall Forecast

Sanjay Sriraj [1], Govindan Kutty[1], and Rakesh V [2]

[1] *Department of Earth and Space Sciences, Indian Institute of Space Science and Technology,*

[2] *Council of Scientific and Industrial Research,Fourth Paradigm Institute (CSIR-4PI)*

E-Mail: sanjaysriraj98p@gmail.com

ABSTRACT

The present study compares the performance of two data assimilation (DA) systems:Hybrid ensemble-3DVAR (HYBRID) and Dual-Resolution (9km to 3km) Hybrid ensemble-3DVAR (DRH) in the Weather Research and Forecast (WRF) model. HYBRID assimilation is performed at a horizontal grid spacing of 3 km. A set of five afternoon rainfall events that occured over the state of Karnataka have been considered. A dense network of surface observations collected from 6000 telemetric weather stations are assimilated along with Conventional surface and upper air observations collected by the National Centers for Environmental Prediction (NCEP) at every 6 h interval for five cycles. On evaluating post-assimilation rainfall forecasts, it is found that the forecasts from DRH are at par with that from HYBRID assimilation. This suggests that DualResolution assimilation schemes can be considered as a viable alternative to the computationally expensive fine resolution assimilations that are employed in operational weather forecasts.

Keywords: Weather Data Assimilation, Numerical Weather Prediction

Synoptic forcing and thermo-dynamical processes during cloudburst event over Sauni Binsar, Uttarakhand, India

Debojit Sarkar[a,b], Amit Kesarkar[a], Jyoti Bhate[a], Pavani Goriparthi[a] and Anantharaman Chandrasekar[b]

[a]National Atmospheric Research Laboratory, Gadanki, Tirupati District, Andhra Pradesh 517112, India
[b]Indian Institute of Space Science and Technology, Valiamala, Thiruvananthapuram, Kerala 695547, India
E-Mail:debojitsarkar306@gmail.com

ABSTRACT

Cloud bursts have become a pressing concern with their devastating impact and increasing frequency over the Himalayan region. Therefore, understanding the physical mechanisms associated with their occurrence is essential and urgent. Our investigation into the physical mechanisms of a cloud burst over Sauni Binsar, Uttarakhand, India, which occurred on 10 June 2021 around 06 UTC, is a step towards addressing this urgency. On the day of the cloud burst, there was a continuous accumulation/stagnation (at 850 hPa) of moist air over Sauni Binsar due to the northward propagation of the southwest monsoon, leading to atmospheric column supersaturation. The advection of warm air (dry) from the monsoon heat low at higher (700 hPa) caused potential instability over this region. Orographic lifting and a gradual increase in convergence over this region caused moist convection. Further, the analysis of Richardson's number indicated that turbulence was maximum in the middle and upper troposphere. Just a few hours before the cloud burst event (02-06 UTC 10 June 2021), the decrease in potential vorticity indicates the squashing of the moist columns and the decrease in the vorticity. The sudden squashing of the supersaturated atmospheric column might have caused enormous rainfall (Cloud burst) over the Sauni Binsar region.

Keywords: Cloud burst, preconditioning, triggering, heavy rainfall, Uttarakhand.

Forecasting Extreme Climatic Events using Physics Informed Neural Networks: A case study on Cyclone YAAS

Pinaki Ranjan Sarkar[a],

[a]*Atmospheric and Space Research Facility*
Satish Dhawan Space Centre
E-Mail: pinaki.rs@shar.gov.in

ABSTRACT

Deep learning has proven its effectiveness across various applied domains, such as computer vision, natural language processing, and speech recognition. Among these advancements, Physics-informed Neural Networks (PINNs) have emerged as a groundbreaking approach by integrating traditional data-driven neural networks with prior knowledge of physics. This combination facilitates the high-level abstraction of natural phenomena, addressing critical challenges like limited training data, enhancing physical plausibility, and solving complex differential equations. Despite these advancements, applying PINNs to model and forecast the dynamics of extreme climatic events in geophysical systems remains a challenging and largely unresolved area of research.

In this study, we used the Van der Pol-informed Neural Network (VPINN), a physics-informed differential learning approach tailored for multi-step-ahead forecasting of extreme nonlinear dynamical systems. As a case study, we examined Cyclone YAAS which formed on May 23, 2021, and dissipated on May 28, 2021. This cyclone serves as a prime example of the type of extreme climatic event that our model aims to forecast. Wind speed data from this event was sourced from MOSDAC-ISRO [ISRO1631_15F65F (ITR-Balasore)], providing a comprehensive dataset for our analysis.

The VPINN model leverages the Van der Pol oscillator's differential equations as a physicsderived loss function, which is particularly well-suited for capturing the oscillatory nature of such extreme events. The results underscore the potential of VPINN to advance the forecasting of extreme climatic events, offering a valuable tool for mitigating the impacts of such events in the future.

Keywords: Extreme weather events; Physics Informed Neural Network (PINN); Van der Pol Oscillator, Cyclone YAAS

Development of a Low-cost Electric Field Mill and Machine Learning based Calibration for Atmospheric Electricity measurement.

Diptangshu Sekhar Raj[a], Pinaki Ranjan Sarkar[a], Asish Kumar Ghosh[a]

[a]*Atmospheric and Space Research Facility*
Satish Dhawan Space Centre
E-Mail: sekhar.raj@shar.gov.in

ABSTRACT

Rotating Vane Electric Field Mill is designed to measure atmospheric electric field. This tool is used for mitigating the impacts of severe weather events, such as lightning strikes, by providing better predictive capabilities and contributing to the safety of human activities in vulnerable areas. In this work, we present the development of an in-house and indigenous Rotating Vane Electric Field Mill (REFM), including the design of mechanical hardware, instrumentation, data acquisition, AI/ML based calibration, and the development of a Graphical User Interface (GUI).

The REFM, also known as a Generating Voltmeter, operates as a varying capacitance device commonly used to measure atmospheric quasi-static electric fields. The instrument which is constructed from stainless steel, features grounded rotating plates positioned above sensor/stator plates of sector vane type. The design includes six rotor blades, achieving a rotation speed of 150±5 Hz. The measurement chain involves amplification (unity gain follower), filtering, rectification (with a precision rectifier/synchronous detector), and signal processing to detect the signal from noise and display it via a GUI.

The calibration and validation of the REFM is done by using Machine Learning (ML) techniques during June, July month - 2024 (Indian Monsoon Season) with respect to a co-located existing EFM. The REFM achieved an impressive R (MSE) value of 0.99 (0.13) & 0.97 (0.25) for Random Forest Regression and Recurrent Neural Network Model respectively for the events detected. This successful implementation underscores the REFM's potential as a low-cost & indigenous tool for atmospheric electricity measurement.

Keywords: Indegenous, Extreme weather events, Rotating Vane Electric Field Mill, Calibration and Validation, Signal Processing, Machine Leaning.

Exchange between the Atmospheric Boundary Layer and Free Troposphere over the Indian region: Roles of Topography and Monsoons

Seetha C J[1] and Sanjay Kumar Mehta[1]

[1]*Atmospheric Observation and Modelling Laboratory, Department of Physics, SRM Institute of Science and Technology (SRM IST), Kattankulathur-603203, India*
E-Mail: seethacj1@gmail.com

ABSTRACT

The exchange between the atmospheric boundary layer (ABL) and the free troposphere (FT) plays a crucial role in addressing pollution dispersion amidst growing population and industrialization. To understand the ABL and FT exchange during various seasons in 2016, radiosonde and ERA5 datasets were analyzed over Delhi, Nagpur, Mumbai, and Kolkata (in the southwest monsoon region) and Gadanki and Chennai (in the northeast monsoon region). The diurnal patterns of ABL and FT exchange fluxes reveal maximum entrainment around 11:0012:00 IST and maximum detrainment around 17:00-18:00 IST across different stations.The total ABL and FT flux is primarily influenced by subsidence-driven entrainment in Delhi and Mumbai, and horizontal advection in Gadanki, while in Chennai, winter season detrainment is driven by both subsidence and horizontal advection. During the summer monsoon, horizontal advection and convection-induced detrainment is dominant in southwest monsoon stations, whereas northeast monsoon stations mainly experience detrainment due to horizontal advection. Spatial patterns of ABL and FT exchange fluxes in winter and pre-monsoon seasons are characterized by detrainment over the Deccan Plateau and entrainment over the Indo-Gangetic Plain (IGP), reflecting India's topography. However, during the summer monsoon and postmonsoon seasons, entrainment dominates over southern India, while detrainment prevails over central India and along the eastern and western coasts, closely resembling the spatial distribution of climatological mean rainfall. Stronger advective and convective detrainments during the monsoon season lead to an increase in water vapor transport. In contrast, subsidence over the IGP during winter results in increased ozone transport, which exacerbates pollution levels.

Keywords: Atmospheric Boundary Layer, Exchange Flux, Monsoon, Topography, Rainfall, Pollution

Large-scale influences on extreme rainfall events during 9-10 July 2023 over New Delhi

Soumyajyoti Jana[a], Sahadat Sarkar[a], and Parthasarathi Mukhopadhyay[a,b]

[a] *Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune-411021, India*
[b] *Department of Earth and Environmental Sciences, Indian Institute of Science Education and Research, Berhampur, Odisha-760003, India*

E-Mail:mantu.abc@gmail.com; sahadat.cat@tropmet.res.in; parthasarathi64@gmail.com

ABSTRACT

The Indian capital, New Delhi, experienced extraordinary rainfall events on July 9-10, 2023, resulting in severe flooding and disruptions. This study aims to analyze the convective nature of these storms, the underlying atmospheric conditions, and the predictability of such events using a state-of-the-art global forecast systems (GFS) model. Disdrometer data revealed the anomalous nature of this rainfall, characterized by unusually intense precipitation rates. Vertically integrated moisture convergence analysis using ERA5 reanalysis and GFS forecasts indicated a significant increase in moisture within the boundary layer during the event compared to the monsoon climatology. The influence of the extra-tropical jet is also evident in the 200mb wind and potential vorticity. Additionally, by applying a Rossby wave filter to rainfall anomalies, we found a strong association with westward-propagating barotropic Rossby waves. This suggests that large-scale atmospheric patterns play a crucial role in driving these extreme rainfall events, enhancing their predictability.

Keywords: Extreme weather events; Monsoons; Large-scale influences; Weather Prediction; Rossby wave propagation.

ROLE OF HADLEY CELL ON DELAYING INDIAN SUMMER MONSOON ONSET ROLE OF HADLEY CELL

Vaishnavi Wadhai[a], Mihir Kumar Dash[a],

[a] *Centre for Oceans, Rivers, Atmosphereand Land Sciences, Indian Institute of Technology Kharagpur,Kharagpur, West Bengal, India*

E-Mail: vaishnaviwadhai86@gmail.com

ABSTRACT

A change in the Indian Summer Monsoon (ISM) onset timing impacts agriculture, food production,economy, and above all the livelihoods of people in India. In this study, we investigate the dynamics associated with the delayed onset using a composite analysis of meteorological variablesover the years 1979-2023. According to Parker et al., 2016, the onset of the ISM is significantly influenced by both mid-level northwesterly dry winds and low-level southwesterly moist winds. However, during the delayed onset years, the main driver is the weakening of the southwesterly winds. In these delayed ISM years, the northwesterly winds are not anomalous; instead, the southwesterly winds weaken, owing to the presence of high pressure over the Arabian Sea. This high pressure reduces the strong gradient necessary for the southwesterly winds to transport moisture from the Indian Ocean to the southeastern tip of India. The subsidence over the region caused by the weakening of the Hadley cell is thus responsible for the anomalous high pressure, further inhibiting the southwesterly flow. The study concludes that strong southwesterly winds have a dominant role in leading the monsoon onset. This research contributes to a better physical understanding of the monsoon onset mechanism, addressing existing challenges in modeling and prediction.

Keywords: ISM, Onset, Southwesterly winds, Northwesterly winds, Hadley cell.

ENSO-induced latitudinal variation of the subtropical jet modulates extreme winter precipitation over the Western Himalaya

Priya Bharati[a], Pranab Deb[a], Kieran. M. R. Hunt[bc], Andrew Orr[d], Mihir Kumar Dash[a]

[a]CORAL, Indian Institute of Technology Kharagpur, Kharagpur, India

[b]Department of Meteorology, University of Reading, Reading, UK

[c]National Centre for Atmospheric Science, University of Reading, UK

[d]*British Antarctic Survey, Cambridge, UK*

ABSTRACT

In this study, we investigate the complex relationship between western disturbances (WDs), the El Niño Southern Oscillation (ENSO), and extreme precipitation events (EPEs) in the Western Himalayas (WH) during the extended winter season (November-March). WDs west of WH coincide with 97% of recorded EPEs, contributing substantially (32% in winter, 11% annually) to total precipitation within WH. WDs are 6% less frequent and 4% more intense during El Niño than La Niña to the west of WH. During El Niño (compared to La Niña) years, WDs co- occurring with EPEs are significantly more intense and associated with 17% higher moisture transport over WH box. This results in doubling of EPEs frequency during El Niño periods than La Niña periods. A substantial southward shift (~180 km) of the subtropical jet (STJ) axis during El Niño brings WD tracks further south towards their primary moisture sources, especially the Arabian Sea. We have shown that WDs that are both more intense and pass to the south of their typical latitudes have higher levels of vertical integrated moisture flux (VIMF) within them. VIMF convergence in the most intense pentile of WDs is 5.7 times higher than in the weakest, and is 3.4 times higher in the second lowest latitude pentile than in the highest. Overall, this study demonstrates a direct link between changes in the latitudinal position and intensity of WDs associated with winter STJ, and moisture convergence, which leads to the occurrence of EPEs over the WH during ENSO phases.

Keywords: Western Himalaya, extreme precipitation, western disturbances, ENSO, moisture flux, winter.

Differences in rain microphysics between Eastern and Western Ghats of Indiabased on GPM satellite observation

Amit Kumar[a,*], D.R. Pattanaik [a],

[a] *India Meteorological Department, New DelhiE-Mail: amitkriitm@gmail.com*

ABSTRACT

The Eastern and Western Ghats along India's east and west coast are two orographically distinct mountain ranges with different rainfall patterns. Both ranges receive rainfall during the Indian monsoon, depending on the latitude, topography, and windward-leeward effects, resulting in considerable variation in rain microphysics. We investigated differences in rain microphysics using the Global Precipitation Measurement (GPM) satellite Level 2 data (V07) from 2015 to 2023. Spatial variability of rain-integral parameters like rain rate (R), reflectivity (Z), liquid water content (LWC), mass-weighted mean diameter (D_m), and normalized-intercept parameter (N_w) is determined to understand the characteristics of raindrop size distribution (DSD) in both mountainous regions. Extreme rain event frequency and intensity are high during the south-west monsoon (June to September) over the Western Ghats. Enormous availability of moist winds coming from the Arabian Sea and uneven terrain favouring orographic lifting, causing extreme rainfall with large R and bigger raindrops (high D_m). Less elevated Eastern Ghats receive moderaterainfall (medium R and D_m value) during the south-west and north-east (October to December) monsoon; latter contribution is more. Gamma distribution of DSD is derived by fitting the GPM observation captured over the Western and Eastern Ghats of India. The derived gamma distributionis broader (large value of intercept parameter and shape parameter) over the Western Ghats due tothe significant concentration of bigger raindrops, especially at the time of convective rainfall, which causes strong updrafts and vigorous collision-coalescence processes. Meanwhile, thegamma distribution for the Eastern Ghats region is narrower (smaller value of intercept parameterand shape parameter), signifying a higher concentration of smaller raindrops with low-intensity rain during the stratiform rainfall. Differences in wind speeds and orographic lifting between thesetwo regions also contribute to the distinction of DSD characteristics.

Keywords: Raindrop size distribution; GPM satellite; Western Ghats; Eastern Ghats

Early Warning System On Extreme Weather Events Using Machine Learning And Deep Learning Techniques

Prakash Kumar Jala1[a], Immanuel Selvakumar A2[b], Meenal R3[c] and Rajan D4[d]

[a,b] *Electrical and Electronics Engineering,*
[a,b,d] *Karunya Institute of Technology and Sciences,Coimbatore,*
[c] *Electrical and Electronics Engineering, V.S.B. Engineering College, Karur, India*
jprakashkumar@gmail.com

ABSTRACT

Prediction of extreme weather events like heat waves, heavy rainfall, cold wave and issuing an early warning using weather forecast data is vital for reducing any potential adverse impacts of climate change. Short-term changes in the atmosphere make up weather. Minute by minute, hour by hour, day by day, and season by season, the weather might change. The average weather for a certain place and time period is referred to as the climate, which is the long-term weather pattern.Commonly influenced input parameters of extreme events are various cloud conditions, heavy aerosol conditions, soil moisture, heavy rainfall, solar radiation, temperature, heavy precipitation, evapotranspiration, relative humidity, strong winds, water current velocity, ice storms, lightning, tropical storm and so on. This article reviews the applications of Machine Learning and Deep Learning Techniques on early warning systems for extreme weather or extreme climate conditions.The most commonly used models are Extreme Learning Machines, Ensemble Machine Learning, Support Vector Machines, Random Forest Models, Artificial Neural Networks, Principal Components Analysis, Long Short-Term Memory, Generative Adversarial Networks Models, andDeep Neural Networks. An extensive review of the applications of ML and deep learningtechniques for early warning systems is presented in this paper.

Keywords: Early warning system, Extreme events, Climate conditions, Machine learning, Deep learning.

REPORTING OF NATIONAL INVENTORY OF AMMONIA EMISSIONS FROM 24 ANTHROPOGENIC SOURCES IN INDIA

Pallavi Sahoo[a,b], Saroj Kumar Sahu[b]

[a] *Department of Botany, Utkal University*
[b] *Department of Environmental Science, Berhampur University*
E-Mail: pallavisahoo570@gmail.com

ABSTRACT

Ammonia (NH_3) is a highly alkaline constituent in the atmosphere, which acts as a key precursor towards the particulate matter by reacting with gaseous nitric acid and sulfuric acid. This indirect greenhouse gas could reduce visibility, deplete stratospheric ozone, and trigger perturbation in ecosystems. The major sources of ammonia are livestock excreta and fertilizer applications. These sectors jointly contribute to ~57% and ~80% of total ammonia at the global scale and in Asia respectively. Being an agrarian country with a large livestock population and uncontrolled fertilizer application, India could be accountable as a major stakeholder of global NH_3 emissions. This study developed a comprehensive gridded (0.1° x 0.1°) ammonia inventory for India considering 24 types of sources. The total NH_3 emission is estimated to be 10.54 Tg/yr in 2022, where synthetic fertilizer application accounts for ~47% followed by livestock (~34%). Minor unattended sectors such as biomass burning, agricultural soil, human excrement, waste disposal, etc. contribute 0.68 Tg/yr, 0.32 Tg/yr, 0.3 Tg/yr, and 0.14 Tg/yr, respectively. Our results indicate that such high emissions of ammonia could impose a serious threat to the ecosystems and human health unless strategic mitigation efforts are taken for its reduction. The overall uncertainty of the inventory lies at ± 55%. These emission datasets are essential for atmospheric chemistry models and could be a crucial tool for policymakers to combat ammonia pollution.

Keywords: Ammonia; Emission inventory; Fertilizer; Livestock; Anthropogenic sources

Analysis of Central India Monsoon (1901-2022)for above and below normal rainfall years

Mamta Yadav[a], Pushpa Saroja[a],and Devendra Pradhan[b]

[a] *India Meteorological Depeartment, Pune*[b] *Mansarovar Global University, Sehore E-Mail: mamta.yadavbhopal@gmail.com*

ABSTRACT

This Study mainly focuses on Extremely heavy rainfall events over Central India, which are very important for contribution towards all India rainfall and overall performance of monsoon during aparticular year. As we look into rainfall data for the period (1901-2022) for the All India Monsoonand Rainfall over four homogeneous regions, NE India, NW India, Central India and South Peninsular India. We found that the rainfall over Central India is highly correlated (0.85) with allIndia Rainfall as compared to other three homogeneous regions. As some part of central India is present in the monsoon core zone like some districts of east MP and some districts of West MP. Oscillation of Monsoon trough and persistence of the monsoon trough over monsoon core zone for 2-3 days along with movement of low pressure systems like deep depression, depression, WellMarked Low pressure (WML) and Low pressure systems (LOPAR). Central India rainfall remainbelow normal in nine years and above normal in ten years during the above mentioned period (1901-2022). The lowest rainfall(690mm) recorded for the year 1918 and the highest rainfall(1307mm) recorded during monsoon season for the year 1994 over central India which resulted in all India monsoon rainfall with negative normal (-13%) and positive normal (13.9%) departure respectively. Studies have shown that tropospheric temperature gradient plays an important role in shifting of high wind speed wind currents facilitating the advancement of monsoon over Indian landmass. Some portion of central India comes under monsoon core zone and various parameters like wind field, mean specific humidity, mean vertically integrated moisture transport in premonsoon and monsoon season with respect to above normal and below normal years has been compared for understanding monsoon circulation over central Indian region.

Keywords: LOPAR, Monsoon trough, All India rainfall, Above and below normal, wind field, specific humidity, Vertically Integrated Moisture transport

SUB-SURFACE SALINITY VARIATION AND ITS IMPACTON THE INDIAN OCEAN CIRCULATION

Limonlisa, Sahu[a], Mihir Kumar Dash[a],[a] *Centre for Ocean, River, Atmosphereand Land Sciences,*
Indian Institute of Technology Kharagpur,Kharagpur, West Bengal, India
E-Mail: sahulimona1995@gmail.com

ABSTRACT

Sea surface salinity (SSS) changes over a longer period of time are an essential aspect of climate change and an effective indicator for alterations in the global water cycle. On an inter-annual to decadal time scale, salinity shows a dipole mode of variability on the surface of the Tropical IndianOcean (TIO). However, the sub-surface salinity variability is still unclear. So, to observe the fluctuations, we used empirical orthogonal function (EOF) on ARGO observational and EN4 reanalysis data sets in the upper layers of the Indian Ocean (IO). In contrast to the dipole mechanism, this study provides a different pattern of salinity variability with fluctuations over a decadal time range. It sheds new light on ocean-atmosphere coupling through wind-salinity- density-MLD-SST feedback. The spatio-temporal links between salinity and precipitation reveal a strong coupling through the wind field, which demonstrates the atmospheric dynamics. Meanwhile, quantitative examinations reveal the ocean contribution. Considering the significant impact of salinity variability on upper ocean stratification and circulation, it is crucial to accuratelysimulate the upper ocean dynamics in coupled climate models.

Keywords: Salinity Variability; wind-salinity-density-MLD-SST feedback; Climate change;Indian Ocean; ARGO

A study of upper ocean characteristics in response to the three intense re-curving tropical cyclones from the Arabian Sea using satellite and in-situ measurements

Adarsh Dube[a,d]*, Ajeet Ku Maurya[b], Rajesh Singh[c], T Dharmaraj[a],
a Indian Institute of Tropical Meteorology, Pune, India
b Department of Physics, Babasaheb Bhimrao Ambedkar University, Lucknow, India
c K S Krishnan Geomagnetic Research Laboratory, IIG, Prayagraj, India
[d] India Meteorological Department, Pune, India
E-Mail: adarshdube92@gmail.com

ABSTRACT

We present the sea surface temperature (SST), latent heat flux (LHF), and sensible heat flux (SHF) studies of three tropical cyclones in the Indian subcontinent region. These three tropical cyclones were scrutinized based on their intensity scale ranging from Category 2 (Very Severe Cyclonic Storm, VSCS) to Category 5 (Super Cyclonic Storm, SuCS) on a hurricane scale (IMD scale). VSCS Vayu, SuCS Kyarr, and ESCS (Extremely Severe Cyclonic Storm) Maha formed over the Arabian Sea in June, October, and November 2019, respectively. There is a 2 to 4 °C difference in the SST during the pre and post-cyclone period along the best track. The maximum reductions in SST up to 8 °C have occurred in the region from where the cyclones have re-curved. The enthalpy fluxes (LHF and SHF) are highest at 280 W/m^2 around the cyclone's best track and follow the same direction of the cyclone development. Prior flux changes in the cyclone region may have a role in directing the cyclone's best track. Argo floats within 1° from the best track revealing that pre-cyclone SST was warmer at the surface than post-cyclone SST. The sub-surface SST at a depth of 100-150m suggests a warming of the ocean in the post-cyclone period near and adjacent to cyclone intensification regions due to the upwelling of the warm subsurface waters. The upper ocean response is crucial to studying the increasing intensity of TCs and the re-curvature of its best track over the Arabian Sea.

Keywords: Tropical cyclones re-curvature, Argo floats, SST, Enthalpy fluxes

Comparative Study of Ventilation Coefficient and its Impact on Air Pollutionover the Two Mega Cities of India

Gauravendra P Singh1[a], G K Sawaisarje2[a] ,and Geeta Agnihotri3[a],
[a] *India Meteorological Department, Pune,E-Mail: gauravendra.singh@gmail.com*

ABSTRACT

Air pollution has garnered international attention as a significant issue. It is crucial to identify its sources for adequate control. One crucial aspect to consider is the meteorological factors that affecturban air pollution. The two most critical meteorological metrics are mixing layer height (MLH) and wind speed. The mixing layer height represents the vertical dilution ability of air pollutants, while wind speed aids in the dispersion of air pollution through horizontal ventilation. An important metric, the ventilation coefficient, calculated by multiplying the mixing layer height bythe average wind speed, is a key variable influencing the potential for pollution over a specific area and is essential for the dilution and removal of aerosols. Over the span of 55 years (1967– 2022), radiosonde data from 00 UTC and 12 UTC for all months in Mumbai and Delhi was analyzed to assess the trends and long-term variations in ventilation coefficients and their impact on air quality. The analysis revealed a decreasing trend in ventilation coefficient in both New Delhiand Mumbai over the 55-year period, indicating an increase in pollution potential and degradationof air quality in these urban areas. In Delhi, the 00 UTC ventilation coefficient showed a decreaseat the rate of 130.85 m^2/sec/year during the pre-monsoon season and 109.87 m^2/sec/year during the winter season over the 55-year period. Meanwhile, the 12 UTC ventilation coefficient in Delhi decreased at the rate of 3.73 m^2/sec/year during the pre-monsoon season and 11.34 m^2/sec/year during the winter season. In Mumbai, the 00 UTC ventilation coefficient decreased at the rate of 89.87 m^2/sec/year during the pre-monsoon season and 101.06 m^2/sec/year during the winter seasonover the same period. Similarly, the 12 UTC ventilation coefficient in Mumbai decreased at the rate of 35.66 m^2/sec/year during the pre-monsoon season and 24.12 m^2/sec/year during the winterseason. The reduction in ventilation coefficient contributed to increased ground-level pollution, leading to a decline in air quality for the urban population. In Mumbai, the reduction in mixing depths and wind speed played a role in the declining ventilation coefficient, while in Delhi, decreasing wind speed was the primary factor. Additionally, the pollution potential was higher inDelhi, an inland station, compared to Mumbai, a coastal station influenced by the marineenvironment. This difference was attributed to the prevailing sea-breeze in Mumbai aiding in the dispersal of pollutants, thereby reducing their ground-level concentration.

Keywords: Ventilation coefficient; Mixing layer height; Air Pollution; Atmospheric boundary layer; radiosonde data.

Comprehensive Analysis and Modeling of Extreme Rainfall Events for Enhanced Hydrological Risk Assessment and Resilience

Ruhiteswar, Choudhury[a], Tanusree Deb Roy[a], and Sebul Islam Laskar[b]

[a] *Department of Statistics, Assam University Silchar.*
[b] *India Meteorological Department (IMD), New Delhi.*
E-Mail: sonu.choudhury2015@gmail.com

ABSTRACT

Extreme rainfall events have significant implications for hydrological planning and disaster management. This study presents a comprehensive analysis of extreme rainfall over a 37-year period, utilizing a dataset with a threshold set at the 90th percentile to identify extreme events. Anomalies and outliers were detected using boxplot visualizations. Subsequently, the Generalized Extreme Value (GEV), Generalized Pareto, and Generalized Logistic distributions were fitted to the extreme rainfall data employing three estimation methods: Maximum Likelihood Estimation (MLE), L-Moments, and Trimmed L-Moments (TL-Moments). The performance of these distributions and estimation methods were compared to determine the most suitable model for extreme rainfall prediction. The results provide valuable insights for enhancing the accuracy of extreme rainfall forecasting and improving the robustness of hydrological risk assessments. This study underscores the importance of selecting appropriate statistical models and estimation techniques in the analysis of extreme weather events.

Keywords – Extreme events, Hydrology, Boxplot, Maximum Likelihood Estimation, L-Moments, TL-Moments.

A detail study to understand the different physical causes of lightning through satellite, ground based observations and NWP model

Swagata Payra[a], Pramod Yadav[b],
Sunita Verma[b,c],
Mili Ghosh Nee Lala[a] , Divya Prakash[d]
and Sibalika Kundu[a]

a Department of Remote Sensing , BIT Mesra,Ranchi, Jharkhand
b Institute of Environment and Sustainable Development, BHU, Varanasi, UP
c DST-Mahamana Centre of Excellence in Climate Change Research, BHU, Varanasi, UP
d Department of Civil Engineering, Poornima University, Jaipur, Rajasthan
E-Mail:spayra@gmail.com

ABSTRACT

Lightning, a climate-related highly localized natural phenomenon, claims several lives and damages properties every year. These losses could only be reduced by the identification of regions, active seasons, and proper understanding of causative factors behind the occurrence of lightning. The present study identifies the lightning-prone regions of India with the help of data retrieved from Lightning Imaging Sensor (LIS) onboard International Space Station (ISS). Further, the relationship has been explored between the occurrences of lightning incidences with the Land Surface Temperature (LST), elevation, Relative Humidity (RH) and prevalent wind, especially with the vertical wind speed. Seasonal analysis shows that most lightning incidences occur during the pre-monsoon period over the northeastern region of India. During the winter period, the lightning dominates over Jammu and Kashmir. The favorable climatic conditions, such as high LST, high RH, abrupt change in elevation, wind speed and direction are key parameters for understanding lightning phenomenon. To analyse the impact of these parameters on lightning incidences,different case studies of Indian states have been taken into consideration.. It was found that LST favors the lightning formation, but at the same time it was also observed that even low LST can produce lightning depending upon the strong anabatic wind and available high RH. Further, the cloud radius was also found to be a fair estimator of lightning occurrences. Apart from extensive observation, non-hydrostatic numerical model has been used to understand the dynamics of meteorological parameters along with CAPE and CIN. For the firstime the comparative analysis of four different observation sources like satellite based LIS and groundbased NRSC, IITM and WWLLN network has been done with remarkable results. This better understanding will help us to predict the lightning occurrences and accordingly will be helpful in adopting the mitigation measures to minimize the lightning induced causalities.

Keywords: Extreme weather events; Lightning, LST, CAPE, LIS

CHARACTERISTICS OF THE TROPOSPHERIC AEROSOLS AND THEIR RADIATIVE EFFECT DURING THE EXTREME AND PROLONGED HEATWAVE CONDITIONS OVER INDIA

Betsy Karaikkattu Benzigar[a], Sanjay Kumar Mehta

[a] *Atmospheric Observation and Modelling Laboratory (AOML), Department of Physics andNanotechnology, SRM Institute of Science and Technology, Chennai*
E-Mail:betsykaraikkattu@gmail.com

ABSTRACT

This study investigates the role of aerosols, the atmospheric boundary layer (ABL) variations, and the direct aerosol radiative effects under prolonged heat wave conditions in northwest India. Heat waves were categorized as dry or moist based on relative humidity thresholds, with dry conditions defined as RH below 33% and moist conditions above 55%. Analyzing heat wave days identified by the 90th percentile of daily maximum temperatures, we observed extremely dry weather overnorthwest India, characterized by subsidence, reduced total cloud cover (TCC), and a persistent temperature inversion that trapped cooler air near the surface, contributing to the prolonged heat wave. The increased ABL height, driven by intense surface heating and low soil moisture, persisted throughout the heat wave. Aerosol analysis revealed a significant increase in absorbing aerosols over northwest India and the Indo-Gangetic Plain, contributing to extreme warming conditions. The total aerosol optical depth (AOD) increased from 0.32 to 0.5 during the heat wave, due to absorbing aerosols. The radiative forcing within the atmosphere changes as like absorbing aerosols, with higher heating rates for moist heat waves than dry ones, associated with increased aerosol radiative forcing. PM2.5 concentrations also varied, with dry heat waves showing higher dust emissions and elevated PM2.5 levels, posing a greater threat to public health and air quality.These findings highlight the complex interactions between aerosols, boundary layer dynamics, and radiative forcing during heat wave conditions, emphasizing the need for targeted mitigation strategies to reduce health risks associated with extreme weather events.

Keywords: Heat wave; Heat Stress; Aerosols; Radiative Forcing

Evaluation of very high-Resolution model performance in capturing Delhi'sextreme rainfall event during July 2023

Sahadat Sarkar[1],Soumyajyoti Jana[1],Malay Ganai1,Medha Deshpande[1], Phani R[1], P. Mukhopadhyay[1]

1 Indian Institute of Tropical Meteorology,

Pune, India-411008

E-Mail: Sahadat.cat@tropmet.res.in

ABSTRACT

In early July 2023, Delhi, the capital city of India, witnessed an extraordinary rainfall event from the 7th to the 10th, leading to significant disruption. This study seeks to provide an in-depth analysis of the convective characteristics of these weather events, alongside the larger atmospheric mechanisms at play. To achieve this, we have examined two state-of-the-art models: the 6.5 km High-Resolution Global Forecast Model (HGFM) in TCO grid, developed by IITM (IITM-HGFM), and the widely recognized ECMWF model. Our analysis indicates that both the HGFM and ECMWF models exhibit a strong capability in simulating large-scale atmospheric processes, such as moisture transport and the influence of extra-tropical systems. The key factors identified in the study was the interaction between the Rossby wave, potential vorticity-induced low pressure systems, and large-scale moisture convergence, which collectively set the stage for this extreme rainfall event. While both models show considerable skill in capturing the structure of potential vorticity and the propagation of the Rossby wave, they tend to slightly underestimate the magnitude of moisture transport. Furthermore, our investigation into the cloud liquid water path (CLWP) reveals that while the models accurately represent this parameter, they still display a slight underestimation. In terms of rainfall duration and intensity, both models fall short, particularly in forecasting the precise intensity and longevity of the rainfall, which is slightly underestimated. Overall, this study sheds light on the strengths and limitations of these advanced models in simulating and predicting such extreme weather events.

Keywords: Extreme rain, Delhi, IITM-HGFM, TCO grid

INTEGRATING METEOROLOGICAL SENSORS IN SMART ENVIRONMENTAL SYSTEM FOR IMPROVED DATA ACCURACY

Ishika Rajesh Warwade, Vipul Mishra

[a] *Department of Environmental Science,*
Institute of science, Nagpur
[b] *Department of Electronics,*
Nagpur University Campus

E-Mail: *ishikawarwade2020@gmail.com*
vipulm767@gmail.com

ABSTRACT

This research is mainly for the protect the Gender from Tsunami and Flood, prone zone area like coastal areas, Eastern ghats, western ghats. With the help of Satellite Data It will transfer the message and communicate the data in their language, it will be more easier to understand and to provide safeguards. Gender will move out to a safer place for safety purpose. The prediction of Tsunami and flood using their occurrence parameter before disaster. Installation and maintenance of broken sensors in Tsunami and flood conditions are significantly complicated. This study intends to provide best practices for increasing the lifecycle, operational availability, and data quality of sensors, with particular attention to Tsunami and flood. The Tsunami and flood affects specifically the performance of the sensors. It makes the operation of the met mast in cold climates very difficult and transforms it into a real challenge. Besides, the Tsunami and flood induces various meteorological conditions: increase in water scale, low-temperature. The Tsunami and flood accumulation generates big debris throw. These throw can break the sensors and reduce the data availability. Also, events cause the degradation of the quality of measurement values. We focus in this paper on the causes of the sensor malfunctioning and the characteristics of each sensor.

Conclusions: The study suggests how sensors should be configured and selected to extend their life-cycle and data availability in cold climate conditions.

Keywords: Sensors, Climate change; Weather Prediction; Disaster management, Debrie throw

A Study Emphasizing on Probability Distribution Function and Implication of L-Moment Ratio Diagram in Temperature Data

Dipanjali Ray1[a], Tanusree Deb Roy2[b], and Sebul Islam Laskar3[c]

[a ,b]*Department of Statistics, Assam University, Silchar*
[c] *India Meteorological Department, New Delhi*
E-Mail:dipanjali0298@gmail.com

ABSTRACT

This study examines various criteria for assessing the goodness of fit of probability distribution functions using monthly mean maximum and minimum temperature data of Guwahati City, Assam, spanning 1985 to 2022. To gain a deeper understanding of the higher-order moments of the temperature data, L-moments and L-moment ratio diagrams are utilized. The fit of probability distribution functions is evaluated using both L-moment ratio diagrams and a range of goodness- of-fit criteria, including Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC), Kolmogorov-Smirnov (K-S) test, Chi-square test statistic, coefficients of determination (R^2) from P-P and Q-Q plots, and Root Mean Square Error (RMSE). Nine probability distribution functions are considered, based on existing literature: Generalized Extreme Value (GEV) distribution, Weibull distribution, Gumbel distribution, Gamma distribution, Log-Normal distribution, Pearson Type I distribution, Pearson Type III distribution, and Pearson Type V distribution. The sample L-moments are computed, and L-moment ratio diagrams are presented monthly for both maximum and minimum temperatures in Guwahati City.

Keywords: AIC, BIC, K-S test, L-moment ratio diagram, Temperature

Investigating the Possibility of Brown Ocean Effect Signature in Tropical Cyclones Formed over the Bay of Bengal During the Pre-Monsoon Season

Shritu Badoniya[a], Anantharaman Chandrasekar[a]

[a] *Department of Earth System Sciences,*
Indian Institute of Space Science and Technology (IIST),
Trivandrum, India
E-Mail: *shritu.badoniya99@gmail.com*

ABSTRACT

This study presents a diagnostic investigation of the Brown Ocean Effect in tropical cyclones (TC)formed over the Bay of Bengal Indian region during the pre-monsoon season. Three tropical cyclones (TC Remal, TC Aila, and TC Asani) were analyzed, each of which formed in the Bay ofBengal and made landfall along the Indian coast during different years in the moth of May. ERA5reanalysis data, with a spatial resolution of 0.25 degrees and a temporal resolution of 1 hour, wasemployed in this study. TC Remal experienced landfall on the coast of Sundarban Delta, West Bengal at 15 UTC on Sunday, 26 May 2024. While TC Aila had landfall on the coastal parts of West Bengal, particularlyin South 24-Parganas and North 24-Parganasat around 08:30 UTC on 25th May 2009, TC Asani crossed land over the coastal parts of Andhra Pradesh around 12 UTC on 11 May 2022. The resultsprovide a clear signature of diurnal variation in the sensible and latent heat fluxes over a land locations along the cyclone track as compared to an oceanic location, (also along the cyclone track)for a period of two weeks, before landfall, in all the three tropical cyclones that are investigated. The analysis focuses on key parameters such as surface latent heat flux, surface sensible heat flux, surface air temperature, surface humidity, soil temperature, soil moisture, planetary boundary layerheight, precipitation, and the surface wind speed. The afore-mentioned variables were examined both from (i) cyclone-centric coordinates as well as (ii) fixed latitude-longitude coordinatelocations along the tropical cyclone paths. Preliminary results indicate a potential Brown Ocean Effect signature in TC Remal and TC Aila, suggesting that land surface conditions may have contributed to the intensification and sustenance of these tropical cyclones post-landfall, while the results indicated that this was not the case for TC Asani.

Keywords: Brown Ocean Effect; Tropical cyclones; Bay of Bengal; Pre-monsoon; ERA5 reanalysis

Decreasing Trend of Fog at Kolkata Airport

Abhishek Anand [a], Sunny Chug[a], Rajdeep Saha[a]
,G.K. Das[a] ,Somnath Dutta[b]

[a] *Meteorological Watch Office (MWO), Kolkata*
[b]*Regional Meteorological Centre, KolkataE-Mail: abhipat.13@gmail.com*

ABSTRACT

This study investigates the decreasing trend of fog occurrences at Kolkata's Netaji Subhas Chandra Bose International (NSCBI) Airport, a critical aviation hub in eastern India. Fog is a significant weather phenomenon affecting visibility, which in turn impacts flight operations, leading to delays, diversions, and cancellations. The research addresses the problem of understanding how fog patterns have changed over recent decades, particularly in the context of global climate variability and urbanization. The study's purpose is to analyze the long-term trend of fog at Kolkata Airport and determine whether there has been a statistically significant decrease in its frequency. The research employs a comprehensive analysis of historical METAR data, spanning from 2008 to 2024 (November to March). Additionally, the study considers contributing factors, including changes in temperature, dew point temperature, humidity, and wind patterns. Results indicate a clear downward trend in fog occurrences, during the November to March, when fog is most prevalent in the Indo-Gangetic plains. This decrease is attributed to several factors, including rising temperatures, changes in moisture availability, and alterations in wind patterns due to urban expansion and increased pollution. The findings are corroborated by the analysis of visibility records from METAR and synoptic observations from SYNOP data. In conclusion, the study provides evidence of a significant decrease in fog events at Kolkata Airport, which has implications for aviation safety and operational efficiency. Theresults suggest that while the declining trend may reduce fog-related disruptions, it also highlights the broader impacts of climate change and urbanization on local weather patterns. Further research is required to explore the implications of these changes on other weather-relatedphenomena affecting aviation in the region.

Keywords: METAR; Aviation; Fog; Kolkata Airport; Climate Change (maximum 5 words)

ON ASSESSING INFLUENCE OF AEROSOLS ON TROPICAL CYCLONE-INDUCED PRECIPITATION IN BAY OF BENGAL: A CASE STUDY OF VARDAH

Arun Kumar[a], Vivek Singh[b],
and Samiran Mandal[a],

[a] *Centre for Atmospheric Sciences, Indian Institute of Technology Delhi.*
[b] *Indian Institute of Tropical Meteorology,*
New Delhi Branch, Ministry of Earth Sciences
E-Mail: asz238206@iitd.ac.in

ABSTRACT

Utilizing reanalysis and satellite observations, the present study investigates the interactions and redistribution of aerosols during a very severe cyclonic storm (VSCS) tropical cyclone (TC) Vardah (4th December to 13th December 2016) in the Bay of Bengal (BoB). The analysis focuses on the effects of aerosols on the cyclone-induced precipitation, including an examination of aerosol loading, changes in their distribution during the passage of this TC, and their influence on cloud microphysics and rainfall patterns. As this cyclone Vardah matured from a SCS to VSCS, a gradual reduction in the precipitation rate was observed, accompanied by an increasing trend of the lower tropospheric stability. Stronger winds from the aerosol-rich north-eastern Himalayan region directing towards the cyclone resulted in a significant influx of aerosols into the cyclonic system. Enhanced aerosol loading was observed over the central and western BoB during the SCS and VSCS stages of the cyclone, respectively. This could be due to the strong drag of winds from the northeastern Himalayan regions towards the cyclone as it approached the coastal region. Investigation of the spatial distribution of aerosols and precipitation rate during different stages revealed the crucial role of presence of aerosols in suppressing the precipitation before the tropical cyclone made landfall. Further, this investigation suggested that the tropical cyclone Vardah deposited a significant number of aerosols over Chennai, bringing it from the ocean. These results are important to understand the redistribution of aerosols and their impact on precipitation induced by cyclones over the BoB.

Keywords: Tropical Cyclones, Precipitation Rate, Aerosols, Lower Tropospheric Stability, Stability Indices.

CHARACTERISTICS OF MARINE HEATWAVES ALONG JAVA COASTIN THE SOUTHEASTERN INDIAN OCEAN

Bhushan Shirwadkar, and Samiran Mandal[a],

[a] *Centre for Atmospheric Sciences, Indian Instituteof Technology Delhi.*
E-Mail: *shirwadkarbhushan@gmail.com*

ABSTRACT

Marine heatwaves (MHW) pose a growing threat to marine ecosystems, with rising intensity and frequency globally. This study investigates the spatio-temporal variations of MHWs over the Maritime Continent from 1982 to 2021. High standard deviation values of sea surface temperature(SST) and surface chlorophyll-a concentration identify the southern Java coast as a hotspot for MHWs. During 1982-2021, in total 63 MHW events have been detected, of which 54 are moderate,8 are strong, and one can be classified as a severe event. Notably, two strong and intense MHW events identified, within a gap of 15 days, combined to emerge into a yearlong MHW event duringDecember 2015 – November 2016. This heatwave persisted for 285 days with a maximum intensity of 2.31°C strength and cumulative intensity of 414.49 °C days. Additionally, the surfacechlorophyll-a concentrations and subsurface temperature anomalies depict two phases: Phase I during December 2015–May 2016) and Phase II during June 2016–December 2016. Moreover, the wind speed anomalies suggest strongly reduced wind-driven mixing, supported by negative mixed layer depth anomalies. The mixed layer heat budget analysis suggests that change in the heat storage term is prominentlydriven by the net surface heat fluxes during the first phase, but horizontal advection and vertical processes are also found to play significant roles in the second phase. The first phase is found to the driven solely by the net surface heat fluxes, whereas the second phase of the MHW event is prominently driven by the downwelling phase of the coastal Kelvin waves. Note that, the variationsin Ekman pumping velocity are almost negligible in either of the phases. As an implication to themarine ecosystem, the significant reduction in surface chlorophyll-a concentration and higher SSTs led to reduced fish catch during the study period.

Keywords: Southeastern Indian Ocean, Marine heatwaves, Java Coast, Mixed layer Heat Budget,Coastal Kelvin Waves.

OBSERVED CHANGES IN SURFACE OZONE POLLUTION DURING MAJOR HEATWAVE EVENTS IN INDIA

Anagha. K. S and Jayanarayanan. K

CORAL, Indian Institute of Technology KharagpurE-Mail: anaghaks@kgpian.iitkgp.ac.in

ABSTRACT

Heat waves (HWs) has become one of the most severe weather extremes and natural hazards in recent decades, with their frequency and intensity expected to rise in the future. Surface ozone (SfO_3) pollution is another significant environmental and health hazard, impacting both human health and agriculture. Ozone pollution events are often triggered by the release of precursor emissions combined with hot, stagnant weather conditions. The simultaneous occurrence of HWsand SfO_3 pollution is now recognized as a critical compound extreme event globally. The meteorological conditions favorable for ozone production such as extreme temperatures, strong solar radiation, prolonged sunshine and low wind speeds are also characteristic of HWs, leading to increased SfO_3 levels that may continue to escalate in the future. Due to global warming, thesecompound events are projected to become more frequent in many parts of the world by the end ofthis century. Here, we analyse the changes in SfO_3 during major heatwave events in India during 2010–2020 using the daily maximum temperature (Tmax) data from India Meteorological Department (IMD) and updated tropospheric chemical reanalysis version2 (TCR-2) SfO_3 data. Composite mean of Tmax and Maximum Daily Average 8hour SfO_3 concentrations (MDA8) are analysed for the major HWs in two prone areas, northwest (NW [22ºN–31ºN, 70ºE–78ºE]) and southeast (SE[12ºN–16ºN, 78ºE–81ºE]) India. MDA8 in HW days are found to be higher than non-HW days, of about 5.8 µg/m^3 in the SE and 7.84 µg/m^3 in the NW regions during March and May months, respecively. Henceforth, the relevant authorities may issue warnings through their operational services if forecasts indicate that there will be more compound HWs and SfO_3 extremes in the upcoming pre-monsoon season.

Keywords: Heat waves; Ozone pollution; Climate change; Compound events

DEEP LEARNING BASED PREDICTION OF CLOUDBURST EVENTS OVER THE NWH REGION

Hritul, Raturi[a,b], Charu, Singh[b]

[a] Atmospheric Sciences Department, MASG, *Indian Institute ofRemote Sensing, ISRO, Dehradun*
[b] *School of Environment and Natural Resources, Doon University,Dehradun*
E-Mail: hritul.raturi@gmail.com , charu@iirs.gov.in

ABSTRACT

The intricate orographic features of the North-West Himalayan region play a significant role in modifying the weather and climatic conditions of this region. The Western Disturbances and Monsoon Circulations are the two synoptic-scale circulations which cause rainfall over the state. The monsoons are crucial for life and sustenance in the region, but they also lead to many potential hazards. Several regions of Himachal Pradesh and Uttarakhand witness Heavy toExtreme Rainfall Events (EREs) every year. Climate change and the warming of the environmenthave drastically changed the pattern of rainfall as well as enhanced the frequency and intensity ofthese events. The prediction of EREs in this region has been a challenge for years due to their localised nature and uneven topography of the region. The current study aims to understand the efficacy of Deep Learning (DL) algorithms for the prediction of EREs/cloudbursts. We have utilized the Deep Learning Algorithm called DeepRaNe (Seok-Geun Oh et. al., 2024) over the NWH region for the series of EREs in August 2022 using satellite-based estimates of priori conditions and assessed the suitability of the algorithm in predicting the event with better lead time. Overall, our results show a good potential of the DL algorithm in analyzing and monitoringthe EREs over the Indian Himalayan Region. More details will be discussed during the symposium.

Keywords: Cloudburst, Prediction; Deep Learning, NWH, DeepRaNe

Calibration of INSAT-3D Imager Visible Channel using Deep Convective Clouds

Danish Hussain *, Munn V. Shukla, Sanjib Kr. Deb

Earth & Planetary Science and Applications Area (EPSA),
Space Applications Centre, ISRO, Ahmedabad-380015, Gujarat
**Corresponding Author:* danish@sac.isro.gov.in

ABSTRACT

Deep Convective Clouds (DCCs) are the invariant brightest targets located near the tropopause where the radiative impact of surface visible radiance effects, aerosols and water vapour absorption are minimum. Because of these reasons DCC are used to calibrate visible channel of INSAT-3D imager. These types of clouds can be identified by using relatively simple IR threshold techniques which make them ideal invariant target for the purpose of calibration. Thus, DCCs has the potential to calibrate the satellite imager data, in the visible channel, in a consistent and robust manner. In this study, monthly calibration of INSAT-3D imager visible channel is done using DCCs. INSAT-3D L1B imager data for 2023 was taken from the Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC) website (www.mosdac.gov.in) and processed to get the radiances and brightness temperature corresponding to visible, water vapour (WV) & thermal infrared (TIR1) channels. Detection of DCCs is being done using thresholds of IR Brightness Temperature and Brightness Temperature Difference (BTD) of WV and TIR1 channel data, the spatial homogeneity of DCCs, spatio-temporal- geographical criterion and solar geometrical-illumination conditions. Monthly Probability Density Function (PDF) of INSAT-3D DCC visible radiance are generated. The DCCs calibration coefficients are calculated by comparing the mode of PDF of INSAT-3D visible radiance with mode value of PDF of simulated DCC radiance by using SBDART radiative- transfer-model (RTM) Calibration coefficients are in the range of *1.28 to 2.19*. These calibration coefficients can be used to regenerate the visible channel radiances, which in turn can improve the quality of geo-physical parameters.

Keywords: Calibration; satellite data; deep convective clouds; radiative transfer model; INSAT- 3D imager

Impact of Assimilating High Resolution Sattelite Derived Soil Moisture Data on the Soil Moisture Obtained From Land Surface Models

Devvrat Sahai[a], Anantharaman Chandrasekar[a]

[a] *Department of Earth and Space Sciences, Indian Institute of Space Science and Technology (IIST), Trivandrum, India*
E-Mail: *devvratsahaiofficial@gmail.com*, *chandra@iist.ac.in*

ABSTRACT

Typically, Land Surface Models (LSMs) which take precipitation and meteorological forcing as input do not reflect the impact of irrigation in their soil moisture estimates as the model processes do not provide any account for irrigation of croplands done by humans. This however, can be taken care, in an indirect manner by assimilating high resolution soil moisture data obtained from satellites, since the latter can account for irrigation effects. It is expected that the LSM output after assimilating with 9 km SMAP satellite soil moisture observations should show a signature corresponding to irrigation. In this study we will assimilate high resolution 9 Km soil moisture data from NASA's SMAP (Soil Moisture Active Passive) satellite into the Noah LSM using NASA's Land Information System Framework (LISF), over the Indian domain. Since India is a highly irrigated country, when we compare the LSM output without assimilating the 9 Km SMAP soil moisture data, to the same LSM model output where SMAP 9 km satellite soil moisture is assimilated, we should be able to discern the impact of irrigation. The assimilation of the high resolution data is carried out using the Ensemble Kalman Filter (EnKF) technique which is a data assimilation method that updates system states by integrating observational data with model predictions, using an ensemble of simulations to represent uncertainties and improve forecasts. The method used in this study will help bring soil moisture output from LSMs closer to the ground truth by accounting for irrigation effects. It will also help better irrigation impact assessment, enhanced model forecasting and can be used for informed water resource management.

Keywords: Soil Moisture, Signal of Irrigation, Land Surface Models, Ensemble Kalman Filter

Spatio-temporal changes in the pre-monsoon thunderstorm activities of, northeast India over the past four decades

Arpita Rastogi[a,b], J. Kuttippurath[b],and V. K. Patel[b]

[a] *India Meteorological Department, New Delhi, 110003.*
[b] *CORAL, Indian Institute of Technology Kharagpur, Kharagpur, 721302.*
E-Mail:arpita.rastogi@imd.gov.in

ABSTRACT

The development of catastrophic mesoscale convective systems in the atmosphere, such as thunderstorms, is caused by several factors, the most important of which is moisture in the lower troposphere and then the instability and lifting of air parcels. In pre-monsoon, northeast and adjoining eastern India are susceptible to thunderstorms. Herein, we analyse the spatial and temporal changes in thunderstorm activities in terms of convective available potential energy (CAPE) and other parameters during the pre-monsoon period (March, April and May) in northeast(NE) and adjoining eastern India using ground-based and reanalysis data. It is observed that atmospheric instability is relatively higher in southern West Bengal and Tripura compared to the other regions in NE and adjoining eastern India, with a CAPE value of about 1500–3000 J kg−1 during pre-monsoon and 2000–3500 J kg−1 in May, indicating that these regions are more vulnerable to thunderstorms. Other thunderstorm indicators such as convective inhibition (CIN), K-index (KI) and total totals index (TTI) also exhibit relatively higher values in these regions during pre-monsoon. Causal discovery and correlation analysis reveal a positive association of thunderstorm days with CAPE and TTI, but a negative link with CIN. A significant negative trendis estimated in CAPE and other parameters in NE and eastern India during May, which is more dominant in southern West Bengal and Tripura (about −8 to −12 J per kg per year). Stability indicessuch as KI and TTI also show significant negative trends in NE India. There is a negative trend in thunderstorm days at Mohanbari, Barapani, Jorhat, Pasighat and Silchar, while positive trends at Dhubri, Imphal, Tezpur and Lengpui in the recent decade (2011–2020), which is consistent with the changes in thunderstorm indicators at these stations. This study provides an important insight into thunderstorm activity in areas susceptible to extreme weather events in the context of recent climate change and global warming.

Keywords: Thunderstorms; CAPE; Northeastern India; Pre-monsoon; TTI; Climate Change

Tropical Extreme Rainfall Events: Sub-hourly Scale Variability

Pavankumar Olekar [a],Kalapureddy,M.C.R [a],

[a]*Radar & Satellite Meteorology, Indian Institute of Tropical Meteorology,Pune. E-Mail:pavankumar.olekar@tropmet.res.in*

ABSTRACT

Frequent Extreme Rainfall Events (EREs) have been challenging recently due to the changing climate and global warming scenarios. ERE scales involve cyclones of five to seven days to a turbulent cloud cluster of less than ten minutes. This study investigates the tropical India region- specific rainfall intensity using reanalysis and satellite datasets: hourly (ERA5, IMDAA) and sub hourly (IMERG and CMORPH). The main objective is to characterize the sub-hourly scale variability pertinent to tri-model convection associated with all vigorous weather events. The study evaluates the various cloud dynamical processes involved in sub-hourly variations, which helps understand the short lifespan of hazardous weather events such as turbulent cloud clusters, cloudbursts /mini-cloudbursts, and thunderstorms, the organized convection with the varied temporal scales. The region of current focus has latitude bounds between 17°N and 20°N and longitude bounds between 72°E and 74°E. This analysis provides insights using cloud vertical structure, moisture influx, and its conversion to the cloud /precipitation water content ratios. The results underscore the variability in precipitation estimates among the datasets, reflecting the influence of differing methodologies and resolutions.

Keywords: Extreme Rainfall Events; Mini-Cloudburst; Climate change;Cloud Dynamics; Organized Convection.

EVALUATION OF SOIL TEXTURE DATA AND SOIL HYDRAULIC PROPERTIES FOR LAND SURFACE MODELLING

Jiteshwar Dadich[a, b], Amit P. Kesarkar[a],
Jyoti Bhate[a], A. Chandrasekar[b]
,

a. *National Atmospheric Research Laboratory, Gadanki, Andhra Pradesh, 517112*

b. *Indian Institute of Space Science and Technology, Valiamala P.O., Thiruvananthapuram, 695547, Kerala*

Email: jiteshnarl@gmail.com

ABSTRACT

To effectively model runoff, surface energy exchanges, and moisture fluxes, land surface models (LSMs) require a comprehensive and precise depiction of soil water content. The Richards equation is prominently utilized in land surface models (LSMs) to determine soil water content. Because of the complexities in having laboratory measurements and unavailability of required pressure heads and hydraulic conductivities for various regions these parameters are predicted using pedotransfer functions. We have simulated the pressure head (H) and hydraulic conductivity (K) for a number of isolated thunderstorm cases over Gadanki (13.4593 ^{0}N, 79.168 ^{0}E) region where we have used different pedotransfer functions for K and van Genuchtem-Maulem (VG-M), 1980 model for H, respectively. The soil physical properties i.e. bulk density, and fractions of sand, silt, and clay, and organic matters present in soil medium at different depths are used at 250m resolution to calculate the hydraulic properties whereas required VG-M shape parameters are taken from global datasets (Montzka C. 2017, et al). Estimated hydraulic conductivities were compared statistically among results from different pedotransfer functions. van Genuchtem-Maulem (VG- M, 1980) model was used to predict the range of pressure head for different soil depths. The results were compared with the same types of soils given by different approaches. These values of pressure heads and hydraulic conductivities were used to predict the soil water content at various depths.

Keywords: soil water content, soil hydraulic properties, land surface modelling.

Retrieval of cloud top properties from Sounder on-board newly launched INSAT-3DS

Chandrani Chatterjee*, Tapan Ka Patel,
and Pradeep Kumar Thapliyal

*Atmospheric & Oceanic Sciences and Applications Group, EPSA
Space Applications Centre (ISRO), Ahmedabad
E-Mail: chandrani.chatterjee9@gmail.com

ABSTRACT

Clouds are an integral part of the atmosphere governing all the major weather events like precipitation, thunderstorms etc. Therefore, accurate retrieval of the cloud properties is very crucial in weather monitoring. Observing the clouds from the satellites is an excellent pathway in the said process. INSAT-3D series of satellites, primarily with the advanced meteorological payloads is a breakthrough in India's weather monitoring journey. The recently launched Imager and Sounder payloads on-board INSAT-3DS with improved blackbody calibration and reduced midnight Sun-intrusion has made the calibration process even more precise. The current study presents a physical retrieval framework for assessing cloud top pressure from the Sounder instrument in INSAT-3DS. The five CO_2 Channels (with central wavelengths around 14.37-12.66 mm) of the Sounder have been used for the retrieval of high/medium clouds, whereas; the window channel at 11 mm was utilized for the low altitude clouds. Thevalidation of the results was carried out by co-located MODIS cloud properties with satisfactory matching. An improved assessment of cloud top pressure not only facilitates in better weather and climatic forecasts but also acts as the basis of accurate estimation of other crucial cloud properties, like cloud top temperature and cloud fraction. Therefore, the output of the framework can be beneficial to all the applications demanding a precise cloud property estimation, in near future.

Keywords: Satellite meteorology, INSAT-3DS, clouds top pressure, CO2 slicing, Atmospheric retrieval

Role of Tropical Intraseasonal Oscillations on Cyclogenesis Trends over Northern Indian Ocean

Agnijita, Bandyopadhyay, Kiranmayi, Landu

School of Earth, Ocean and Climate Sciences,
Indian Institute of Technology Bhubaneswar
School of Earth, Ocean and Climate Sciences,
Indian Institute of Technology Bhubaneswar
E-Mail: a22es09001@iitbbs.ac.in

ABSTRACT

The tropical intraseasonal oscillations which consist of the Madden Jullian Oscillations (MJO) andthe Convectively Coupled Equatorial Waves (CCEWs), namely the Equatorial Rossby waves (ER), Kelvin waves, and Mixed Rossby Gravity (MRG) waves and Tropical Depression (TD) together known as MT waves, are important in understanding and predicting tropical atmosphericvariability. Recent research indicates that these oscillations are crucial in the regulation of extremeweather events, like cyclones, heatwaves, droughts, and floods. The CCEWs and MJO are knownto affect the genesis and intensification of tropical cyclones (TCs). The CCEWs and MJO intensities exhibit distinct long-term trends over different basins and seasons and these variationsmay affect cyclogenesis significantly. The present study investigates the role of tropical intraseasonal oscillations and their long-term variability on cyclogenesis trends over the Bay of Bengal (BoB) and Arabian Sea (AS) from 1979 to 2022 during the two major cyclone seasons (pre-monsoon and post-monsoon). The genesis potential index/parameter (GPP) during the presence of each wave and its trends have been analyzed in this study. It was observed that the wave-modulated GPP has a higher value in post-monsoon in general, with ER showing the highestmodulation followed by MT and MJO. The trends in the wave-modulated GPP are observed to beheterogeneous in nature and are latitude-dependent. GPP in the presence of ER mostly has a tendency to increase over AS and BoB, especially in pre-monsoon. The next major trend is observed in the presence of MT. The MJO shows a suppressing effect over both AS and BoB. Thestudy further explores different cyclogenesis factors contributing to these observed heterogeneous trends including relative humidity, low-level relative vorticity, and VWS.

Keywords: Tropical Cyclones; Cyclogenesis; Convectively Coupled Equatorial Waves; Madden Julian Oscillation; Extreme weather events.

Relationship between relative humidity and Lightning over Andhra Pradesh, India

Nandivada Umakanth[1] and Deen Mani Lal[1]

[1]Indian Institute of Tropical Meteorology, pune, India

ABSTRACT

Essential elements for all atmospheric activities are atmospheric humidity and aerosol. The size of cloud droplets is determined by the ratio of atmospheric humidity to aerosol, which occurs when atmospheric water vapour condenses on the aerosol. Using satellite and surface observation data, a link between generated lightning per vertical column aerosol of unit cross section (AOD) has been studied for the south-east Indian peninsula, particularly Hyderabad and surrounding areas, from 2019 to 2022. The study domain area has been divided into three sub-regions based on the healthy finding: (i) Region R1 (Lat: 17.7 - 19.5; Lon: 78.5 -84.5), R2 (Lat: 15.1 - 17.5; Lon: 76 -80.1), and R3 (Lat: 12.5 - 15; Lon: 76 - 80.1). A non-homogeneous association between aerosol and lightning was discovered during the experiment, and it was observed to increase as latitude decreased (going towards the south). Additionally, it has been discovered that when relative humidity rises, so does the yield of rainfall, clouds, and lightning per AOD. With or without rain, lightning is present in the majority of the clouds in region R2. It has been determined that there is a regression equation that accurately describes the lightning of R1 and R2. In Region R2, lightning was present in most clouds at low humidity levels and became less frequent as humidity rose. When it rains, there is a nonlinear relationship between relative humidity and lightning. Rainy clouds make up most of the clouds in regions R1 and R3, however they might not be present in area R2.

Diurnal and seasonal variations of XCO2 over differentland cover categories over Indian region using OCO-3 satellite observations

Debanjan, Paul1[a],

Ravi Kumar Kunchala2[a] and Chiranjit Das3[a]

[a] Centre for Atmospheric Sciences,

Indian Institute of Technology Delhi, New Delhi, 110016

E-mail: debanjanrealpaul@gmail.com

ABSTRACT

This study primarily examines the diurnal variability of columnar CO_2 (XCO_2) over different land cover of Indian landmass using data from Orbiting Carbon Observatory (OCO)-3 during 2020-2022. Additionally, the relationship between XCO_2 and Solar-induced Chlorophyll Fluorescence (SIF) is explored. Different ecosystem and land use types across regions can either act as carbon sinks or sources, influencing local climate patterns. Understanding regional CO_2 variability is vital for climate monitoring and policy formulation. The diurnal cycle of CO_2 offersinsight into the balance between carbon uptake and carbon release which is essential for graspingcarbon dynamics and improving climate models. A comprehensive analysis of the monthly variations of XCO_2 and SIF was carried over the study area. The spatial distribution of diurnal distribution reveals elevated XCO_2 concentrations in the Indo-Gangetic Plain (IGP) and Delhi regions. For SIF, higher values were noted in IGP, northeast India and the western part of southern India. The diurnal pattern of XCO_2 generally exhibits a sinusoidal trend, with concentrations rising after late afternoon as photosynthesis declines, leading to a reduction in SIF. The maximum and minimum diurnal XCO_2 concentration is observed in urban and barren land respectively. While no significant correlation between XCO_2 and SIF was found on a diurnal scale, a negative correlation was observed in their monthly variations, with the strongest correlation found in urban (-0.73), followed by cropland areas (-0.71).

Keywords: Diurnal cycle; OCO-3 satellite; XCO_2; SIF; Land Cover biomes.

IS TREE RING- CLIMATE RELATIONSHIP INWESTERN GHAT SENSITIVE TO ALTITUDE?

AN ANSWER FROM KARNATAKA TEAKCHRONOLOGIES

Shirin Sulthana[a], Uttam Pandey[a], Saikat Sengupta[a],
Piyush Yele[b], Preethi Bhaskar[b]

[a] *Department of Marine Geology and Geophysics, Cochin University of Science and Technology, Kochi, India*
[b] *Indian Institute of Tropical Meteorology, Pune, India*

shirinsulthana066@gmail.com

ABSTRACT

Western Ghat mountain of Peninsular India is one of the biodiversity hotspots of southern Asia. In recent years heat waves have significantly affected the growth of the Western Ghat biota. The region hosts a rich repository of tropical teak (*Tectona grandis)* trees. Ring width pattern obtained from those teak samples provided earlier useful information on past monsoonal rainfall variability.However, the magnitude of many climate parameters (rainfall, humidity, etc.) drastically changesacross the mountain. This necessitates the altitude-specific evaluation of climate teak growth relationship in the region. To address this, we are presenting here two regional chronologies fromBhadra (1819-2017 CE; 198 years) and Thithimati–Nagarhole (1725-2017 C.E.; 293 years; henceforth referred to as TNT) from Central Karnataka developed based on 37 and 63 samples collected from 21 and 31 trees respectively. Both sampling regions are situated at the lee side of the mountain at 1210 m and 850 m altitude respectively from mean sea level. Our analysis showsthat TNT chronology bears a strong relation with Sea Surface Temperature (SST) over the southernocean (48 to 56°S and 36 to 50°E) for the months of August-September. On the other hand, a significant negative relationship between Bhadra and its local temperatures observed for Monsoon(JJAS) and premonsoon (MAM) seasons. In addition, our study shows that soil moisture affects teak growth differently in the two regions for the various seasons. We attribute the variation mentioned above in the growth-climate relationship is related to the altitude differences between the sampling locations.

Keywords: *Tectona grandis*; Tree rings; Western Ghats; Soil moisture; Altitude

Leveraging Google Earth Engine to Study Land Use Land Cover Change in the Western GhatsRegion

Priya Priyadarshni, Puneeta Pandey

Centre of Environmental
Studies University of
Allahabad

Faculty of Science, Colonel Ganj, George Town, Prayagraj, Uttar Pradesh 211002, India

ABSTRACT

The western ghats is the one the critical biodiversity hotspot of the world which is a shelter to largevariety of flora and fauna, some of which are endemic to the region. It runs parallel to the western coast of India and plays a crucial role in maintaining ecological balance and regulates local weatherpatterns. It is experiencing significant changes in land use and land cover (LULC) driven by factorslike urbanization, deforestation, and agricultural expansion. Such alteration can disrupt ecologicalbalance. This study aims to examine the extent of LULC change over the past decades using satellite data and geospatial analysis and how these LULC changes relate to shifts in local climateconditions. To achieve this, firstly we harness MODIS (Moderate Resolution Imaging Spectroradiometer) data which well suited for the comprehensive analysis of long-term trend monitoring due to its high temporal resolution. MODIS data is processed using google earth engine's computational capabilities, by performing supervised classification to track changes in land cover. This process involves identifying various land cover types such as forests, agriculturalfields, urban areas, and water bodies. Regression analysis is employed to derive relationships between land cover changes and climate variables. Climate data such as temperature and precipitation are sourced from reliable records to study the regional climate dynamics and how it has been affected over the period. Through this study we offer valuable information for stakeholders and policymakers involved in environmental conservation and climate adaptation.

Keywords- Google Earth Engine, LULC, MODIS, Regression analysis

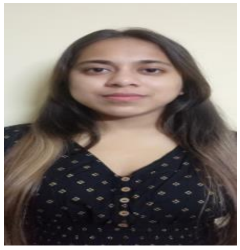
SIMULATION OF EXTREME RAINFALL EVENT USING NUMERICAL WEATHER PREDICTION WRF MODEL

Aanchal, Goel [a], Charu, Singh [a]

[a] Atmospheric Science Department, Marine and Atmospheric Sciences Group, Indian Institute of Remote Sensing ISRO, Dehradun, Uttarakhand, India

Pin- 248001

E-Mail:aanchalg798@gmail.com



ABSTRACT

The North-West Himalayan (NWH) region of India is highly vulnerable to heavy rainfall events which result in several disasters leading to loss of human lives and economy during summer monsoon season. Due to the remoteness of the region, it suffers with the lack of observational network and thereby poses a challenge to the researchers to study, analyze and monitor the extreme rainfall events. With the advancement of satellite technology and availability of better NWP models, such an important research problem may be addressed. Numerical weather prediction model with suitable configuration may be utilized to bridge this gap. The present study addresses one such extreme rainfall event in the NWH region which was reported by the IMD on the next day of its occurrence based on their ground-based measurements of rainfall. We have examined the impact of updated ISRO LULC 2018-19 on simulating the extreme rainfall event in Rishikesh, observed on August 10, 2023 instead of using default MODIS LULC available in WRF static data. The variation in LULC affects surface energy fluxes, boundary layer dynamics, and convective rainfall patterns. Qualitative analysis demonstrated that the NWP model WRF configured with latest ISRO-LULC dataset is able to capture the rainfall event in the study region. The ISRO- LULC dataset overestimated the total accumulated rainfall (496 mm/day) compared to GPM-IMERG (~294 mm/day). These findings underscore the critical need for up-to-date LULC datasets to enhance rainfall predictions and understand the impacts of land cover changes on extreme weather events.

Keywords: EREs, LULC, WRF, NWH, GPM-IMERG

INVESTIGATION OF THE DEGREE OF UNCOMFORTABILITY ANALYSING VARIOUS WEATHER PARAMETERS THROUGH CLIMOGRAPH AND HEAT INDEX IN GUWAHATI, ASSAM

Sudip Kumar Kundu*, Gayatry Kalita, Sunit Das,
Doli Haloi, Sanjay O'Neill Shaw, K N Mohan

Regional Meteorological Centre, India Meteorological Department,
Ministry of Earth Sciences, Government of India,
LGBI Airport, Guwahati – 781015, Assam, India
E-Mail: sudipkrkundugeoh@gmail.com

ABSTRACT

The present investigation deals with the degree of thermal discomfort (TD) by analysing key weather parameters during 2022 to 2024 in Guwahati, Assam known for its humid subtropical climate. Understanding the impacts of these parameters on TD is crucial for optimising agricultural practices and improving human well-being. Taylor's Climograph, employing a 12-sided polygon to graphically represent monthly wet bulb temperature and relative humidity (RH), was employed in this study to provide insights into climatic patterns and associated discomfort levels. Additionally, Heat Index (HI), a metric combining air temperature and RH to estimate perceived temperature ("feels-like" conditions), offered a comprehensive assessment of thermal stress for this study. Guwahati experienced high temperatures and significant humidity leading to elevated HI values and substantial thermal stress. These conditions adversely affected agricultural productivity and livestock health, while also posing health risks to humans. The Climograph data revealed that all months, except for March and April, fell into the "Muggy" category (hot and humid) in Guwahati. Months like December, January and February were "sometimes uncomfortable", while the period from May to October was classified as "usually uncomfortable". HI analysis showed that maximum temperatures exceeded 40°C during May to October, with the highest perceived temperature peaked at 55.5°C in September which is classified as "Extreme Danger" where heat stroke is highly likely. Considering the hot and humid conditions during the pre-monsoon (May), monsoon (June-September), and post-monsoon (October) as reflected in the present assessment, it is crucial to monitor agricultural fields to maintain optimal soil moisture and nutrient levels. For human health, this study emphasised the importance of staying hydrated and minimising exposure to direct sunlight. By integrating Climograph and HI data, this research identified critical periods of discomfort and provided adaptive strategies for agriculture and public health, aiding informed decision-making in regions like Guwahati amidst climate change.

Keywords: Wet Bulb Temperature, Relative Humidity, Climograph, Heat Index, Thermal discomfort.

Effect of climate change and climate resilient practices on spices

Kheyali Ghosh[a],V.S. Devadas[b], Debasmita Das[c] and Sumana Balo[d]
[a]*Assistant Professor, Department of Horticulture, School of Agriculture, GIET University,Gunupur, Rayagada, Odisha-765022, India.*
[b]*Dean(R&D), School of Agriculture, GIET University, Gunupur, Rayagada, Odisha-765022, India.*
[c]*Assistant Professor, Department of Agricultural Meteorology, School of Agriculture, GIET University, Gunupur, Rayagada, Odisha-765022, India.*
[d]*Assistant Professor, Department of Soil Science and Agricultural Chemistry, School ofAgriculture GIET University, Gunupur, Rayagada, Odisha-765022, India.*
E-mail:ghosh.kheyali13@gmail.com

ABSTRACT

In 21st century era, the global warming effect and changing pattern of climate is one of the significant concern of ecosystem, especially its influence on the production of spices. Due to the abiotic stress condition of climate change, the performance of the varieties of spices is hampered and it procures less production and inferior quality of produce which will be unmarketable. The low rainfall, shift of monsoon season and reduction in total precipitation hampers the growth in ginger and turmeric. The flowering is delayed in black pepper and cardamom due to prolonged drought period. The chilling period required for the flowering of spice crop like saffron is reduced drastically due to the glacier and ice-cap melting. The production of several commercial spice crops is severely hampered. Due to fluctuation in the temperature, relative humidity, moisture levels in soil, the advent of various physiological disorders occur. Since, the environmental and climate change is severely affecting the spice crops, so protection of these high-value spice crops like saffron, turmeric, black pepper, ginger, cardamom, etc. is the need of the hour. Sustainably to combat the climate change and improve the production technology of spices includes the techniques like conservation agriculture, utilizing sustainable and renewable energy resources, conservation strategies to protect the forests and water resources, afforestation techniques and reforestation methods. In order to sustain the productivity of the spice crops, alterations and modifications of existing practices of spices production and high-tech horticulture practices should be adopted to minimize the effect of changing climate scenario. Novel and improved cultivars of various spice crops should be developed which are tolerant to high temperature stresses, biotic stress like disease and pest attack, short-duration crops producing significantly higher yield , sustainably and judiciously managing the natural resources will be the main strategic approaches to mitigate the climate change.

Keywords: Climate change, spices, mitigation, resilience, sustainability

A case study of Moinagyri/Jalpaiguri Tornedo formation on 31st March, 2024 through the transformation of advective energy into convective energy by small hills in the vicinity

Somasree Mondal[a],
Ramkrishna Datta[b]
[a] *India Meteorological Department, Meteorological Centre Gangtok,*
[b]*Department of Atmospheric Sciences, University of Calcutta*

E-Mail:somasreem40@gmail.com

ABSTRACT

Thunderstorms, tornadoes, cloudbursts, and cyclones are distinct weather phenomena characterized by varying spatial and temporal scales, speeds, and thermodynamic atmospheric instabilities. Although tornadoes and cyclones share similarities in terms of energy, tornadoes, with only a few kilometers of spatial dimension, cause more concentrated destruction over land than cyclones. In the United States, radars are used for continuous tracking and detection of tornadoes due to their intense local impact, while synoptic analysis is less commonly employed. Northeast India, including the Jalpaiguri district in West Bengal, is particularly prone to these phenomena. The region's proximity to the Chotanagpur Hills, the Himalayas, the Chakma Plateau, and the Bay of Bengal, combined with its varied topography, leads to frequent thunderstorms and occasional tornadoes and cloudbursts due to the convergence of different atmospheric constituents in this vast basin. On March 31, 2024, at around 15:30 IST (10:00 UTC), a tornado struck the Jalpaiguri district. Due to the lack of direct RSRW measurements of the vertical wind profile, CAPE values from nearby stations were analyzed, showing significant atmospheric instability. Guwahati had low CAPE but a high CINE/CAPE ratio, suggesting potential thunderstorm development that further progressed towards Jalpaiguri. Jalpaiguri, located on the windward side of the hills, saw increased temperatures in warm, moist air crossing the hills. High CAPE values from the surrounding stations caused wind convergence near Jalpaiguri, which created strong updrafts, leading to severe thunderstorms and a tornado. This case study depicts the role of regional instability and topographic effects in severe weather events.

Keywords: Cloud-burst, Instabilities , CAPE, Vertical wind profile, RSRW

Performance of high resolution WRF modeling system in a gray zone scale forsimulation of super cyclonic storm Kyarr over the Arabian Sea

Kuvar Satya Singh[a, b] and Rohini Ashok[b]

[a]Centre for Disaster Mitigation and Management (CDMM), Vellore Institute of Technology, Vellore, Tamil Nadu
[b]Department of Mathematics, School of Advanced Sciences (SAS),Vellore Institute of Technology, Vellore, Tamil Nadu

E-Mail: kuvarsatya.singh@vit.ac.in

ABSTRACT

The present study examines the performance of high resolution WRF modeling system in a gray zone scale for simulation of super cyclonic storm Kyarr over the Arabian Sea using Advanced Research version of WRF (ARW) model. The model initial and lateral boundary conditions derived from the FNL analysis and integration is considered up to 1 – 2 weeks before the landfallusing a double nested domains 15 km and 3 km. The initial conditions for the model was improvedthrough three dimensional data assimilation technique by using satellite radiances with conventional observations from NCEP. The study also used regional background error statistics toimprove the model initial condition. The model performance was evaluated by using 3 km resultsand compared with available observational datasets namely best fit data from the Indian Metrological Department (IMD) and CIRA - Cooperative Institute for Research in the Atmosphere. The statistical analysis was also conducted in this study in terms of bias, mean error,and standard deviation, and it exhibited the significance and importance of the prediction of supercyclone Kyaar. Result suggest that model is able to predict the super cyclone Kyarr 1-2 week advance.

Keywords: Kyaar, Super cyclonic storm, WRF, Arabian Sea

Effect of Climate Change and Climate Resilient Practices on Fruits

Debasmita Das[a], V.S. Devadas[b],
Rajababu K.[c], Nirmala Patel[d]

[a] *Assistant Professor, Department of Agro- Meteorology, GIET University,Gunupur, Rayagada, Odisha, India ,765022*

[b] Dean (R &D), School Of Agriculture, *GIET University, Gunupur, Rayagada, Odisha, India,765022*

[c] *Assistant Professor, Department of Horticulture, GIET University,Gunupur,Odisha, India,765022*

[d] *Assistant Professor, Department of Agronomy, GIET University,Gunupur,Odisha, India,765022*

E-Mail:avipshadas14aug@gmail.com

ABSTRACT

Global climate change and increased climatic variability are major concerns for agriculture, including fruit crops. A temperature increase of 0.7 to 1.0 °C could potentially shift the regions currently suitable for high-quality production of Dashehari and Alphanso mango varieties, whereastemperature increase of 0.2 °C could significantly reduce the areas where guavas can develop redcolouration. Mandarins exposed to direct sunlight at 35 °C are 2.5 times firmer than those kept in the shade at 20 °C. Climate is a critical factor which influences the distribution, phenology, fruit quality, pest and disease dynamics of fruit crops. High temperatures can exacerbate physiologicaldisorders in fruit, such as spongy tissue in mangoes, fruit cracking in litchis, and the abscission offlowers and fruit. Air pollution also impacts the yield of various fruit crops and intensifies certaindisorders, such as black tip in mangoes. Additionally, extremely low winter temperatures can affect tropical fruit crops like bananas, leading to chilling injuries and other issues. Mitigation is a proactive approach aimed at preventing the worst impacts of climate change by addressing the root causes. The effects of climate change can be mitigated by reducing greenhouse gas emissions,enhancing carbon sequestration, promoting sustainable practices, supporting technological innovations. Carbon sequestration plays crucial role in mitigating the effects of climate change byremoving CO_2 from the atmosphere and storing it in various natural sinks. Salinity and alkalinity can be controlled by using prominent rootstocks. Modifying current horticultural practices, changing the date of sowing or planting, greenhouse technology, developing new hybrids and cultivars that are resistant to both abiotic and biotic stresses, grafting, mulching and managing judicious use of water and fertilizer during critical stages are few effective strategies for minimizing the impact of climate change on fruit crops.

Keywords: Carbon sequestration, Climate Change, Fruit Crops, Mitigation, Physiological disorders

Heat Stress and Urbanization in Coastal Odisha: Insights fromRemote Sensing and WRF Modelling

Roshan Beuria[1], Sarat Chandra Sahu[1], Debabrata Nandi[2]

[1]Centre for Environment and Climate, ITER, Siksha 'O' Anusandhan (Deemed tobe) University, Bhubaneswar
[2]Department of Remote Sensing and GIS, MSCBD University, Baripada[a]

E-Mail: roshanbeuria922@gmail.com

ABSTRACT

The coastal Odisha region has experienced significant climatic shifts due to rapid urbanisation, deforestation, and industrial development, leading to increased surface temperatures. This study examines the spatio-temporal changes in Land Surface Temperature (LST) from 1990 to 2024 (a 30-year analysis) in relation to different vegetation indices using satellite-derived data such as theNDVI, TVI, SAVI, EVI, and NDBI especially across the three cities—Bhubaneswar, Baleshwar,and Baripada which ranked among the top 10 hottest cities in the world, highlighting the severityof heat stress in the region. Remote sensing and Geographic Information Systems (GIS) techniqueswere applied to assess the formation of Heat stress and temperature variations in these regions. Additionally, the Weather Research and Forecasting (WRF) model was employed to analyse vertical velocity and pressure-level thickness, revealing key contributing factors such as subsidence in the vertical wind profile, increased thickness between different pressure levels, andalmost zero relative humidity. These factors, combined with decreased NDVI and increased NDBI,have exacerbated the region's vulnerability to heat waves. The study utilized LANDSAT imagery,NCEP gridded data, and ECMWF ERA-5 reanalysis data for LST, vegetation indices, and meteorological parameters. The findings underscore the need for adaptive climate strategies, particularly in coastal areas, to mitigate the growing impact of heat stress and ensure sustainable urban development in Odisha's vulnerable coastal regions.

Keywords: WRF Model, Remote Sensing, Land Surface Temperature (LST), Heatstress, Atmospheric Parameters.

A Study on Dynamic and Thermodynamic Properties of Tropical Cyclones over Arabian Sea through Composite Analysis

Ipshita Bhasi, Jagabandhu Panda, and Geo Tom

Department of Earth and Atmospheric Sciences NIT RKL, Odisha

Sciences,E-Mail: ipshitabhasi@gmail.com

ABSTRACT

Employing Weather Research and Forecasting (WRF) modelling system with three-dimensional variational data assimilation (3DVAR), the study emphasizes on the dynamic and thermodynamiccharacteristics associated with Arabian Sea (AS) tropical cyclones (TCs) occurred during 2001- 2020 pre-monsoon and post-monsoon seasons. Two sets of numerical simulations are conducted,viz., the CTRL experiment without data assimilation and the DA experiment, with data assimilation. The CTRL simulations are initialized with NCEP-FNL and NOAA Sea surface temperature (SST) datasets, and DA simulations consider modified initial conditions generated employing the 3DVAR technique by incorporating scatterometer wind datasets. In total, 23 TCs categorized as Cyclonic Storm (CS), Severe Cyclonic Storm (SCS; also includes Very Severe Cyclonic Storm), and Highly Intensified Cyclonic Storm (HICS, including both Extremely Severe Cyclonic Storm and Super Cyclonic Storm types), are simulated, resulting in 46 simulations for the analysis purpose. Composite cross-sectional analysis involving parameters like vorticity, temperature anomaly, and specific humidity are compared against observations from the India Meteorological Department (IMD) and the Indian Monsoon Data Assimilation and Analysis (IMDAA) datasets. Results demonstrate that DA simulations consistently yield comparablepredictions for CS and SCS-type TCs, while underestimating temperature and potential temperature anomalies for HICS-type TCs in the pre-monsoon period. CTRL simulations predominantly overestimate dynamic parameters for all categories, whereas they underestimate thermodynamic parameters. The study also provides insights into the TC vertical structure througha composite analysis by highlighting the performance of both simulations to capture dynamic andthermodynamic features, closely aligned with IMDAA data.

Keywords: Tropical cyclone; Scatterometer wind; WRF; 3DVAR, IMDAA

Evolution of the Mixed Layer Characteristics During the Withdrawal Phaseof the Indian Summer Monsoon over Central India

Sachin Kakkanattu Philip[a, b], Anil V[a],
Yang Lian[a],Jeni Victor[a], Udaya Sahoo[a], G. Pandithurai[a], Priyabrata Nandi[a], T R Libin[a],
Sunil Sonbawne[a],
Sanjay Kumar Mehta[b]

[a]*Atmospheric Research Testbed Central India, Silkheda, Indian Institute of Tropical Meteorology, Pune, India* [b]*Atmospheric Observation and Modelling Laboratory, SRMInstitute of Science and Technology, Kattankulathur, Chennai, India*

E-Mail: sachin.philip@tropmet.res.in, *sachinkphilip@gmail.com*

ABSTRACT

We report the characteristics of the Atmospheric boundary layer over central India that develops during the withdrawal phase of the Indian summer monsoon (ISM). The establishment of a low- level Anticyclone at 850 hPa, the Cessation of rainfall activity over the area for five continuous days and the reduction of moisture content are the withdrawal features of ISM. According to IMDreport the withdrawal of ISM 2023 starts on September 30 and ends on 19 October 2023. Hence, we have categorized the study period into three phases namely, the withdrawal phase, theAnticyclone phase and the post withdrawal phase. The monsoon campaign at AtmosphericResearch Testbeds, central India starts in June 2023 and ends in October 2023. It has been observedthat central India falls into the central core of Anticyclone during the period of 10 October to 19 October 2023. The high geopotential height, negative vorticity and high pressure identified confirm the existence of Anticyclonic circulation over central India at 850 hPa. In contrast to the Anticyclonic features, we have identified the deeper cloud top convective boundary layer (CTBL)during the anticyclonic period with an average magnitude of ~3 km identified from the radiosondeobservation. It is identified that the ABL from the ERA5 data shows the difference in magnitude with the radiosonde observation during the Anticyclonic period. The identified lifting condensation level from the radiosonde highly correlates with the ERA ABL height. The derived advection component confirms that the warm air advected from the Arabian Sea to land and cold air advection from the foothills of Himalaya merges at the central part of India lifts the warm air into higher altitude could be one of the reasons for the enhanced mixed layer during the Anticyclonic period. The different heat fluxes over the warm front and cold front favors the verticaldistribution during the period.

Keywords: Indian Summer Monsoon; Anticyclonic circulation; Cloud Top Boundary Layer; Advection; Frontal Process

Sensitivity study of WRF model cumulus parameterization schemes for simulating Very Sever Cyclonic Storm

Sanjitava Biswas, C.S. Dwibedi, and Rapeti pushpa saroja

Department of Geoinformatics, Central University of Jharkhand Meteorological Training Institute, Indian MeterologicalDepartment
E-Mail: biswassanjitava.2000@gmail.com

ABSTRACT

The study focuses on simulating Very Sever Cyclonic Storm NIVAR, which formed in the Bay of Bengal from November 22 - 27, 2020. Initially a depression, it intensified into a Very Sever Cyclonic Storm before making landfall on November 25, 2020 as a Very Sever Cyclonic Storm along the Tamil Nadu & Puducherry coast. Using the WRF model with NCEP FNL data at 0.25° x 0.25° resolution and varying cumulus schemes, the study aims to evaluate model accuracy in predicting rainfall and wind velocity along NIVAR's path, comparing results with IMD Automatic Weather Stations (AWS) observations. While the model effectively captures rainfall patterns in some regions, discrepancies in wind speeds and rainfall underscore the importance of standardized cyclone monitoring techniques. Comparison of cyclone path observed by IMD (Best Tracks Data) and model simulated path. Optimal scheme combinations have yielded favourable outcomes, emphasizing the potential of the WRF model for cyclone simulation and forecasting.

Keywords: cyclone, wrf model, track.

Effect of different climate resilient crop management practices on growth parameters (CGR, RGR, and NAR) and agro meteorological indices of green gram (*Vigna radiate* L.) in rice fallow

Susri B Barnana Behera[1], Sarat Chandra Sahu[1]

[1]*Centre for Environment and Climate, ITER, Siksha 'O' Anusandhan (Deemed to be) University, Bhubaneswar*
E-Mail: susribarnana12@gmail.com

ABSTRACT

Rice is the staple food of India and India holds second position after China in rice production. The Kharif rice area has occupied 26.8 m ha equivalent to 63.3% of the total rice growing area of the country and about 11.7 m ha of the area under rice production during *Kharif* season in India remaining fallow in the subsequent *rabi* due to number of biotic, abiotic and socioeconomic constraints. These areas have a vast potential to cultivate low input and low water requiring upland pulse crops (such as lentils, chickpeas, Lathyrus, greengram and blackgram). India is the largest producer and consumer of pulses in the world accounting for about 35 percent and 25 percent of world's area and production respectively. An experiment was conducted to study climate resilient crop management practices for increasing production and productivity of greengram in rice fallow by application of hydrogel and nano solution at the instructional farm of Odisha University of Agriculture and Technology, Bhubaneswar during *rabi* 2018-19 based on sixteen treatments with combination of two cultivar such as Virat , IPM 02- 14 and eight combination of moisture saving elements along with control of environmental and improved practices. All the plants grown in T8 (Plants grown with improved practice, Hydrogel, Nano Solution and *Trichoderma*) with Virat variety produces maximum yield and required less water and its water use efficiency was also high. Due to treatment with hydrogel and nano solution, the root proliferation occurs and number of root nodules were also increased resulting maximum yield. The growth of plant is very good here and the plants finish their life cycle at exact time due to availability of water at short depth. Crop growth rate (5.76 g m^{-2} day^{-1}), relative growth rate (1.41* 10^{-2} g g^{-1} day^{-1}), net assimilation rate (0.021 g cm^{-2} day^{-1}) are also high in the plants which are grown under T_8 treatment. The highest Growing degree days (GDD) (1132.5 °C), Heliothermal unit (HTU) (7974.2 °Chr) and Photothermal unit (PTU) (13075.8 °C hr) have been recorded in the plants grown in T_8 (Plants grown with Improved practice, Hydrogel, Nano Solution and *Trichoderma*) as compared to farmers' practice.

Keywords: Climate Resilient Crop Management, Agro-meteorological Indices, Rice Fallow

Valuating the WRF Model's Efficacy in Cyclone Path Forecasting: A Study Focused on Coastal Odisha

Swarnamayee Das[1], Sarat Chandra Sahu[1]

[1]Centre for Environment and Climate, ITER,
Siksha 'O' Anusandhan (Deemed to be) University, Bhubaneswar

E-Mail: swarnamayeedas22@gmail.com

ABSTRACT

This study assesses the performance of the Weather Research and Forecasting (WRF) model in simulating cyclone events in the Bay of Bengal, with a focus on improving cyclone path prediction accuracy for the coastal Odisha region. The WRF model was run at varying horizontal resolutions: 27 km for the entire Bay of Bengal (d01) and 9 km for the coastal Odisha region (d02). Six different combinations of microphysics, planetary boundary layer (PBL), and convective parameterisation schemes were tested. The model output was compared with observational data from the India Meteorological Department (IMD) during recent cyclone events. Among the six experiments, Exp2 produced the most accurate cyclone paths, with a margin of error of ± 50 km. To further validate the model's performance, cyclone events from the past five years were incorporated into the analysis. The study highlights how regional factors, such as topography and coastal geography, can influence cyclone paths. Statistical analysis confirms that Exp2 delivered the best performance for accurate path prediction. Furthermore, detailed case studies of significant cyclone events showcase the model's ability to simulate critical meteorological parameters, such as wind speed, pressure distribution, and precipitation. These results offer valuable insights for refining WRF model configurations, ultimately contributing to more reliable cyclone forecasts for coastal Odisha in future events.

Keywords: Cyclone Path Prediction, WRF Model, Parameterization Schemes, Bay of Bengal

Effect Of Climate Change And Climate Resilience On Plantation Crops

Sumana Balo[a], V.S.Devadas[b], Kheyali Ghosh[c] and Debasmita Das[d]

[a] Assistant Professor, Department of Soil Science and Agricultural Chemistry, GIET, University,Gunupur, Rayagada, Odisha-765022, India.
[b] Dean (R&D), School of Agriculture, GIET University, Gunupur, Rayagada,Odisha-765022, India
[c] Assistant Professor, Department of Horticulture, GIET University, Gunupur, Rayagada, Odisha-765022, India.
[d]Assistant Professor, Department of Agricultural Meterology, GIET University, Gunupur, Rayagada, Odisha-765022, India.
E-Mail:balosumanaagri@gmail.com

ABSTRACT

The term 'climate change' refers to a shift in the pattern of climate in a specific location, region with changing weather components such as temperature, wind and precipitation patterns. Due to the erratic climate events like global warming, intense drought condition, floods and cyclones leads to hampering in the agricultural productivity. The major plantations crops like rubber, coconut, tea, coffee, oil palm, cashew nut are also severely affected due the change in climate. The yield and quality of the produce is severely reduced due to the erratic monsoons and flood perods. Due to the change in the temperature regime, elevation in the carbon dioxide level, changes in the pattern of precipitation, there is an increase in the disease and pest incidence, weed growth is enormous and the crop is severely affected. High temperature stress condition causes wilting, stunted growth and reduction in photosynthesis in tea, coffee and cocoa. Climate change could also give rise to new disease infestations in tea plantations, thereby destroying the tea bushes. The ill-effects of climate change poses a threat to long standing crops like coconut affecting its flowering and fruiting. The plantation crops are cash crops which has the potential for export and to fetch foreign income, thereby leading to increase in Indian economy. Therefore, to saveguard the plantation crops from the vagaries of weather, several climate mitigation and resilient techniques should be adopted. Similarly they can also helps in mitatigating climate effect by sequestering carbon through their long-term biomass and soil organic matter. Additionally, plantation systems can reduce deforestation by providing sustainable land use and economic alternatives, lessening the pressure on natural forests. With their perennial nature and ability to improve soil health, plantation crops are valuable in reducing greenhouse gas emissions and promoting carbon storage, helping mitigate climate change.

Keyword: Carbon sequestration, Climate change, Deforestation, Plantation crops, Resilient techniques

IMPACT OF CLIMATE VARIABILITY IN THE PREDICTION OF SMALL PELAGIC FISHERY OF INDIAN WESTCOAST USING DYNAMIC MODELLING OF FISHERY POPULATION

Bhavani IVG1[a], Hamza Faseela2[a], and Valsala Vinu3[a],

[a] Indian Institute of Tropical Meteorology, Ministry of Earth Sciences (MoES), Pune, India

E-Mail:ivg.bhavani123@gmail.com

ABSTRACT

Predicting and understanding the role of global climate change on marine ecosystem and fishery resources are crucial to manage sustainable marine resources. Among the wide variety of small pelagics inhabit in the Indian west coast region and Indian oil sardine (*Sardinella longiceps*) is a major contributor to small pelagic fishery and yields a high value as it uses in several commercial preparations in addition to direct human consumption. Past studies have reported that, oil sardine population in this region exhibited an out-of-phase relation with the Pacific Decadal Oscillation (PDO), and El Nino-Southern Oscillation (ENSO), and shown an in-phase relationship with the Atlantic Multidecadal Oscillation (AMO). The links between climate variability and pelagic fishery potentially open avenues for predicting such long-term changes in a mathematically meaningful way. For example, an out-of-phase variation between the Indian oil sardines and the PDO and ENSO gives us handles to predict its long-term variability. Fully coupled population dynamics models with multiple trophic levels are valuable for understanding the impact of climate change on fisheries. However, such models have not been utilized to study population dynamics along the Indian coast. Therefore, in the present study, we have developed a bioenergitic-based population dynamics model for a small pelagic fishery and discussed the ability of model. Model simulated population (in tonnes) for 60 years from 1960 to 2017 with the provided food, temperature and climate variables. The correlation coefficient between the modelled population of all locations on the southwest coast of India and the actual landing reported is 0.53, which is statistically significant. The driving forces for seasonal and inter-annual variablility of the population is discussed further.

Keywords: Small pelagic fishery; fishery prediction; fishery modeling ; Climate change; Indian West coast

FOG FORECASTING AND VERIFICATION USING FOG STABILITY INDEX TECHNIQUE AT IGI AIRPORT, NEW DELHI

Ankur Garg[a], Arun S H[a], Sebin John[b], Brajesh KumarKanaujiya[a], Siddhartha Singha[a], Rakesh Kumar[a] [a]*India Meteorological Department, Ministry of Earth Sciences, New Delhi-110003, India*
[b]*College of Marine Sciences, University of South Florida,Saint Petersburg,Florida, USA- 32644*
E-Mail : garg.ankur@imd.gov.in

ABSTRACT

Indira Gandhi International Airport (IGIA), New Delhi is the busiest Airport in India in terms of both passenger and cargo traffic. A significant number of flight cancelation and diversion are more frequent due to reduced visibility during fog in the winter season at IGIA. An accurate detection, monitoring and forecasting of fog with sufficient lead time can play a crucial role in safer and economical flight operations. Even though, Numerical Weather Prediction (NWP) models have been improved significantly in recent years, fog forecasting is still remains a challenging task to the forecasters due to its complex nature of formation. In the present study, the feasibility of fog forecasting at IGIA using an empirical method known as Fog Stability Index (FSI) has been carried out. The study has been performed using the Indian Monsoon Data Assimilation and Analysis reanalysis (IMDAA) reanalysis data of National Centre for Medium Range Weather Forecasting (NCMRWF) for the winter season from 2010 to 2017. The three hourly IMDAA data of temperature, dew point temperature and wind speed are used for the generation of FSI and a detailed verification has been followed using the METAR data of IGIA. The results indicated that the FSI is promising with a correlation coefficient of more than 0.60 with the fog. The automation of this product on GIS based aviation decision support system can further enhance the forecast accuracy of fog events over the IGIA.

Keywords: FSI, Fog, Aviation, Forecasting, IGI Airport

ON THE ARABIAN SEA WARMING AND ITS IMPACTON TROPICAL CYCLONES

Sidha Sankalpa Moharana[a], and Debadatta Swain[a]

[a] *SEOCS, Indian Institute of Technology Bhubaneswar, Argul, Jatni,Odisha, 752050 INDIA*

E-Mail:ssm20@iitbbs.ac.in

ABSTRACT

Tropical cyclones (TCs) are one of the most extreme weather events, bearing intense winds and heavy precipitations in the coastal regions. Since these events are fueled by the latent heat from warm ocean waters, an enhancement in TC activities is currently being observed under the influence of global warming. This effect translates to either an enhanced cyclogenesis frequency or intensification tendencies. Even though Arabian Sea (AS) experiences a lesser number of TCs compared to the Bay of Bengal, trends show a rise in the cyclogenesis frequency in the AS in therecent decades. The concurrent surface and sub-surface warming in the AS basin is expected to play the major role in such enhancement in TC activity. This study explores the impact of AS warming on tropical cyclogenesis during the 1994-2020 period. Trends of sea surface temperature, 700m ocean heat content, and tropical cyclone heat potential were estimated to be 0.1 °C, 4×10^8 J/m^2, and 3 kJ/cm^2 per decade, respectively. A ststistical change-point analysis marked 1998 as a change-point for sea surface temperature and tropical cyclone heat potential, while that for oceanheat content was 2011. Interestingly, the two changepoints in TC activity in the basin were 1998 and 2011. A data-driven random forest regression technique showed tropical cyclone heat potentialas the most influential parameter, impacting cyclogenesis in the basin. Relative vorticity was identified as the most influential atmospheric parameter in the recent years. All statistical inferences drawn were significant at 95% confidence level. The mechanism of coupling between the AS warming and cyclogenesis in the basin is under investigation, which is expected to furtherthe understanding of the ocean-atmosphere interactions in the current climate change scenario.

Keywords: Tropical Cyclones; Arabian Sea; Tropical Cylone Heat Potential; Relative Vorticity; Random Forest

Understanding Climate Indices related to Maximum Temperaturesover Madhya Pradesh

Divya E.Surendran
Meteorological Centre, Bhopal
India Meteorological
Department

divya.surendran@imd.gov.in

ABSTRACT

In Madhya Pradesh, the summer season is characterized by high temperatures, making it essential to understand the patterns of extreme heat events due to their potential impacts on various sectors. The increasing global temperatures have led to a rise in the intensity and frequency of extreme weather events, including heatwaves, both globally and locally. This study aims to analyse climate indices related to extreme heat and temperature, as recommended by the World Meteorological Organization (WMO), across major stations in Madhya Pradesh. By examining these indices, the study tries to identify any trends or variabilities in extreme heat events over the region. Additionally, it seeks to assessthe impacts associated with these extreme temperatures on sectors such as agriculture and health. One significant aspect of the research involves examining the maximum temperature records during summerto provide insights into the severity and duration of heatwaves experienced in the state.

Keywords: Extreme Temperature, Heatwave, Climate Indices

Land-Atmospheric Feedback Determines Pre-Monsoon Thunderstorm Initiation and Invigoration over India

Swarnendu Bhattacharya [1], and Subhadeep Halder [11]

Department of Geophysics, Institute of Science, Banaras Hindu University, Varanasi 221005
E-Mail: swarnendu.bhattacharya02@gmail.com; subhadeeph@bhu.ac.in

ABSTRACT

This study is aimed at quantifying the role of land-atmosphere feedbacks in the initiation, intensification and variability of pre-monsoon thunderstorms over the Indian region to improve its short-range prediction using numerical models. We demonstrate that the pre-monsoon (March- May) thunderstorms and lightning activity have been increasing significantly over the Indian region in the last few decades leading to an alarming increase in casualties. Since lightning in clouds has a microphysical origin, it is expected to be strongly correlated with the type and intensity of convective activity. Firstly, the mechanisms underlying the long-term changes in thunderstorm and lightning activity are explored from observational data analysis for the last fourdecades and appropriate statistical methods. It is demonstrated that changes in the intensity of land-atmosphere coupling have had a significant impact on the genesis and intensification of thunderstorm and lightning activity over few regions of India which has not been addressed so far.It is hypothesized that errors in the representation of land-atmosphere feedbacks in numerical models reduces their skill in the simulation of precipitation and lightning activity associated with thunderstorms. With this premise, several sensitivity experiments for thunderstorms over India are done with the WRF-ARW model in cloud-resolving scale by suitably developing the parameterization schemes and the representation of land-atmosphere feedback in the model. Development of the model land-atmosphere feedback improves the simulated characteristics of thunderstorm vertical structure including precipitation, hydrometeors and lightning distribution and the forecast skill. The authors gratefully acknowledge the financial support given by the EarthSystem Science Organization, Ministry of Earth Sciences, Government of India to conduct this research.

Keywords: Extreme weather events, thunderstorm, lightning, land-atmosphere feedback, numerical modelling

SURFACE ENERGY BALANCE SCENARIOS OF CITIES IN DIFFERENT CLIMATE ZONES OF INDIA

Dikshika Mahapatra[a], and Debadatta Swain[a]

[a] *School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar Argul, Jatni, Odisha, 752050, India*

E-Mail:s22es09002@iitbbs.ac.in

ABSTRACT

Changes in Land Use Land Cover (LULC) modulates the climate and Surface Energy Balance (SEB) of a region. SEB has been an important component in modulating the radiation budget in urbanized cities. Net All-wave Radiation (NAR), Sensible Heat Flux (SHF), Latent Heat Flux (LHF), and Storage Heat Flux (StHF) are the major components in SEB analysis. The present study attempts to analyse the diurnal and seasonal SEB variation of different Indian cities situated on different climate zones. The analysis has been carried out using Moderate Resolution Imaging Spectroradiometer (MODIS) data from TERRA and AQUA satellites available four times in a day (10:30, 13:30, 22:30 and 01:30) during pre-monsoon (March, April, May) and winter (January, February) season from 2003 to 2022. To obtain the surface NAR, proportion of vegetation, Land Surface Temperature (LST), surface albedo and various components of the energy balance, such as downward shortwave radiation (K_{down}), downward longwave radiation (L_{down}) and upward longwave radiation (L_{up}) have been calculated following the Surface Energy Balance Algorithm for Land (SEBAL). SHF was calculated using LST, and air temperature and the StHF was calculated using vegetation fractions, surface albedo and NAR. LHF has been calculated as the residual heat flux in the SEBAL algorithm. Spatio-temporal trends in the seasonally averaged SEB components were calculated for the four available time periods to build a day-night contrast of their evolution over the cities. Out of the analyzed cities, Kota showed decreased LST over the urban centre during daytime and increased during nighttime in the pre-monsoon season. Also, LHF increased during daytime and decreased during nighttime over most parts of the city in the pre- monsoon season. For Mysuru, LST and SHF showed increasing trend during night time in both pre-monsoon and winter season. Similar analysis in other cities would assist sustainable urbanization planning and mitigation strategies.

Keywords: Land Use Land Cover; Land Surface Temperature; Surface Energy Balance; Normalized Difference Vegetation Index; Urbanization

Assessment of the IMD+ GPM-IMERG Merged Dataset and Analysis of Extreme Precipitation events in South Asia for the period 2001–2020

Sandhya Jose[a], O.P Sreejith[a], B.P.Patkar[a], C.N. Shaligram[a], Aiswarya R[a], K Amar Jyothi[b] and A.K.Mitra[b]

[a] *Climate Research and Services, India Meteorological Department, Pune*

[b] *National Centre for Medium-Range Weather Forecast, New Delhi*

ABSTRACT

Climatological datasets are vital for studying climate variability and change. It serves as a critical tool for evidence-based decision-making in climate adaptation and mitigation. The India Meteorological Department (IMD) provides the daily merged satellite and gauge data for the Indian subcontinent and the South Asian region since June 2012. IMD's merged dataset integrates data from the Global Precipitation Measurement (GPM) Integrated Multi-satellite Retrievals (IMERG) system with the IMD's extensive network of ground-based rain gauges. Successive correction method developed by A.K. Mitra is employed to generate the IMD merged dataset, which effectively combines satellite and gauge data to provide a more comprehensive and accurate representation of precipitation patterns across the region. This approach is expected to correct biases and improve the reliability of the merged data, making it a valuable resource for climatological studies. This paper presents a detailed analysis of the 20-years (2001-2020) climatological dataset of the IMD merged rainfall data, focusing on its application in the South Asian region. This study evaluates the performance of the IMD merged dataset by comparing it with other prominent precipitation datasets, such as the Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) dataset and the IMD gridded dataset over the four homogeneous regions. Besides, the paper explores the extreme precipitation patterns and trends in the region over 20 years using the merged dataset, to comprehend the evolving nature of extreme weather events in the region. The study also discusses the extreme precipitation events in the context of large-scale climate drivers to understand their role in modulating the frequency and intensity of these events.

Keywords: IMD merged dataset, GPM-IMERG, extreme precipitation events, climate drivers

MEANS CLUSTERING TECHNIQUE OF DATA MINING FORTHE INTERPRETATION OF CLOUDBURST OVER KONKAN REGION

Abhishek Singh[a], Vijai Kumar[a],Somnath Mahato[a], Pushpa Saroj[a] Sandip Ghosal[b], Jogesh Chandra Dash[b]

[a]*India Meteorological Department, Pune*
[b]*Department of ECE, NIT Rourkela*
E-mail: abhishek.singh1991@imd.gov.in

ABSTRACT

The multidimensional data model can be effectively utilized for analyzing huge & detailed meteorological data sets forecasted by numerical weather prediction (NWP)model. The NWP model cannot predict any weather event directly, hence output product of model i.e Model output statistics (MOS) are interpreted by AIML, statistics & database systems. In this paper data mining technique is used for the interpretation of severe & disastrous weather phenomenon viz. Cloudbursts. Recent case study of various events i.e. Chiplun- 22nd july 2021 & 19th may 2024, Pimpri-chinchwad- 23rd june2024, Hingoli, Taluka-Vasmat- 9th july 2022, Kalamassery-27th may 2024 can be identified by applying k-means clustering technique of data mining. The forecasting & warning of these sub-grid scale events is very difficult but with the mining of NWPmodel forecast data, the signals of formation of cloudburst events can be predicted 1 or 2 days in advance.

Keywords: Numerical weather prediction, Data mining, Clustering technique, Cloudburst.

Assessment of Atmospheric temperature and moisture profiles from recently launched INSAT-3DS observations: Initial results

Tapan Ka Patel*, M. Seemanth, Chandrani Chatterjee,
Rishi Gangwar and P. K. Thapliyal
AOSG/EPSA, Space Applications Centre(ISRO)
*Email:tapan11011999@gmail.com/tapan111@sac.isro.gov.in

ABSTRACT

Precise and regular monitoring of weather events and timely prediction of calamities happen to be of crucial societal importance. Satellites are the only feasible pathway for continuous monitoring with both satisfactory temporal (hourly) and spatial coverage. The pivotal role of Indian Geostationary satellites (INSAT-3D/3DR/3DS) in meteorological observations are of prime importance, especially considering their advanced instruments and comprehensive coverage capabilities. The retrieval of atmospheric temperature and moisture profiles at every hour by the Sounder on-board recently launched INSAT-3DS provides an excellent opportunity of improved weather and climatic forecasts. The INSAT-3DS has a better on-board blackbody calibration and reduced sun-intrusion as compared to its predecessors (INSAT-3D/INSAT-3DR), which should culminate into improved profile retrievals. This study presents the initial results of the atmospheric retrievals by INSAT -3DS Sounder. The retrieval of the atmospheric temperature and moisture (mixing ratio) profiles is carried out using optimal estimation or one-dimensional Variational(1DVAR) technique. The retrieved profiles then are validated against the profiles obtained from in-situ measurements (i.e. Radiosondes) and ECMWF Reanalysis v5 (ERA5). The comparison analysis shows a noteworthy improvement in retrieved profile errors as compared to its predecessor INSAT-3DR.

Keywords: INSAT-3DS Sounder, Retrieval, 1DVAR

Assessing Thunderstorm and Monsoon Effects on Flooding in Odisha's Baitarani River Using WRF Model Simulations

Susmita Behera[1], Sarat Chandra Sahu[1a]
Centre for Environment & Climate, ITER, Siksha 'O' Anusandhan (Deemed to be) University,Bhubaneswar
E-Mail: susmitabehera33@gmail.com

ABSTRACT

The Baitarani River, a major river system in Odisha, India, flows through several key districts, significantly influencing local hydrology and the livelihoods of the population. This study focuses on the seasonal rainfall patterns, thunderstorm activity, and flooding in the Baitarani River basin, particularly during the pre-monsoon, monsoon, and post-monsoon periods. Using the Weather Research and Forecasting (WRF) model, the research analyses the relationship between rainfall, thunderstorms, and flood risks across the districts of Keonjhar, Bhadrak, Jajpur, and Kendujhar, among others.

In the pre-monsoon season, thunderstorms, characterized by intense, localized rainfall, contribute to flash floods, particularly affecting the low-lying areas of Bhadrak and Jajpur districts. During themonsoon, the WRF model simulations show sustained heavy rainfall, intensified by frequent thunderstorms, causing significant flooding in Keonjhar and downstream regions such as Bhadrak and Kendrapara. The saturated soils and increased river discharge during this period heightened thevulnerability of these districts to severe floods. In the post-monsoon phase, residual thunderstorms combined with waterlogged conditions continue to impact these districts, prolonging flood conditions.

The WRF model highlights how changes in land use, particularly deforestation in Keonjhar and urbanization in Bhadrak and Jajpur, have reduced the natural water absorption capacity of the land,accelerating runoff during thunderstorms. Flood modelling scenarios show that these districts are increasingly prone to flooding due to more intense thunderstorms, especially during the pre- monsoon and monsoon periods.

The study emphasizes the need for improved flood management strategies in these districts, focusingon early warning systems and disaster preparedness for the vulnerable populations. Insights derivedfrom WRF model simulations are crucial for mitigating the growing risks of seasonal thunderstormsand flooding in the Baitarani River basin, protecting both infrastructure and livelihoods in the affected districts.

Keywords: Flooding; Baitarani River; Thunderstorms;WRF Model & Seasonal Rainfall

SMART SAFER ENVIRONMENT MONITORING LANDSLIDING SYSTEMUSING GEO SPATIAL TECHNOLOGY

[a]Dr. Rahul M. Pethe,[b] Ms. Krutika U. Punpreddiwar, [c] Ms. Divyani L. Wadhwani

[a] *Electronics and Telecommunication Department, S. B. Jain Institute ofTechnology Managementand Research, Nagpur, MH, India*

[b] *Electronics and Telecommunication Department, S. B. Jain Institute ofTechnology Managementand Research, Nagpur, MH, India*

[c] *Electronics and Telecommunication Department, S. B. Jain Institute ofTechnology Managementand Research, Nagpur, MH, India*

rahul2480@gmail.com, punpreddiwarkrutika@gmail.com, divyanwadhwanii26@gmail.com

ABSTRACT

One of the natural events to which life is significantly threatened is a landslide. Landslides are a phenomenon that which greatly endangers life, structures, and the environment at large. Such interventions are often too slow and lack accuracy to avert the threat posed by landslides. There remains an acute scarcity of a relatively modern, integrated systems that utilizes the best and most recent geospatial tools and in intelligently advancing the landslide management system. The background of our research is Before now,the suitable method of landslide risk assessment, monitoring, mapping and management based on small amounts of data. Add this is something mainly, which is always on the brink of, the scare of the Engines of which we are in an age of, ironically enough. Development of the geospatial technology such as GIS, remotesensing, and machine learning brings us to the new era of technology with geospatial technologies. These advances enable the collection of high-resolution data and the development of complex models, which not only present more accurate results for hazards but have suggestions for the prevention of further disasters to the GRA. However, data involved in the practical use of the technologies for edging of the healthed remain out of exploration. Following parameter are observed during the landslide incident happened Climate changes, wind speed, deforestation planting, farming, type of soil, types of tree plantations, earthquakes, sliding type. The objectives of this research include the evaluation of GIS and remote sensing and machine learning in the field of landslide risk assessment, monitoring and management and design a compact sensor based prototype model which includes various types of sensor like Temperature sensor, humidity, pressure, wind speed, it also include sprinkler for maintaining the equilibrium condition of hilly place The focus is placed on examining for a change of the magnitude of these technologies predicting landslides. Advanced technologies due to the geospatial revolution go a long way in improving landslide management, especially through the use of remote sensing, ultrasonic sensors and GIS. Further enhancements in risk assessment, early warning systems, and emergency response would be helpful in making better preventive measures and mitigation strategies. This would enable us to look toward the protection of our communities and infrastructure from landslide impacts, opening up pathways toward a safer, resilient environment with better incorporation of geospatial data into planning and policy.

Keywords: - Sensor, GIS and Remote sensing, weather monitoring, Disaster management.

The Potential drivers of cold waves over India under the climate change scenarios

Rani Devi[1,2], K C Gouda[1,2]and Smrutishree Lenka[1, 3]

[1]*CSIR Fourth Paradigm Institute, Wind Tunnel Road, Bangalore-37, India*

[2]*Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, UP, India*

[3]*Department of Physics, Dayananda Sagar College of Engineering (VTU), Bangalore, India*

E-Mail:ranijangra1992@gmail.com

ABSTRACT

Cold waves are significant extreme weather phenomena affecting the Indian subcontinent, with profound socio-economic impacts. This study explores the dynamic drivers of cold waves, focusing on the interactions between large-scale atmospheric processes such as the Madden-Julian Oscillation (MJO), Western Disturbances, and Rossby waves under the influence of climate change. The analysis highlights the role of Western Disturbances in transporting cold air masses from higher latitudes into northern India, often intensified by the modulation of Rossby wave patterns. The phase and amplitude of the MJO significantly influence these cold air intrusions by altering atmospheric circulation and jet stream dynamics. Additionally, climate change introduces new complexities, as altered global circulation patterns can affect the frequency and intensity of cold waves. The wet phase of MJO over Indian region leads to higher convective activity development over southern equatorial region and influences the cold wind transport into Indian region. The active phase of MJO and Rossby wave found to be linked with the more likelihood of cold waves over northern parts of country. The relationship of MJO and Rossby waves with the occurrence, intensity and duration of cold wave have been explored. This research explores how these waves affect the onset, duration, and intensity of cold waves in India through changes in temperature distribution, wind patterns, and atmospheric blocking. Understanding these interactions is crucial for improving cold wave prediction and developing adaptation strategies in a warming world. The findings underscore the need for integrated modeling approaches to capture the intricate linkages between cold wave occurrences and the evolving climate system.

Keywords: Cold waves; MJO; Climate change; western disturbance; Rossby wave.

Drag scaling in Truly Neutral Atmospheric BoundaryLayer Using LES

Abhishek Gupta, Harish Choudhary, Deepash Jain, Pranav Sood,
Shibani Bhatt, Nitesh Raghuvanshi, Prajyot Sapkal, Thara
Prabhakarasn, Shivsai Ajit Dixit
Indian Institute of Tropical Meteorology, Pashan, Pune 411008
E-Mail:abhishek.gupta@tropmet.res.in

ABSTRACT

In every turbulent flow, one of the most important characteristics is turbulent drag. This is the result of friction between the surface and the fluid, which is primarily air. The air's viscosity and the surface's roughness are the key variables. There is a sharp velocity gradient close to the wall, making accurate drag estimation difficult. Dixit et al. (2020, 2022 & 2024) provide an asymptotic drag law—a method for scaling drag for hydrodynamically smooth wall-bounded laboratory flows, such as zero pressure gradient (ZPG) Laboratory Turbulent Boundary Layers (TBLs). Atmospheric Boundary Layer (ABL) flows are extremely complicated, and TBLs can bethought of as a particular instance of them. Comparing an ABL to a Lab TBL, the Reynolds number of an ABL is very high, almost two decades higher. The ABL presents a unique opportunity to examine drag scaling of laboratory TBL relations across orders of magnitude range in Reynolds number. As stability plays a unique role in the ABL, the near neutral conditions of the ABL are closer to the Lab TBLs, i.e., the buoyancy flux at the surface is closeto zero. The boundary layer is neither stable nor unstable. According to the study, if the Brunt– Väisälä frequency (N) is nearly zero in the outer part of the boundary layer, the flow can be treated as a Truly Neutral Atmospheric Boundary Layer (TNABL), and the atmospheric conditions are even close to lab conditions. It's even difficult to find such conditions in ABLs. Inrecent years, UCLA has emerged as a better tool to simulate atmospheric boundary layer flows. Ideal UCLA LES (large eddy simulation) mimics the TNABLs. Within the UCLA LES, the boundary layer can quickly evolve in neutrally stratified fluid background conditions. Resultssuggest that the TBLs and ABLs both follow the same asymptotic drag law.

Keywords: Boundary Layers; turbulence; Scaling; Truly Neutral Atmospheric Boundary Layer;LES;

The role of Ocean Memory in the Interannual Variability of Indian Summer Monsoon

Saran Rajendran[a], Sandeep Sukumaran[a]
[a] *Centre For Atmospheric Sciences, IIT Delhi*
E-Mail:asz188003@iitd.ac.in

ABSTRACT

The interannual variability in Indian Summer Monsoon (ISM) rainfall shows a quasi-biennial nature, with more than two consecutive droughts or floods a rare occurrence. This led to a claim that the ISM is a self-regulated coupled-ocean atmosphere system, in which the cross-equatorial ocean heat transport (OHT) over the Indian Ocean (IO) by the ISM winds is assumed to have a crucial role. A long ocean ”memory” is needed to support this mechanism of self-regulated monsoon interannual variability, as the warm/cold oceanic anomalies must persist for one year. However, the effectiveness of this cross-equatorial OHT in warming the ocean surface is not yet examined. Here, we present a critical examination of the role of OHT in the regulation of the interannual variability of ISM. Our analyses suggest that the effect of cross-equatorial OHT does not last beyond one season. While the difference in the ISM rainfall between flood and drought years can exceed 20%, the difference in OHT is only about 5%. On the other hand, low pressure systems (LPS) tracks over India show a major difference between flood and drought years, with a 27% increase in LPS days in the flood years. During drought monsoon years, on average the LPS genesis decreased by two storms per summer season. Also, the propagation of LPSs over continental India was incoherent in drought monsoon seasons compared to the flood monsoon seasons. This suggests that the LPS activity contributes more to the interannual variability of ISM than the changes in the heat storage over the Indian Ocean.

Keywords: Monsoon Variability; Ocean Heat Transport

Potential usefulness of a few non-conventional derived NWP products as guidance to operational forecasters for high impact weather phenomena

Anwesha Bhattacharya[1], Ishita Sarkar[1], Shubhendu Karmakar[1,2], Sourish Bandhyopadhyay[1] , H R Biswas[1], Somenath Dutta[1], Srestha Karmakar[2], Swagata roy[2], Sampriti Dan[2], Nabanita Majumdar[2], Pushan Bhattacharyya[2]

[1] *Regional Meteorological Centre, IMD, Kolkata*
[2] *JIS University, Agarpara, Kolkata*
E-Mail: ishitasarkar07@yahoo.com

ABSTRACT

Numerical weather prediction (NWP) model outputs greatly help the operational weather forecasters as forecast guidance in predicting movement and intensity of weather systems. NWP model outputs can be broadly divided into two types, viz., direct products (values of the input variables valid at some future time) and derived products (vorticity, divergence, etc.). Derived products are always more indicative than the direct products. NWP products are so vast that often it is colloquially said that NWP products are under-utilized. NWP wings of Meteorological services generally produce certain important routine derived NWP products, even though many higher order derived NWP products can be generated which are of great use as guidance to operational forecasters.

An attempt has been made, to assess the potential usefulness of a couple of non-conventional higher order derived NWP products as guidance to operational weather forecasters in predicting movement and intensity of different high impact weather systems, like severe local storm, cyclonic storms, etc. For that using ERA5 high resolution wind, temperature and humidity data, differential vorticity advection (DVA), Net vertically integrated horizontal divergence (NVIHD), net vertically integrated moist static energy (NVIMSE), differential thermal advection (DTA), differential moisture advection (DMA) have been computed during the life cycle of a couple of selected intense cyclonic storms (SCS/VSCS/ESCS/SuCS) and severe local storms for assessing the potential utility of these products as guidance to operational forecasters in predicting the movement and intensity of the above mentioned high impact weather systems. Preliminary results suggest that DVA & NVIMSE have potential for intensification prediction about 36Hours prior, NVIHD has a good potential for track prediction and DTA & DMA also have very good potential.

Keywords: Non-conventional NWP product, Differential Vorticity Advection, Maximum surface wind.

Temperature extremities under current and future SSPs scenarios for Indian States

Vidya S[1] Pradeep MS[1] and Dr. Anushiya J[1]

[1]Center for Study of Science Technology and Policy, Bengaluru, Karnataka, India
vidyas@cstep.in

ABSTRACT

According to the IPCC AR6 report, the frequency and intensity of hot extremes (including heatwaves) have increased globally since 1950 and will continue to rise as global warming increases. This also applies at the regional level. The increasing heat extremities will have a wide range of negative effects, including major fatalities, health problems, and higher expenses for infrastructure, energy, transportation, and agricultural output.

This study examines the temporal and spatial variability of temperature extremities across all states of India. Multi model ensemble of Coupled Model Inter-comparison Project phase 6 (CMIP6) models is used to compute temperature extremities over all the states of India for the annual, summer season (March, April, May) and monsoon months (June & July). The multi model ensemble will be validated with observed IMD(India Meteorological Department) gridded data for the period 1994-2023. All Shared socio economic pathways (SSP1- 1.9, SSP2-2.6, SSP 3-4.5, SSP4-7 and SSP 5- 8.5) will be used for future scenarios. IMD criteria (heat wave) and ETCCDI indices such as TX10p, TX90p, TN10p, TN90p, DTR, 20TXx, 20TXn, 20TNx, 20TNn, will be calculated under both present (1994-2023) and future climate scenarios (2050's and 2080's).

Keywords: Extremities, CMIP6, ETCCDI Indies , Shared socio economic pathways(SSPs)

IMPACT OF ASSIMILATION OF UPPER AIR OBSERVATION TO SIMULATE THE SEVERE THUNDERSTORM OVER BIHAR AND WESTBENGAL, INDIA USING 3DVAR OF WRF MODEL

Vinisha[a], S. K. Panda[a], Anish Kumar[a,b], Unashish Mondal[a], Gitesh Wasson[a,c] and DeveshSharma[a]

[a] *Department of Atmospheric Science, School of Earth Sciences, Central University of Rajasthan*
[b] *Institute for Meteorology, Leipzig University, Leipzig, Germany*
[c] *School of Earth and Environment, University of Canterbury, Christchurch, New ZealandE-Mail: vinishaashokan5@gmail.com*

ABSTRACT

Severe thunderstorms present significant challenges to communities and infrastructure, making timely and accurate predictions increasingly difficult. This study compares a control run (CNTL) with a 3DVAR run, where upper-air observational data was assimilated to investigate severe thunderstorm events over Bihar on June 25, 2020, and West Bengal on June 7, 2021. The study evaluates the influence of data assimilation on thunderstorm initiation and intensification, focusingon parameters like Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), rainfall, wind, and relative humidity. Using 0.25° × 0.25° NCEP GDAS FNL data, the model was run for 48 hours, incorporating eight 6-hourly assimilation cycles for the 3DVAR in both cases. CAPE values of 1800 J/kg in Bihar and 5000 J/kg in West Bengal signaled severe thunderstorm conditions. Performance metrics, including Accuracy (ACC), Equitable Threat Score (ETS), Heidke Skill Score (HSS), Probability of Detection (POD), True Skill Statistic (TSS), Critical Success Index (CSI), and False Alarm Ratio (FAR), were used to assess the model. Assimilation of upper-air observations significantly improved the model's accuracy, correcting issues such as rainfall overestimation of 20–40 mm in Bihar and addressing both overestimations (up to 100 mm)and underestimations (80–100 mm) in West Bengal. Additionally, the 3DVAR method reduced both spatial and temporal lags. For Bihar's rainfall, the ACC approached 1, while the FAR for West Bengal's CIN during the event time dropped close to 0 in the 3DVAR run. Despite similar patterns during peak intervals across model runs, the 3DVAR consistently aligned more closely with observations, demonstrating its effectiveness in enhancing thunderstorm prediction accuracy.

Keywords: Severe thunderstorms; 3DVAR; WRF modeling system; Variational data assimilation

SENSITIVITY OF MICROPHYSICAL CHARACTERISTICS OF HAILSTORMS OVER ASSAM AND BIHAR USING WEATHER RESEARCH AND FORECASTING (WRF) MODEL

Bhavyasree[a], S. K. Panda[a], Gitesh Wasson[a,b], Unashish Mondal[a], Anish Kumar[a,c], DeveshSharma[a]

[a] *Department of Atmospheric Science, School of Earth Sciences, Central University of Rajasthan,Bandar Sindri, Kishangarh, District: Ajmer, State: Rajasthan, India (305817)*
[b] *School of Earth and Environment, University of Canterbury, Christchurch, New Zealand*
[c] *Institute of Meteorology, Leipzig, Germany*
E-Mail: bhavyasree012016@gmail.com

ABSTRACT

This study evaluates the performance of the Advanced Research Weather Research and Forecasting (WRF-ARW) model in simulating two severe hailstorm events. The simulations focus on hailstorms that occurred during the post-monsoon and pre-monsoon periods: on 26 December 2022 in Assam and 19 May 2022 in Bihar. A continuous 48-hour model integration was used. The WRF model was run on a double nested domain with horizontal resolutions of 9 and 3 km, utilizing the Milbrandt 2-moment microphysics and Kain Fritsch cumulus parameterization schemes. Key analyses included hydrometeor mixing ratios, maximum reflectivity, wind speed and direction, temperature contours, and relative humidity. The results were validated using ERA-5 reanalysis data. Instability indices such as Convective Available Potential Energy (CAPE), Total Totals Index(TTI), and Significant Hail Parameter (SHIP) were examined to assess the hailstorm environment. A peak hail mixing ratio was observed between altitudes of 600–700 hPa, indicating a significant presence of hail in the mid-troposphere. A high-level jet was detected during the Assam event. TheSHIP value derived from the model output was 0.1 for Assam, indicating a non-significant hail environment, while for Bihar, the SHIP value was 2.0, suggesting a significant hail environment. Despite a relatively low CAPE value of around 500 J/kg for the Assam event, hail still occurred.In contrast, Bihar had a CAPE value of approximately 3000 J/kg, indicating severe thunderstorm conditions. The WRF model successfully simulated both hailstorm events with the selected configuration.

Keywords: Hailstorm, Hailstorm indices, WRF-ARW model, Model skill score

Prediction of visibility for Lucknow Airport using Deep Learning

M. Danish
Scientist-D, IMD Lucknow

ABSTRACT

Weather forecasting has long been an essential aspect of predicting environmental conditions, influencing sectors such as agriculture, transportation, and disastermanagement. Traditional methods of weather prediction rely on numerical models that process vast amounts of meteorological data to simulate atmospheric dynamics. However, these models are computationally intensive and often suffer from limitations in prediction accuracy, especially for short-term forecasts or localized weather phenomena.The application of Deep Learning in weather forecasting aims to enhance accuracy, reduce computational costs, and provide more adaptable models. AI and ML models can analyze historical weather data, recognize complex patterns, and make predictions based on real-time data inputs. By leveraging techniques like supervised learning, neural networks, deep learning, and ensemble methods, AIMLmodels are capable of learning from large datasets and improving prediction quality over time. In this approach, AI models are used to fine-tune predictions from traditional weather models or replace them in some contexts, offering higher precision inareas like temperature prediction, rainfall estimation, and storm tracking. Theintegration of satellite imagery, sensor data, and advanced data analytics has also improved the speed and granularity of forecasts.This paper explores use Meteorological Optical Range, Runway Visual Range and meteorological parameters obtained from a recently installed Automated Weather Observing System installed at Lucknow Airport by employing Convolution Neural Network (CNN) technique for visibility prediction for Lucknow airport. The strengths and limitations of the technique are also presented. With advancements in data availability and computational power, AIML presents a promising additional tool for forecasting of severe weather systems.

A Unified Framework for Visibility Estimation Through Fusion of Multi-Feature Streams and Meteorological Data

Anand Shankar1[a]

[a] *India Meteorological Department, Ministry of Earth Sciences, Govt. of India, Patna, India*
E-Mail:anand.shankar@imd.gov.in

ABSTRACT

Visibility has a significant impact on a human's socioeconomic activity and is one of the most common causes of economic losses (accidents) on a global scale. Despite ongoing research into meteorological visibility estimation, challenges persist due to foggy environments' inherent complexity. Traditional deep learning approaches frequently fall short due to their inability to effectively capture "specific features" of foggy images, whereas physical model-based methods are limited by their dependence on specialized auxiliary parameters and are often restricted to specific scenarios. This paper introduces a novel end-to-end framework for enhanced visibility estimation. To improve accuracy, our approach integrates meteorological (air temperature, winds, pressure, etc.), engineered, and learned features. More specifically, our proposed framework utilizes a groundbreaking 3D multi-feature stream matrix, known as DDT, which consists of a transmittance matrix, a dark channel matrix, and a depth matrix. Unlike conventional deep learning techniques that rely solely on convolutional neural networks (CNNs) for processing image data, our method synergistically combines CNN and Transformer architectures. The Swin-Transformer (Swin-T) module processes the original image, while the CNN module operates on the DDT matrix. To effectively merge the diverse features from CNN and Swin-T, we incorporate a Coordinate Attention (CA) module within the framework. For evaluation, we have created three sets of visibility datasets: visibility image dataset I, which features real-world visibility scenarios of Patna Airport during the day; visibility image dataset II, which includes a real-world visibility dataset for nighttime conditions; and Visibility dataset III, which combines the two. Results from experiments show that the proposed framework works better than traditional methods on three datasets. In dataset 1, it is 7% more accurate; in dataset 2, it is 3% better; and in dataset 3, it is 5% better than the best approach.

Keywords: Visibility Estimation, Feature Extraction, Tranfromers, Multi Fusion, and Deep Learning.

Forecasting Dengue Incidence in Bihar, India, Using an Attention LSTM Model Based on Meteorological Data

Anand Shankar1[a]

[a] *India Meteorological Department, Ministry of Earth Sciences, Govt. of India, Patna, India*
E-Mail:anand.shankar@imd.gov.in

ABSTRACT

Dengue fever, affecting approximately 400 million people worldwide, continues to strain healthcare systems across over 100 tropical and subtropical nations. In the absence of a targeted drug and a readily available vaccine, sophisticated early warning systems are required for effective intervention. However, existing forecasting models, such as weather-driven mechanistics, statistical time series, and machine learning models, often fall short in predictive accuracy and stability due to their fragmented understanding of influencing factors. To tackle this challenge, we propose an innovative approach that combines a self-supervised LSTM neural network with an exogenous meteorological factor model to improve dengue outbreak prediction in Bihar's districts. This model seamlessly integrates weather variables, validated using statistical Dengue IMAPCT data, into a robust and scalable framework. By employing self-supervision transformation within an LSTM neural network, the model offers superior long-term forecast reliability. It adeptly handles the intricate non-linear relationships between dengue cases and meteorological factors, ensuring mathematical clarity, rapid execution, and user-friendly interpretation. There are computer tests that show the suggested self-supervised LSTM can predict dengue cases better than traditional statistical, machine learning, and deep learning models 75% of the time. This is true for both short-term and long-term predictions.

Keywords: Dengue outbreak, meteorological factors, eastern India, self-supervised LSTM

Enhancing Ensemble Extreme Precipitation Predictions through Generative AI

Anand Shankar1[a]

[a] *India Meteorological Department, Ministry of Earth Sciences, Govt. of India, Patna, India*
E-Mail:anand.shankar@imd.gov.in

ABSTRACT

A novel ensemble post-processing method has been developed to enhance probabilistic forecasts of extreme precipitation events over the Indian subcontinent. This approach combines a 3-D Vision Transformer (ViT) for bias correction with a Latent Diffusion Model (LDM), a generative AI method. Its objective is to post-process 6-hourly precipitation ensemble forecasts, generating an expanded ensemble that maintains spatiotemporal consistency in precipitation trajectories. These improvements are aimed at better characterizing extreme precipitation events and providing more accurate multi-day accumulated and 6-hourly precipitation guidance. The method was evaluated using Global Ensemble Forecast System (GEFS) precipitation forecasts up to day 6, validated against Climate-Calibrated Precipitation Analysis (CCPA) data. Verification results demonstrate that the method produces ensemble members with significantly improved Continuous Ranked Probabilistic Skill Scores (CRPSSs) and Brier Skill Scores (BSSs) compared to raw GEFS outputs and a multivariate statistical postprocessing baseline. It effectively generates reliable probabilities for events exceeding extreme precipitation thresholds. Explain ability studies were also conducted to elucidate the decision-making process of the method, affirming its effectiveness in generating ensemble members. This innovative approach addresses the limitations of small numerical ensembles by using generative AI to produce larger ensembles capable of identifying and forecasting extreme precipitation events more accurately.

Keywords: Generative AI, Ensemble Post Processing, Multivariate Statistical Post-Processing, Extreme Precipitation Thresholds

Regional signatures of Monsoon weakening ofglobal abrupt climate events

Surabhi Verma[a], Yama Dixit[a]

[a] *Centre for Atmospheric Sciences, Indian Institute of Technology Delhi,New Delhi-110016,*
E-Mail:surabhi.ver98@gmail.com

ABSTRACT

Holocene climate variability (past 11,700 years) is important to study as the boundary conditionsof the climate system did not change significantly (in comparison to larger glacial - interglacial changes). Palaeoclimatic reconstructions using in-situ observations are essential for understanding extreme weather and abrupt climate events during Holocene. These centennial - scale climate events (also known as **Bond Events**) of monsoon weakening coincide with the cold periods in North Atlantic. Based on the climate events globally, Holocene epoch has been divided into 3 stages – Greenlandian Stage (11.5 - 8.2 ka), Northgrippian Stage (8.2 – 4.2 ka) and Meghalayan stage (4.2 ka to present). This study is the analysis of published Holocene records of monsoon variability from Indian subcontinent to quantify the amplitude and duration of abrupt climate events that occurred during onset of these stages. The records are selected for the analysis based on the availability of high resolution data and chronological dates to the nearest of these three climate events (i.e. 11.1 ka, 8.2 ka and 4.2 ka events). Proxy records are detrended and duration is estimated by examining the deviation of data from baseline average. The amplitude is mean of z-score values between the determined duration of the event. Additionally, Principal Component Analysis (PCA) is done to elucidate the climatic pattern in the records and regional coherency in the monsoon variability. By effectively evaluating the amplitude and magnitude of climate events, this study contributes to our understanding of abrupt change in climate and focuses that comprehensive analysis is essential to enhance our predictive accuracyand long - term climate forecasting models.

Keywords: Abrupt Climate events; Monsoon; Climate change; Holocene

Derived NWP products in forecasting the track and intensity of tropical cyclone MOCHA

Pallavi Prabhu[a], Somenath Dutta[b], Raja Boragapu[a], Pushpa Saroja[a] and Somnath Mahato[a]

[a] *Meteorological Training Institute, India Meteorological Department, Pashan, Pune – 411008*

[b] *India Meterological Department, Alipore, Kolkata-700027*

E-Mail:pallavi.ozone@gmail.com

ABSTRACT

An attempt has been made to examine the potential usefulness of a few non-conventional customized derived numerical weather prediction (NWP) products, viz., the differential vorticity advection (DVA) , differential thermal advection (DTA), differential moisture advection (DMA),Net vertically integrated Moist Static Energy (NVIMSE) and net vertically integrated horizontal divergence (NVIHD) as NWP guidance to the operational forecasters in predicting the intensity and track of the Cyclone ‘MOCHA’. Differential advection of different dynamical and thermodynamic parameters, as mentioned above have been computed by subtracting the advectionat surface/1000hPa from that at 200hPa followed by dividing it by the depth of the column betweensurface and 200hPa , i.e., Differential advection = (Advection at 200hPa - Advection at surface) divided by the depth of the column. For that changes in the daily means and six hourly values of the derived products are analysed overparts of the Bay of Bengal and the total basin. A basin wise increase in the differential vorticity advection has been found approximately 12 hours prior to the peak intensity indicating further intensification of extremely severe cyclone “MOCHA" that formed over the Bay of Bengal in May,2023. DMA and DTA have shown strong negative values 6-12 hours prior in the inner cloud region. This indicates enhancement of convective instability and more low level influx of moistureand hence more buoyancy leading to strong vertical updrafts for the cyclone to intensify. On the other hand, the normalised vertically integrated horizontal divergence pattern strongly hints at a north-eastward movement. The lag Correlation coefficient of maximum sustainable winds of MOCHA cyclone and of the vertically integrated moist static energy and shows 0.8 correlation at12 hours and 18 hours prior which also supports our analysis.

Keywords: NWP Products, Cyclone intensity and track, MOCHA

Climate Impact on Fishery variability of commercial fish species in the Indian Exclusive Economic Zone (EEZ)

Faseela Hamza, Vinu Valsala, Hamza Varikoden, IVG Bhavani
E-Mail:faseela@tromet.res.in

ABSTRACT

Understanding the impact of climate change on fishery variability exhibited by major commercial fish species is critical for policy making and fisheries management. We have analysed the fishery variability and trend of different fish population along the Indian Exclusive Economic Zone (EEZ). These fish belongs to different habitat and classified as small pelagics, large pelagics and demersal. Their total landing biomass in the Indian EEZ from 1981-2019 was cross-examined and correlated with leading climate variability. Among these, Sardine was the single largest contributor to total fish catch and displayed the highest climate variability. All the fishes show a significant increasing trend indicative of modern mechanised fishing and demand- driven exploitation except for Stolephorus and Sharks. Stolephorus showed an insignificant increasing trend, while Sharks displayed a declining trend in total catch. The four decades of landing data (1981-2019) studied here show that, in small pelagics, Sardine fluctuated with distinct episodes of abundance and scarcity with prominent intradecadal and intradecadal variabilities. It also showed an out-of-phase pattern in abundance and scarcity with anchovies. Large pelagics and demersals displayed prominent interannual variability without distinct phases of abundance or decline in decadal scale. Small pelagics displayed a prominent relation to climate variability compared to the other two groups, indicating the potential predictability of these species on a decadal scale. Sardine landings were strongly associated with negative Pacific Decadal Oscillation (PDO) as identified from SST and wind patterns, and a contrasting pattern was observed with Mackerel and anchovies. Regional wind patterns regressed with landing variability in the Indian EEZ revealed the teleconnections of environmental variability and fisheries. Modelling studies also elucidated the linkages between leading climate variability and fishery.

Keywords: Climate variability; Fishery variability; Sea surface temperature; wind; Climate oscillations

Comparison and Validation of Global Forecast System Datasets with Observations from Radiosonde

M. Ashok Williams[1], Anshul Chauhan[1], Akhil Raj S T[1], M. I. Ansari[1], and Gajendra Kumar[1]

[1]*Upper Air Instrument Division, India Meteorological Department, New Delhi-110003, India*

E-Mail: mashokw4@gmail.com

ABSTRACT

Estimating atmospheric stability indices during critical weather conditions is very important. Using sounding profiles, meteorologists can calculate these stability indices. However, sometimes due to bad weather or gusty wind conditions, obtaining a sounding profile is not possible. This research work provides a scientific analysis comparing the Global Forecast System (GFS) and Radiosonde data to address the lack of sounding data. Atmospheric stability indices such as convective available potential energy (CAPE), convective inhibition (CIN), K-index, lifted index (LI), and updraft speed were calculated using both datasets and compared during Cyclone Michaung, which formed in the Bay of Bengal, India, from December 1st to 6th, 2023. Although the patterns of temperature and relative humidity are similar between the Radiosonde and GFS data, the atmospheric stability indices differ. Particularly for CIN, the GFS tends to overestimate compared to the observed Radiosonde profile. Significant correlations have been observed for the K-index and lifted index, followed by CAPE and updraft speed, with comparatively less correlation observed for CIN.

Keywords: Atnospheric stability indices; Global Forecast System; convective available potential energy; K-index; lifted index

HIGH-RESOLUTION GREENHOUSE GAS OBSERVATIONS IN INDIA: UNDERSTANDING ITS VARIABILITY AT DIFFERENT TEMPORAL SCALES

Jitender Singh, G. Sreenivas, Priyabrata Nandi, Karuna Rao, Smrati Gupta, Yogesh K. Tiwari*

Centre for Climate Change Research, Indian Institute of Tropical Meteorology, Pune, Ministry of Earth Sciences
E-Mail: jitender.singh@tropmet.res.in

ABSTRACT

This study presents an intercomparison of greenhouse gas (GHG) measurements—carbon monoxide (CO), carbon dioxide (CO_2), and methane (CH_4)—across three distinct monitoring sites in India: Sinhagad (SNG) Pune, IITM Pune, and at tall tower site at Atmospheric Research Testbed (ART) Silkheda, near Bhopal during 2023. The sites represent varied environments, with SNG at the top of a mountain, IITM in a semi-urban environment, and ART in a remote rural area. Data were collected with a high-resolution frequency (near one second). Measurements were taken at multiple heights (12m, 36m, and 72m) using a tall tower at ART Bhopal. SNG is a mountain site with an altitude of 1600 amsl, and the GHG observation site at IITM Pune is located at the 30- meter tall building. The primary objective is to analyse these gases' temporal evolution, diurnal cycles, and seasonal variations to understand regional GHG dynamics better. The diurnal cycles of CO, CO_2, and CH_4 display significant daily variability, with peak concentrations observed during early morning and afternoon hours, corresponding to boundary layer dynamics and local emissions. CO diurnal patterns, in particular, exhibit sharp peaks in the early afternoon at all sites, consistent with combustion-related sources and temperature-driven vertical mixing. CO_2 and CH_4 also show distinct diurnal profiles, with variations more prominent in winter and post-monsoon periods. An inter-site comparison indicates that the Bhopal site, with its vertical profiling at three heights, shows a clear stratification of GHG concentrations. Higher levels of CO_2 and CH_4 were detected at 12m, with lower concentrations at 72m, highlighting the influence of surface emissions and boundary layer mixing. This vertical gradient is less pronounced at SNG and Prithvi, where data at a single height were recorded. Overall, this study highlights the spatial and temporal variability of key GHGs across diverse environments in India. The high-resolution data collection provides unprecedented insights into emission sources and atmospheric processes modulating GHG concentrations in mountain, urban, and rural settings.

Keywords: Greenhouse Gases; Surface Observations; Monsoon; Climate change

WESTERN DISTURBANCE VARIABILITY IN RECENT YEARS: EVALUATION OF THE CAUSES AND THE IMPACTS ON NORTH INDIA

Siddhant, Arya[a] and Amita Prabhu[b]
Indian Institute of Tropical Meteorology,Pune, India – 411008
E-Mail: siddhant.arya@tropmet.res.in

ABSTRACT

Western Disturbances (WD) are upper-level troughs frequently linked with lower-troposphere depressions over North Western India, exhibiting certain dynamic similarities to temperate cyclones. Traditionally considered a winter phenomenon (December to February), WD occurrences have been documented throughout the year, although their frequency and intensity are markedly higher during the winter months. The seasonal northward migration of the subtropical jet, driven by increased heating in the northern hemisphere tropics from April to October, governs the WD cycle. This study employs ERA-5 reanalysis data from the past 30 years (1993-2023) with a focus on the last decade, to analyze the trends and their implications. Recent observations indicate significant winter rainfall deficits in North India, impacting the Rabi cropping season, and a shift in the WD cycle with increased frequency during summer. Thisshift has led to heightened hailstorm activity and subsequent crop losses. Despite their generally weaker summer presence, WD can still cause substantial rainfall and even cloudbursts if interacting with tropical depressions. Additionally, decreased snowfall in the Himalayas has adversely affected the water security of North India's river basins, as WD-induced snowfall is a key source of glacial ice. The reduced intensity and frequency of WD, attributed to climate change and a northward shift in the subtropical jet, has diminished moisture supply from the Arabian Sea, the primary moisture source for these disturbances. This has also contributed to more frequent severe cold waves in the northern plains and delays in the arrival of the Southwest Monsoon, potentially linked to increased snowfall in the Tibetan Plateau. The research will also review existing literature to address research gaps and will examine the impacts of these shifts onNorth India and the Western Himalayas.

Keywords: Western Disturbances; Extreme weather events; Climate change; Agriculture; Water security

ROLE OF EQUATORIAL INDIAN OCEAN ON THE REGIONAL

ASPECTS OF TOTAL CLOUD AMOUNT AND SUMMER MONSOON RAINFALL OVER INDIA

Amita Prabhu*, Sachin Deshpande, Siddhant Arya and

Govindan Pandithurai

Indian Institute of Tropical Meteorology, Pune, India - 411008

E-Mail:amitaprabhu@tropmet.res.in

ABSTRACT

This observational study uses the International Satellite Cloud Climatology Project (H series) (ISCCPH) dataset to study the concurrent interrelationships between Equatorial Indian Ocean (EIO) SSTs, total cloud amount and the summer (JJAS) monsoon rainfall over India during the 33-year period from 1983-2016. Regional correlation patterns reveal robust clusters of inverse relationship between EIO SSTs with cloud amount and rainfall over the north-eastern regions of India. Further, dominant modes of interannual variability over the EIO region also reveal that first mode of empirical orthogonal function (EOF1), which explains 50.5% of variance, also is strongly associated with summer monsoon rainfall and total cloud amount patterns over the northern and eastern parts of India. Furthermore, this phenomenon is explored by understanding how the EIO-SST extremes influence rainfall over India through large-scale atmospheric circulations. The composites analyses of extreme EIO SSTs reveal that ocean-cloud- rainfall link is manifested by triggering large scale anomalous Hadley circulations over the Indian region, demonstrating the significant association between EIO-SSTs, cloud amounts and summer monsoon rainfall over India.

Keywords: Indian summer monsoon rainfall, total cloud amount, Indian Ocean SST, large scale atmospheric circulation, ISCCPH dataset

Assessment of Forecast of ESCS "Fani" using NCMRWF Regional and Global Ensemble Prediction Systems

Arpit Mohapatra1[a], Ashish Routray2[b],and S Kiran Prasad[b]

[a] *P.G. Department of Marine Sciences, Berhampur University*
[b] *National Centre for Medium Range Weather Forecasting*
E-Mail: arpitmohapatra99@gmail.com

ABSTRACT

The study compares the prediction skills of the high-resolution National Centre for Medium RangeWeather and Forecasting (NCMRWF) Regional Model (NEPS-R) and Global Model (NEPS-G) for tropical cyclone characteristics. NCMRWF global and regional ensemble prediction systems (NEPS-G and NEPS-R) have been used in forecasting the intensity and track of the ESCS ‘Fani’,which hit eastern India (primarily Odisha) in April 2019. In terms of track forecasting, the regionalmodel clearly outshines the global model because it predicts the track with high probability. The ensemble means track forecast of the regional model also did a better job than the global one. TheNEPS-R is doing significantly better in the track error analysis. The DPE of the NEPS-R track becomes less after 30 hours and up to 24 hours, the global model has less error than the regional model highlighting the better performance of the regional model at longer lead times. The regionalmodel caught the rapid intensification during 1430 IST on April 29th and 2030 IST on April 30th,whereas the global model was unable to catch it, which is clearly visible in the EPSGRAM. The intensification of the system during 1130 IST on May 1 and 2330 IST on May 3 was also caught by the regional model only. The Day-2 forecast of Mean Sea Level Pressure (MSLP) at 00 UTC on May 2, 2019 was better captured by the regional model than the global model. But for the Day-3 forecast, both models underperformed. The precipitation spread was better captured in the regional model forecast, but the regional model was unable to pick up the intensity of the rainfall.The global model captured the intensity of the rainfall but was unable to capture the spread. Overall, the regional model (NEPS -R) show reasonable skill in prediction of tropical cyclone ‘FANI’.

Keywords: Ensemble Prediction; Tropical Cyclone; Strike Probability; Intensity; Track Error.

Assessment of the Seasonal Prediction Models in Representing the Monsoonal Rainfall

Swapnilkumar Kori [1], O.P. Sreejith [1], and S.D. Sanap [1]

[1]Climate and Research Services, India Meteorological Department, Pune, India Presenting Author's Name: *Kori. SK.*

E-Mail: koriswapnil1@gmail.com

ABSTRACT

The Indian Summer Monsoon Rainfall (ISMR) is vital for India's agriculture, disaster preparedness, and public health. However, its prediction remains a challenge due to complex atmospheric dynamics, interactions with land, and oceans, and the influence of climate drivers like the El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). General Circulation Models (GCMs) often show significant errors in replicating ISMR, requiring bias correction methods to enhance their accuracy. This study aims to evaluate the performance of different seasonal prediction models for ISMR and assess the effectiveness of bias correction methods. We use observed India Meteorological Department (IMD) gridded data (1993–2009) and seasonal forecast data from the Copernicus C3S and NMME models. The climatologies of each model are compared against observations, and bias correction techniques are applied to improve model outputs. Model performance is evaluated using Pattern Correlation Coefficient (PCC) metrics. A detailed assessment of the model performance will be presented.

Keywords: Indian Summer Monsoon Rainfall, Seasonal Prediction Models, Bias Correction

Analyzing Carbon Sink Dynamics in India:Insights from Climate Model Projections

Smrati Gupta[a], and Yogesh K. Tiwari[a],

[a] *Indian Institute of Tropical Meteorology, Pune, MoES, GOI*
E-Mail: *smrati.cat@tropmet.res.in*

ABSTRACT

Amid growing concerns over global warming and rising greenhouse gas emissions, this research examines the changing dynamics of carbon dioxide (CO_2) sequestration by the terrestrial biospherethrough Gross Primary Productivity (GPP), using models and observations from past to future timescales. Approximately 30% of anthropogenic CO_2 emissions are absorbed by terrestrial ecosystems via primary productivity. This study explores how land use changes, climate change, and physiological responses to shifting meteorological conditions collectively influence the carbonsink potential of the terrestrial biosphere. Focusing on India, a region highly vulnerable to climateimpacts, the research utilizes simulations from the Climate Models Inter-comparison Project (CMIP). Recent findings reveal an increase in GPP across India. Analyzing both historical and future scenarios using CMIP models, the study found that the historical trend in annual GPP was 2.37 gC $m^{-2}y^{-2}$. Under the highest emission scenarios, projections suggest an increase to approximately 6 gC $m^{-2}y^{-2}$, based on the socio-economic pathway-5 of CMIP6 experiments. The results highlight spatial variability in GPP trends across India, with regions like the North East, Indo-Gangetic Plains, and Western Ghats showing significant increases, while some southern areasexhibit little to no growth in future projections. The study also investigates recent land use changesand how alterations in forest and crop cover have influenced GPP. Additionally, it examines the potential impact of increased rainfall, as projected by CMIP6 models, on GPP trends. This researchoffers valuable insights into shifting GPP patterns in India and underscores the complex interactions between climate change, land use, and carbon cycling. The findings are crucial for improving future climate models and emphasize the importance of integrating real-world observations to enhance predictions of terrestrial ecosystem responses to ongoing environmental changes.

Keywords: Climate change scenarios; Gross Primary Productivity, CMIP models, Indian region

Statistical Downscaling and Future projection of CMIP GCM'sMinimum Temperature data over India

Manisha Chaturvedi, R.K. Mall & Shreya Rai

DST-Mahamana Centre of Excellence in Climate Change Research, Institute of Environment andSustainable Development, Banaras Hindu University, Varanasi

Corresponding Author Email: manishacs13@gmail.com, rkmall@bhu.ac.in

ABSTRACT

Statistical Downscaling method is a powerful method for downscaling of GCMS data to assessment of climate change at regional level. There has been an unprecedented rate of increasingin minimum temperature (Tmin) across the world causing severe impacts which are more pronounced at a local level. Fine resolution climate data at a local level are mandatory for many applications and impact assessments in agriculture, public health, environmental and livelihood. This study presents a best deep learning approach: Bidirectional long short-term memory network(BiLSTM) and Gated recurrent unit (GRU) to downscale the CMIP6 GCMS models (1.25° coarseresolution) daily minimum temperature (Tmin) data at a regional scale of 0.5° spatial high resolution for the period 1951-2010 over India. The results showed that both method are performing very well in downscaling for all GCMs model dataset but BiLSTM method is slightlybetter perform than GRU method when evaluate against observed minimum temperature and in terms of RMSE, MAE, correlation and spatiotemporal variability. In addition, an assessment of the future change in Tmin over the India under future scenarios have been also analyzed in the study. Overall, the study concludes that BiLSTM approach is thus a powerful tool for downscaling(performs better than GRU) daily Tmin over India with best parameter tuning. Hence, we proposeto utilize a BiLSTM method for downscaling GCMs dataset at a high resolution over India.

Keywords: Minimum Temperature, Deep learning, Downscaling, CMIP6

Impact of extreme events (El Nino) on Algal bloom(Microplankton) in IndianOcean

Bhubaneswari Panda[a], Arvind Sahay[a], K N Babu[a]

[a] *Biological Oceanography, Space Applications Centre (ISRO), Ahmedabad 380015,India*
E-Mail: bhubaneswari.panda7@gmail.com

ABSTRACT

The El Nino Southern Oscillation (ENSO) is widely recognized as the primary driver of inter annual climatic variability, arising from a complex interaction between atmosphere and ocean in the tropical pacific region with far reaching impact on global atmospheric circulation and weather pattern. Marine phytoplankton is particularly vulnerable to the effects of climate change,making it crucial indicator of ocean ecosystem health. However, long term impacts of these extreme events on phytoplankton community structure in bloom hotpot regions remain unknown.In the present study, we investigated impact of two significant El Nino events i.e. 2009-2010 and2015-2016 which occurred over the last 2 decades. The result showed that, among environmentalparameters, SST significantly influenced the Phytoplankton size class. Among the 4 hotspot regions studied, El Nino events has a greater influence in NE Arabian Sea. A 2% rise in SST anddecreased Chl-a concentration during 2009-2010 El Nino event has led to decrease of 38% in Microplankton, 23%in Nanoplankton and 5% in Picoplankton concentration in NE Arabian Sea region. In contrast, in bloom hotspot regions in the Bay of Bengal, a 0.1 ºC rise in SST during the 2009-2010 El Niño event led to increase of microplankton concentration by 11% in Gopalpurand 14% in the Gulf of Mannar region. Similarly, a 0.2ºC increase in SST led to a 36% increase in Microplankton concentration in the Gulf of Mannar region during the 2015-2016 El Niño event, which was attributed to an 18% increase in chlorophyll concentration, signifying that increase in SST is not only the main environmental factor governing microplankton growth but there are other factors also influencing the growth of microplankton.

Keywords: Extreme events, El Nino, Bloom hotspot regions, SST, Microplankton

Investigating Air Pollution Dispersion from Forest Fires: A casestudy on Uttarakhand Using the HYSPLIT Model

Agniva Pal, E.S. Saiprasad, Tejas Turakhia, Rajesh Iyer
Department of Physics-Electronics, St Xavier's College, AhmedabadE-Mail:agniva.pal002@gmail.com

ABSTRACT

Air dispersion models are essential tools for understanding the distribution and concentration of contaminants in the environment. This study utilizes the Hybrid Single Particle Lagrangian Integrated Trajectory (HySPLIT) model to investigate air dispersion processes. The HySPLIT model combines grid-based atmospheric dynamics with particle trajectories, employing both Lagrangian and Eulerian approaches to provide a comprehensive understanding of pollution dispersion. We examined the underlying physics of different modeling methods, emphasizing their accuracy in representing contaminant behavior. A case study was conducted to further explore the functionality of HySPLIT in the context of a series of forest fires that occurred in the Almora region of Uttarakhand, India, during April and May. To achieve this, we utilized MODIS Terra & Aqua MAIAC Land Aerosol Optical Depth Daily 1 km data to analyze the dispersion of air pollutants. The findings of this study offer significant insights into the dispersion patterns of smoke and pollutants resulting from the fires, which are critical for public healthand environmental protection. Our results underscore the reliability and effectiveness ofthe HySPLIT model in predicting dispersion patterns and informing mitigation strategies.

Keywords: Air Dispersion Model, Forest Fire, HySPLIT

Climate Change Impact on Rice Production in theIndo-Gangetic Plain: Adaptive Solutions

Mrinalini Srivastava[1]*, R.K Mall[1]

[1] DST – Mahamana Centre of Excellence in Climate Change Research,
Institute of Environment & Sustainable development, Banaras Hindu University,
Varanasi, India
*Corresponding email- mrisri18@gmail.com , rkmall@bhu.ac.in

ABSTRACT

Assessing the impact of climate change on crop production is crucial for the sustainability of globalfood systems. This study investigates the effects of climate change on rice yields in the Indo- Gangetic Plain using the CERES-Rice model, with high-resolution climate projections from Global Climate Models (GCMs) for the mid-future (2040–2069) and far-future (2070–2099) underSSP2-4.5 and SSP5-8.5 emission scenarios Results indicate yield reductions due to shifts in crop phenological stages, with losses ranging from 1.4% to 23% in the mid-future. Far-future projections suggest slight increases in yield up to 7.2% in specific regions, mitigated by elevated CO_2 levels. To counteract these negative effects, shifting sowing dates is explored as an adaptationstrategy. Simulations indicate that adjusting planting dates to later in the growing season, specifically from late July to early August, can reduce yield losses. This approach helps mitigate the impact of climate change by optimizing the timing of crop development relative to changing climate conditions. The study underscores the varying impacts across different regions and seasons. The early season faces the most severe reductions, while the late season, especially in theTrans Gangetic Plain, demonstrates some potential for yield increases. These findings highlight the importance of targeted adaptation measures, such as adjusting sowing dates, to enhance rice production resilience. By strategically planning planting schedules, it is possible to optimize yieldsand improve food security in the face of climate change.

Keywords: CERES Model, CMIP6, Elevated temperature, CO2, Climate Change

TROPICAL CYCLONE DYNAMICS AND THE ROLE OF HEAT FLUXESIN THE BAY OF BENGAL

Samar Kumar Ghose, Subham Maharana,Uday Narayan Rana.

P.G. Department of Atmospheric Science, Fakir Mohan University, Balasore- 756020

E-Mail: ghosesamar@gmail.com

ABSTRACT

The transport of heat energy from the ocean to atmosphere is a continuous and steady process. It iscompelling to divide the kinetic energy of the flow into two components: one related to the mean wind, known as mean kinetic energy (MKE), and the other associated with turbulence, known as turbulent kinetic energy (TKE). At the early stages of tropical cyclone (TC) development, heat andmoisture flux from the ocean surface rises as the cyclone intensifies. However, as the TC continuesto strengthen, it triggers intense turbulent mixing in the ocean beneath it. The mixing eventually cools the upper ocean layer, reducing its temperature. As a result, the heat and moisture flux from the ocean to the atmosphere begins to decrease, limiting further energy transfer. The primary objective of the study is to investigate the role of turbulent heat flux in relation to MKE and TKE in the formation and intensification of TC. This study examines the role of air-sea heat fluxes in theBay of Bengal (BoB), over a 20-year period by using objectively analyzed flux (OAflux) data. Further sea surface temperature wind speed and air temperature were investigated for better understanding of these flux terms. Initial findings indicates that during the development of a TC, heat and moisture flux from the oceanincreases with TC intensity. However, as the TC strengthens further, turbulent mixing cools the upper ocean, reducing heat and moisture flux. Analysis shows that the negative TC-ocean feedback begins when maximum surface wind speeds exceed 30 m/s and minimum sea level pressure drops below 950 hPa. It is also found that, latent heat flux shows a strong correlation with tropical cyclone intensity during its growing stage but a negligible correlation during the decaying stage, highlighting the role of sensible heat flux in TC development.

Keywords: Tropical Cyclone, Latent Heat Flux, Sensible Heat Flux, Turbulence Kinetic Energy, Turbulent Mixing

Summer melt trends across West Antarctic ice shelves linked toInterdecadal Pacific oscillation

Pranab Deb, Arnab Sen

E-Mail:pranab@coral.iitkgp.ac.in

ABSTRACT

Since the late 1990s, there has been a significant increase in summer surface melt across multipleice shelves in the Ross-Amundsen Sea sector of West Antarctica, as demonstrated by satellite measurements and simulations using MetUM. These trends can be attributed to rising geopotential height along the coastal West Antarctica, which have led to intensified northerly winds over the Ross-Amundsen Sea sector, resulting in excessive surface melting. In contrast, a substantial decline in summer surface melt was witnessed during 1979-1998 across these ice shelves, primarily driven by a positive trend in the Southern Annular Mode. Our analysis reveals a close association between melt indices and sea surface temperature in the South Pacific Convergence Zone (SPCZ). The shift in melting trend during the late 1990s is linked to an enhanced Rossby wave teleconnection from SPCZ directed towards West Antarctica, which is driven by increasedprecipitation within the SPCZ. This is consistent with the transition of the Interdecadal Pacific Oscillation to its negative phase during the same period.

Keywords: Antarctica; Surface melting; IPO; MetUM; ice shelf

CMIP6-based projections of sea surface height (SSH) forthe west coast of India

Dhanya Joseph and M.G. Manoj

Advanced Centre for Atmospheric Radar Research, Cochin University of Science andTechnology, Kochi, Kerala 682022
E-Mail:dhanyajosephs@gmail.com

ABSTRACT

Regional sea-level rise is a significant concern for current period and the future, specifically for coastal regions. Recent reports by the Intergovernmental Panel on Climate Change (IPCC) highlight that the Indian coastal region is vulnerable to the rising sea level. This study withrecent data from the coupled model intercomparison project phase 6 (CMIP6), analyses the sea surface height (SSH) projections along the west coast of India (WCI). The futuristic sea level trends are evaluated in four shared socioeconomic pathways (SSPs), viz., SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. The data from three different climate models were analyzed for the near future (2015-2039) and the mid-future (2040-2069) periods to portray a comprehensive view of future SSH trends. The historical simulation for the baseline period of 1985 to 2014 indicated an increasing trend of about 0.64 mm/year, much lower than the observations. All SSPs of the near future shows positive trend for SSH, with observation of marked increase in the last decade. Thisupward trend is observed to continue in the coming decades also. Mid-future projections indicatea significant (at 90% confidence level) increase in the rate of SSH, ranging from 0.25 mm/year under the SSP1-2.6 to 1.31 mm/year under the SSP5-8.5. It is observed that the increase in SSH is not uniform, and current observations points out the possibility that the west coast of Indiamay experience significant impacts, including flooding, coastal erosion and the submergence of low-lying areas. As the trends continue to show variability and acceleration across different SSP scenarios, it is crucial to implement policies that account for these projections to safeguard coastal communities and ecosystems from future risks.

Keywords: Climate Change; Sea Level Rise; CMIP6, West coast of India.

Changing Extreme Precipitation Patterns over India and the Attribution of External Influences

[a]Chaithra S T , [a]Krishna AchutaRao and [b]Dileepkumar R

[a] *Centre for Atmospheric Sciences, Indian Institute of Technology Delhi*

[b] *Department of Mathematics, KSMDB College Sasthamcotta, Kerala, India*
E-Mail: chaithra@cas.iitd.ac.in

ABSTRACT

The IPCC Sixth Assessment Report found a worldwide increase in weather and climate extremes and the effects of anthropogenic climate change on it. Though the changes in temperatureextremes are well-documented, rainfall extremes are significantly heterogeneous worldwide. Recent studies over India report increasing trends in frequency and intensity precipitation extremes. However, despite the severity of such events, attributing observed changes to specific drivers of change remains underexplored in India. This understanding is critical, as it is essential for making informed decisions on mitigation and adaptation strategies. Given India's dense population and its exposure to frequent extreme events that often result in substantial economic losses, the urgency for climate change attribution studies in the region is necessary. This study analyzes the spatio-temporal variability of extreme precipitation indices, developedby the Expert Team on Climate Change Detection and Indices (ETCCDI), over India, followed by Detection and Attribution (D&A) analysis. The analysis is carried out over the seven homogeneous regions of India with emphasis on the Indian Summer monsoon season. We use daily gridded precipitation data from the India Meteorological Department (IMD) and individual historical forcing runs from the Detection and Attribution Model Intercomparison Project (DAMIP), including natural-only (hist-nat), well-mixed greenhouse gas-only (hist-GHG), and anthropogenic aerosol-only (hist-aer) simulations. D&A is conducted using the regularized optimal fingerprinting method, considering three pattern combinations of individual forcings to quantify their respective contributions to changes in extreme precipitation. The long-term trends in extreme precipitation indices from IMD's daily gridded rainfall data indicate distinct significant positive trends in intense rainfall over the west coast and northwest regions and a decrease over northeast regions. At the same time, there has been a decrease in consecutive dry days (CDD) over the northwest. The multimodel ensemble mean of CMIP6 individual forcing simulations from 12 models indicate that GHGs drive an overall increase in extreme precipitation with the aerosol effects counteracting across India. Results from attribution analysisfor individual homogeneous regions and the country as a whole will be discussed.

Keywords: Extreme precipitation; Climate change; Detection and Attribution

Drought Risk Analysis of Southern Bihar: An integrated Approach

Anuranjan Harsh[a], Anjani Kumari[b] , C. N Prabhu[a], Vikram Kumar[a]
[a] *Bihar Mausam Sewa Kendra, Patna, 800025, India*
[b] *Government Engineering College Arwal, 804407 BiharE-Mail:anuranjanharsh@gmail.com*

ABSTRACT

An integrated drought vulnerability and risk study was carried out, for southern Bihar using multiple indicesand datasets comprising Standardized Precipitation Index (SPI : 1921-2020), Palmer Drought SeverityIndex (PDSI: 1951-2020), gross crop area, crop intensity, groundwater (GW) extraction, and population. The SPI, a widely used index of the deviation in precipitation over a specific period (6,9 and 12 monthsetc.), provides insights into short-term and long-term drought conditions. On the other hand, PDSI offers amore refined understanding of drought by considering both precipitation and temperature. Thus, PDSIserves as a measure of soil moisture conditions. Integrating SPI and PDSI with other critical parameters,such as gross crop area and crop intensity, GW extraction and population data enabled a multifacetedanalysis of drought vulnerability and risk. Gross crop area and crop intensity data were crucial forunderstanding the impact of drought on agriculture. The amount and rate of GW extraction data providedinsights into dependency on GW, especially during Drought conditions in the region. Analytical HierarchyProcess (AHP) is employed to assign weightage for each drought-inducing parameter. The results show that Patna, Gaya, Nalanda and Rohtas districts are at high risk of drought, which has significant implications for agricultural productivity, water resources and sustainable socio-economic conditions. The combination of high population density, intensive agriculture, and over-reliance on GW makes these districts much more vulnerable to the spiraling effects of drought. The ”Jal Jeevan Hariyali Mission”, a flagship program of the government of Bihar, taken up since 2019 torejuvenate water bodies, maintain GW level, and ensure climate resilient agriculture has been effective in improving the GW level through rainwater harvesting and efficient use of water in rivers and streams. Themission will serve as a Drought mitigation measure in Southern Bihar in the coming years.

Keywords: Bihar, Drought, AHP, SPI, PDSI

Adaptation strategies to southwest monsoon rainfall in the eastern coast of India based on 72 years of data

Pradip Sarkar, R.K. Mall, Manisha Chaturvedi
DST-Mahamana Centre of Excellence in Climate Change Research,
IESD,Banaras Hindu University, Varanasi, India.
E-Mail: Pradipsarkarcob52@gmail.com; rkmall@bhu.ac.in

ABSTRACT

The study of Extreme events is crucial for implementing adaptation strategies, especially in coastalareas to climate change. The eastern coast of India (ECI) is very much affected to southwest monsoon rainfall (SMR) which makes ECI more vulnerable. This study aims to suggest the adaptation strategies for SMR in ECI. This study used three climate Indices: consecutive dry day (cdd), consecutive wet day (cwd), and Precipitation days index per time period (eca_pd) with the help of the India Meteorological Department (IMD) data from 1951-2023 (June to September). The results show that cdd is changing over times and cwd is increasing few areas such as the Indian Sundarbans etc. Precipitation days have fluctuated during the past 72 years. ECI faced flood due to rainfall pattern changes such as floods in the Indian Sundarbans, and the coastal part of Odisha.However, drought is occurring in different parts of ECI like the Odisha drought due to the deficientof southwest monsoon rainfall in the year 2021. Due to the lack of proper adaptation strategies floods and drought frequently increase the loss and damage that induced poverty through livelihood issues and the economic condition of the people becomes worse. The study suggests that early warning systems, climate change-related education, increase irrigation facilities, propermanagement, and embankment development in flood- and drought-affected areas. This study will help policymakers to implement the best adaptation strategies for sustainable development.

Keywords: Extreme events, adaptation, loss and damage, monsoon rainfall, policy

Impact of Climate Change On the Potato Productionin West Bengal: Developing an Adaptation Strategy

Progya Mukherjee[a*], Shiv Mangal Singh[a,b], R.K Mall [a]

[a] *DST – Mahamana Centre of Excellence in Climate Change Research, Institute of Environment& Sustainable development, Banaras Hindu University, Varanasi, India*

[b]*Department of Geophysics, Institute of Science, Banaras Hindu University, Varanasi, India*

[*] *email- mukherjeeprogya@gmail.com, rkmall@bhu.ac.in*

ABSTRACT

Climate change consequences have severe impact on vulnerable sectors like agriculture. Therefore,adversely affecting the yield of the staple crops of the country. Indian agriculture forms the pivot of the country's economy. Therefore, the assessment of the impact of climate change on the production of staples in the country is essential. Multi-model climate projects have been popularlyused in the quantification of the climate change consequences on the crop yield. In the present study, we have used the SUBSTOR- Potato model embedded in DSSATv4.8 for the impact assessment of climate change on potato production in West Bengal under climate change scenario SSP2-4.5(intermediate emission) and SSP5-8.5(very high emission) for mid-future (2040-2069) and far-future (2070-2099) time periods. We have analysed the impact of rising temperature conditions from the baseline time period on the yield as well as the phenology of the crop. Further,we have observed the impact CO_2 fertilisation under varying CO_2 concentrations under different climate change scenarios. Reduction in the yield up to 26.6 and 28% under SSP2-4.5 and SSP5- 8.5, respectively, in the 2050s is projected under baseline CO_2 conditions. However, an increase is predicted under transient CO_2 concentration. Therefore, to deal with the reduction in yield shifting of sowing date has proven to be an effective adaptation strategy.

Keywords: Climate Change, Agriculture, Potato, SUBSTOR-Potato, CO_2, CO2 fertilization, CMIP6, Adaptation

Potato Yields in India Under Warming Scenarios – A Simulation study

Shiv Mangal Singh[1,2], R K Mall[1*], R S Singh[2], R K Dubey[3]
[1]DST-Mahamana Centre of Excellence in Climate Change Research, Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi-221005, India
[2]Department of Geophysics, Banaras Hindu University, Varanasi-221005, India
[3]Indian Institute of Vegetable Research, Varanasi-221305, India
Email: smsinghchf@gmail.com, rkmall@bhu.ac.in

ABSTRACT

The latest IPCC report underscores a rise in extreme climatic events over the coming decades, posing a serious risk to agriculture in India. As potato is a key crop in the country, evaluating the impact of climate change on their yields is vital. This study examines how climate change might affect potato production by analyzing outputs from various Regional Climate Models (RCMs) under different scenarios for two future periods: 2040-2069 (mid-future) and 2070-2099 (far- future). The analysis focuses on five major potato-growing states in India, using the SUBSTOR- Potato model and downscaled future climate data to project potential impacts. The findings indicate a general increase in both maximum and minimum temperatures, while the diurnal temperature range (DTR) is expected to decline under all warming scenarios. With baseline CO_2 concentrations, potato yields are anticipated to decrease by 3.6% to 17.5% in the mid-future and by 0.1% to 15.2% in the far-future under optimistic scenarios. In pessimistic scenarios, yield reductions could range from 2.4% to 20.5% in the mid-future and 0.3% to 20.5% in the far-future. Conversely, when considering elevated CO_2 levels, potato yields are projected to increase by 28.7% to 36.5% under optimistic scenarios and by 34.4% to 35.9% under pessimistic scenarios for both future periods. Overall, future climate conditions combined with higher CO_2 levels are expected to positively impact potato yields across all states, with Madhya Pradesh seeing the greatest increase (+36.5%). Without considering CO_2, most states are likely to face negative impacts, except for Madhya Pradesh. Despite some uncertainties related to the choice of crop models and RCMs, these findings offer valuable insights for policymakers, crucial for developing effective strategies to sustain and enhance potato production in India.

Keywords: Potato, DSSAT, SUBSTOR-Potato Model, Climate Change, Multi-Model Projection, Impact Assessment, CO_2 Concentration.

Decadal Analysis of Vegetation Dynamics and ClimateVariable Interactions in the Indo-Gangetic Plain

Rupam Singh, R.K Mall

DST – Mahamana Centre of Excellence in Climate Change Research, Institute of Environment &Sustainable Development, Banaras Hindu University, Varanasi, India
E-Mail: rupamsingh1895@gmail.com, rkmall@bhu.ac.in

ABSTRACT

Climate change is characterized by shifting temperature and precipitation patterns, significantly impacting vegetation stability. These alterations influence plant growth, development, and distribution, often in conjunction with changes in soil moisture conditions. This study investigatesthe dynamics of vegetation health in the Indo-Gangetic Plain, India, using Normalized DifferenceVegetation Index (NDVI) data derived from MODIS/TERRA satellite imagery over the decade 2013-2023. The analysis explores the intricate relationships between NDVI and three critical climatic variables: Land Surface Temperature (LST), Soil Moisture (SM), and precipitation. The region encompasses a wide range of land cover types, including agricultural lands, forests, and rapidly urbanizing areas. This diversity provides a rich context for studying the climate variabilityon vegetation dynamics and its accompanying factors. Results indicate pronounced seasonal NDVIpatterns, with winter exhibiting the highest values followed by monsoon, post-monsoon, and pre-monsoon. Correlation analysis reveals a stronger association between NDVI and LST compared to SM or precipitation. These findings offer crucial insights into the climate-vegetation interactionswithin this ecologically vital region. By elucidating the primary drivers of vegetation health and their relative impacts, this research contributes valuable knowledge for informed environmental management, agricultural planning, and climate change adaptation strategies in the Indo-GangeticPlain.

Keywords: Normalized Difference Vegetation Index, Precipitation, Land Surface Temperature, Soil Moisture

INVESTIGATING THE INFLUENCE OF ATMOSPHERIC RIVERS ON PRECIPITATION PATTERNS IN INDIA: SEASONAL AND INTRASEASONAL PERSPECTIVE

Pritam, Anurag[a] ; Nilanjan Debasharma[b] ; and Shubhi Agrawal[a]

[a] *Earth and Environmental Sciences,*
Indian Institute of Science Education and Research,Bhopal
[b] *School of Environmental sciences, University of Waikato*
E-Mail: pritam19@iiserb.ac.in

ABSTRACT

Atmospheric rivers (ARs) are narrow, elongated synoptic jets of water vapor that play crucial roles in the global water cycle. These phenomena, often associated with intense rainfall and significant weather events, can profoundly impact regional weather patterns, hydrology, and water resources. The Indian subcontinent, due to its complex topography and monsoon-driven climate, is particularly vulnerable to the influence of ARs. Using an AR detection algorithm developed by Guan et al. (2015), an AR dataset has been created to identify ARs over India. This study investigates the seasonal variation of AR events and their impact on precipitation patterns over India and its sub-regions, aiming to characterize AR encounters with the Indian landmass and understand their dynamics. Through extensive synoptic analysis and frequency assessments spanning 1979-2018, the study reveals significant differences in rainfall distribution and intensity between AR and non-AR days across various regions and seasons. Particularly, AR days exhibit notably higher rainfall intensity, with seasonal variations observed across different parts of India. The study also expands towards understanding the influence and charectristics of ARs during active and break phase of Indian summer monsoon (ISM). The analysis was carried out from 1979-2007. It reveals the spatio-temporal patterns of ARs across the Indian subcontinent during these phases and explores their relationship with rainfall patterns. Additionally, the research examines the contribution of ARs to extreme precipitation events in India. The findings emphasize the significant role of AR events in triggering precipitation and provide valuable insights into the atmospheric conditions associated with AR occurrences. This study contributes to a deeper understanding of the synoptic dynamics during AR events and their impact on precipitation, offering important information for predicting AR events and their effects on regional rainfall patterns.

Keywords: Atmospheric River, Rainfall, Indian Summer Monsoon, Active and Break Phase, Extreme Precipitation Event

Machine Learning-Based Detection of Convective Initiation Using INSAT-3DR

Ayushi Singh[a], Abhishek Chhari[b] and Pradeep Kumar Thapliyal[b]
[a] *B.Tech CSE, Indian Institute of Information Technology Kalyani*
[b] *Space Application Centre, Ahmedabad ISRO*
E-Mail: ayushi0628@gmail.com

ABSTRACT

Convective clouds are critical indicators of severe weather events such as thunderstorms, heavy rainfall, and even tornadoes, making their early detection essential for effective weather forecasting and disaster preparedness. These clouds form under conditions of atmospheric instability, and their identification can significantly improve the accuracy of weather predictions. In this study, we developed a machine learning model to identify convective initiation clouds over the Indian region using INSAT-3DR satellite imagery. Our approach integrates atmospheric instability and cloud-related information derived from satellite data to enhance detection capabilities. The detection process begins by assessing atmospheric instability, which is a crucial factor in the formation of convective clouds. We calculate instability indices such as the K-Index (KI), Lifted Index (LI), and Showalter Index (SHW) using GFS 0.25° data. These indices help isolate areas witha high potential for convection. Next, clouds that are eligible for convective initiation are detected using MSG-IODC 2 data. To refine this, we analyze the growth potential of these clouds by evaluating the rate of change in Brightness Temperature (BT) across various bands of INSAT-3DR and the derived Brightness Temperature Differences (BTDs). This ensures that only clouds exhibiting significant instability and development are flagged. The selected pixels are classified into convective initiation probabilities (low, moderate, or high). The labeled data is then used to train machine learning models, including Random Forest and Gradient Boosting, which demonstrated strong performance in accurately identifying convective clouds. The model's ability to detect convective initiation with high accuracy underscores its potential for enhancing short-term weather forecasting. The use of satellite data provides wide spatial coverage and frequent updates, offering an effective tool for monitoring dynamic weather systems and improving forecasting in the region.

Keyword : Convective Cloud, INSAT-3DR, Atmospheric Instability and Machine Learning

Intraseasonal variability in rainfall over the Indian region in Multi-Physics Multi-Model Ensemble

Nirupam Karmakar [1], Manpreet Kaur [2], Susmitha Joseph [3], Atul Kumar Sahai [3], R Phani [3], Raju
Mandal [3], Avijit Dey [3]
[1] *Indian Institute of Technology, Bhubaneswar, India*
[2] *Institute for Atmospheric and Environmental Sciences, Johann Wolfgang Goethe University, Frankfurt am Main, Germany*
[3] *Indian Institute of Tropical Meteorology, Pune, Maharashtra, India*
Presenting Author's Name: Karmakar, N.
E Mail: nirupam.ju@gmail.com; nirupam @iitbbs.ac.in

ABSTRACT

An assessment of a multi-physics multi-model ensemble (MPMME) strategy is provided to simulate the critical aspects of the Indian summer monsoon (ISM) and its intraseasonal variability. Using various physics combinations of Climate Forecast System (CFS) and its atmospheric component Global Forecast System (GFS), a 15-year hindcast for May—October is generated. Three different convective parameterizations, Simplified-Arakawa Shubert (*sas*), revised deep-convection SAS (*nsas*), and revised SAS with modified shallow-convection (*nsas_sc*) are coupled with two microphysics schemes Zhao and Carr (*zc*) and Ferrier (*fer*). Spatiotemporal characteristics of predicted ISM climatology and 20—70-day periodic intraseasonal oscillations (ISO) are evaluated using observations. MPMME members reproduce the overall characteristics of the seasonal mean, but they have significant biases over different regions. Pattern correlations reveal that *CFS_nsaszc* performs best among MPMME in simulating the observed characteristics of rainfall ISO and providing significant ISO forecast up to pentad-3 lead. A diagnostic based on the vorticity budget equation during strong convective events (SCE) associated with ISO is used to understand better the mechanism of northward propagating ISO and the responsible factors that develop a vorticity tendency to the north of a convectionmaxima. The tilting term in the vorticity equation shows northward propagation and leadsprecipitation maxima by about a week over the Bay of Bengal. Vertical shear of mean zonal winds and meridional gradients of vertical winds are found to be essential in developing vorticitytendency. SCE are better represented in CFS compared to GFS. Notably, along with *CFS_nsaszc*, two *CFS_sas* members capture the occurrence of SCE reasonably well. However, errors in vertical shear of mean zonal winds are remarkably high after pentad-2 lead in *CFS_sas* and GFS, explaining their relative weakness in simulating ISO during June—September. This study demonstrates that the MPMME strategy could utilize individual physical schemes' strengths to provide better sub-seasonal forecasts.

Keywords: Indian Summer Monsoon; Intraseasonal Oscillation; Northward Propagation;Vorticity Budget; Climate Model; Physical parameterizations.

Advancing Weather Forecast Accuracy: A Hyperlocal Ensemble AI/ML Approach to Predicting Extreme Weather Events

Biswajit Sahoo[a], Sridhar Balasubramanian[b]
[ab]*Indian Institute of Technology, Bombay*
E-Mail: biswajit.msahoo@gmail.com

ABSTRACT

Accurate and reliable weather forecasting is critical across various sectors such as agriculture, healthcare, energy, disaster management, and insurance. Predicting weather events with precision allows decision-makers to take timely measures & minimizing the losses associated with extreme weather phenomena. However, current numerical weather forecasting models (NWFs) need huge computing power and often take hours of time to run. Also due to the inadequate spatial and temporal resolution, NWFs may not be able to capture the hyperlocal variations. Recognizing the significant impact that localized weather dynamics can have, our work is driven by the need for granular-level forecasts. In this study, we introduce hyperlocal weather models that integrates meteorological dynamics with advanced data analytics and machine learning (ML) techniques, which aims to enhance the accuracy and reliability of weather forecasts, especially during extreme weather events. Utilizing ensemble approach (Transformer & XgBoost) in AI/ML weather models, which trained on historical data, we achieved higher accuracy in nowcast as well as short range weather forecasts than the traditionalNWFs in hyperlocal scale(0.1 degree resolution).

Keywords: Extreme weather events; AI/ML; NWFs; Weather Prediction; Hyperlocal

Differential effects of Extreme Climatic Modes on the Biogeochemical Parameters in the Arabian Sea

Madhurima Paul, Rashmi R Nayak, and Arun Chakraborty*Centre for Ocean, River, Atmosphere and Land Sciences, Indian Institute of Technology Kharagpur, India*
E-Mail: write2madhurima@gmail.com

ABSTRACT

The Arabian Sea (AS) is the most productive basin of the world's oceans. The collaborative effectsof the El-Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) events are believed to have a tremendous impact on the productivity patterns of the basin. This study thus utilizes 30-year datasets to ascertain the effects of these extreme climatic modes on AS productivity. Positivechlorophyll-a (Chl-a) variance identified four (western, eastern, northern, and central AS) regions, indicating dynamic and heterogeneous environmental conditions such as varying nutrient levels, light availability, and ocean mixing processes. The seasonal variations of physiochemical and productivity parameters over different regions highlight the distinct patterns and magnitude of seasonality, indicating the role of various physical forcing mechanisms. The area-averagedinterannual anomaly patterns of Chl-a show a decreasing trend in all regions throughout the studyperiod from 1993 to 2022. The nutrient anomaly patterns, which largely influence productivity, show varied and non-identical patterns with varying rates of change. The co-occurrence of ENSO and IOD enhances the anomaly patterns, whose effect varies by region within the basin. The study reveals that IOD (ENSO) has a greater impact on the eastern (western) AS region, whereas the extreme climatic modes had the least effect on the northern AS region. Nutrient supply essential for ocean productivity varies in different regions. All regions have a decreasing nutrient anomalytrend except for silicate in the eastern AS. Correlation patterns suggest silicate to have the least effect on productivity in the eastern region. The high correlation of iron with Chl-a suggests a noticeable impact on the eastern AS productivity. This work seeks to evaluate the link between thespatiotemporal variability of biogeochemical parameters and extreme climatic events, as well as their differential effect over the AS basin along the north-south and east-west transects.

Keywords: Extreme events; Chlorophyll-a; Productivity; Arabian Sea; Nutrients

Initial studies of Electric Field Effects on the Drop Size Distribution of thunderstorms over North-Eastern region of India

Lapynsuk Thabah[a], Abhay Srivastava[a], Shyam Sundar Kundu[a], Arup Borgohain[a]

[a]*Space and Atmospheric Science Division, North Eastern Space Applications CentreE-Mail: lapynsukthabah97@gmail.com*

ABSTRACT

Understanding the role of atmospheric electric effects in cloud microphysics and precipitation dynamics is crucial for enhancing weather prediction models. The importance of electrical processes in weather phenomena has been emphasized by recent research, especially in relation totheir effects on drop size distribution (DSD) of precipitation in various phases of the thunderstorms. Previous experiments and theories suggest that, the presence of atmospheric electric field can change how precipitation's drops grow and break apart (Mudiar et al., 2018), leading to a wider variety of hydrometeor sizes. However, the North Eastern Region (NER) of India lacks observation in this field and so this research aims to fill the gap in some extent. This study investigates the relation between atmospheric electric field and the DSD of thunderstorms by utilizing Laser Precipitation Monitor (LPM) and Electric Field Mill (EFM) data. It was observed that hydrometeors with larger diameter sizes are fewer in number and fall at a much faster rate while, hydrometeors with smaller diameter size are more numerous and fall at a much slower rate. The size and rate of drop of hydrometeors are positively correlated with the changes of the atmospheric electric field as a result of collision and coalescence processes. Thus, improvement can be made in weather and climate research given the complex topography of the NER by analyzing the presence of a thunderstorm's electric field and how it impacts DSD.

Keywords: Atmospheric electric effects; Drop size distribution; Thunderstorms; North EasternRegion, India.

PHYSICAL AND DYNAMICAL FACTORSAFFECTING THE BOUNDARY LAYER TRACER PATHWAY TO THE ASIAN SUMMER MONSOON ANTICYCLONE

P. P. Musaid[a], Sanjay Kumar Mehta[a],
Susann Tegtmeier[b], Masatomo Fujiwara[c]

[a] *Atmospheric Observations and Modelling Laboratory (AOML),*
Dept. of Physics and Nanotechnology, SRM Institute of Science and Technology,
Kattankulathur, 603203, India[b] *Institute of Space and Atmospheric Studies,*
University of Saskatchewan, Saskatoon, SK, Canada
[c]*Faculty of Environmental Earth Science, Hokkaido University,*
Sapporo 060-0810, Japan
E-Mail:musaidpp@gmail.com

ABSTRACT

The trace gas enhancement observed within the Asian Summer Monsoon Anticyclone (ASMA) is due to the uplift of lower tropospheric air parcels from the Southeast Asian region to the ASMA level. Studies have shown that the trajectories of these air parcels within the ASMA originate mostly from the Indian region or the Tibetan Plateau. The major factors contributing to the vertical pathway of tracers are the deepconvective systems of the Asian summer monsoon and the orography of Tibetan plateau. However, Asian summer monsoon exhibits strong intra seasonal variability. The lower-level spatial distribution of carbon monoxide (CO) over Southeast Asia shows a significant difference in concentration between the Indo- Gangetic Plain (IGP) of India and the Sichuan region of east China. The variability of the vertical pathwayof trace gases from the atmospheric boundary layer (ABL) to the ASMA is investigated using backward trajectory analysis initiated from the ASMA. The vertical distribution of CO shows a two-conduit-like structure over both 80°E and 100°E longitudes. Three cases, namely Case01, Case02, and Case03, were identified based on whether the vertical structure is at 80°E, 100°E, or neither during the July-August months of 2019. Considering the large abundance of CO over the Sichuan region, the Southeast Asian region is classified into Deep Convective Region, Higher Elevation Region, Higher CO Region, and the West Pacific South China Sea. We find that each region in Southeast Asia classified in this study has a dominant role in the vertical distribution of CO depending on the background meteorology. The mean background meteorological analysis revealed that Case01 exhibits normal monsoon characteristics, Case02shows break monsoon features, and Case03 displays active monsoon features. The mean cumulative of trajectory intersections at the ABL revealed that the source region is found over eastern India and the Tibetan Plateau during the normal monsoon case, over the Sichuan region during the break monsoon case,and over the IGP region during the active monsoon case

Keywords: ASMA; Trace gases; Break monsoon

Development of Data-driven Method for Improving Sub-seasonal Forecast of IndianSummer Monsoon Rainfall

Venkata Anirudh, S., Karmakar, N.,

School of Earth, Ocean and Climate Sciences,Indian Institute of Technology Bhubaneswar

E-Mail: 23cl06006@iitbbs.ac.in

ABSTRACT

The Indian Summer Monsoon Rainfall (ISMR) significantly impacts the agriculture and economyof the nation. It is of utmost priority to skillfully predict the rainfall well in-advance. However, theskill of forecasting by the dynamic models drops significantly beyond the extended rangeforecasting period. This can be attributed to the transition of the dynamic system from initial valueproblem to the boundary value problem. This gray area of the forecast period is known as the period of sub-seasonal forecast. The monsoon is known to possess intraseasonal variability in the form of active and break phaseswith periodicity of about 20-70 days. Many recent studies have shown that the data-driven modelsshow an impressive skill of predicting these Intraseasonal Oscillations (ISO) up to three weeks, due to the ISOs underlying pattern of predictability.

This study aims to develop a data-driven method that can be devised to enhance the skill of the dynamic model's forecast in the sub-seasonal range by assigning the weights to ensemble membersof the dynamic model according to the inverse of the distance of their projections onto ISO subspace from the data-driven ISO forecast, in real-time context.

The Singular Spectrum Analysis (SSA) is designed to project the rainfall data into ISO subspace. However, in real-time, the extraction of the ISO using SSA faces a challenge because of its need of a longer dataset, which may not be available during the beginning of the monsoon season. To overcome this challenge, another preliminary data-driven method has to be employed to approximate the ISO from the corresponding rainfall data. So, the ISO data extracted from SSA isused to train the data-driven models to approximate, as well as, forecast the ISO.

Keywords: Monsoons; Sub-seasonal forecast; Data-Driven Predictions; Intraseasonal Oscillations;Singular Spectrum Analysis

Analog-Ensemble-based Fog Early Warning System in Bihar, India

A. K Mishra[a], C. N Prabhu[a], Will Cheng[b], Stefano Alessandrini[b], R. Kumar[b]
[a] *Bihar Mausam Sewa Kendra, Patna, 800025, India*
[b] *National Center for Atmospheric Research, Boulder, 80307, USAE-Mail:Abhishekkumar.mishra21@gmail.com*

ABSTRACT

Bihar, characterized by its distinct geomorphic and climatic features, has been a region highly vulnerable to various hydro-meteorological hazards viz. floods, droughts, thunderstorms, heat waves, cold waves, fogwith varied intensity. The analysis of historical weather data shows that Bihar is subjected to one or more Hydro-met hazards every month during a calendar year. The Fog cover during the winter has been a majorhazard causing numerous losses of lives, livelihood, and economy in the state.

As a mitigation measure, Bihar has taken a big leap towards monitoring, forecasting, and generating earlywarnings about extreme weather conditions. A multi-hazard early warning system supported with dense weather monitoring stations network up to Block / Panchayat level, Multi-Model Ensemble (MME) weather forecasting system and ICT-enabled Information dissemination platform.

As a part of the Multi-hazard Early Warning System, an Analog Ensemble (An-En) based Fog ForecastingSystem has been developed and operationalised. The system leverages WRF model output and high- resolution weather data collected through a dense network of over 534 Automatic Weather Stations (AWS).The Dew point depression is the primary predictand, complemented by other variables viz Temperature, Relative humidity, and Wind Speed .

The An-En WRF coupled system achieved an R^2 value above 0.7, a Probability of Detection (POD) between80% and 95%, a PREC value close to 0.7, and more than 75% improvement in efficiency compared to thedefault WRF output. The model trained over one winter season and tested for two more seasons shows significant improvements in forecast accuracy during the 2023-24 winter.

The An-En-based Fog Early Warning system provides forecasts of fog density and spread at Block level (~100 sq km) for the next 5 days (120 hrs). The system would enable the administration to take necessary measures to mitigate the adverse impact of Fog and related low-visibility conditions. It is expected to minimise the fog-induced losses not only in Bihar but the entire Indo-Gangetic belt, where Fog is a major hazard during the winter.

Keywords: Bihar, Early Warning System, Analog Ensemble; Fog Forecasting, WRF

MODULATION OF CYCLONE INTENSITY AND TRACK IN RESPONSETO MJO: A CASE STUDY ON CYCLONE MOCHA AND BIPARJOY

A.K. Jena[a], M. R. Behera[a], S. Mohanty[b] and V.K. Srineash[a]
[a]Indian Institute of Technology Bombay
[b]Indian Institute of Remote Sensing, Dehradun
E-Mail: amitkumarjena@iitb.ac.in

ABSTRACT

The Madden-Julian Oscillation (MJO) exerts a profound influence on the formation, intensification, and steering of tropical cyclones. This study focuses on the impact of the MJO ontwo prominent cyclones, Mocha in the Bay of Bengal and Biparjoy in the Arabian Sea. Cyclone Mocha underwent marked intensification during the favorable MJO phase 5, which significantly enhanced convective activity, moisture influx, and upper-level divergence. Similarly, cyclone Biparjoy exhibited rapid intensification under the auspices of an active MJO phase 2 and 3, whichcreated a highly conducive environment for cyclogenesis. The MJO further modulates wind shear, atmospheric circulation, and steering currents, thereby dictating the cyclonic tracks and overall motion. Furthermore, the interaction between the MJO and Rossby waves amplified cyclonic vorticity and convection, further accelerating the intensification processes of both cyclones by establishing favorable atmospheric conditions. This analysis elucidates the complex atmospheric interactions that govern tropical cyclone behavior, offering critical insights for advancing the predictive capabilities of cyclone paths and intensities under intra-seasonal variability.

Keywords: Madden-Julian Oscillation, Steering flow; Cyclone Biparjoy; Cyclone Mocha; Intensification

INVESTIGATING LAND-ATMOSPHERE COUPLING DYNAMICS AT DAILY TIME SCALE OVER CENTRAL INDIA

Suparya S. Raj[a], and Shubhi, Agrawal[a]

[a] *Department of Earth and Environmental Sciences*
Indian Institute of Science Education and Research Bhopal,
Madhya PradeshE-Mail: suparya22@iiserb.ac.in

ABSTRACT

Land–atmosphere (L–A) interactions play a vital role in modulating convective processes, climate feedback mechanisms, and the development of weather extremes such as droughts and heatwaves. These interactions are especially important in monsoon-dominated regions like Central India, where regional climate variability is driven by the interplay of atmospheric processes with land surface variables like vegetation, soil moisture, and surface heat fluxes. The complex feedbacks between soil moisture, surface fluxes, and the atmospheric boundary layer (ABL) are captured by local Land–Atmosphere Coupling (LoCo), yet there remains a gap in understanding how these processes unfold on daily scales, especially across different land cover types. This study aims to address this gap by investigating the daily variability of key atmospheric and land surface parameters—such as temperature, humidity, wind speed, soil moisture, and surface fluxes—in two contrasting regions of Central India. Region 1 (western Central India) is primarily cropland, while Region 2 (eastern Central India) is characterized by dense vegetation. By analyzing high-resolution ERA5 and ERA5-Land reanalysis data during the monsoon season, this research seeks to elucidate how surface characteristics impact daily atmospheric processes across these regions. Preliminary results reveal that Region 1 is predominantly influenced by land surface processes, with higher sensible heat flux and stronger surface heating, leading to significant boundary layer growth. While Region 2 shows stronger correlation between wind speed and boundary layer height especially in september. Furthermore, the study reveals that convective precipitation is closely tied to specific humidity and wind speed, with correlations that evolve over time and vary between regions. These findings underscore the significant influence of land surface heterogeneity on daily atmospheric variability, providing insights for improving regional climate models and enhancing monsoon forecasting capabilities.

Key Words: local Land–Atmosphere Coupling, Convective Processes, Boundary Layer Height, Daily Variability

URBAN HEAT ISLAND: A CLIMATOLOGICAL PERSPECTIVE

Harinandana S[a,b] ,
Gayatri Kulkarni[b],and Thara Prabhakaran
[a] *Department of Atmospheric Sciences, CUSAT, Cochin, Kerala*[b] *Indian Institute of Tropical Meteorology, Pune, Maharashtra E-Mail:msharinandana2001@gmail.com*

ABSTRACT

This study investigates the long-term spatial and temporal trends in urban heat island (UHI) intensities across Delhi from 1979 to 2023. Rapid urbanization has significantly amplified UHI effects, particularly at night, due to the thermal inertia of urban surfaces. In cities like Delhi, UHIintensities have increased, driven by changes in land use and anthropogenic heat emissions. The study also emphasizes the importance of wet-bulb temperature (WBT) in assessing heat stress in urban environments, especially in semi-arid regions. Rising WBT anomalies in urban areas like Delhi highlight growing public health concerns due to the combined effects of rising temperaturesand humidity. The study's analysis includes trends in UHI anomalies, diurnal temperature variations, and long-term UHI patterns, offering valuable insights for guiding sustainable urban development in rapidly urbanizing cities like Delhi and Ayodhya. The findings reveal an increasing trend in UHI which call for the incorporation of UHI effects and wet-bulb temperatureinto city planning, with a focus on enhancing green infrastructure and reducing heat retention in urban areas. Future research should employ advanced modeling techniques and finer spatial and temporal resolution datasets to refine predictions of UHI trends, explore their interactions with airpollution and climate change, and assess their implications for urban heat stress and public health.

Keywords: Urban heat island; Wet bulb temperature; thermal heat stress; diurnal temperature variation; UHI anomaly trend

Climate change weakens South Asian monsoon circulation and its associationwith western north Pacific tropical convection.

Aswin Sagar [a,b]R Krishnan [a] Sabin T P [a]

[a] Indian Institute of Tropical Meteorology[b] Savitribai Phule Pune University *aswin.sagar@tropmet.res.in*

ABSTRACT

Climate change affects the Indian Summer monsoon rainfall (ISMR) and western north Pacific (WNP) convective activity. We used a variable resolution model to analyze two high-resolution climate model simulations, HIST and HISTNAT, with and without anthropogenic forcing. Detailed diagnostics and novel methods like causal network analysis show how anthropogenicallycaused climate change alters convective activity between the two locations. We found that decreasing ISMR re-orients cross-equatorial winds and large-scale moisture transport toward the western tropical Pacific, increasing the region's genesis potential index (GPI) by 9.6%. The HISTsimulation shows a 10.3% greater likelihood of very low sea-level pressure (SLP) < 995.5 hPa around Taiwan and portions of the Chinese mainland compared to HISTNAT. The Indian monsooncirculation index (IMI), WNP tropical cyclone activity (GPI), and tropical Indo-Pacific winds weresignificantly linked by causal effect network analysis. With a time delay, weakening the IMI can improve GPI and IPWND. Note that HIST has a lower time lag for interaction between IMI, GPI, and IPWND (~5 days) compared to HISTNAT (>20 days).

Keywords: Monsoons; Climate change; West North Pacific; Cyclonic Activities
(maximum 5 words)

Comprehensive Evaluation of Aeolus Wind Products against In-Situ Observations and Re-Analysis datasets over the Indian Monsoon Region

Bv Balasundhar [1,2] and Alladi Hemanth Kumar [1,2*]

[1] Department of Physics and Nanotechnology, Faculty of Engineering and Technology,
SRM Institute of Science and Technology (SRMIST), Kattankulathur,
Tamil Nadu-603203, India.

[2] Centre for Atmospheric Sciences and Climate Studies (TROPIC), Faculty of Engineering
and Technology, SRM Institute of Science andTechnology,
Kattankulathur, Tamil Nadu 603203.

E-mail: bb0223@srmist.edu.in, hemantha1@srmist.edu.in

ABSTRACT

To date, several instruments, both ground-based and balloon borne are available for wind measurements. However, these measurments are limited only to a particular location. At this juncture, the launch of Aeolus satellite by the European Space Agency (ESA) on 22nd August 2018, equipped with the First Doppler Wind Lidar instrument in space, ALADIN (Atmospheric Laser Doppler Instrument) made it possible to obtain the wind profiles globally throughout the troposphere and lower stratosphere. The Aeolus satellite provides the Horizontal Line of Sight (HLOS) wind in Rayleigh and Mie channels. In this study, a comprehensive comparision of the Aeolus L2B wind products in these two channels has been made with the GPS radiosonde observations launched at 00 UTC and 12 UTC over 34 India Meteorological Department (IMD) stations for period June 2019 to October 2022. We also compared the Aeolus wind products by segregating them into different regions like South India (SI), Central India (CI), Western India (WI), North East India (NEI), Indo-Gangetic Plain (IGP) and also into different seasons like pre-monsoon, monsoon, post monsoon and winter as per the IMD. Comparisons were also made over Indian region with ERA-5 re-analysis obtained from European Centre for Medium-Range Weather Forecast (ECMWF) and Indian Monsoon Data Assimilation and Analysis reanalysis (IMDAA) reanalysis datasets. Good correlation is noticed in the wind between Aeolus and in- situ measurements particularly in Rayleigh- Clear and Mie cloudy channels. This study provides the estimates of the biases in the wind measurements over the Indian Monsoon region which further can be directly assimilated in the WRF-models for better forecasts.

Keywords: Aeolus, ALADIN, Radiosonde.

RADAR DATA ASSIMILATION AND ITS IMPACT ON THE FORECASTOF AFTERNOON CONVECTIVE STORMS

Tunga S G[1], Govindan Kutty[1]

[a] *Department of Earth System Science, Indian Institute of Space Science and TechnologyE-Mail : tungaginiwar@gmail.com*

ABSTRACT

Afternoon convective storms, often associated with the pre-monsoon season, are characterized byintense rainfall, and having short spatial and temporal extent, making them challenging to predict.In this paper, Kerala having the highest average annual frequency in the southern India is considered to investigate the impacts of the radar data assimilation (DA). Previous studies have shown convective-scale radar data assimilation has contributed tremendous progress in improvingshort-term quantitative precipitation forecasting and radar data assimilation can effectively initialize the three-dimensional structure, intensity, and movement of precipitation fields to an NWP at a high resolution (±250 m). The weather research and forecasting (WRF) four- dimensional variation (4D-Var) DA system is used to assimilate radial velocity and reflectivity data. The analysis showed that higher-frequency of 30-min and 1-h assimilation intervals producedwater vapour convergence at low levels and a greater overprediction bias of precipitation. Radar data thinning has reduced analysis cost with the benefit of making uncorrelated observation errorassumption more valid as radar data is more dense. Hence the regular frequency of 30-min and 1-h assimilation after thinning of the radar data has improved the overprediction in precipitation anda better forecast is generated.

Keywords: Convective storms, Radial velocity and Reflectivity, 4D-Var assimilation, Radar datathinning

ROLE OF OCEAN IN MODULATION OF TROPICAL CYCLONES

Harikrishnan N[a], Anup Kumar Mandel[b],
Neeru Jaiswal[b] and Suchandra Aich Bhowmick[ba]
Department of Physical Oceanography, Cochin University of Science and Technology, Kerala
[b] *Space Applications Centre,ISRO, Ahmedabad-*

380058

E-Mail:harikrishnann2017@gmail.com

ABSTRACT

Tropical cyclones (TCs) are among the most devastating natural disasters, particularly affecting coastal regions. While the North Indian Ocean (NIO) accounts for only 7% of global TCs, the impact on Indian coasts is severe due to factors such as low bathymetry, funnel-shaped coastal boundaries, and high coastal population density. The Bay of Bengal (BoB) is especially vulnerable, experiencing four times more cyclones than the Arabian Sea (AS). Timely prediction of TC genesis, track, and intensity is crucial for issuing warnings and preparing for potential losses.

Numerical and statistical models are used to predict TC tracks and intensities with reasonable accuracy. This research investigates the influence of oceanic parameters on tropical cyclogenesis, aiming to predict cyclone development regions and distinguish between developing and non- developing cases with a lead time of 4 to 5 days. Key parameters such as sea level anomaly, the difference between sea surface temperature (SST) and 2-meter air temperature, wind speed, and ocean heat content are analyzed.

A combined index is calculated over the five days preceding the ten days leading to cyclone formation, providing a comprehensive view of the oceanic conditions contributing to cyclone genesis. Threshold values for parameters during the 10 days prior to cyclogenesis are establishedto identify regions with a high probability of cyclone development. Additionally, the fractal dimension of the combined index is computed, offering insights into the spatial and temporal complexities associated with cyclogenesis.

This study enhances understanding of the role of oceanic parameters in modulating tropical cyclone formation, potentially improving early warning systems and disaster preparedness efforts.By incorporating this combined index into a model, it may be possible to forecast cyclogenesis more accurately, aiding in mitigation efforts against these destructive storms. This knowledge can aid in the refinement of cyclone prediction models, enabling more accurate forecasts and reducedfalse alarms.

Keywords: Extreme weather events; Tropical Cyclones; Ocean impact; Cyclone Prediction; Disaster management

Land Use Land Cover Prediction For Bhubaneswar City

Chitikireddy Anand

INDIAN INSTITUTE OF TECHNOLOGY BHUBANESWAR

ABSTRACT

Urban expansion and land-use changes have significant environmental and socio- economic impacts on growing cities like Bhubaneswar, the capital of Odisha, India.This study presents an analysis of Land Use and Land Cover (LULC) changes and predicts future trends in the region using satellite imagery and advanced machine learning techniques. We utilized multi-temporal Landsat images spanning the years2000 to 2023 to assess historical patterns in land cover, including urban areas, vegetation, water bodies, and barren land. The methodology involves preprocessing satellite data, applying supervised classification techniques, and validating theaccuracy of classified images. We employed machine learning models such as Random Forest (RF), Cellular Automata (CA), Markov chains and Aritificial Neural Networks (ANN) for precise classification and prediction. Geographic Information System (GIS) tools were integrated to evaluate spatial patterns and visualize LULCtransitions. Our findings indicate rapid urban growth in Bhubaneswar, particularly over the past two decades, with a significant conversion of agricultural and vegetative land into built-up areas. Predictive models forecast that, urban expansionwill intensify, potentially leading to more ecological strain and reduced green cover. The study underscores the importance of informed urban planning and sustainable land management policies to mitigate the environmental challenges posed by unchecked urban sprawl. This research contributes to a deeper understanding of urban dynamics in Bhubaneswar and offers critical insights for policymakers, urban planners, and environmentalists to make data-driven decisions for future land management strategies.

Optimizing Predictors for Drought, Flood, and Normal Conditions in India: A Regional Correlation and Classification Approach

Ankita Singh[1], Dr. Kiranmayi Landu[1]

[1] *School of Earth, Ocean and Climate Science, Indian Institute of Technology, Bhubaneswar*
E-Mail: a21es09006@iitbbs.ac.in

ABSTRACT

Extreme weather events, particularly droughts and floods, significantly impact the socio-economic conditions of India. Accurate prediction of these events is crucial for mitigating their impacts, which requires a deep understanding of the key atmospheric drivers that influence precipitation variability. Previous studies have shown that large-scale atmospheric variables play a significant role in modulating rainfall extremes over India. However, there is a need for more comprehensive assessments of multiple atmospheric variables to identify the predictors that havethe greatest influence on rainfall during flood and drought months.

This study aims to determine the optimal predictors for extreme events such as drought, flood, and normal months by analyzing ERA5 reanalysis data at three different pressure levels (500 hPa, 850 hPa, and 1000 hPa) and correlating them with daily JJAS (June to September) IMD rainfall data for the 44-year period from 1971 to 2014 over India. The Standardized Precipitation Index (SPI) is used to classify months into flood, drought, and normal categories. Comprehensive statistical techniques, such as correlation analysis, are applied between the predictors—including geopotential height, relative humidity, specific humidity, air temperature, wind patterns (both zonal and meridional) at various pressure levels, and mean sea level pressure—for each classification. The study then divides India into distinct zones based on the spatial correlation patterns of these predictors during flood, drought, and normal months. Each zone is subsequently analyzed to determine the physical drivers or dominant factors of precipitation variability.

This research highlights the importance of large-scale atmospheric circulation in driving extremeevents and provides insights into region-specific predictors, enhancing the accuracy of early warning systems. Such findings could contribute to improved flood and drought preparedness, mitigating the adverse effects of these extreme events.

Keywords: Droughts; Standardized Precipitation Index (SPI); Optimal Predictors; Correlation Analysis; Classification.

ENHANCING THE PREDICTION OF MONSOON INTRASEASONAL OSCILLATIONS: A DEEP LEARNING APPROACH

Anirudh K M[a], Prasang Raj[b],
Sandeep Sukumaran[a,b] and
Hariprasad Kodamana[b,c][a] *Centre for Atmospheric Sciences, IIT Delhi*
[b] *Department of Chemical Engineering, IIT Delhi*[b] *Yardi School of Articial Intelligence, IIT Delhi E-Mail: asz238478@iitd.ac.in*

ABSTRACT

The northward propagating 30–60-day mode of monsoon rainfall anomaly over India, known as the Monsoon Intraseasonal Oscillation (MISO), is crucial for understanding active and break spells within the monsoon zone. Accurately predicting MISO is essential for improving monsoon forecasts. This study utilises high-resolution (0.25° x 0.25°) TRMM/GPM daily precipitation datato derive MISO indices (MISO1 and MISO2) through an extended EOF (EEOF) analysis of 25 years of June-September rainfall anomalies over India. The resulting time series of MISO1 and MISO2 indices were then employed to forecast future values using a deep learning model. We employed a sequence-to-sequence encoder-decoder model with teacher forcing, using Long Short- Term Memory (LSTM) units as the core recurrent components. This deep learning approach was applied to predict MISO indices for the years 2018-2022, extending forecasts up to 18 days ahead.The results reveal that the LSTM model demonstrates superior predictive skill compared to traditional numerical weather prediction models. This enhancement in forecasting capability underscores the potential of deep learning models to significantly improve subseasonal to seasonal(S2S) prediction of the monsoon. Our findings highlight the effectiveness of advanced deep learning techniques in advancing MISO prediction and provide a more reliable framework for understanding monsoon variability.

Keywords: : Monsoon Intra-seasonal oscillation (MISO); Deep learning; Long short-term memory(LSTM); Teacher forcing; S2S prediction

Spatial and temporal trends of mean and extreme rainfall for the75 districts of the state of Uttar Pradesh, India

Sushil Kumar [a], Amarendra Singh [b], Bhumika [a], Jagabandhu Panda [c]

[a]Department of Applied Mathematics, SoVSAS, Gautam Buddha University, Greater Noida, Uttar Pradesh, India.

[b]Centre for Atmospheric Sciences, Indian Institute of Technology, Delhi, India.

[c]Department of Earth and Atmospheric Sciences, National Institute of Technology Rourkela, Odisha, India.

Email: sushil.kumar@gbu.ac.in

ABSTRACT

An attempt has been made to analyse the pattern of rainfall and to examine the trends and variationsof extreme events of rainfall at the spatial and temporal scales for all the 75 districts of the state of Uttar Pradesh, India. Statistical trend analysis techniques, namely the Mann–Kendall test and Sen's slope estimator, were used on the two data sets of daily rainfall of 50 years (1973-2023) from IMD Pune and MSWEP to examine the trends of rainfall over the state of Uttar Pradesh.

Positive, negative and no trends were observed in mean and extreme events of rainfall in different districts of Uttar Pradesh state. The spatial variations of the trends in mean (monsoon season, non- monsoon season and annual) and extreme annual daily rainfall were also determined using the inverse-distance-weighted (IDW) interpolation technique. Mostly districts of Uttar Pradesh have either no trend or decreasing trend in annual average of rainfall. However, the districts namely Bijnor, Chitrakoot, Hamirpur, Hathras, Kaushambi, Muzaffarnagar, Sambhal, Shahjahanpur, Jaunpur and Mathura have increasing trend in average rainfall. The same trend is observed in monsoon season asin the annual average rainfall in all the districts except Agra, Bahraich, Hathras, Pilibhit, Sultanpur and Mathura. The observed rainfall events in different categories (Non rainy day, 0-2.4 mm; Category I, 2.5-64.4; Category II, 64.5 to 124.4; Category III, 124.5 mm or more) have a decreasingtrend in mostly districts in monsoon season over the entire period of study. The IDW technique is applied to identify the trends and variability in mean and extreme rainfall in space and time to map the data on the study locations of all the districts of Uttar Pradesh. The results are of vital importancein understanding the risks and vulnerabilities related to climate change for the extreme events in theregion.

Keywords: Extreme rainfall events, Interpolation, Monsoon, Mann-Kendall test and IDW

SPATIOTEMPORAL VARIATION OF POTENTIAL EVAPOTRANSPIRATION OVER NORTH-EAST INDIA

Anindita Borah1[a] , Binita Pathak2 [a, b]

[a] *Department of Physics, Dibrugarh University, Dibrugarh, Assam-786004, India*
[b]*Centre for Atmospheric Studies, Dibrugarh University, Assam-786004, India*
E-Mail:borahanindita97@gmail.com

ABSTRACT

Potential evapotranspiration (PET) is very frequently used to assess the drought intensity throughdrought indices in a large variety of geographical regions. It is the largest possible evaporation under the condition of a sufficient underground water supply. North-East India (NEI) region is richin water resources including mighty river Brahmaputra and Barak and their tributaries and is highlyvegetated with 50% vegetation cover. This region is a vulnerable zone to climate change as the people in this region are dependent on the natural resources – water bodies, forest ecosystem, oil-gas deposits, coal deposits for livelihood, development, and sustainability. As such, the present study analyses the climate change and its impact on the hydrological cycle through investigating the seasonal and annual variation of PET and Aridity Index AI (Precipitation P/PET) using Mann-Kendall test. The ERA5-Land reanalysis data exhibits an insignificant increasing trend of PET at a rate of 0.56 mm year^{-1} over NEI during 1971-2021. The analysis revealed that the highest PET occurs in pre-monsoon season (650 mm yr $^{-1}$- 1100 mm yr^{-1}) and lowest in post-monsoon (300 mmyr^{-1}- 450 mm yr^{-1}). Decreasing trend of precipitation (-6.38 mm yr^{-1}) pattern is found over NEI, itis anticipated that this trend will continue in the 21st century. PET correlated positively with temperature and negatively with precipitation. Thus, fluctuation of climatic variables in different regions and under different climatic conditions will result a significant change in PET. Increasingtrend of PET amplifies the impact of reduced precipitation on the drying trend. Our investigation major implications for sustainable water resource management under climate change.

Keywords: Potential evapotranspiration; Precipitation; Drought intensity; Mann-Kendall test; North-East India

ASSESSMENT OF BLUE CARBON STOCKS IN MANGROVES OF AMBARIVER ESTUARY, RAIGAD DISTRICT, MAHARASHTRA: A CASE STUDY FROM INDIA USING REMOTE SENSING AND GROUND DATA

Kajal Barman[a], Swapnil Vyas[b], Pramit Kumar Deb Burman[c]

[a] Department of Geography (Geoinfomatics), Savitribai Phule Pune University, Pune [b] Department of Geography (Geoinfomatics), Savitribai Phule Pune University, Pune [C]Centre for Climate Change Research, Indian Institute of Tropical Meteorology, Pune

E-Mail: kajalbarman.geoinfo@gmail.com

ABSTRACT

Mangroves play a crucial role in carbon sequestration, yet precise evaluations of their blue carbonpotential are key to supporting conservation and climate change mitigation. This study quantifiesblue carbon stocks in the mangrove ecosystem of the Amba River estuary, Raigad District, Maharashtra, using a combination of remote sensing data and ground-based measurements. The region, dominated by giant mangrove trees, particularly ***Avicennia marina,*** *and Sonneratiaapetala*, offers an ideal environment to analyze biomass and carbon storage. Ground-based data showed that the plant carbon stock was 361.33 t C ha^{-1}, while the biomass above and below ground totalled 816.61 t ha^{-1}. The diversity of soil depth and spatial position in the soil organic carbon (SOC) content, which was determined through laboratory analysis, reflectsthe intricacy of carbon sequestration in different ecosystems. With soil carbon at 556.86 (t C ha^{-1})and plant carbon at 361.33 (t C ha^{-1}), the total ecosystem blue carbon stock is projected to be

918.19 (t C ha $^{-1}$). Using high-resolution satellite imagery and GEDI data, we supplemented ground validation with detailed carbon stock estimations. Additionally, historical change detection from 1972 to 2024 highlighted the impacts of land degradation on mangroves. The results show significant spatial and temporal variation in carbon stocks, influenced by factors such as salinity, sea-level rise, andhuman activities. This study provides critical insights into carbon dynamics in ***Avicennia marina*** *and Sonneratia apetala* mangrove habitats, advocating for continued research and informed conservation strategies to enhance the role of mangroves in climate mitigation.

Keywords: Mangroves, Carbon Sequestration, Blue Carbon, Biomass, Vegetative Carbon Stock, Soil Organic Carbon (SOC), Remote Sensing

Machine Learning-Based Identification of Convective Clouds UsingINSAT-3DR Data and Ground Based Lightning Data

Amee Chhatbar[a], Abhishek Chhari[b], Bipasha Shukla[b], Alok Taori[c], Pradeep KumarThapliyal[b]

[a] Computer Science, Indus University, Ahmedabad

[b] Space Application Centre, Ahmedabad

[c]National Remote Sensing Centre, Hyderabad

E-Mail: chhatbaramee3@gmail.com

ABSTRACT

Convective clouds, which are closely linked to severe weather events such as thunderstorms, heavy rainfall, and lightning, play a critical role in the atmospheric system. Accurate identification and monitoring of these clouds are essential for improving weather prediction models and mitigating the impacts of extreme weather. In this study, we developed a machine learning model to identify convective clouds using data from the INSAT-3DR satellite, aiming toenhance real-time weather monitoring and forecasting capabilities. We trained the model using ground-based lightning detection sensor data, which provided labeled data. Since lightning is strongly correlated with the presence of convective clouds, it served as an effective indicator for training the model. The input features included all available bands from the INSAT-3DR satellite,along with two Brightness Temperature Differences (BTDs): (TIR1 - TIR2) and (WV - TIR1). We selected these BTDs based on their relevance in detecting cloud top temperatures and water vapor content, both of which are key indicators of convective activity.To ensure robust training and validation, we utilized five months of lightning data, from June 2022 to October 2022. We employed feature extraction techniques to identify the most correlated parameters, bands, and BTDs with lightning activity, refining the model's predictive accuracy. Additionally, we used symbolic regression to uncover interpretable relationships between the input features and lightning density, providing deeper insights into the physical processes linking convective clouds and lightning occurrence. Our machine learning model reliably identified convective clouds, offering a valuable tool for real-time weather forecasting and early warning systems. By integrating satellite data and lightning observations, the model shows significant potential for operational meteorology, particularly in regions prone to severe weather. The ability to accurately detect and track convective clouds in real time greatly enhances preparedness and response efforts, ultimately reducing the risks associated with extreme weather conditions.

Keywords : Convective Cloud, Lightning, INSAT-3DR, Machine learning

2022 INDIAN SUMMER MONSOON RAINFALL

Priyanka N. Maraskolhe[a,b], and Ramesh Kumar Yadav[a]
[a] *Indian Institute of Tropical Meteorology, Pune, India*
[b] *Savitribai Phule Pune University, Pune, India*
E-Mail: priyanka.maraskolhe@tropmet.res.in

ABSTRACT

The variability of Indian summer monsoon rainfall (ISMR) has a socioeconomic impact on India.Recently it has been observed that the relationship between ISMR and El Nino Southern Oscillation (ENSO) is getting weaker. Due to this, it becomes necessary to check the impact of other climate modes on ISMR. Mid-latitude interaction with the monsoonal flow has increased inrecent decades. Azores High is a high-pressure cell over the North Atlantic. Azores High modulates the midlatitude wave pattern over the Eurasian region and consequently affects Asian jet and Tibetan High. Because of the repositioning of Tibetan High, the ISMR band is shifted westward causing above-normal rainfall in west and central India and below-normal rainfall in east and northeast India. The ISMR has significantly decreased over the Gangetic Plain adverselyaffecting this region. This case study for the year 2022 summer monsoon has reflected one of thepieces of evidence of subdued rainfall over the Gangetic Plain of India. The situation is unique because normal to above-normal rainfall was observed over the rest of the country. After analyzingvarious parameters, it is observed that the surface pressure anomaly over north India is against climatology, suggesting a rise in surface pressure and hence, weakening of the monsoon trough over the Gangetic Plain. This weak monsoon trough over the Gangetic Plain has reduced the monsoonal flow towards this region. Also, the strengthened Azore's High impact through midlatitude wave reinforced the large deficit of ISMR over the Gangetic Plain during 2022.

Keywords: Indian summer monsoon rainfall; El Nino southern oscillation; Azores High; Asian Jet; Tibetan High.

WESTERN DISTURBANCES: A CASE STUDY OF JANUARY-APRIL 2023

Mukesh, Dr. Akhilesh Kumar Mishra

[a] *Department of Atmospheric Science, Central University of Rajasthan*
[b] *National Centre for Medium Range Weather Forecasting (NCMRWF), Noida*
E-Mail: mukeshkhadav94@gmail.com

ABSTRACT

In India there are four seasons winter (December to February), summer (March to May), monsoon or rainy season (June to September), and a post-monsoon period (October and November). There are many atmospheric phenomena which impact the parameters like precipitation, temperature etc.Western disturbances are one such phenomena which brings rainfall in Northwestern and some northern parts of India during winters and summers respectively. This is a non-monsoonal rainfall.They are the cause for most winter and post-monsoon season rainfall. Winter precipitation is veryimportant for agriculture, especially for rabi crops like wheat, one of the most significant crops inIndia. Western disturbances are usually associated with cloudy sky, higher night temperatures andunusual rain. Excessive precipitation due to western disturbances can cause crop damage, landslides, floods and avalanches. Over the Indo-Gangetic plains, they occasionally bring cold wave conditions and dense fog. During the summer months of April and May, they move across north India. In 2023, the northern parts of India experienced rainfall in summer months especiallyin March which is not normal. IMD categorises Northwest India having 10 states and Union territories. Out of the 10 states six have recorded a large excess in rainfall in march 2023 includingDelhi, Uttar Pradesh, Punjab, Haryana, Rajasthan and Chandigarh. Northwest India recorded a large deficit of 76% in February and its because of western disturbance. Objective of this study is to compare the Observed rainfall, wind (magnitude and direction) with the predictions of rainfall and wind (magnitude and direction) by Global (NCUM-G) and Regional (NCUM-R) models of NCMRWF.

Keywords: Extreme weather events; Monsoon; Western disturbances; Excessive precipitation; Floods

CHARACTERISTICS OF MONSOON HOURLY RAINFALL EVENTS ASSOCIATED WITH EXTREME RAINFALL AND THEIR CONNECTIONWITH LOW PRESSURE SYSTEMS OVER A COMPLEX TERRAIN OF INDIAN SUBCONTINENT

AbhayBhattarai, Partha Roy[b] and Atri Deshamukhya[a]

[a]*Department of Physics, Assam University, Silchar*
[b] *Indian Meteorological Department, AgartalaE-Mail:abhaybhattarai@gmail.com*

ABSTRACT

Extreme rainfall is becoming increasingly prevalent in our changing climate, mostly associated with flood over the eastern and northeastern region of India and Indian subcontinents, which is the largest contributors to natural disasters worldwide as per the Emergency Event Database (EM- DAT). The characteristics of monsoon rainfall events associated with extreme rainfall events (EREs) over this complex terrain is studies using long term Global Precipitation Measurement (IMERG) sub daily scale rainfall data along with satellite radar data over 24 years (2000-2023) toquantify (1) Spatio-temporal distribution of the EREs and associated parameters (frequency and peak intensity) (2) different categories of the ERE based on duration (3) Diurnal variation of the ERE associated with its different categories. (4) possible linkage of the ERE to the Low pressure systems (LPSs) (5) interannual variation of the ERE linking to LPS. Results shows that the maximum ERE concentration (3.5-6%) are observed over the Meghalaya plateau, upper Assam border part of Arunachal Pradesh, foot hills of Himalayas, Chicken's neck area, border area between Tripura, Mizoram, and Bangladesh, and over the Bay of Bengal region in the costal part of India and Myanmar. Mere 1-6% of the total rainfall events contribute 6 to 60% of the total monsoon rainfall. EREs formed over this complex regions are less associated with deep and intense convection. It is observed that some of the events reaches the high intense cloud burst threshold of100mm/hr. ERE occurence peaked during the late night (0230IST). ERE associated with the LPS is maximum over the CI region (50-80%) and these gradient decreases as we move north-eastward.Maximum ERE associated with LPS are contributed by the long duration ERE.

Keywords: Extreme Rainfall; Monsoons; Low-Pressure Systems; Complex Terrain.

Analysis of the heat wave over the North-Indian regions

Neha Kumari[a], Neetak Kumar[a],
Sushil Kumar[a], and Vivek Singh[b]

[a] *Department of Applied Mathematics, School of vocational studies and applied sciencesGautam Buddha University, Greater Noida U.P. 201312*

[b] *Indian Institute of Tropical Meteorology, (New Delhi Branch), R-Block, New Rajendra Nagar,Ministry of Earth Sciences (MoES) Government of India, 110060, India*

E-Mail: neha16052000@gmail.com

ABSTRACT

The world's deadliest heat waves (HW) occur in the tropical and subtropical regions. This study depicts the HW features of North-Indian region, and the region is primarily divided into differentstates and two distinct landmasses: plains, and mountainous. Our work will give the quantificationof the HW characteristics depending on the physiography of the North-Indian region evaluated over a 50-year period from 1973 to 2023 using data from observations provided by the Indian Meteorological Department (IMD). Two thresholds for daily maximum temperature (DMT) are being applied according on topographical features: DMT>40 °C (plains) and DMT>30 °C (hilly).To measure the effectiveness of capturing the HW parameters in contrast to IMD data, the modeloutput for different models from the coupled model intercomparison project phase (CMIP6) has been evaluated. Under the various emission scenarios (SSP126 and SSP585), future changes in theheat wave parameters across North-Indian region have been projected using the ensemble mean oftwo CMIP6 models. This study indicates that in the next decades, plain and hilly regions will seea dramatic increase in the number of HW days and HW events. In comparison to SSP 126, there will likely be significantly longer, intense, and frequent HW occurrences in the North-Indian region under SSP 585, as well as more new hotspots. The results are vital importance inunderstanding the increasing trend of HW in North-Indian regions and it is prelude study for the numerical simulation of HW.

Keywords: Heat Wave (HW), Daily Mean Temperature (DMT), North-Indian, CMIP6.

DIAGNOSTIC STUDY OF GLOBAL HEAT WAVES

Jyoti Bhate[a], Amit Kesarkar, G. Pavani,

[a] *National Atmospheric Research Laboratory, Department ofSpace, Govt. of India, Gadanki,Andhra Pradesh 517502*
E-Mail:jnbhate@gmail.com

ABSTRACT

A heat waves (HWs) is extended periods of unusually hot weather compared to what is typically expected at a specific time and location. These severe weather episodes are very concerning because they have the potential to have catastrophic effects on ecosystems, agriculture, human health, and the economy. HWs can concur with other hazards or drivers in the form of compoundevents with cumulative impacts. HW-compounded hazards include high humidity, air pollution, or wildfires can lead to strong perturbations of the global carbon cycle, and affects the densely- populated areas and major agriculture regions. HWs have an inherent compound nature since theirdrivers interact at multiple spatio-temporal scales and influence in other climate-related hazards. Overall, knowledge on compound events is still limited, partially due to insufficient understandingof the underlying hazards, their spatio-temporal dependences, and the multiplicity of drivers and interactions. In recent decades, there has been an increase in the frequency, persistence, and intensity of hurricanes (HWs) worldwide. Several regions have also seen unprecedented events that would have been extremely unlikely in the absence of rising greenhouse gas (GHG) emissions.Under continued global warming, it is predicted that the observed changes and related effects of HWs will increase substantially causing risks and damage to ecosystems. Hence the study of heatwaves is very important in view of climate change. The objective of the present study is to carry out diagnostic studies using long-term datasets to identify changes in global heatwave conditions and their trends in occurrences, durations, and intensities vis-a-vis land use, land cover changes, anthropogenic forcing, and demographic changes. We have analysed the global heat wave eventsusing observational and reanalysis data sets for the period 1951 to 2024. Our results indicate that the heat wave episodes are increasing in the presence of anthropogenic climate change. Also the decadal variation cause the spatial extension of heat wave over mid latitude countries and centralIndia.

Keywords: Extreme weather events; Heat wave; Climate change; anthropogenic forcing.

Analyzing the impact of a severe Dust Storm on the Boundary Layer in theWestern-Indian Region

Dharmendra Kumar Kamat[a,b], Som Kumar Sharma[a], P. Kumar[c], K.N. Kumar[d], R. Shah[a]

[a] *Physical Research Laboratory, Ahmedabad, India*
[b] *Indian Institute of Technology Gandhinagar, Gandhinagar, India*
[c] *Space Applications Centre, Ahmedabad, India*
[d] *NCMRWF, Noida, India*

E-Mail: dharmendrakamat@prl.res.in

ABSTRACT

This study investigates the impact of a severe dust storm on boundary layer over Ahmedabad (23.02° N, 72.57° E), a semi-arid Western-Indian region, during the pre-monsoon season on 13 May 2024. The storm was triggered by the outflow from convective systems originating in southwest Gujarat and northeast Rajasthan. These systems and the dust storm were captured by the INSAT-3D satellite and MODIS instruments on NASA's Aqua and Terra satellites. The ground-based Ceilometer Lidar backscatter profile showed an abrupt change in the mixed layer height (MLH) from ~2.5 km to about 250 m during the storm due to attenuation of the signal by heavy dust load. The MLH, ~2 km on 12 May (previous day), shallowed to ~800 m on 14 May (post dust storm day), with increased backscatter indicating high dust concentration. Vertical visibility dropped to 340-660 m during the dust storm. After the storm, cumulonimbus clouds formed resulting in approximately 19 mm of rainfall over the Ahmedabad region. On the dust storm day (13 May), the maximum temperature was 42°C, 1°C higher than the previous day, dropping by 7°C on 14 May due to dust interaction with shortwave radiation. Relative humidity near the surface increased from 29% to 48% during the storm due to the transport of moisture. Strong winds with a magnitude ~6 m/s were also observed. This study highlights the impact of moist convection and subsequent dust storm on boundary layer dynamics over a semi-arid region.Understanding the causes, mechanisms, and consequences of dust storms is critical for mitigatingtheir effects and adapting to the changing climate patterns that may influence their frequency andintensity.

Keywords: Dust storm, boundary layer, mixed layer height, clouds, Lidar.

Characteristics of rain bearing clouds of southwest monsoon season over India during recent years

G K Sawaisarje[a]

[a] *India Meteorological Department,*

Ministry of Earth Sciences

E-Mail: gksawaisarje@gmail.com

ABSTRACT

Clouds are continuously in the process of evolving in the atmosphere. Our weather depends greatlyon the type of clouds which form in the skies. For this reason, meteorologists direct a great deal ofattention towards the study of the structure and development of clouds. In this study we shall investigate rain bearing clouds of the southwest monsoon over India during recent years and discuss some of important characteristics of clouds genera. The data used for this study are individual cloud type observations and cloud amount of synoptic observations taken at the surfaceobservatories of India Meteorological Department. During recent years it has been observed that rainfall intensity has increased in relation to shorter durations. Whether the hydrometers occur as showers or not depends on clouds in which they originate. Altostratus (As), Nimbostratus (Ns), Stratocumulus (Sc), Stratus (St), Cumulus (Cu), Cumulonimbus (Cb) are the cloud genera with which different hydrometers are associated seen during southwest monsoon season. Data period used in this study is 2011 to 2023 (recent 13 years). As southwest monsoon consists 4 months (June to September) and month contains 6 pentads, Pentads FROM 1st June are computed for individual cloud amount, total cloud amount, air temperature, relative humidity, average wind speed and individual cloud types. Composites of El Nino, LaNina, positive IOD and negative IODyears and total years of period of study will be prepared to see the effect of cloudiness. Cressmaninterpolation technique is used to plot pentads.

The expected results are evolution of clouds during monsoon period, NLM of monsoon and extent of cloud coverage over India, cloud amounts seen at 03 UTC and 12 UTC, cloud characteristics in El Nino, LaNina, positive IOD and negative IOD years and total years of period of study.

The present study undertaken is synoptic surface observations based.

Keywords: Monsoons; clouds; ElNino; LaNina; IOD

Driver of the Dipolar Aerosol Loading Pattern over the Indian Region

Binisia Sanatan[a], V Vinoj[a], and Kiranmayi Landu[a]

[a]*Indian Institute of Technology Bhubaneswar*

E-Mail: s21es09002@iitbbs.ac.in

ABSTRACT

Recent studies have indicated the presence of an aerosol dipole over the Indian domain, however, the reason for it is not understood. Utilizing long-term satellite observation and reanalysis datasets,our analysis shows that the Equatorial Rossby (ER) waves and Madden Jullian Oscillation (MJOs)have the highest effect in creating such dipolar patterns followed by Mixed-Rossby-Gravity and Tropical depressions (MT) and Kelvin wave (KE). Quantitatively, MJO and ER modulate the aerosol loading by 15 -20% and MT and KE by 5 - 15% of the mean. Similar patterns are also observed in the atmospheric aerosol radiative forcing but poles are observed at slightly different locations than the aerosol poles indicating differential aerosol properties on the aerosol radiative forcing. Further, the analyses of various meteorological parameters show that the aerosol patterns are primarily driven by the anomalous circulation patterns associated with the ISOs. The ER, MJO,and KE are observed to influence aerosol loading by enhancing/suppressing the aerosol supply from hotspots such as the Arabian Peninsula and IGP by their large-scale circulations, whereas due to its limited circulation, the MT influences local aerosols only. Thus, ER, MJO, and KE (relatively weaker than ER and MJO) create a clear East-west aerosol dipole between the ArabianSea and the Bay of Bengal.

Keywords: Aerosol loading over India; Intraseasonal Oscillations; Pollution over India; Aerosols

Performance of A Novel NWP-AI Hybrid Lightning Early Warning System (C_{2AE}) over Indian Subcontinent

Rituparna Sarkar[a,b], Parthasarathi Mukhopadhyay[a] , Sunil D. Pawar[a]

[a] Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune411008, India
[b] Department of Atmospheric and Space Sciences, Savitribai Phule Pune University, Pune 411007, India
E-Mail: rituparna.sarkar@tropmet.res.in

ABSTRACT

The atmospheric processes associated with lightning are yet to be fully understood, making it challenging to forecast using numerical weather prediction (NWP) models with significant skill. As artificial intelligence (AI) is becoming one of the most common technologies in recent years, scientists focus on incorporating AI for weather forecasting. However, the highly imbalanced nature of the lightning-to-non-lightning ratio poses one major constraint for AI-based models. Gridded lightning flash density derived from the Indian Institute of Tropical Meteorology (IITM)Lightning Location Network (LLN) shows that between 2019 and 2020, over Maharashtra, India,lightning was only 0.20 % of the total dataset. To address the "curse of imbalance dataset", we have developed a two-autoencoder-based classifier model (C_{2AE}). C_{2AE}, a deep-learning-based algorithm, is trained to correctly encode meteorological features associated with lightning and non-lightning incidents. For examining our methodology, the Indian Meteorology Department (IMD) WRF operational forecasts at 9 km resolution with 00 UTC initial condition and 24-hour lead timehas been selected as input for the deep learning model. IITM LLN data is the target vector for training and verification of the model. Following training and finetuning, C_{2AE} can forecast lightning activity with an error of 3% when tested over training region (Maharasthra, India). Further analysis of the model over different thunderstorm-prone regions outside Maharashtra, India shows the robustness of C_{2AE}, which is able to capture the mean spatio-temporal distributionof lightning, independent of the training region. Hence this study shows that a simple deep-learning algorithm can forecast lightning with sufficient skill using WRF 24-hour lead time at 9 km resolution, a considerable step toward building lightning early warning systems in India.

Keywords: Extreme weather events; Weather Prediction; Disaster management

An Observing System Simulation Experiment for the Impact of GNSS Zenith Tropospheric Delay Assimilationon Regional Weather Prediction

Sreehari V 1[a], Dr. Randhir Singh 2[b]

[a] *Department of Atmospheric Science, Cochin University of Science and Technology*
[b] *Space application centre,*

E-Mail:sreehariew007@gmail.com

ABSTRACT

Observing system simulation experiments (OSSEs) have been performed to explore the added value of GNSS-ZTD (GNSS: Global Navigation Satellite System, ZTD: Zenith Tropospheric Delay) observations with various spatial resolutions on regional weather predictions over the Indian region. A whole summer monsoon season (June to September 2020) was used to show how changing the horizontal resolution (i.e. number of GNSS receivers) of ZTD data impacted regional-scale weather forecasts. The WRF (Weather Research and Forecasting) model was used to produce a nature run at a horizontal resolution of 10 km. Then the WRF model and its data assimilation system with 12-km horizontal resolution was used to carry out assimilation/forecast experiments with varying numbers of simulated ZTD observations. When energy norm is employed as a measure of performance, the installation of 3351 GNSS-ZTD receivers (one receiver within a 25 km x25 km grid) across India increases weather prediction accuracy by 10-13% when ZTD data is included in the assimilation system, compared to forecasts without ZTD observations. Reducing the number of GNSS receivers from 3351 to 1187 (one receiver within a 50 kmx 50 km grid) improves prediction accuracy by 8-12%. The prediction accuracy improved by 5 to 7% with 294 receivers (one receiver within a 100 km x 100 km grid) and 3 to 4% with 132 GNSS receivers (one receiver within a 150 km x 150 km grid). The ability to predict rainfall, especially heavy rainfall, improved by 30 to 40% when ZTD data was assimilated, especially with ZTD observation resolution of 25 and 50 km. Overall, the improvement in prediction accuracy is pretty similar comparing a set of 3351 and 1187 receivers, indicating that installing 1187 GNSS receivers is sufficient, and we don't gain much more after that. This suggests that one GNSS receiver per 50 km × 50 km grid spacing is sufficient. This study is important for the deployment of a cost-effective GNSS-ZTD observing system for improved weather forecasting over the Indian region.

Understanding the long-term trends in solar radiation using ground based in-situ observations in India

B.L. Sudeepkumar*, Ranjan Phukan, Raja Boragapu,
C. B. Nalage, A. D. Tathe and K. S.Hosalikar
India Meteorological Department, Earth System Science Organisation, Ministry of EarthSciences, Pune - 411 005, India

ABSTRACT

Understanding the long-variations of solar radiation and solar power potential over the country isessential to know the solar radiation forcing and optimum utilisation of solar energy in power generation. The present study investigates the climatology and trends of global radiation (GR), diffuse radiation (DR) and technical potential of solar power (Solar Photovoltaic potential; SPV potential) for the period 1985-2019 using in-situ data from India Meteorological Department. High (low) GR is observed over the northwest and inland areas of peninsular (extreme north and northeast) India, and high (low) DR is observed over the coastal stations (extreme northern parts of the country). The SPV potential of the country is in the range of 1800-3400 Wm^{-2}, which exhibit substantial regional variations. High (low) SPV potential is observed in the northwest regions (north, northeast and southern peninsular India). A significant decreasing (increasing) trend in GR (DR) is observed over most parts of the country, which has weakened (strengthened)in the last decade. A significant decreasing trend in the SPV potential in most of the stations has also been observed, which is alarming. It necessitates the wide use of solar panels with better efficiency to meet the energy requirements from solar resources.

Keywords: Solar radiation; In-situ observations; Technical potential of solar power; Trend analysis

Simulation of heavy precipitation event over Kayalpattinam, Indiausing WRF: Sensitivity to Cumulus and Microphysics schemes

Vasana Madhuri Sai Latha[a], R. Maheswarana[b],

[a] *Department of Climate Change, Indian Institute of Technology, Hyderabad*

[b] *Department of Climate Change, Indian Institute of Technology, Hyderabad*

E-Mail: madhurisailathav@gmail.com

ABSTRACT

Kayalpattinam, in Tamilnadu received a rainfall of 94.6cm between 08.30am of 17 Dec 2023 to 08.30am of 18 Dec 2023, it was equivalent to 90% of usual rainfall received by the entire districtin a year. It was the highest rainfall witnessed in 24 hours during the Northeast Monsoon in Tamilnadu. The research includes, studying the synoptic conditions that existed before and duringthe event and the simulation of this event was performed using the Advanced Research and Weather Research and Forecasting (WRF-ARW) model. The numerical experiments were setup with nested domains keeping resolutions 27km, 9km, 3km to study the sensitivity to microphysicsand cumulus parameterization schemes for the Kessler, Lin et al., Thomson, Morrison microphysics schemes and Kain-Fritsch, BMJ, Multi-Scale Kain-Fritsch cumulus schemes. Further the model simulations are compared with the different available observations. The rainfallestimated by different schemes is compared with IMD gridded rainfall data and GPM data. The schemes strongly influenced the rainfall estimation. The Thomson scheme and BMJ scheme performed well compared with other schemes.

Keywords:Heavy precipitation event; Northeast Monsoon

Applications of Agri-Photovoltaics in Agrometeorology

Shantanu Dhawase[a], Pralhad Jaybhaye[a], Anjali Kale[a], Ankush Chougule[a] & Swapnali Mahude[a] [a]*Department of Agricultural Meteorology,Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra-431402*
E-Mail: shantanu.dhawase@gmail.com

ABSTRACT

Agri-photovoltaics (APVs), the integration of agriculture and photovoltaic (PV) systems on the same land, present a promising approach to address land-use efficiency and sustainability challenges in agriculture. This abstract explores the review of applications on effects of agri-photovoltaics on crops microclimate, growth and yield. It is also useful to understand its effect on changing microclimate of the surrounding field.

Agri-photovoltaic systems modify the microclimate by altering variables such as temperature, humidity, wind speed, and radiation (quantity and quality) within the crops grown under PV systems and nearby agricultural field environment. These modifications can influence crop physiology, phenology, and radiation/water/nutrient use efficiency. Understanding these effects is crucial for optimizing crop management practices and enhancing agricultural productivity.

Furthermore, APV systems provide opportunities for synergistic benefits where PV panels can serve dual purposes by providing shade for crops which protect the crop from heavy rainfall and hailstorm, reducing water requirement, and potentially enhancing crop yields under certain conditions. However, careful planning is required to minimize potential drawbacks such as reduced sunlight availability and altered soil moisture regimes, which can affect crop growth negatively.

This study reviews recent studies and findings on the applications of Agri-photovoltaics in agrometeorology, highlighting both the opportunities and challenges associated with this integrated approach. It underscores the importance of interdisciplinary research involving agronomy, meteorology, and renewable energy engineering to fully realize the potential of Agri- photovoltaics in sustainable agriculture.

Keywords: Agri-photovoltaics, LUE, microclimate, IWUE, NUE etc.

Impacts of aerosols on radiation fog structure and lifetime over North India

Arun N.[a], Chandan Sarangi[a], Vijay P. Kanawade[b,c], Ritesh Gautam[d] and Yun Qian[e]

[a] Department of Civil Engineering, Indian Insitute of Technology Madras
[b] Centre for Earth, Ocean, and Atmospheric Sciences, University of Hyderabad, Hyderabad, India
[c] Climate and Atmosphere Research Centre, The Cyprus Institute, Nicosia, Cyprus
[d] Environmental Defense Fund, Washington DC, USA
[e] Pacific Northwest National Laboratory, Washington, USA

E-Mail: chandansarangi@civil.iitm.ac.in

ABSTRACT

Frequent pollution and fog episodes occur in North India during the winter. Prolonged severe fogevents lead to significant economic losses and are one of the deadliest weather phenomena to occurin North India. Incidentally, these fog layers evolve and dissipate in the heavily aerosol-loaded boundary layer. However, whether and how aerosols affect the fog is unclear due to observational constraints. This uncertainty has made fog modeling challenging in recent decades. We use a synergy of satellite and in-situ observations to show the unequivocal importance of aerosols on fog formation in the nighttime and vertical structuring. Our high-resolution chemistry-coupled simulations capture the widespread fog event of 2014 with reasonable accuracy and substantiate the aerosol-fog interaction over North India. During the nighttime, enhanced humid conditions favor more aerosol activation and fog droplet formation, leading to early intensification. This intense fog attenuates the incoming shortwave radiation the subsequent morning, leading to cool and moist surface conditions and prolog the dissipation. Further, the aerosol-radiation interaction effects become prominent during the daytime and favor the fog layer's vertical re-structuring. Intricate aerosol-fog feedback and the relative role of aerosol-cloud interaction and aerosol- radiation interactions will be comprehensively discussed in the conference meeting. Nonetheless,our study demonstrates the importance of aerosols in fog simulations and clarifies the need to regulate them to restrict fog evolution. Moreover, considering the important implications reportedhere, our results underline the urgent efforts to incorporate aerosol effects into operational fog forecasting systems.

Keywords: Extreme haze; Fog events; Indo-Gangetic Plain; Fog Prediction.

ADVANCED CLIMATE DATA ANALYSIS AND PROJECTIONS FOR KODAIKANAL USING MACHINE LEARNING TECHNIQUES

Sruthi S [a,b],

[a]*India Meteorological Department, Chennai*
[b]*Earth and Atmospheric Sciences, NIT Rourkela*
E-Mail:sruthiswaminadhan@gmail.com

ABSTRACT

Kodaikanal, a prominent hill station in southern India, situated at 2,225 meters above sea level inthe Palani hills of the Western Ghats, is characterized by its distinct climate influenced by its highelevation. The analysis and projection of Kodaikanal's climatic data utilizing surface observationsgathered over the previous 15 years is the main goal of this study. It is crucial to comprehend andforecast the local climate to manage resources, promote agriculture, and protect the environment.

The climatic data were analyzed using machine learning algorithms. Long Short-Term Memory Networks (LSTMs) were used for time-series forecasting to predict future climate conditions by capturing complex temporal patterns. Gradient Boosting Machines (GBMs) were applied to improve model accuracy by addressing non-linear relationships between climate variables. Random Forests were used to explore interactions among various climate factors, providing deeperinsights into their effects.

Geographic Information System (GIS) tools, such as QGIS, were used to make detailed maps andheat maps. These tools make it easier to see trends and changes in the climate by illustrating howclimate data varies over time and across different regions.

The results provide important insights into the dynamics of the climate in Kodaikanal as well as insightful projections for potential future climates. This integration of machine learning and GIS technology demonstrates a robust approach to climate analysis, facilitating informed decision- making and sustainable development in this region. The findings highlight how crucial it is to useadvanced analytical techniques to solve problems associated with climate change and guide regional planning initiatives.

Keywords: Climate analysis; Machine learning; GIS; Time-series forecasting; Kodaikanal

Predicting Indian Summer Monsoon Onset with a month lead: Unlocking thePotential of Ocean Heat Content-Based Indices Over the Indo-Pacific Region

Shivam Saxena[a,b], Mahendra Nimakanti[a,c],and Nagaraju Chilukoti[a]

[a] *Department of Earth & Atmospheric Sciences, National Institute ofTechnology, Rourkela, India*

[b] *Data Science Division, 50Hertz Limited, New Delhi, India*

[c] *Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, United States*

E-Mail: svidhjohari27@gmail.com

ABSTRACT

The onset and withdrawal of the Indian Summer Monsoon (ISM) exhibit substantial interannual variability, with the climatological onset typically occurring on 1st June and a standard deviation of approximately eight days. The tropical oceans, particularly the Indo-Pacific region, play a crucial role in influencing ISM circulation. Large-scale phenomena such as the El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) disrupt oceanic conditions, which, in turn, modulate the ISM circulation. While Sea Surface Temperature (SST) is commonly used to predictISM onset, it is often influenced by transient atmospheric factors such as strong winds, evaporation, or dense cloud cover, making it a less reliable indicator of the upper ocean's thermalenergy. In contrast, Ocean Heat Content (OHC), measured as an integral from the ocean surface to various depths, offers greater stability and spatial consistency and has been shown to have a stronger impact on ISM than SST. Recent studies suggest that OHC could be a more effective predictor for ISM onset than SST. This work aims to provide a comprehensive review of mean trends, ENSO-related variability in OHC anomalies, and their relationship with ISM onset. The analysis focuses on the Indo-Pacific OHC over an extended period to account for ENSO fluctuations and validate the role of large-scale processes such as El Niño, Modoki, and IOD as dominant modes of OHC anomaly variability. The central-eastern Pacific region, where OHC anomalies exhibit the greatest magnitude, shows the most significant signals at the ENSO time scale. Additionally, this study introduces new OHC indices designed to predict ISM onset with a one-month lead time. By applying the Empirical Orthogonal Function (EOF) method to OHC anomalies in the Indo-Pacific Ocean, the spatial patterns of dominant modes causing the change in OHC anomalies are investigated. Statistical techniques, including correlation and regression analyses, are employed to examine the relationship between different atmospheric circulation parameters and the dominant EOF modes. The results demonstrate that both atmospheric and oceanic variability influences ISM onset. Developing these new OHC indices offers improved prediction capabilities for ISM onset, advancing our understanding and forecasting of monsoon dynamics.

Keywords: Ocean Heat Content; Indian Summer Monsoons; EOF; ENSO; IOD

Microphysical features of widespread Deep Convective Cores with profuse lightning activity over Uttar Pradesh during 8-11 September 2023.

Dr Manish R. Ranalkar
Meteorological Centre, Lucknow, India Meteorological Department, Ministry of Earth Sciences

Email: mr.ranalkar@imd.gov.in

ABSTRACT

During the Southwest monsoon season, convective systems often become embedded within larger stratiform systems, contributing to complex atmospheric interactions that significantly influence regional weather patterns. Between September 8 and 11, 2023, the monsoon trough shifted slightly southward from its climatological position. Concurrently, mid-latitude westerlies intruded southward, forming a westerly trough due to the passage of a Western Disturbance. Such synoptic-scale interactions are well-documented for their role in enhancing atmospheric instability, particularly through the juxtaposition of warm, moist air in the lower troposphere and cold, dry air aloft in the upper troposphere. This vertical differential in temperature and moisture content is a critical factor that drives the development of deep convective cores, capable of producing severe weather phenomena.

In this study, we present a detailed analysis of the deep convective cores that developed during this period, utilizing an extensive suite of observational tools. The GPM Precipitation Feature database provides high-resolution insights into precipitation structures, while ground-based S- band Doppler Weather Radar (DWR) at Lucknow offers localized observations of storm dynamics. Additionally, Ku and Ka band Precipitation Radars onboard the GPM Core Observatory provide vertically resolved radar reflectivity profiles, allowing us to examine the vertical structure and intensity of the convective systems.

The synoptic conditions observed during this period facilitated the formation of extensive deep convection, which manifested in an extraordinary increase in lightning activity across Uttar Pradesh as observed by the ground-based network established by the Indian Institute of Tropical Meteorology, Pune. On September 10, 2023, the region experienced 18,564 lightning strokes, followed by 25,390 strokes on September 11, 2023. This heightened lightning activity is indicative of the robust updrafts and substantial moisture content within the convective systems, which are characteristic of such deep convective events. Our analysis provides valuable insights into the microphysical processes within these convective systems, particularly the role of cloud microphysics in modulating lightning activity, and underscores the importance of synoptic-scale interactions in the development of severe weather during the monsoon season. This study contributes to a deeper understanding of the atmospheric processes that govern monsoonal convection, with implications for improving weather forecasting and Disaster Risk Reduction (DRR) in the region.

Keyword : Monsoon, Microphysics, Deep Convective Core, Lightning, DRR

Assimilation of INSAT-3DR Rapid Scan WV/VIS/TIR AMVs inthe WRF Model: A Case Study for Tauktae Tropical Cyclone

Adil Muhammed I K* Prashant Kumar† Sanjib K. Deb† K F Muhammed†
*Cochin University of Science and Technology
†Space Applications Centre, ISRO, Ahmedabad

Abstract

A series of data assimilation and forecast experiments are attempted here to evaluate the impact of Rapid Scan Atmospheric Motion Vectors (RS-AMVs) derived from Indian geostationary satellite INSAT-3DR for the track and intensity forecast of the 2021 Arabian Sea Cyclonic Storm Tauktae using the Advanced Research Weather Research and Forecast (WRF) model and its 4D-Var assimilation method. INSAT-3DR was configured in rapid- scan mode during the lifetime of Tauktae. The RS-AMVs are derived by tracking cloud motions through successive 5-min images. The AMVs derived from the water vapour, vis- ible, and thermal infrared channels of INSAT-3D/3DR are utilised, in which INSAT-3DR AMVs were RS-AMVs. Three sets of experiments were performed. The first set evaluates the collective impact of assimilating INSAT-3D/3DR AMVs from all three channels, result- ing in a reduction of track and intensity forecast errors, even without other satellite AMV observations. In the second set, individual channel retrieved AMVs were assimilated sepa- rately, highlighting the significant positive impact of water vapor channel retrieved AMVs on track and intensity forecasts. Assimilating INSAT-3D/3DR AMVs collectively reduces track error by 18% compared to control experiment, outperforming AMVs from NCEP GTS. The third set of experiments evaluated the impact of different physics parameterization schemes in the forecast, with the Kain-Fritsch and Thompson schemes showing consistent improve- ment across whole forecast hours. The WDM6 and Multiscale KF schemes performed better in later forecast hours, while WSM6, WDM6, KF, and Tiedtke schemes showed an improved forecast of reflectivity.

UNRAVELING THE METEOROLOGICAL DRIVERS OF FLOODS ON THE LEEWARD SIDE OF THE WESTERN GHATS IN MAHARASHTRA

T.S.Nitha [1],P. Jismy[2], Nair.Sushma[3], R.Shambu[4] [1, 2,3,4]*India Meteorological Department, Regional Meteorological Centre Mumbai*
E-Mail: nithats23@gmail.com

ABSTRACT

The Indian summer monsoon is characterized by high variability, with active monsoon conditions frequently leading to significant flooding across various regions of India. Maharashtra, particularlywest coast, experiences intense rainfall due to favorable orographic effects. However, flooding events on the leeward side of the Western Ghats is relatively rare. This study investigates the meteorological conditions associated with major large-scale flooding events on the leeward side of the Western Ghats in Maharashtra, specifically during the years 1956, 2005, 2006, 2019, 2020,2021 and 2024.Through an analysis of atmospheric dynamics, including streamline analysis at various levels, the study identifies key factors contributing to these rare flood events. It was observed that intense and persistent heavy rainfall episodes were linked to the presence and movement of low-pressure systems over the Bay of Bengal and an offshore trough along the westcoast. The combined influence of these synoptic systems led to increased westerly wind strength,reaching up to 30 knots, and enhanced moisture transport. The depth of moisture-laden westerlies, even at higher altitudes, was sufficient to overcome the steep orography of the Western Ghats, resulting in significant spillover rainfall on the leeward side.Persistent and slow-moving large- scale systems were found to be conducive to extreme precipitation, with dynamic parameters such as vorticity, divergence, and vertical velocity aligning to facilitate intense rainfall. The study concludes that specific synoptic configurations, when present simultaneously, are capable of inducing exceptionally heavy rainfall on the leeward side during the active phase of the southwestmonsoon. These findings provide insights into potential indicators for predicting extreme rainfall events, contributing to improved early warning mechanisms and flood mitigation strategies in theregion.

Keywords: floods,leeward side,heavy rainfall

Analysis and Prediction of Weather Using Logistic Regression

SUMANA CHATTERJEE
MET A, India Meteorological Department
Ph.D. Scholar (Computer Science),
NIRWAN UNIVERSITY, JAIPUR, RAJASTHAN,
E-Mail Id: sumana.spssaha.chatterjee@gmail.comgovt.
Mail id : sumana.chatterjee@imd.gov.in

ABSTRACT

Predicting weather using machine learning methods is a great challenge. Attempts have been made since long .The objective is to predict weather for a place for certain day and also for a span. For data analysis, we collected 'ALIPORE surface data' for the period, 1969-2023. After collection of this big data from the data supply portal of IMD PUNE, we started process of necessary 'feature engineering' steps in Python code ,on google collaboratory platform . For analysis, all the weather phenomena as obtained from this big data set, were classified into two categories. 1)SIGNIFICANT WEATHER and 2)CLEAR WEATHER. Weather having thunder or rain or lightning or drizzle was considered assignificant else clear. With the help of machine learning , we completed analysis to predict outcome. Several machine learning packages like 'Pandas', 'SEABORN', 'STATS MODEL' etc. ,under 'SCIKIT LEARN' ,were imported for code execution as well as various machine learning codes and techniques like 'Shape', 'drop null', 'info', 'Describe', 'Label-encoding', 'IV-method', 'VIF method' etc. were alsoused . All these helped in successful execution of python programme for analysis of the weather dataset to understand trend of weather parameters ,statistical aspects ,as well as relationship between dependent and independent variables to determine which parameters directly had impacts on the outcome. Ultimately equation of 'Logistic Regression' had been built with test-train split formula to predict future weather for some test period and also for a day when we gave input for previous day weather parameter. Thus we predicted weather ,either 'SIGNIFICANT' or 'CLEAR'. To check the success rate of this model ,F1 score, confusion matrix, accuracy score, classification report , heatmap etc were obtained which also supported the performance of this model.

Keywords: Weather Prediction , Logistic Regression ,Disaster Management, Accuracy score, Confusion *matrix.*

INVESTIGATION OF HEATWAVES THROUGH SOIL MOISTURE AND VEGETATION DYNAMICS

Shreya Bhowmick[a] and Subhadeep Halder[a]

[a]*Department of Geophysics, Institute of Science*
Banaras Hindu University, Varanasi 221005.
E-mail: bhowmickshreya@gmail.com

ABSTRACT

The unprecedented increase in the frequency, intensity and duration of heatwaves globally and over India in the recent decades has been a reason for serious concern for agriculture and human health. Understanding of the mechanism of initiation and intensification of heatwaves is essential for their accurate numerical simulation and prediction. During heatwave conditions, anomalous soil moisture and vegetation changes can alter local temperature, humidity and wind distribution through surface fluxes and associated feedback through the boundary layer. It is hypothesized that,anomalous land surface states namely soil moisture and vegetation may also align with atmospheric circulation to initiate or enhance the persistence of heatwaves. To further address this question, observational data are firstly used to characterize and quantify the anomalous soil moisture and atmospheric conditions prior to and during the occurrence of observed heatwaves insummer. Thereafter, multiyear simulations using the state-of-the-art NCAR Community Earth System Model (CESMver2) with a dynamic land-use land-cover are analyzed to identify heatwaveevents using the criteria set by the India Meteorological Department and explore the impact of soilmoisture and vegetation anomalies. Computation of long-term trend, composite and regression analysis and model sensitivity studies are performed to investigate the physical mechanisms and feedback. It is inferred that the spatial scale and sign of soil moisture and vegetation anomalies does affect the intensity and duration of heatwaves. Our results imply that accurate land surface initialization, a realistic representation of soil moisture and vegetation states and associated land- atmosphere feedback in operational models can significantly improve heatwave forecasts. The authors gratefully acknowledge the financial support from the Science and Engineering ResearchBoard, Department of Science and Technology, Government of India to conduct this research. Thesecond author also gratefully acknowledges the financial support in the form of Seed Grant underIoE scheme of BHU to conduct this research.

Keywords: Land-atmosphere feedback, land use land cover change, soil moisture, heatwaves, global modeling

GREENHOUSE GAS EMISSION FROM A MANGROVE PATCH AT KERALA, INDIA

N G Vishnu and E V Ramasamy* Research Scholar
School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala – 686560, India
Presenting author email id: vishnung2012@gmail.com
**Corresponding author email: evramasamymgu@gmail.com*

ABSTRACT

Greenhouse gases (GHG) have become a significant factor influencing the climate change being experienced globally. Mangroves are one of the natural ecosystems which act as source as well as sink for many of the GHGs. Kerala once had 700 km^2 of Mangrove ecosystem , but now it has declined to 17.0 km^2 Present study aims to assess the GHG emission from this site during the post- and pre-monsoon seasons of 2023-24 using photoacoustic gas analyser INNOVA 1512 instrument, which is based on the Photoacoustic spectrometry (referred as PAS in rest of the text) and provides live data from the site. Data collection was done during 09:00 to 13:00 hrs on the sampling days. To aid the PAS measurements, a plastic Chamber of 100L volume placed in the site was connected to a moisture trap (Genie_ membrane separator) using a plastic tube of 3 mm diameter and the trap was attached to the PAS gas analyser. Prior to the GHG measurements, the PAS was allowed to suck air from the chamber for about 15–30 min, until the readings for CO2, N2O, and CH4 were stabilized. During sampling , the PAS was switched on for 15minutes per hour including the initial 5 minutes of flush out time and the data of this 5 miniutes was excluded. Hence, we consider only 10 minutes data measured every hour for this study. Three consecutive days of monitoring was conducted in the Ayiramthengu mangrove site which includes 3 sampling sites. This results indicate that the emissions during post monsoon is higher than pre monsoon season. The highest CO2 value of 1295.769 ppm,N2O 1.327ppm& CH4 42.572PPMwas recorded in post monsoon while CO2 769.354 ppm, N2O 0.913 ppm & CH4 27.333 ppm was recorded in pre monsoon. The findings of this study lead to the conclusion that the selected site of Mangroves is a source of GHG emission.

Keywords: Greenhouse gas, Photoacoustic Spectroscopy, Mangroves, Climate change.

Improving an Extreme Precipitationsimulation: Sensitivity to Resolutionand Time-Stepping schemes

Oscar Paul[a], Chandan Sarangi[a],R T Konduru[b]

[a] *Department of Civil Engineering, IIT Madras, Chennai, India*
[b]*RIKEN Centre for Computational Science, Kobe, Japan*
E-Mail: oscarpaul2050@gmail.com

ABSTRACT

Extreme precipitation events are the new normal over India, with regional modeling simulations projecting a future intensification in both frequency and magnitude. This change has beenobserved at all diverse topographical settings where most modeling studies have focused on enhancing precipitation distribution by improving boundary layer processes, convection, and cloud microphysics, either through explicit resolution or region-specific parameterization settings. However, a comprehensive guideline framework for improving the simulation of such events beyond these methods, remains undocumented. The present study examines a series of sensitivity experiments using the Weather Research Forecasting (WRF) model for the 2015 Chennai event, investigating the impact of varying vertical and horizontal resolutions. Thesimulations were integrated using both conventional static time step and adaptive time step methods. The primary objective is not only to understand how these factors affect the spatio-temporal distribution of precipitation but also develop a modeling framework capable of simulating similar extreme events in the future. Results indicate that while the increment in vertical resolution has enhanced the spatial distribution of precipitation by up to 70% during the event, higher horizontal resolution has improved the temporal distribution, especially over the Chennai Metropolitan area, when compared with GPM-IMERG satellite data and rain gauge observations in the region. These improvements in simulations are more evident with the adaptive time step configuration, which better simulated the atmospheric variables like wind speed and relative humidity, aligning more closely with radiosonde data from the region.

Keywords: Extreme Precipitation; Chennai; GPM-IMERG; Rain Gauges; WRF

Impact of advanced cloud microphysics schemes for the Kerala flood events in2018 and 2019 using NCMRWF regional model

Rose Raphel[a], Anurose T J[b]and A. Jayakumar[b]

[a] *Department of Atmospheric science, Cochin University of Science and technology*
[b] *National Centre for medium range weather forecasting*
E-Mail: roseraphel26@gmail.com

ABSTRACT

Kerala, tropical coastal city in Southern Indian peninsula, received back to back devastating floodsfor the consecutive summers of 2018 and 2019. August 2018 witnessed the large-scale flooding,which affected millions of people and caused 400 or more deaths as a result of above normalreservoir storage and the extreme precipitation associated with Remotely Aligned Intense TropicalCirculations (RAITC), while 2019 event is found to be caused by more localised phenomenon leading to flash flooding, and landslides. Current work utilized the NCMRWF operational regional forecasting model based on Unified Model (NCUM-R) at convection permitted scale in simulatingboth flood cases along with the upgraded version of the model with 'New physics' which includes a double moment microphysics scheme, namely Cloud Aerosol Interacting Microphysics(CASIM)and a bimodal(BM) cloud fraction scheme. 'New physics' gives a better skill in simulating thedeep convective activity of 2019 cases in compared to the former one. Advanced features in the 'New physics' exhibited a higher graupel distribution in the middle atmosphere and the associatelatent heating changes supports the baroclinicity for the aforementioned period. Whilst, thewestward propagating barotropic waves interaction with the mean flow and the moistureconvergence are evident for the both flood cases at synoptic scale irrespective of the scienceconfiguration used in NCUM-R. The current study utilized the potential vorticity tendency tracer(PVT) analysis at the convective scale, generates the strength and limitation of the physicsconfigurations of the model with respect to the prediction of the extreme precipitation events. Thetwisting term signifies the coupling of the synoptic and meso-scale scale features, found to bebetter correlated with the diabatic terms of the PVT calculated in the 'New Physics' version of themodel.

Keywords: cloud microphysics;diabatic heat;Potential vorticity;twisting term;

DYNAMICS OF SHIFTING OF OFFSHORE TROUGHS AND MONSOON WET SPELL IN JUNE 2024

P. K. Pradhan, Raghavendra Ashrit, and V. S. Prasad
BIMSTEC Centre for Weather and Climate (BCWC)
National Centre for Medium Range Weather Forecasting, Noida
Ministry of Earth Sciences
Email: prabodha.svu@gmail.com

ABSTRACT

The arrival of the southwest monsoon (SWM) is often used to denote the onset of the summer rainsover Kerala. In 2024, the onset of the monsoon was on 31 May, which is 1-day in advance of the normal date. The advancement of SWM is guided by the appearance of off-shore troughs (OST) and low-level jets (LLJ) at 850 hPa level. In June 2024, the NCMRWF-IMD merged rainfall analysis showed that the Indian land region had deficient rainfall except over peninsular India. Tounderstand the processes after the onset and strength of SWM in June 2024, global operational NCUM-G of NCMRWF analysis and forecast fields are analyzed using OST, LLJ, moisture transport, total cloud cover rainfall, and Tropical Easterly Jet (TEJ). Initial analysis shows a shifting of OSTs leeward-side of the Western Ghats along the west coast of India. In contrast, OSTs are quite significant in the Bay of Bengal, which strengthens the monsoonal wet spell (MWS) along the west coast of Myanmar. Large-scale ocean-atmospheric process, such as heatingover the Tibetan Plateau (TP), control the onset conditions of SWM. Moreover, the sea surface temperature (SST) over the central Indian Oceanic region was also analyzed to understand the MWS associated with the change of OSTs along India's west and east coasts.

Keywords: Off-shore Trough; Monsoon Wet Spell; NUCM-Global; Tibetan Plateau

A STUDY ON VARIATION IN INDIAN SUMMER MONSOON RAINFALL (ISMR) IN RELATION WITH ENSO CYCLE

Lt Cdr Santhoshkumar G[a],
[a] *Met Officer, Indian Navy*
E-Mail:Santhosharmedforce@gmail.com

ABSTRACT

Globally, Climate change has led to significant shift in temperature/ precipitation patterns, Sea level rise and frequent extreme weather events. This is severely affecting our ecosystem, agricultural yield and water resources. The ongoing situation of increase in price of vegetable, riceand other commodities could be considered as direct outcome of Climate change.

The fear of Heavy rainfall situations in India due to Climate change is increasing day by day. Thisis mainly attributable to the opinion of weather experts around the world who are foreseeing a LaNina condition in 2025. In India, these developments are feared to lead to Extreme weather eventssuch as increased Rainfall activity and related consequences. In the last 23 years, out of the sevenEl Nino years globally, four resulted in Indian droughts. Since the 1980s, almost nine droughts faced by India were in El Nino years, but not all El Nino years led to drought situations in the country. As ENSO is a natural cycle, climate change can potentially amplify its effects. Understanding these interactions is important for predicting and managing the impacts of both ENSO and Climate Change.

This paper is an effort to understand the relationship between ENSO cycle and Indian Summer Monsoon Rainfall based on existing scientific work towards exploring the timing of El Nino/La Nina developments in a year and their relation to Indian monsoon rains. By constructing an Indiaspecific El Nino model, based on tracking temperature anomalies of three months moving averages for specific months (April-May-June to September-October-November), captured in the OceanicNino Index (ONI). The choice of these months is dictated by the fact that June-September rainfallmonths must be part of three monthly moving ONI anomalies, either as the ending month or beginning month.

As the conditions always favored that the presence of El Nino phase had resulted in enhanced ISMR activity based on past 30 years. This work may lead to early prediction for possibilities ofenhanced Rainfall Monsoon Rainfall as per Ocean Nino Index and will set as a standard for understanding and estimating Normal, Decifit, Excess condition in the upcoming years.

Keywords: Climate Change, El Nino, Temperature anomalies, Drought, Indian Summer MonsoonRainfall.

Aerosol volatility over a High-Altitude site in India:Effect of semi-volatile organics

Subrata Mukherjee[a,b,*], Rohit D. Patil[a]
, Aslam M.Y.[a] , Meena G.S[a] , Anil Kumar V.[a]
, Sachin S. Patil[a] , Anoop S. Mahajan[a], Liselotte Tinel[c], G. Pandithurai[a]
[a] *Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune, India*
[b] *Sabitribai Phule Pune University, Pune India*
[c] *IMT Nord Europe, Institut Mines-Télécom, University of Lille, Centre for Energy andEnvironment, F-59000, Lille, France*
E-Mail:subrata.cat@tropmet.res.in

ABSTRACT

Sub-micron aerosols primarily consist of organics, sulfate, nitrate, ammonium etc. Of these, organics have high complexity in their chemical and physical characteristics. In this study, aerosol volatility of non-refractory sub-micron aerosol was studied from 6 th to 26th 13 February2021 using a thermal denuder (at constant temperature of 150° C) coupled High-Resolution Timeof flight Aerosol Mass Spectrometer (HR-TOF AMS) for the period from 6th to 26th February 2021. Nitrate and ammonium had the highest volatility (80% and 68%), followed by organics (54%). The lowest volatility rate was observed for sulfate (26%) indicating the tendency of sulfate aerosols to be more in the particle phase at higher temperature. The volatility for organics decreases during afternoon and night to early morning hours due to the prevalence of oxygenatedorganic aerosols (secondary organic aerosol). Further PMF analysis on both the denuded and ambient organics aerosol revealed four factors, namely, hydrocarbon like organic aerosols (HOA), biomass-burning organic aerosol (BBOA), semi-volatile oxygenated organic aerosol (SV-OOA) and low-volatile oxygenated organic aerosol (LVOOA). Over the campaign, LV- OOA showed an increase in fractional contribution from 31% to 56% of total organics. SV- OOA, HOA, BBOA all showed decreasing trends, as they have higher volatility than LV-OOA. Surprisingly, SV-OOA exhibited higher volatility than that of HOA, and BBOA. Further, the volatility of high-resolution fitted peaks of oxygenated hydrocarbons were extracted and compared with the hydrocarbon peaks to evaluate the higher volatility extent for SV-OOA aerosols and the oxygenated hydrocarbons were estimated to be more volatile as compared to hydrocarbons.

Keywords: aerosol volatility, thermal denuder, positive matrix factorization, oxygenated organic aerosol, semi-volatile organics coating.

MECHANISMS INFLUENCING STRATOSPHERE TROPOSPHEREEXCHANGE (STE) OF OZONE OVER COSTA RICA DURING 2016

Salauddin Mohammad[a], Gopa Dutta[b],

[a] *Department of Physics, BVRIT(N), Hyderabad, TG, India*
[b] *Convicity, NEWTON Road, Kolkata, WB, India*
E-Mail:salauddin.mohammad@bvrit.ac.in

ABSTRACT

High vertical resolution radiosondes and ozonesondes are launched every week fromstations in Southern Hemisphere ADitional OZonesondes (SHADOZ) network. Wehave analyzed the data of ozone mixing ratio, winds and temperature, of a tropical station Costa Rica (10° N, 83.4° W) for the year 2016 to study transport of ozone between stratosphere and troposphere (STE/TSE). Eight STE and Five TSE events could be identified in the data. The intrusions are normally shallow with a maximumof 5.7 DU in the month of August. Transport of ozone is observed to occur mostly during May to August when strong convection prevails in the region. Spectral analyses and correlation studies confirm gravity wave and Inertia gravity wave (IGW) /Rossby gravity wave (RW) activities to be responsible for the transport. Exchange of ozone between stratosphere and troposphere is also found to beassociated with Kelvin wave near the tropopause and Madden-Julian oscillation (MJO) in the troposphere. Eddy diffusivity computed by using simultaneous radiosonde measurements display high values of turbulence, particularly, below thetropopause where laminar structures are mostly observed. Wind shear is also high inthe region. We conclude that a combination of wind shear, wave activities and local turbulence is responsible for the exchange of minor constituents between troposphere and stratosphere.

Keywords: Troposphere; Stratosphere; Gravity wave; Rossby wave

How Human-Caused Climate Change is Impacting Mountain Cities of the Himalayas

Pramod Kumar, and Arnab Mondal

Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi,UP, India, 221005.

Email: promnagar1@gmail.com

ABSTRACT

This research explores how different environmental factors interact to influence the cities of the Himalayas, in India. Specifically, it glances at radiation levels, the occurrence of extreme temperature events (heat and cold days), the Normalized Difference Vegetation Index (NDVI),and Aerosol Optical Depth (AOD). This can measure the amount of particulate matter in the atmosphere using the AOD, which provides important information on pollution levels and airquality. Local climates and weather patterns are significantly influenced by amounts of radiation, both solar and earth. It is easier to understand the energy balance in urban environments and how it affects residents' thermal comfort since we are aware of these levels.City population's health and well-being are strongly impacted by the frequency and severity ofhot and cold days, which are crucial indicators of weather extremes. During the studyperiod several seasons and a long period (1980-2024), this is expected to extensively analyze all of these factors. Through this, we intend to find trends and connections that will help clarify the intricate relationships that exist between temperature extremes, radiation exposure, air quality, road traffic and vegetation health. For example, high road traffic emissions, and a decrease in the NDVI correlated with higher AOD values, indicating a negative impact of air pollution on vegetation, and the health of the indigenous Himalayan. However, following comparable, elevated radiation levels could render heat days more frequent, creating uncomfortable and sometimes dangerous forest fire circumstances. The findings of this research aim to enable policymakers and mountain city planners to undertake well-informed decisions that enhance urban resilience. To mitigate the adverse effects of anthropogenic climate change, efficient environmental management strategies might be implemented. Some of these include building metropolitan areas that are resilient to extreme weather events, enhancing air quality, and implementing green infrastructure. In the end, we believe our study may assist the Himalayan Mountain cities' development of more sustainable, healthier urban settings.

Keywords: Anthropogenic; Road-traffic; AOD; Himalayan cities; Extremes.

Impact of El Nino on Indian Monsoon

*Neeraj Kumar, B. M. Mote, T. U. Patel, H. H. Patel and D. D. Patel
Department of Agronomy,
College of Agriculture Navsari Agricultural
University Bharuch-392012 Gujarat
Email: neeraj34012@gmail.com

ABSTRACT

The term El Niño (Spanish for 'the Christ Child') refers to a warming of the ocean surface, or above-average sea surface temperatures, in the central and eastern tropical Pacific Ocean. The low-level surface winds, which normally blow from east to west along the equator (“easterly winds”), instead weaken or, in some cases, start blowing the other direction (from west to east or “westerly winds”). El Niño recurs irregularly, from two years to a decade, and no two events are exactly alike. El Niño events can disrupt normal weather patterns globally. El Niño is characterized by unusually warm ocean temperatures in the Equatorial Pacific, as opposed to La Niña, which is characterized by unusually cold ocean temperatures in the Equatorial Pacific. El Niño is an oscillation of the ocean-atmosphere system in the tropical Pacific having important consequences for weather around the globe. El Niño has an impact on ocean temperatures, the speed and strength of ocean currents, the health of coastal fisheries, and local weather from Australia to South America and beyond. El Niño events occur irregularly at two- to seven-year intervals. However, El Niño is not a regular cycle, or predictable in the sense that ocean tides are. El Niño was recognized by fishers off the coast of Peru as the appearance of unusually warm water. We have no real record of what indigenous Peruvians called the phenomenon, but Spanish immigrants called it El Niño, meaning “the little boy” in Spanish. When capitalized, El Niño means the Christ Child, and was used because the phenomenon often arrived around Christmas. El Niño soon came to describe irregular and intense climate changes rather than just the warming of coastal surface waters. El Niño events are defined by their wide-ranging teleconnections. Teleconnections are large-scale, long-lasting climate anomalies or patterns that are related to each other and can affect much of the globe. During an El Niño event, westward-blowing trade winds weaken along the Equator. These changes in air pressure and wind speed cause warm surface water to move eastward along the Equator, from the western Pacific to the coast of northern South America. These warm surface waters deepen the thermocline, the level of ocean depth that separates warm surface water from the colder water below. During an El Niño event, the thermocline can dip as far as 152 meters (500 feet). India's monsoon rainfall for the year 2023 has hit a five-year low, marking the lowest since 2018 due to El Nino. The monsoon season, which is crucial for India's $3 trillion economy, provides nearly 70 per cent of the rain needed to irrigate crops and replenish reservoirs and aquifers. Staples such as sugar, pulses, rice, and vegetables could become more expensive due to lower production. This could also prompt India, the world's second-largest producer of rice, wheat, and sugar, to impose further restrictions on the export of these commodities.

Key words: El Niño, La Niña, Indian Monsoon, Agriculture

AI-Based Agricultural System for Crop-Specific Querying and Weather Forecasting

Darvesh Bansal[a], Dr. Gunavathi R[b], and Dr. Ashutosh Kumar Mishra[c].

[a] *Department of Data Science*
CHRIST (Deemed to be University), Lavasa ,Pune, India
[b] *Department of Data Science*
CHRIST (Deemed to be University), Lavasa ,Pune, India
[c] *Agriculture Meteorlogy Division, India Meterological Department,Pune,India*

E-Mail: darvesh.bansal@msds.christuniversity.in

ABSTRACT

An AI-based agricultural system designed to revolutionize farm management practices. The system integrates a language chain, Large Language Model (LLM) retrieval Question-Answering (QA), and OpenAI embeddings. This innovative approach enables farmers to utilize voice queries in English and Hindi for crop-specific inquiries and weather forecasts covering designated date ranges. By leveraging advanced AI algorithms, the system extracts relevant information from extensive agricultural databases, providing farmers with actionable insights. This empowers them to optimize cultivation strategies, mitigate weather-related risks, and ultimately foster sustainable crop yield outcomes. The system's seamless integration of multilingual capabilities and real-time weather analysis equips farmers with unparalleled decision-making support, paving the way for a future of precision agriculture.

Keywords: Lang-chain, Large Language model, Artificial Intelligence, OpenAI,Advisory System

A Novel drone mounted Smartphone based Weather Data logger for Atmospheric observations

Shijo Zacharia, Sruthy Prakash, K.S.Hosalikar, Akshay Kumar, Akhilesh Mathwale, Theertha Nambiar
Office of the Head Climate Research and Services,
India Meteorological Department, Ministry of Earth Sciences, Government of India, Shivajinagar, Pune 411005
shijo.zacharia@imd.gov.in

ABSTRACT

Metrological observations are enhanced with breakthroughs in sensor technology, artificial intelligence (AI) integration, Internet of Things (IoT) connectivity, mobile weather stations, and cloud computing. Recent technological advancements have remarkably augmented meteorological data logging platforms. The drone-based observations overcome the limitations of conventional surface metrological stations. Long-range wireless communication for drone-based measurements nevertheless, unresolved technical difficulties and concerns remain in terms of communication failures and interruptions in environments with numerous obstacles, extreme reduction of transmission speed, and communication data loss. Climate Research & Services, India Meteorological Department, Pune a novel drone-mounted smartphone-based Weather Data logger for Atmospheric observations. The battery-powered system consists of a controller board (ESP8266), an integrated Temperature Humidity and Pressure sensor (BME280), a GPS Module (Neo 6M) and a smartphone to record the data. This system captures atmospheric temperature, humidity, pressure, position and altitude. This article depicts its design and capabilities. This study examines an economical solution for researchers with market-available IoT sensors. The drone- mounted sensor payload observes weather at different heights and is recorded on a smartphone. The results from a field study are also discussed in this article. The experimental results show that the system has an endurance of 2.5 hours and is instrumental in observation of near-surface atmospheric observation. Portability, lightweight and high-resolution measurement capability are the unique features of this system. The novel instrument platform has immense applications in agriculture, weather prediction, disaster management etc.

Role of Pre-Monsoon salinity anomalies in Influencing the Onset of Indian Summer Monsoon

Dinesh K Yadav1, B. Mandal1 and R. Bhatla1,2
1.Department of Geophysics, Institute of Science, Banaras Hindu University, Varanasi, India.
2.DST-Mahamana Centre of Excellence in Climate Change Research, Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi, India.

ABSTRACT

The Indian Ocean (IO) has complex interactions with the atmosphere, and its various features, including sea surface temperature and salinity, can impact the onset, intensity, and duration of the Indian summer monsoon (ISM). This study investigates the variability of the salinity in the IO during the onset phase over the Indian Peninsula (specifically over the Kerala coast) by analyzing reanalysis datasets. This research utilized daily averaged reanalysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF's) Ocean Reanalysis System 5 (ORAS) between 1992 and 2017. Significant salinity fluctuations have been documented in the IO during the pre-monsoon period. The upper subsurface layers of the western Indian Ocean (WIO), specifically the Arabian Sea (AS), manifest the highest salinity levels, while the corresponding layers in the eastern Indian Ocean (EIO), encompassing the Bay of Bengal (BOB), exhibit the lowest salinity concentrations. Wind over the western Indian coast and the amount of salt in IO play a crucial role in the onset of ISM over India. During the pre-monsoon season, high salt concentration in IO and weak northeasterly (NE) in eastern AS leads to early onset, and as the amount of salt decreases in IO and NE in eastern AS becomes stronger during the pre-monsoon season, it extends onset of monsoon over India. During the pre-monsoon seasons of the early onset year, intense evaporation may cause a large amount of salt in IO, which leads to elevated atmospheric relative humidity (RH). Conversely, RH is low during typical onset and late onset years, with wind-driven moisture transport towards the Kerala coast.

Keywords: Indian Ocean, Summer Monsoon, Sea Surface Temperature, Salinity.

LIGHTNING INDUCED VULNERABILITIES OVER INDIAN SUB-CONTINENT

Kumar Upavan[a], Samyaditya Maity[a], Mili Ghosh Nee Lala[a], Abhishek Anand[b]and Swagata Payra[a]

[a] *Department of Remote Sensing, BIT Mesra, Ranchi, Jharkhand*

[b] *India Meteorological Department, Met Centre, Ranchi, JharkhandE-Mail:kumarupavan17may1999@gmail.com*

ABSTRACT

Lightning is one of the most rapidly increasing climate induced threat having devastating impact on human life and property. As per Accidental Deaths and Suicides in India(ADSI) reports, lightning has resulted more casualties than any other natural disasters. The present study focuses on the spatio-temporal distribution of lightning incidences captured by Lightning Imaging Sensor(LIS) from two different platforms i.e. **T**ropical **R**ainfall **M**easuring **M**ission(TRMM) and**I**nternational **S**pace **S**tation(ISS). The associated deaths over India from 2001 to 2022, divided intotwo different time frames i.e. T1(2001-2014) and T2(2017-2022). The vector layers of lightning incidence locations, derived from LIS, have been processed in GIS environment whereas lightninginduced death data was extracted from ADSI reports. As per the analysis of Scaled FlashDensity(SFD) measured in flashes/km^2/yr, it was found that Meghalaya(58), Himachal Pradesh(46),Tripura(45), Punjab(44) and Assam(36) are coming among the top 5 states in time frame T1 whereas Chandigarh(31), Meghalaya(25), Tripura(25), West Bengal(20) and Punjab(19)are the top 5 states in time frame T2 . Comparative analysis of death rates reveals that Madhya Pradesh is having highest death rate of 343 and 443 deaths/yr in both the time frame T1 and T2 respectively besides having low SFD. Considering India as a whole,death trend is increasing alongthe entire study period (2001-2022) except in the year 2015. Detailed analysis clearly shows that climate change is attributing for this remarkable variation. Further, different conditions, like urban/rural area, agricultural practices, terrain, time of lightning etc. have been analysed to find out the major contributing factors towards lightning induced deaths apart from favourable environmental conditions. The analysis reveals that rural area with water intensive cropland/fisheries is more prone to lightning induced deaths in post noon period.

Keywords: Lightning Induced Vulnerabilities, Spatio-Temporal Analysis, TRMM ,LIS, ScaledFlash Density

The Role of Atmospheric Circulation Anomalieson Extreme Wet and Dry Years in ISMR

ANMOL YADAV[1], G.P SINGH[1*],

[1] *Department Of Geophysics ,Banaras Hindu UniversityVaranasi 221005*
anmol123@bhu.ac.in

ABSTRACT

This study investigates extreme wet and dry events driven by atmospheric circulation patterns in the Indian summer monsoon rainfall(ISMR). We used IMD and various reanalysis data products spanning 1981–2022. Here, we utilized the various Empirical orthogonal function (EOF), along with its principal component (PC) analysis and various statistical methods such as coefficient of variation (CV) and correlation Coefficient (CC) and precipitation concentration index (PCI). Thisanalysis reveals significant increasing variability in rainfall from western to eastern India. However, a dominant pattern is captured by the first mode of the EOF which explains 14.9% of the total variation, and six extremely dry and nine extremely wet years are identified.Composite analysis during wet periods indicated patterns of converging or diverging velocity potential, alongside vertical velocity variations in the lower and upper troposphere. These conditions facilitated upward vertical motion. Conversely, dry years exhibited contrasting atmospheric phenomena. Furthermore, we identified a negative correlation between the Nino 3.4 index and thefirst principal component (PC1), and a positive correlation between Nino 3.4 and the second principal component (PC2).The study underscores that predictive factors for Indian summer monsoon rainfall forecasting include Indian Ocean Sea Surface Temperatures (SST), the Nino 3.4index, Mascarene High Sea Level Pressure (SLP), Indian Ocean 850-hPa westerly winds, and vertical velocity anomalies. These elements interact to influence the strengthen and distribution ofthe monsoon precipitation, These findings underscore the understanding of the monsoonal extremes and further implications for weather forecasting.

Keywords: ISMR; EOF; PCI; Extreme Wet and Dry Events; Nino 3.4 Index

Importance of Flood Early Warning System under Changing Climate in South Gangetic West Bengal

Suman Chattopadhyay1 & Raja Acharya2
1. Regional Meteorological Centre Kolkata
2.Indian Meteorological Society, Life Member

ABSTRACT

Flooding is one of the costliest and most common natural disasters in India. It claims lives and also presents a danger to infrastructure development and public safety and security. The destructive capabilities of flooding have the potential to destabilize entire nations due to the large-scale economic damage inflicted as well as the death and displacement of a large population. Modern flood warning systems (FWSs) have been developed and evolved to serve various needs of different communities, regions, or nations, especially those that are prone to flooding. India Meteorological Department through Flood Meteorological Offices all over India and Damodar Valley Corporation(DVC) Meteorological unit in Jharkhand and Gangetic West Bengal issuing heavy rainfall warnings and flood forecasting through CWC(Central Water Commission) during monsoon season. Modern flood warning systems (FWS) may be developed, including rain gauge networks, radar and satellite precipitation measurements, hydrologic and hydraulic modeling, and data-driven (AAP) methods. Due to climatic changes, mainly temperature and humidity changes in the monsoon period. Delay of monsoon onset, changing of average monthly rainfall have been occurred, and extreme rainfall in a very short time causes water lodging and, ultimately, flood situation. Early flood warning systems and correct runoff analysis may be minimized flood damages to the greatest extent. In this paper heavy rainfall in high flood-prone areas of the lower valley of Damodar, Barakar, Ajoy, Mayurakshi, and Kansa Bati catchments in Gangetic West Bengal and climate-changing phenomena have been studied, and the following findings are found (i) Timely and advance issuing of QPF based on numerical weather modeling and synoptic analog modeling in monsoon season. (ii) Correct analysis of AAP and rainfall runoff for dam operations. (iii) Early and well- communicated Flood Warning System (FWS) can control these devastating occurrences.

Key words: Early warning system, Quantitative precipitation forecast(QPF), Average Areal Forecast(AAP),Flooding, Flood alert, Flood forecast , FWS

Exploring the role of western Indian Ocean on seasonal extremes of rainfall over Indian region

R.D Ruchith[1*], P. S Karthika[1]

[1] *CSIR-National Institute of Oceanography, Dona Paula, Goa, India*

Email : ruchithrd@nio.res.in

ABSTRACT

The influential role of western Indian Ocean on the seasonal extremes rainfall events of Indian summer monsoon is investigated. The flood and drought years were categorized by using the precipitation indices Standardized Precipitation Index (SPI) and Percent of Normal Precipitation (PNP). The western coast, central part of Indian sub-continent and central Bay of Bengal shows contrasting differences in precipitation during flood and drought years. The dynamical and thermosdynamical factors that favours these extreme conditions were analysed. Through this study it is emphasized that the southern sub-tropical Indian Ocean process are having an upper hand in delivering the dynamical and thermodynamical feedback for the occurrence of flood and drought conditions over Indian sub-continent.

Keywords: Monsoon, rainfall, extremes, moisture transport, air-sea interaction, climate change


DTPLENVIRO
OUR
METEOROLOGICAL
SOLUTIONS
WE BELIEVE IN MAKING A
DIFFERENCE
About Us:
At DTPLENVIRO Techsolutions, we specialize in providing innovative solutions across four key areas: Hydrology, Renewable Energy, Agriculture, and Meteorology—what we proudly refer to as H-RAM. Our diverse range of products is designed to meet the needs of these critical fields, helping to monitor and manage natural resources, optimize energy usage, and support sustainable agriculture practices. With a commitment to quality and sustainability, DTPLENVIRO is dedicated to making a meaningful impact through our H-RAM solutions.
+91-129-2972048
dtplenviro.com
sales@dtplenviro.com

SCIENTOMETRIC ANALYSIS OF CLIMATECHANGE RESEARCH IN INDIA

Archana, Sarkar[a], Jyoti Patil[a]
a National Institute of Hydrology, Roorkee, India
E-Mail:archana_sarkar@yahoo.com

ABSTRACT

Potential climate change and its unfavourable impacts on hydrologic systems pose a threat to waterresources throughout the world. As a populous, tropical developing country, India faces a bigger challenge in coping with the consequences of Climate Change. It is now clear that enhanced climate variability and climate change due to continued emission of greenhouse gases in the Earth's atmosphere will alter the key characteristics of summer monsoon rainfall and could significantly impact water supply and demand throughout the Indian subcontinent. There is a strong need to reconnect climate science and policy development with the local context to generaterelevant knowledge supporting future climate change adaptation and disaster risk reductionstrategies. The ability to undertake policy action requires information, knowledge, tools, and skills. Many researchers/academicians/policy makers in India have studied and published various aspectsof climate change impact on hydrology vis-à-vis water resources and policy implications. However, such studies have been carried out in isolation focusing on specific region/river basin and specific aspect of climate change impact (floods/droughts/water availability/etc). The presentpaper presents scientometric analysis of research on climate change impact on hydrology and waterresources by Indian scientists using Scopus cited research database of 31 years (1992-2021) providing information on most cited documents, most relevant documents, word cloud andthematic evolution. The Word Cloud result showed that research in the hydrology along with climate change are mainly focused on climate models, water supply, hydrological modelling, waterresources, environmental monitoring, rainfall, runoff, rivers, evapotranspiration and hydrological response etc. The thematic evolution observed in the research database from 1992 to 2021 showsthat in the recent database, the research is not limited to studying the parameters or impact of climate change on hydrology, monsoon patterns and groundwater but impact on humans and environment were evolved in research. Important findings about the most relevant sources of research information, productivity of institutions, most cited authors, thematic evaluation and world collaboration etc. are presented in the paper.

Keywords: Climate Change; Hydrology; Water Resources; Scientometric analysis; India

Possible future changes in Rainfall and Extreme events over Indo Gangetic Plain using CMIP6 models in 21st Century

Ajit Paswan[a], G. P. Singh[a],

[a] *Department, of GeophysicsBhu, Varanasi*
E-Mail:ajit983862@gmail.com

ABSTRACT

The Indo-Gangetic Plain (IGP) is a critical region for agriculture and water resources in South Asia, and understanding its changing climate is vital for future planning. This study investigates temperature and rainfall patterns across the IGP using observational data from the India Meteorological Department (IMD) and model simulations from the CMIP6 ensemble. The region was divided into three distinct sub-regions based on temperature data, and rainfall patterns were analyzed for each division. We first validate CMIP6 rainfall outputs with IMD data to assess the models' performance through various statistical techniques, including Taylor diagrams, skill scores, correlation coefficients, and root mean square error (RMSE). The best-performing model was selected for further analysis. Using this model, we analyzed rainfall trends from 1990 to 2100, comparing the trends for each sub-region with the overall IGP. A distinct shift in rainfall patterns was observed, with varying implications for each sub-region. Additionally, future flood scenarios were evaluated using standardized rainfall anomalies, projecting flood frequency and intensity for near-term (2023–2048), mid-term (2049–2074), and long-term (2075–2100) periods. Our findings suggest an increase in the frequency of extreme rainfall events, highlighting the need for improved flood management strategies in the IGP. This research provides critical insights into the region's evolving climate and offers valuable information for future planning and risk mitigation efforts.

Keywords: Indo Gangetic Plain; CMIP6; Rainfall; Floods; Climate change.

National Symposium on Tropical Meteorology
TROPMET 2024

Rapid Update Cycle Data Assimilation for Severe weather Prediction over Indian Himalayan Region

Ashish Routray*, K. B. R. R. Hari Prasad, and V. S. Prasad

ABSTRACT

The present study presents the first assessment of a High-Resolution Rapid Refresh (HRRR) modelling setup over the Indian Himalayan region, focusing on the simulation of highly localized heavy rainfall events. This region features complex terrain; thus, a very high-resolution modelling framework is essential to resolve the topographical features with much accuracy and thereby refine the simulated weather features. The present work is undertaken by designing a nested HRRR modelling system with 5 and 1km resolutions and assimilating available latest observations in hourly intervals. Ten high-impact heavy rainfall cases during July -August 2023 are selected for the present study. The evaluation includes (i) spatial and diurnal distribution of rainfall, (ii) Equitable Threat Score (ETS) using grid-to-grid verification with various rainfall thresholds, (iii) Fractions Skill Score (FSS) analysis at different rainfall thresholds with neighbourhood lengths ranging from 10-120 km and (iv) Contiguous Rain Area (CRA) method to quantify errors attributed to displacement, volume and pattern of the isolated rainfall objects. The spatial distribution of rainfall shows that the 1 km domain effectively captures the locations and intensities of the peak rainfall. A lead/lag of 1-2 hours is noticed in the diurnal variation of rainfall. Both ETS and FSS analyses indicate that the domain with 1 km resolution outperforms the 5 km domain. The quantification of the errors with CRA reveals that the pattern errors dominate, with minimal displacement errors. The intercomparison of results from 5 km and 1 km domains emphasizes the need for higher resolution models with frequent updation of initial conditions in predicting highly localised high-impact heavy rainfall events.

Key Words: HRRR system, Indian Himalayan, Heavy rainfall, Statistical skill scores

Southern Ocean Climate Dynamics: Observations, Modeling, and Future Projections

Ankita Jadhav[a], Dr. Aditi Deshpande[a],

[a] *Department of Atmospheric and Space Sciences,Savitribai Phule Pune University, Pune*
E-Mail: kjadhavankita@gmail.com

ABSTRACT

The dynamics of the Southern Ocean (SO) region is studied using Sea surface temperature (SST),sea surface salinity (SSS), wind stress (WS) and surface ocean currents using ECMWF Ocean Reanalysis System 5 (ORAS5) for 1979-2018 and simulations from few CMIP6 climate models for 1974-2014. Our analysis reveals distinct seasonal cycles in SST, SSS, and WS across the Southern Ocean region. During austral summer, SST increases gradually, with temperatures reaching 4-8°C in the belts of 50º - 55º latitude, while remaining below -2°C in the Weddell and Ross Seas. Winter exhibits widespread cooling, with SST below -2°C throughout the SO. SSS shows maximum values (34-34.8 psu) during early summer and late winter, attributed to brine rejection from sea ice formation. Wind stress consistently peaks (0.30-0.35 Nm^{-2}) over the easternSO, corresponding to the strong westerly winds associated with the ACC. Long-term analysis (1979-2018) indicates a general warming trend in SST across the SO, with variations in magnitudeamong different models. All models simulate an increase in wind stress, particularly in the Pacificsector of the SO. These regions consistently show lower SSTs and higher SSS compared to the broader SO, emphasizing their importance in deep and bottom water formation processes. The seasonal and long-term changes observed in these areas have significant implications for global ocean circulation and climate. CMIP6 models demonstrate broadly consistent patterns in simulating SO climate variables, but with notable inter-model differences in magnitude and spatialextent. These differences underscore the need for continued model improvement and evaluation against observational data to enhance our understanding of SO dynamics and its response to climate change. The research emphasizes the SO's crucial role in the global climate system, particularly through the ACC's influence on heat and carbon uptake. Changes in SST, SSS, and WS can significantly impact ocean circulation, sea ice dynamics, and marine ecosystems.

Keywords: Climate change; Antarctica circumpolar current; weather prediction; sea surface temperature; salinity changes

Quantifying changes in rainfall patterns for sustainable agricultural planning: An assessment over West Bengal

Amrik Bhattacharya[a], Priyadarshini Ghosh[b] and Amitlal Bhattacharya[c]
[a]Lakhuria High School (H.S.), Kaliganj, Nadia, West Bengal-741150, India [b]S.R. Fatepuria College, Beldanga, Murshidabad, W.B, India
[c]Dukhulal Nibaran Chandra College, Aurangabad, Murshidabad-742201, India
Email. amitlal1980@rediffmail.com

ABSTRACT

Investigating the changes in mean regional rainfall pattern (spatial and temporal) based on the analysis of historical climate data and identifying the trends, anomalies and shifts in annual and South-West (SW) monsoon season. So that alternate method for agriculture can be incorporated and the crops can be chosen accordingly. Due to SW monsoon West Bengal receives rainfall in the months of June,July,August,September (JJAS). The change and mean rainfall pattern has been calculated by analyzing monthly rainfall data from 1989 to 2018. Arithmetic average of all the station rainfall values within the district has been considered to compute Monthly district wise rainfall series. To validate the analysis and result there on R^2 test has done and Microsoft excel is used for statistical analysis the data series and to draw the graphs. The state gets 77 % rainfall during the southwest monsoon season. Highest rainfall of 30% in the month of July and the August month gets 26% of the south west monsoon rainfall. June and September months receive around 22 % of south west monsoon rainfall. The variability of monsoon or annual rainfall is also very less (14%) and highest variation of 28% found in the month of September during the last 30 years. In the time series analysis, it is clear that a decreasing trend is followed for the month of June, July, August and September continuously. The regressions are showing a negative gradient which in turn implies the decreasing trends of the rainfall pattern. The R^2 values are 0.2857 and 0.2286 and which are agan proofing the validity of the results.

$y = -1.15171x + 2086.6$ …….(5) $y = -10721x + 1584.9$………(6)

The district wise variation of the rainfall pattern is showing that the highest average SW Monsoon and annual rainfall of about 3000 mm and 3800 mm occurred in the northern districts like Darjeeling, Jalpaiguri of West Bengal. The average lowest Monsoon seasonal and annual rainfall happened in Nadia. In the monsoon season Cooachbeher, Howrah, Malda, South 24 Parganas and Dakshin Dinajpur districts has a significant decreasing rainfall trend and annually in addition to this district Murshidabad, Birbhum, Purulia, Jhargram, Paschim Medinipur districts also getting lesser rainfall day by day. Maximum rainy days of around 86 to 109 days are found in Northern districts whereas 51 to 86 days in rest of West Bengal. In JJAS 7-12 days and yearly 9-14 days heavy rainfall in North and 2-7 days and 2-9 days in rest part. It is evident that Western part of the state suffers maximum dry days annually. Acordingly, crop selection be made in lieu of traditional cultivation which is getting hampered by the changing rainfall pattern.

Keywords: Monsoon,rainfall,climate change,agriculture

Simulation of Premonsoon Thunderclouds over Two ClimaticRegimes: Evaluation and Dichotomous Detection

Rupraj Biswasharma[1], G. Ch. Satanarayana[2], Sunil D Pawar[1] and Sanjay Sharma[31]
Indian Institute of Tropical Meteorology, Pune, India
[2]K.L. University, Guntur, Andhra Pradesh, India [3]Dimapur Government College, Dimapur, Nagaland, India
E-Mail: ruprajb@tropmet.res.in

ABSTRACT

Accurate simulation of thunderstorms and lightning is crucial for improving hazard predictions, mitigating risks, and enhancing public safety, especially in regions prone to extreme weather events. This study simulates premonsoon (April) thundercloud properties over Northeastern (Kohima, 25.6°N, 94.1°E) and Eastern (Rampurhat, 24.2°N, 87.8°E) India. Thunderclouds were detected using an Electric Field Mill (EFM-100) and a Lightning Detector (LD-350), while the WRF model was employed to simulate thundercloud properties. Simulations were performed for all 30 days in each region, regardless of thundercloud occurrence, to evaluate the model's accuracyin distinguishing between thundercloud and non-thundercloud days. The regional variability of cloud-to-ground (CG) flash density was well represented by model, with higher flash density in Rampurhat (mean: 39×10^{-4} km^{-2} h^{-1}) compared to Kohima (mean: 31×10^{-4} km^{-2} h^{-1}), consistent with observations. Simulated CG flash density showed marginal overestimation in Kohima and underestimation in Rampurhat, with spatiotemporal deviations fromLD-350 observations in both regions. Simulations effectively captured regional variations in dynamical (vertical velocity, wind shear) and microphysical (mixing ratios: q_{ice}, $q_{graupel}$, q_{cloud}) properties, with higher values over Rampurhat. Six stability indices were analyzed to determine the most effective index for detecting thundercloud/non-thundercloud days. TT ≥ 38°C provided the best results in Kohima, while CAPE ≥1680 J kg^{-1} was most effective in Rampurhat, suggestingdifferent mechanisms for thundercloud development in these regions. Dichotomous detection for all 30 days over Kohima (Rampurhat) resulted in 14 (21) successful detections, 5 (1) misses, 3 (1)false alarms, and 8 (7) correct rejections. The study highlights that predicting thunderclouds over the complex hilly terrain of Northeast India is more challenging than over Eastern India and contributes to better strategies for mitigating lightning hazards.

Keywords: CG flash density, thundercloud simulation, stability indices, WRF model, Dichotomous detection

Influence of Initial Condition in Global Forecast System Model (GFS T1534)for Predicting Heavy and Extreme Rainfall over India

Arindam Ghosh[a,b] , Malay Ganai[b]

[a] *Indian Institute of Technology, Jodhpur, India*
[b] *Indian Institute of Tropical Meteorology, Pune, IndiaE-Mail: m23ma1004@iitj.ac.in*

ABSTRACT

Accurately predicting heavy and extreme rainfall events is crucial for early warning systems and disaster management in India, where monsoon rainfall has significant social and economic impacts. This study investigates the role of initial conditions (ICs) in the Global Forecast System (GFS T1534) model for forecasting such rainfall events during the Indian summer monsoon (2020–2023). The ICs at various initialization times (00Z, 06Z, and 12Z) were analyzed to assesstheir influence on prediction accuracy, focusing on heavy rainfall episodes. Observational data from the Global Precipitation Measurement (GPM) satellite and ERA5 reanalysis data were used to validate model forecasts. Several heavy rainfall events were selected, and the forecasts were compared against observed data, considering atmospheric parameters suchas horizontal divergence, moisture convergence, and vertical velocity. The results show that the 06Z initial condition tends to provide better forecasts for most events, achieving improved accuracy in terms of rainfall intensity and spatial distribution. However, the GFS T1534 model generally underestimates the intensity of heavy rainfall across all ICs. The study emphasizes the importance of refining initial conditions to enhance forecast reliability,which is critical for more effective early warnings and disaster mitigation strategies. The findings highlight that model performance varies significantly with IC timings, and ensemble forecasting using multiple ICs can provide a broader range of predictions, thereby improving forecastrobustness.

Keywords: Extreme weather events; Monsoons; Climate change; Weather prediction; Disaster management.

Observed Variation of ITCZ over the Indian monsoon domain during ENSO years

Priya Kumari[a,b] , B.Preethi[a] , M.Mujumdar[a]

[a] *Indian Institute of Tropical Meteorology,Pune*
[b] *Department of Atmospheric and Space Science,SPPU*
E-Mail: priya.kumari@tropmet.res.in

ABSTRACT

The Intertropical Convergence Zone (ITCZ) significantly shapes climate and weather patterns in tropical regions, accounting for about 32% of global precipitation. This zone, which marks the meteorological equator, is characterized by a permanent low-pressure system. It forms where trade winds, carrying heat and moisture from surface evaporation and sensible heating, converge, leading to enhanced convection, cloud formation, and precipitation. The ITCZ is also linked to the monsoon trough, particularly in the Indian region. A northward shift of the ITCZ over the southeast Bay of Bengal has been connected to the early onset of the Indian summer monsoon. Therefore, the spatiotemporal variability in the ITCZ's properties can influence monsoon variability. Since the Indian monsoon is largely driven by the seasonal migration of the ITCZ, understanding its regional characteristics is key to explaining fluctuations in monsoon rainfall, especially in the context of climate change. This study investigates how the characteristics of the ITCZ vary across different monsoon seasons and examines its relationship with Indian Summer Monsoon variability. The findings highlight significant variability in the ITCZ, particularly during El Niño and La Niña years, which further impacts monsoon behavior.

Keywords: Monsoon trough; Monsoon variability; El Niño; La Niña

HEAT WAVES IN NORTHWEST INDIA: NORTH ATLANTIC BLOCKING AND ROSSBY WAVE IMPACTS IN +1.5°C AND +2°C WARMER CLIMATES

Arulalan T [a], Krishna AchutaRao [b]

[a] *India Meteorological Department, Ministry of Earth Sciences, Government of India*
[b] *Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi*
E-Mail: arulalan.t@imd.gov.in

ABSTRACT

Research has identified a significant teleconnection between atmospheric blocking events over theNorth Atlantic and heat waves in Northwest India. This relationship, characterized by a 2-day lag,has been confirmed by previous studies (Ratnam et al., 2016). Our analysis of ERA5 reanalysis and India Meteorological Department (IMD) data reveals further insights into this phenomenon. During the March-June season (MAMJ) from 1979-2018, Geopotential height at 500 hPa (Zg500)over the North Atlantic Granger causes high daily maximum temperature (TMAX) anomalies in Northwest India with a 3-day lag. We investigated the driving force behind this teleconnection, identifying specific Rossby wave numbers associated with North Atlantic blocking and subsequentTMAX anomalies. To explore how this teleconnection might change in a warmer climate, we utilized multi-model outputs from the Half a degree Additional warming, Prognosis and Projected Impacts (HAPPI) project. Granger Causality tests using 1500 ensemble members from 5 HAPPI models indicate thatthis teleconnection will persist in +1.5°C and +2°C warmer worlds, leading to intensified TMAXanomalies. Notably, our projections suggest that warmer climates may trigger more frequent early-season (March-April) heat events over Northwest India via increased Rossby wave activity. However, the overall seasonal frequency of heat events remains unchanged. These findings have significant implications for climate modeling and prediction, highlighting the importance of considering teleconnections and Rossby wave activity in projections of future climate scenarios. Our study contributes to the understanding of climate variability and its impacts on regional weather patterns. The persistence of this teleconnection in warmer climates underscores the need for targeted climate mitigation and adaptation strategies to address heat-related extremes in vulnerable regions like Northwest India.

Keywords: Heatwave; Teleconnection; Rossby wave; North Atlantic ABlocking; Climate change

DEVELOPMENT OF A BIAS CORRECTION ALGORITHM FOR IMPROVING HEAVY RAINFALL FORECASTS FROMMULTIPLE NWP MODELS DURING THE SOUTHWEST MONSOON

M. T. Bushair and D. R. Pattanaik

India Meteorological Department, Ministry of Earth Sciences, New Delhi-3
E-Mail:Bushair.imd@gmail.com

ABSTRACT

Bias correction in rainfall forecasts is crucial for improving the accuracy of predictions from Numerical Weather Prediction (NWP) models, particularly for heavy rainfall events. In this study, an attempt has been made to develop an algorithm for bias correction in rainfall forecasts by comparing the outputs of several NWP models and a Multi-Model Ensemble (MME) with observed rainfall data. The analysis focuses on addressing the common issue of underprediction of heavy rainfall by NWP models during the Indian summer monsoon. We use forecast data from four NWP models: IMD-GFS, NCEP-GFS, NCUM, and ECMWF, covering four southwest monsoon seasons (June–September) from 2021 to 2024. The observed data, sourced from the India Meteorological Department (IMD), are used to train the algorithm, which aims to correct the systematic biases present in the model forecasts. By employing statistical methods for bias correction, we aim to improve the accuracy of rainfall forecasts, particularly for extreme rainfall events, which are critical for effective disaster management and water resource planning in monsoon-prone regions. Preliminary results show significant improvements in forecast accuracy, especially in the prediction of heavy rainfall, when applying the developed bias correction algorithm. This work contributes to enhancing the reliability of operational rainfall forecasts during the monsoon season by leveraging advanced statistical techniques and multi-model data integration.

Keywords: Bias correction; Rainfall forecast; NWP models; Heavy rainfall; Southwest monsoon.

Applying Machine Learning techniques to predict trends of air pollutant PM10 in Indian cities-Delhi and Bangaluru

Gaurav Singh [a]*, Mrs. Suman Gurjar [a], Anikender Kumar [b]

[a] Information System and Services Division (ISSD)
India Meteorological Department Mausam Bhawan,Lodi Road,New Delhi
[b] Environment Monitoring and Research Center (EMRC)
India Meteorological Department Mausam Bhawan,Lodi Road,New Delhi
* **E-mail:** gaurav051823@gmail.com

ABSTRACT

Prediction of air quality is a topic of great interest in air quality research due to direct association with health effect. Air pollution in urban environments, particularly from fine **particulate matters** (PM2.5 and PM10), poses significant health risks. The prediction provides pre-information to the overall population of the area about the status of pollution on which they can take precautionary measures and can protect their health. In this paper, the Machine learning Algorithms-Random Forest Regression and Gradient Boosting Regression, are applied to predict the trend of air pollution in the Delhi and Bangaluru cities of India . These models are leveraged climate variables like temperature, Boundary Layer Height,Wind speed etc from the **ERA5 Reanalysis data** of period 2018-2022.Both the cities lies at almost similar latitude that is why they faces the same type of weather conditions over the year.During the period from 2018 to 2022, the model's accuracy was assessed using air quality monitoring data of PM10 from the CPCB(Central Pollution Control Board) Station network in these cities. The validation results revealed a strong coefficient of determination (R^2) ranging from 0.88 to 0.98. Comparative analysis showed that the **Random Forest (RF) Regression model** exhibited superior predictive performance relative to **Gradient Boosting Regression model** and the R^2 for the delhi city is more better than the case of bangluru city that shows the good model accuracy for the delhi in predicting the **PM10** values for future scenario. The RF model also achieved low root mean squared error (RMSE) and mean absolute error (MAE) values, reflecting its high precision. The extensive evaluation of the RF model across multiple temporal scales provides critical insights for policymakers and environmental health professionals, facilitating the development of data- driven strategies for effective air quality management.

Keywords**:** Particulate matters; PM10; ERA5 Reanalysis data; Random Forest (RF) Regression model; Gradient Boosting Regression model

Air Pollution Monitoring and Its Role in Wheat Crop Yield Reduction

Pradeep Kumar , R. Bhatla, and Arti Choudhary

Department of Geophysics, Banaras Hindu University, Varanasi E-Mail:pradeepph84@gmail.com

ABSTRACT

The continuous increase in air pollution is progressively deteriorating agricultural crop production and has become a significant challenge for food security. To address these emerging challenges and issues, the present study is conducted in Uttar Pradesh, India. In this study aerosol optical depth (AOD) and black carbon (BC) using Moderate Resolution Imaging Spectroradiometer (MODIS) and Modern-Era Retrospective Analysis for Research and Applications, version 2 (MERRA-2) model data at 0.5°×0.625° resolution is used during years 2000 to 2024. The historical wheat crop yield data is collected from the Ministry of Agriculture's Directorate of Economics and Statistics (https://aps.dac.gov.in/APY/Index.htm). Graphical representations indicate that the air pollutants are negatively correlated to wheat crop yield. Its means increasing air pollutions are indicating decreasing wheat crop yield. Air pollution monitoring plays a crucial role in understanding and mitigating the adverse effects on wheat crop yield. Pollutants such as AOD, and BC can impair photosynthesis, reduce growth, and lead to lower yields. Impact analysis of these air pollutants is showed on wheat crop production in different districts of Uttar Pradesh**.** Continuous monitoring allows for the assessment of pollutant levels and their temporal and spatial variations. By correlating air quality data with crop performance, researchers can identify critical thresholds and develop strategies to protect crops. Effective monitoring informs policy decisions, promotes sustainable agricultural practices, and ensures food security by minimizing the detrimental impacts of air pollution on wheat production.

Keywords: AOD, BC, Remote Sensing, Wheat Crop, Correlation

The impact of Quasi-Biennial Oscillation on Indian Summer Monsoon Subseasonal variability

Shubham Waje[a,b], Susmitha Joseph[a] , Phani M. Krishna[a], and A. K. Sahai[a]

[a] *Indian Institute of Tropical Meteorology, MoES, Pune,*

[b] *Department of Atmospheric and Space Sciences, Savitribai Phule Pune University, Pune*

E-Mail: shubham.waje@tropmet.res.in

ABSTRACT

The stratosphere has been identified as an important source of predictability for a range of processes on subseasonal to seasonal (S2S) time scales by various pathways. One of them is an equatorial pathway in which the QBO (Quasi Biennial Oscillation) is a dominant phenomenon. The QBO has a downward propagating easterly and westerly zonal wind pattern dominant in the lower and middle stratosphere bounded vertically (between 100 hPa and 10 hPa) and meridionally (between 10º N and 10º S), which has approximately 28 months of periodicity. The QBO phase influences the Boreal Wintertime convections of eastward propagating ISO (Intra- seasonal Oscillations) called MJO (Madian Jullian Oscillations). MJO is found to be more organized and persistent during the Easterly phase of the QBO. Even MJO prediction skill is enhanced by a couple of days in the easterly phase of the QBO. This study evaluates to what extent the QBO impacts the Indian monsoon and its subseasonal varibilty.

Keywords: Quasi Biennial Oscillation; Indian Summer Monsoon; subseasonal varibilty; Wind Circulation.

Harnessing Deep Learning for Rainfall Prediction: A Comparison of LSTM and ARIMA Models

Rattan K. Datta[a], and Kavita Pabreja[b]

[a]*Mohyal Educational and Research Institute of Technology*
[b]*IT & Systems,*
Lal Bahadur Shastri Institute of Management E-Mail:kavitapabreja1@gmail.com

ABSTRACT

With the advancement of Artificial Intelligence and Machine Learning, alternate prediction models have been explored for Rainfall forecasting. India is highly dependent on accurate rainfall prediction, especially due to its reliance on monsoonal rainfall for agriculture, water resources, and overall economic stability. The inherent variability in rainfall patterns makes it difficult to predict accurately. Traditional statistical models like the AutoRegressive Integrated Moving Average (ARIMA) have been used for a long time to deal with time series forecasting. However, advancements in machine learning, notably using Long Short-Term Memory (LSTM) networks, have yielded promising results that are able to take complex non-linear temporal dependencies into account. This study sets out to compare the effectiveness of traditional ARIMA models with the LSTM models in rainfall forecasts at a monthly scale for Bihar state from 1901 to 2015.The dataset was divided into training (80%) and testing (20%), in order to evaluate the model. ARIMA which is a traditional time series model, predicts linear patterns in this type of data, produced RMSEvalue of 203.9, which was moderate for its class but also signaled the inability that is common in any conventional statistical method when faced with non-linear patterns. On the other hand, deep learning LSTM model delivered very impressive results withRMSEof 92.1, which is quite smaller and testified that the proposed model outperformed conventional ARIMA. The decrease in error implies that the LSTM model is able to handle the temporal complexity and variability in Rainfall datasets.

This work further reinforces the fact that modern machine learning algorithmsare suited for meteorological forecasting because of their ability to model long-term dependencies and non-linear relationships. Further work may go into improving our LSTM-based models by considering more input features like temperature, humidity, and pressure.

Keywords: Rainfall forecasting; Long Short-Term Memory models; AutoRegressive Integrated Moving Average; Deep Learning.

Climatological Analysis of Indian Summer Monsoon Variability

Subhash, Archana Maurya, R Bhatla
Department of Geophysics, ISc,BHU, Varanasi, India
E-Mail: subhash1983bhu@gmail.com

ABSTRACT

Over an extensive temporal span spanning seven decades (1948–2017), this research undertakes a meticulous examination of fundamental meteorological variations significantly shaping the dynamics of the Indian Summer Monsoon (ISM). Employing NCEP/NCAR reanalysis datasets, the study delves into spatial and temporal nuances, employing statistical methodologies such as the standardized anomaly index and the Mann-Kendall trend test. The investigation covers climatology, early and late phases, and multidecadal intervals across distinct regions of India. Focusing on six key regions— Northern India (NI), Central India (CI), Southern India (SI), the Arabian Sea (AS), the Bay of Bengal (BoB), and the Equatorial Indian Ocean (EIO)—the study unveils a comprehensive understanding of ISM variability. Key outcomes emphasize notable shifts in standard deviation values and coefficients of variation, revealing the influence of early-late phase and multidecadal modulations on chosen climatic indicators. Alarming trends emerge in surface temperatures, particularly in Northern, Central, and Southern India, with a disconcerting range of 0.5–1.0°C Prominent areas exhibiting intensified early-late phase and multidecadal variability, coupled with average precipitation increments(approximately 1–3.5 mm/day), are identified over the Bay of Bengal, Equatorial Indian Ocean, and Southern India. The study correlates the reduction in mean rainfall patterns and related variability withescalating surface warming, leading to a pronounced weakening of surface zonal winds over specific regions. This weakening, in turn, significantly impacts crucial atmospheric circulations like the Somalijet and robust low-level jet (LLJ) during the ISM season. Meridional winds at both surface and upper levels demonstrate noteworthy enhancement over the Arabian Sea and Equatorial Indian Ocean of particular concern is the most recent decadal anomaly (2008–2017), indicating decreasing trends in anomalies related to precipitation and wind circulation at 850 and 200 hPa across all regions. Recent years also witness asymmetrical alterations in meteorological parameters and their distribution during the evolving ISM, signaling a response to changing climate dynamics.

Keywords**:** Meteorological parameters; monsoon variability

Projection of Extreme Rainfall in Indian Himalayan Region usingCMIP6 simulations

Payoshni Samantray
CSIR FOURTH PARADIGM INSTITUTE

ABSTRACT

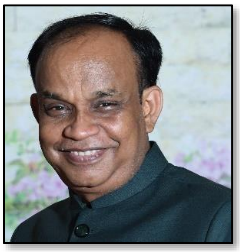
The study utilized a total of twelve General Circulation Models (GCMs) sourced from the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models underwent statistical downscaling and bias correction methodologies. The research aimed to integrate these GCMs within the context of the Shared Socioeconomic Pathways (SSP) scenarios, specifically focusing on SSP126, SSP245, SSP370, and SSP585. The main goal is to analyze the anticipated alterations in mean rainfall intensity and daily extreme rainfall occurrences, including the frequency, intensity and duration during the southwest (SW) and northeast (NE) monsoon seasons in the forthcoming years (2025–2050) over the Indian Himalayan Region (IHR). These projections were benchmarked against the baseline period of 1951–2014. Additionally, the study investigated variations in the quantitative rainfall, along with their corresponding daily extremes.A thorough analysis is performed using a varied array of GCMs to yield a comprehensive understanding of potential climate changes in the near future (2025-2050). An extensive assessment is conducted to evaluate the reliability of the models for these projections. Among the model composites, the selected combination of two models, i.e. Can_ESM and MRI_ESM, exhibited remarkable capability in accurately depicting a broad spectrum of observed characteristics related to extreme rainfall events (ERE) in IHR. The assessment of GCM simulations, particularly regarding their ability to forecast extreme precipitation, is significantly dependent on the application of Multi-Model Ensembles (MMEs). Furthermore, this research highlights the considerable potential of MMEs in improving the precision of climate forecasts, not only within the IHR but also in other regions with analogous climatic conditions.

Keywords: Shared Socioeconomic Pathway; Indian Himalayan region; extreme rainfall event; Multi model ensemble

DIAGNOSTIC ANALYSIS OF EXTREME HOT SUMMER SEASON 2024 IN RAJASTHAN : A CASE STUDY

Roop Narayen Kumawat, Radheshyam Sharma and Himanshu Sharma

Meteorological Centre Jaipur
Presenting Author : Kumawat Roop Narayen
E-Mail:rnk1971@gmail.com



ABSTRACT

The intense and longer spells of heat wave and warm night conditions were observed in Rajasthan in May, 2024. Above normal maximum temperatures by 2-3 degree Celsius observed at most places of the state. The Extreme Maximum temperature 50.5°*C* was observed at Churu on 28^{th} May 2024 followed by 50.0 °C at Phalodi on 25^{th} May 2024. The state disaster management department report suggests 12 human deaths and 4911 cases of heat stroke registered during the period. The daily maximum temperatures data of 18 stations across the state have been utilised to analyse the spatial and temporal distribution of frequency & intensity of heat wave in May 2024. ECMWF ERA5 reanalysis data of wind, mean sea level pressure, specific humidity and temperature data have been used to analyse the atmospheric conditions.

Cumulatively 20 days of heat wave including severe heat wave days were observed against 7 days normal frequency of heat wave days in May. Out of 20 days total 10 days were reported as severe heat wave days in the state. Two spells of heat wave observed during 7^{th}-10^{th} May and 16^{th}- 31^{st} May at many places in the state. The study reveals that absence of western disturbances, formation of anticyclonic flow in mid and upper tropospheric level over West Rajasthan and adjoining Pakistan region and warm air advection in lower level were the main causes of extreme hot summer season.

Keywords: Heat waves, Extreme temperature, Climate change, Warm air advection, Anticyclone.

Impact of Agricultural Biomass Burning on LandSurface Temperature And Aerosol Loading in theUpper Indo-Gangetic Plain

Akanksha Pandey[a] , Tirthankar Banerjee[a,b]

[a] *Institute of Environment and Sustainable Development, Banaras Hindu University*
[b]*DST-Mahamana Centre of Excellence in Climate Change Research, Banaras Hindu University,Varanasi, India*.

E-Mail:akankshapandey@bhu.ac.in

ABSTRACT

This study explores the role of Crop Residue Burning (CRB) in shaping Land Surface Temperature(LST) and influencing meteorological variables in the upper Indo-Gangetic plain, with implications for climate extremes. Understanding these interactions is crucial, as agricultural practices can significantly affect local and regional climate patterns. We analyze the relationshipsbetween CRB, LST, and aerosol loading during the post-monsoon period from 2016 to 2018 usingremotely sensed data. By categorizing CRB hotspots into high and low intensity, we identify a significant correlation between LST and mean Fire Radiative Power (FRP) in high-intensity zones,peaking in 2017. The effects of CRB on LST persist for one to two days post-burning. Additionally, a positive correlation between Aerosol Optical Depth (AOD) and mean FRPhighlights the critical role of aerosols during agricultural burning, particularly in winter when air quality issues intensify. Incorporating meteorological variables, our spatial analyses reveal that theimpacts of CRB on LST vary across different land cover types, potentially influencing soil moisture and nutrient dynamics, which may contribute to broader climate variability. These findings underscore the necessity for sustainable agricultural practices to mitigate the negative effects of crop residue burning on environmental health and climate stability. Future research should focus on the long-term implications of biomass burning and its interactions with meteorological factors to deepen our understanding of its role in exacerbating climate extremes. This systematic approach advances our comprehension of biomass burning dynamics, providing valuable insights for evidence-based environmental policies and climate adaptation strategies.

Keywords: Aerosol loading, Climate variability, Crop residue burning, Land surface temperature

Meteorological Influences on Aerosol Accumulation in the Central and LowerGangetic Plain

Kumari Aditi[a] , Tirthankar Banerjee[b]

[a]*Institute of Environment and Sustainable Development, Banaras HinduUniversity, Varanasi, India.*

[b]*DST-Mahamana Centre of Excellence in Climate Change Research, BanarasHindu University, Varanasi, India.*

E-Mail: aditiiesd@bhu.ac.in

ABSTRACT

The spatio-temporal variations in aerosol loading over the central to lower Gangetic Plain (IGP) in South Asia were investigated, focusing on how regional meteorology influences the accumulation of aerosols. The study utilized Aerosol Optical Depth (AOD) data at 550 nm from the Visible Infrared Imaging Radiometer Suite (VIIRS) on-board Suomi National Polar-orbiting Partnership (S-NPP), along with ERA5 reanalysis meteorological data, for the October to December period from 2020 to 2022. The analysis revealed elevated AOD levels over the lower to central IGP, primarily driven by poor vertical mixing and restricted dispersion of pollutants dueto meteorological conditions. These conditions were characterized by lower temperatures, weak wind speeds, greater subsidence, and a shallow planetary boundary layer height (averaging around1 km), creating an environment conducive to pollutant accumulation within the boundary layer. The study observed a strong inverse relationship between VIIRS DB AOD and planetary boundarylayer height, as well as vertical velocity (omega), where positive omega values (ranging from 0.05to 0.09 Pa/sec) indicated greater subsidence. The presence of a persistent anti-cyclonic system further intensified aerosol accumulation through the downward transport of pollutants from the upper Gangetic Plain to the lower regions, exacerbating AOD levels. This long-range transport of aerosols, coupled with regional meteorological patterns, was found to contribute significantly to aerosol buildup, beyond just local emission sources. The complex interaction between meteorological parameters and AOD over the region underscores that aerosol loading is not solelydriven by local emissions but is significantly influenced by regional transport and synoptic weatherpatterns. These findings highlight the need for integrated air quality management strategies, whichconsider both regional meteorological dynamics and emissions, to mitigate the adverse effects of air pollution in the central to lower IGP.

Keywords: Biomass burning, Extreme events, Planetary boundary layer, subsidence

Investigating climate change impacts over an Indian tropical station, Kolkata, using radiosonde observations for 1987 – 2024

Sristi Shamarthi Das [a], Rajesh Kumar Sahu [b], Bhishma Tyagi [a]
[a] *Department of Earth and Atmospheric Sciences, National Institute of Technology Rourkela, Rourkela 769008, Odisha, India*
[b] *Physical Science and Engineering Division, King Abdullah University of Science and Technology (KAUST), 23955-6900 Thuwal, Saudi Arabia*
E-Mail: ssd041002@gmail.com

ABSTRACT

Recent observations and modelling results suggested increased upper tropospheric warming and lower stratospheric cooling in the past few decades. This reckoning has significantly changed our understanding of complex atmospheric circulation processes that caused frequent intense weather events, raising critical global climate change challenges. In the present study, we have considered the metropolitan city of Kolkata and determined if the vertical profiles of meteorological field variables such as temperature, relative humidity, and wind speed show any trends during pre- monsoon months. Study site, Kolkata, experiences severe thunderstorms during pre-monsoon months, and the present study may be helpful to understand the changing patterns of thunderstorm occureences over the region. The upper-air observations are utilised from radiosonde datasets recorded at 00 and 12 UTC for 1987-2024. Mann Kendall test analysis and Sen's slope estimation verified the slope of the linear trend values. The key findings indicate a substantial increase in temperature trends after 2006 in the average 100 - 300 hPa pressure levels of the upper troposphere, while the relative humidity trends declined at the beginning of the 21st century. The linear trend values of wind speed show reduced values over the years.

Keywords: Thunderstorms; Climate change; Radiosonde; Tropospheric Warming

Effect of BSISO on Long Term Trends in Monsoon Depressions

Abheendra Bandary[a], Kiranmayi Landu[a], and Nirupam Karmakar[a].

[a] *School of Earth Ocean and Climate Science, Indian Institute of TechnologyBhubaneshwar, Khordha, 752050, India*
E-Mail: a23es09002@iitbbs.ac.in

ABSTRACT

Monsoon depressions (MDs) are recognized as one of the primary synoptic rain-producing weathersystems in India, contributing 17–20% of the total precipitation throughout the monsoon season. Additionally, monsoon is accompanied by one of the most prominent sub-seasonal variabilities in the tropics during boreal summer (June–September) called Boreal Summer Intraseasonal Oscillations (BSISO). Despite BSISO operating on distinct space and time scales from synoptic scales, it significantly influences synoptic systems. BSISO can influence the synoptic systems (lows, depressions, etc.) by modulating the large-scale monsoon circulation, achieved by strengthening and weakening low-level monsoon winds in wet and dry phases, respectively.

Analysis of a comprehensive time series spanning 1979 to 2021 reveals a significant declinein MD occurrences across the Bay of Bengal (BoB). Categorizing MDs into two epochs of 19 years each (1979-1997 (past) and 2003-2021 (current)) and investigating the occurrences of MDsin different phases of BSISO over BoB led to identifying the phases exhibiting more reduction forthe current epoch. To ascertain potential underlying reasons, daily anomaly values of several variables are scrutinized by analyzing the phase-wise epoch difference (epoch 2 – epoch 1). Among them, Surface Pressure (SP) revealed a significant increase in SP anomaly values during certain phases, particularly in the head region and central areas of the BoB. We speculate that theincrease in SP anomaly values may account for the decline in MDs. This increase in SP anomaly values may be attributed to the temperature gradient between the head bay (low) and southern BoB(high), resulting in the SP gradient. Besides SP, examining variables like Convective Available Potential Energy (CAPE) and Convective Inhibition (CIN), given that BSISO is linked to convective systems, yielded no significant findings, as anomaly values are decreasing across all phases. Simultaneously, atmospheric variables like Relative Humidity (RH) and Relative Vorticity(RV) at 850 hPa revealed that anomaly values exhibit a slight increase in certain phases relative toothers. The study provides insight into the decrease in the MDs from a long-term period in differentphases of BSISO.

Keywords: Monsoon Depressions; Boreal Summer Intraseasonal Oscillations; Surface Pressure.

INFLUENCE OF LUNAR PHASES ON RAINFALL VARIABILITY OVER TAMIL NADU: A SPATIO-TEMPORAL STUDY

L R Krishna [a], **T V Bharat** [b]

[a] *Research Scholar, Centre for Indian Knowledge Systems, IIT Guwahati.*
[b] *Professor, Centre for Indian Knowledge Systems and Department of Civil Engineering, IIT Guwahati*
E-Mail: krishna.r@iitg.ac.in tvb@iitg.ac.in

ABSTRACT

Understanding the spatio-temporal distribution of rainfall characteristics is crucial for enhancing predictive models, as it facilitates the identification of historical patterns essential for informed decision-making regarding prediction and preparedness. Historically, agricultural communities have relied on various astronomical phenomena, including lunar phases and planetary positions, often guided by the Indian almanac (Panchang), to forecast rainfall events. In this context, the present paper investigates trends in total rainfall, the frequency of rainy days, and classifications of rainfall events—namely, heavy, very heavy, and exceptionally heavy rainfall days—during the Southwest Monsoon (SWM), Northeast Monsoon (NEM), and out-of-monsoon periods. Utilizing almanac-based lunar phase data alongside the Indian Meteorological Department's (IMD) self-recorded rain gauge (SRRG) hourly rainfall data from 1981 to 2022 across selected stations in Tamil Nadu, which experiences rainfall from both monsoons, this study conducts a comprehensive temporal analysis of rainfall variations during the lunar cycle's waxing and waning phases. The findings indicate that significant rainfall events, in terms of both the number of rainy days and total rainfall, tend to occur more frequently during specific lunar phases, with heavy rainfall days exhibiting a pronounced concentration in certain geographic locations. Overall, this research underscores the lunar cycle's significant influence on rainfall patterns, offering valuable insights for agricultural planning and water resource management.

Key words : Lunar phases, Rainfall patterns, Almanac, SRRG

Assessing Future Climate Projections: An In-depth Analysis of CMIP6 Models on Indian Ocean Warming, Sea Surface Temperature Biases, and Precipitation Patterns

ABHIRAMI M

Second Year MSc Climate Science,

Kerala University of Fisheries and Ocean Studies,Panangad, Kochi-682506,
Abhiramimanoj55@gmail.com

Dr. Laxmikant Dhage,Scientist - C,

Indian National Centre for Ocean Information Services(INCOIS) , Ministry of Earth Sciences, Govt. of India,"Ocean Valley", Pragathi Nagar (B.O.), Nizampet (S.O.), Hyderabad – 500090, Telangana. INDIA
laxmikant.d@incois.gov.in

ABSTRACT

The Earth's surface temperature has been gradually increasing, leading to significant changes in global climate patterns. Since 1850, the Global Mean Surface Temperature (GMST) has risen by approximately 1.2°C, with an accelerated rate since the 1980s. The Indian Ocean, in particular, exhibits the fastest warming rate among tropical oceans, contributing significantly to global oceanheat gain since 1990. This study evaluates the performance of five CMIP6 models (BCC-CSM2- MR, CMCC-CM2-SR5, EC-Earth3, IPSL-CM6A-LR, and NorESM2-MM) in simulating sea surface temperature (SST) and precipitation patterns in the Indian Ocean under two socioeconomic pathways: SSP5-8.5 (high emissions) and SSP2-4.5 (moderate emissions). We assess climate changes associated with GMST increases of 1.5°C and 3°C relative to pre-industrial levels, usinga "time-shift method" to reduce uncertainties in future projections. Our findings indicate significant biases in the CMIP6 models, with cold biases in the Arabian Sea and warm biases in the western tropical Indian Ocean, affecting precipitation patterns. Future projections suggest an average warming of 2.2°C in the Indian Ocean region for a 3°C global warming scenario, with more pronounced warming in the Western Indian Ocean. Precipitation patterns indicate increasedrainfall in the Arabian Sea and central Indian Ocean, with decreased precipitation in the SouthernIndian Ocean.The study underscores the critical impact of radiative forcing on future temperatureincreases and associated changes in rainfall patterns, emphasizing the need for high-resolution models to accurately project future changes in the Indian Ocean region.

Case Study Over 2022 Forest Fire event, Uttarakhand, India: Investigation on Heatwave and Drought induced the Forest Fire

Shyam Sunder MS [1], Bhishma Tyagi [1]

[1]*Earth and Atmospheric Sciences, National Institute of Technology RourkelaE-Mail: 521er1012@nitrkl.ac.in*

ABSTRACT

Due to climate change, the decreased mortality rate of Biomes over the forests is drastically affected by drought, heatwaves and forest fires. This case study explores the nexus between extreme heat events, drought, and heatwaves inducing forest fire events for the year 2022 in Uttarakhand, India. The study area is segmented into three minor parts (S1, S2, and S3), making zone-based legitimate analysis; this helped provide small-scale variation analysis with reduced data usage complexities. ERA-5 Land Hourly dataset variables like temperature, dew point temperature, precipitation and volumetric soil water layer 1 (0 – 7 cm) were utilized for calculating Standard Soil Moisture Index (SSMI), heat wave analysis having maximum temperature for three consecutive days and analysis, vapour pressure deficit (VPD) was calculated, MODIS products used over this study such as FIRM's dataset for validation of forest fire episode, MOD13Q1 for NDVI, MOD15A2H for LAI and MOD11A1 for verifying land surface temperature. Moreover, the vegetation condition index (VCI) and canopy density levels were calculated to understand the vegetation dynamics. It was observed that the occurrence of heatwaves during April and May months above ~30 ºC decreased the surface soil moisture level, increasing the drought conditions (below ~ -2). This supported rapid senescence stages, resulting in the worst VCI ranging around ~45 - 50; eventually, this formation of live foliage and wood loads supported, inducing more fire counts (~120) in June 2022. This analysis provides imperative insights for drought and heatwave nexus with forest fires.

Keywords: forest fire; drought; heatwaves; vegetation dynamics

Understanding the regional carbon cycle dynamics over India using remote sensing monitoring and modelling

Ravi Kumar Kunchala*, Chiranjit Das, Vimal Jose, Aparna Aparajita, Debanjan Paul

Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi, 110016

E-Mail: *rkkunchala@cas.iitd.ac.in*

ABSTRACT

Atmospheric Carbon dioxide (CO_2) is one of the most important greenhouse gases (GHGs) contributing to Earth's radiative budget and climate change. Anthropogenic activities like burningof fossil fuels, alterations in land use, and cement production are the major dominant contributorsin the recent substantial increase in CO_2 emissions (Friedlingstein et al., 2020; Canadell et al., 2021). However, quantifications of these emissions are crucial for future emissions strategies at both global and regional levels (IPCC, 2021). The effective mitigation of emissions from anthropogenic activities has been hindered by uncertainties in estimating regional CO_2 sources and sinks fluxes (Ciais et al., 2013). Lack of sufficient ground-based observations are one of the majorlimitations in estimating the source and sinks along with its connectedness with the climatic conditions.

Rapid surge in fossil CO_2 emission increase in India observed at rate 3.8% per year in the period 2012-2021 (Friedlingstein et al., 2022). Earlier studies focused on the ground-based at isolated locations to address the variability of CO_2, assessing the role of the natural and anthropogenic contributions towards these changes are elusive. In this work, we will highlight the advantage thelong-term (GOSAT) and high resolution (OCO-2&3) satellite observations to address the spatio- temporal distributions, growth rates, trends and as well as seasonality associated with the climaticconditions over Indian region. We will also present an analysis using the chemistry transport modelresults in addressing the processes in connection to the source-sink relationship. Based on the analysis, we also found that from OCO-2&3, we found more soundings during the pre-monsoon seasons (March-April-May) compared to the rest of the seasons than the GOSAT satellite, which further help in better resolving the processes at different spatial scales.

Keywords: Carbon dioxide; Emissions; India; Satellite observations

The Growing Impact of Climate Variability on Indian Agriculture: A call for Resilience

Anjali Kale1[a], M. G. Jadhav2[b] and P. R. Jaybhaye3[c]

[a]*Doctoral Program of Agricultural Meteorology, Vasantrao Naik Marathwada Agriculture University, Parbhani (M.S) India*

[b &c]*Faculty Agricultural Meteorology, Vasantrao Naik Marathwada Agriculture University, Parbhani (M.S) India*

E-Mail: anjalikale5555@gmail.com

ABSTRACT

Climate change is significantly impacting Indian agriculture, exacerbating vulnerabilities due to extreme weather events like droughts, floods, heatwaves, and unseasonal rainfall. With over 50% of India's population reliant on agriculture, climate variability poses serious risks to food security, rural livelihoods, and economic stability. Rising temperatures and erratic rainfall patterns have led to water shortages and heat stress, both reducing crop yields and quality. The Indian monsoon, crucial for crop productivity, has become increasingly unpredictable, with altered intensity and distribution. Climate events like El Niño and La Niña further disrupt monsoon behavior, causing excessive rainfall or droughts, both detrimental to farming. Smallholder farmers, who often lack adaptive resources like irrigation or resilient crop varieties, are disproportionately affected. The increased variability in weather patterns adds complexity, making it difficult to predict and plan agricultural activities. Future projections for India indicate a continued rise in temperature and increased rainfall variability, exacerbating these challenges. To address these issues, there is a need for an integrated approach that combines improved climate forecasting, sustainable farming practices, and policy interventions. Climate-resilient agriculture (CRA) focuses on optimizing crop and livestock systems to enhance productivity and income under climate variability. Additionally, improving irrigation infrastructure and promoting sustainable farming techniques are essential to reduce the sector's vulnerability to climate change. Advances in climate science and high-impact weather predictions offer opportunities for better preparedness and resilience.

Keywords: Climate change; Weather events; Agriculture; Monsoon; Climate-resilient agriculture

INFLUENCE OF LOW-PRESSURE SYSTEMS ON EXTREME RAINFALL EVENTS OVER THE INDIAN REGION

(Pritee Priyanka, Mohapatra), Nirupam Karmakar

[a] *SEOCS, IITBBS*
[b] *SEOCS, IITBBS*
E-Mail:a24ao09008@gmail.com

ABSTRACT

The extreme rainfall events (EREs) are increasing globally both in intensity and frequency over the past few years. Over the Indian region they are mostly linked to the Low-pressure systems (LPSs), but still, some of them are occurring without the influence of LPSs. LPS has a typical nonuniform structure of rainfall around it where the significant amount rainfall happens in the southwest quadrant and gradually lessen towards the east. Around 1583 EREs occurred in this significant rainfall area on boreal summer from the year 1998 to 2019. Even though the rest 20% of EREs are not influenced by LPS but rainfall intensity is nearly same as the EREs associated with LPSs. The study of atmospheric dynamics and thermodynamics could not explain this striking similarity. The vortex centric composites of EREs showing specific humidity at 850 hPa showed some southwest-northeast elongated pattern of surplus moisture. This pattern is more prominent for EREs over land than ocean.

Keywords: Indian Monsoon, Extreme rainfall events, Low Pressure system.

Dynamical Diagnostics and WRF Simulation of the Prolonged May-June 2024 Heatwave Over India

Hemadri Bhusan Amat*, Nitin Lohan, D.R. Pattakaik

India Meteorological Department,

New DelhiEmail:*

hbamat@gmail.com

ABSTRACT

The unprecedented heatwave over India in May- June 2024 has raised significant concerns regarding its underlying dynamics and potential impacts. This study investigates the prolonged heatwave event by combining dynamical diagnostics and numerical simulations using the Weather Research and Forecasting (WRF) model. We first analyze the synoptic conditions and large-scale atmospheric patterns contributing to the persistence and intensity of the heatwave. The dynamical diagnostics reveal the role of blocking high-pressure systems, anomalous jet stream patterns, and regional thermodynamic conditions in sustaining extreme temperatures. Subsequently, the WRF model is employed to simulate the heatwave event, focusing on capturing temperature anomalies' spatial and temporal evolution. The model outputs are validated against observational data, demonstrating high accuracy in reproducing the critical characteristics of the heatwave. Sensitivity experiments are conducted to assess the influence of various physical processes and initial conditions on the heatwave dynamics. The results indicate that the combined effect of enhanced solar radiation and anomalous atmospheric circulation patterns played a critical role in the development and persistence of the heatwave. The study also highlights the importance of high-resolution numerical simulations in understanding complex meteorological phenomena and provides insights into improving heatwave prediction and preparedness strategies. This comprehensive analysis of the May-June 2024 heatwave over India would contribute to the broader understanding of extreme weather events in the contextof climate variability and change.

Keywords: Heatwave, WRF, Dynamical Diagnostics

ASSESSMENT OF WET SPELL OVER NORTHWEST INDIA DURING FIRST WEEK OF MARCH 2024

Shashi Kant[a] and Krishna Mishra[a]

[a] *ESSO-India Meteorological Department, Ministry of Earth Sciences, New Delhi 110003E-Mail:onlineskmishra@gmail.com*

ABSTRACT

Winter precipitation in the Western Himalayan Region (WHR) and the plains of Northwest India(NWI) is a notable weather phenomenon that typically occurs between December and early March. The winter months bring critical precipitation to the WHR and NWI, impacting agriculture and water resources. This paper investigates a significant wet spell that took place during the first weekof March, characterized by heavy rainfall, intense thunderstorms, and hailstorms across both regions.

The wet spell was primarily influenced by a Western Disturbance (WD), which led to the formation of induced cyclonic circulation and a induced low-pressure systems. These atmospheric conditions created a conducive environment for the occurrence of heavy precipitation. Additionally, a steadysupply of moisture from the Arabian Sea significantly contributed to the event. This influx of moisture enhanced rainfall intensity and facilitated the development of severe thunderstorms and hail.

This investigation highlights the intricate relationship between Western Disturbances and moisture supply in generating winter precipitation events in the WHR and NWI. Understanding these interactions is vital for improving weather forecasting and managing the effects of extreme weather in the region. Future research should explore the long-term implications of these weather patternsin the context of climate change.

Keywords**:** WD, Western Himalayan Region, Northwest India, Heavy Precipitation, Hailstorm.

Nowcasting of Weather Using Doppler Weather Radar Data

Navdeep Singh*, M.S. Shekhar, Amreek Singh

Defence Geo-informatics Research Establishment, DRDO E-Mail: navdeep.singh.dgre@gov.in

ABSTRACT

This study explores the utilization of Doppler Weather Radar (DWR) data for improving short-term weather forecasting through nowcasting techniques. Nowcasting, which focuses on predicting weather conditions within a few hours, is crucial for timely decision-making in weather- sensitive scenarios. We employ advanced nowcasting algorithms, drawn from well-established literature, to analyze radar data and estimate weather pattern movements with enhanced accuracy. Our approach involves the application of the Lucas-Kanade (LK) method for optical flow estimation, followed by the Spectral Prognosis (S-PROG) method for generating short-term forecasts. The combination of these methods with high-resolution radar data has shown promising results, allowing for the reliable prediction of near-future weather patterns. Additionally, we employed statistical tools like the ROC Curve and Rank Histogram to differentiate between event and non-event scenarios, further validating the effectiveness of our predictions.

The findings suggest that integrating Doppler radar data with these sophisticated nowcasting techniques can significantly enhance the accuracy and practicality of short-term weather forecasts. This improved reliability has wide-ranging implications for applications where precise weather predictions are critical, such as in planning and safety measures.

Our work contributes to the ongoing development of nowcasting techniques, offering a framework that could be adapted for various geographic regions and weather conditions. The positive outcomes from this study underscore the potential of combining advanced radar data with robust forecasting algorithms, paving the way for more practical and widespread use of nowcasting in operational meteorology.

Keywords**:** Nowcasting; Doppler Weather Radar; Short-term Forecasting; Weather Prediction; ROC Curve

Biennial Variability of Boreal Spring Surface Air Temperature over India

Kethavath Lakshma[1,2], Gopinadh Konda[1], J. S. Chowdary[1], and C. Gnanaseelan[1]

[1]Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune, India

[2]Savitribai Phule Pune University, Pune, India

E-Mail: kethavath.lakshma@tropmet.res.in

ABSTRACT

In this study, we report significant biennial variability or oscillation (BO) in the boreal spring (March-May) Surface Air Temperature (SAT) over India and unravelled the causative mechanisms. The positive phase of the BO exhibit significant seasonal warming over India, whereas seasonal cooling is observed during the negative phase of BO. Heat wave days are more during the positive phase of BO compared to negative or neutral phase. The positive (negative) phase of BO is generally coherent with the central (eastern) Pacific warming (cooling) years. Theanomalous low-level divergence associated with low-level anticyclonic circulation induces less cloudiness and intense surface solar radiation during the positive phase, favouring surface warmingover India. The evolution of some positive and/or negative phases of BO without any large scale forcing from the equatorial Pacific suggested the possibility of alternate pathways. The strong anomalous upper-level (at 200 hPa) anticyclonic circulation provoked by mid-latitude Rossby waves is found contributing to the positive phase, thereby highlighting the role of dominant mid- latitude pathways in the biennial SAT variability in addition to El Niño forcing. The sinking motion associated with persistent high, and the associated adiabatic compression also supported surface heating during the positive phase of BO. On the other hand, the mid-latitude Rossby waveinduced upper-level cyclonic circulation is found contributing to the negative phase. The sinking motion associated with persistent high, and the associated adiabatic compression also supported surface heating during the positive phase of BO. In contrast, negative soil temperature anomaliesand high latent heat flux release to the atmosphere supported surface cooling during the negative phase.

Keywords: Surface air temperature, wavelet analysis, biennial oscillation, El Niño, Rossby WaveSource

SQUALLS ASSOCIATED WITH THUNDERSTORMS OVER INDIA

Pradeep Sharma[1], Abul Amir Khan[2], Soma Sen Roy[1], M.Mohapatra[1]

[1] *India Meteorological Department*

[2] *ACOAST, Amity University Haryana*

E-mail: pradeepsh70@gmail.com

ABSTRACT

Thunderstorms over India are common phenomena and occur almost during whole year throughout entire length and breadth of the country, however with varying frequency and degree of severity. The severity of theses thunderstorms is determined in terms of associated hazards like lightning, hail, squall etc. The present study analyzes the severity of thunderstorms as signified by observed data of squall events from IMD stations. The diurnal, monthly, seasonal as well as directional aspects of squalls have been studied by separating the events into different time periods of the day. The study revealed that the squall activity follows a different mechanism than the thunderstorm and hail activities as noticed in earlier studies. The premonsoon to early monsoon period (March to June) is most prone for squall activity with peak frequency in May. The severity was found to be maximum during March to May. Diurnally, the peak squall activity period was noticed during evening hours with 6-7 events per hour during this period on an average per year. The severity was found to have two diurnal peaks one around forenoon to noon hours and another around evening to early night hours with the extension of potentially severe squalls till mid night. The activity decreased significantly from July onwards. The spatial maximum of squall events over India clearly brings out the importance of Sub-Tropical Westerly Jet, Heat Low, Western Disturbance and interaction of southwesterly/southeasterly from Arabian Sea/Bay of Bengal with dry airmass over north India. The directional analysis revealed that the most preferred direction was northwesterly during till June, however from July onwards other direction contributed more significantly. These aspects will be discussed in detail during the presentation.

Key words: Thunderstorm, Squall, Severity, Diurnal

Spatiotemporal Dynamics of Extreme Precipitation in Monsoon Depressionsand Their Relationship with NDVI

Imamah Ali[a] , Krishna Kishore Osuri[a]

[a] *Department of Earth and Atmospheric Sciences, NIT Rourkela*

E-Mail: imamahali11@gmail.com

ABSTRACT

Monsoon depressions (MDs) are significant synoptic-scale disturbances within the quasi-stationary planetary-scale monsoon trough over the Indian region during the summermonsoon season (June to September). These depressions are critical for contributing to the majority of rainfall in agrarian North India, where accurate precipitation estimates are essential for agricultural planning and water resource management. Various studies have analyzed the spatiotemporal structure of precipitation in Indian summer monsoon depressions, exploring their trends and characteristics. However, research on the relationship between vegetation dynamics, particularly the Normalized Difference Vegetation Index (NDVI), and extreme precipitation events associated with MDs remains limited.

NDVI is a crucial indicator of vegetation health and productivity, reflecting changes in biomass and photosynthetic activity in response to climatic variables. This study aims to address the gap by analyzing the impact of MD-induced extreme precipitation events on vegetation cover in Central India (20˚N to 25˚N, 75˚E to 90˚E) from 2003 to 2022. Utilizing MODIS Terra Daily NDVI and GPM IMERG precipitation data, the study investigates temporal and spatial variations in vegetation response to extreme rainfall events. Various analytical methods, including wavelet analysis, cluster analysis, and generalized linear regression models, were employed to examine long-term trends and relationships between NDVI and precipitation. Mann-Kendall trend tests and Sen's slope estimator detected trends, while wavelet analysis revealed periodic variations, and cluster analysis identified distinct vegetation response patterns during different MD events.

Keywords: Extreme precipitation; Monsoon Depressions; NDVI; Agriculture; Disaster management

Sensitivity of cloud microphysics on the simulation of heavy rainfall in WRF- a case study for the 7–10 August 2019 Event over Kerala, India

Mohan Murali Krishna Gorja[1,3], Venkata Srinivas Challa[1], Yesubabu Viswanadhapalli[2], Naresh Krishna Vissa[3], Venkatraman Balasubramanian[1]

[1] *Environmental Assessment Division, Indira Gandhi Centre for Atomic Research, A CI of Homi Bhabha National Institute (HBNI), Kalpakkam 603102, India.*

[2] *Weather and Climate Modelling Group, National Atmospheric Research, Gadanki, Tirupati 517112, India.*

[3] *Dept. of Earth and Atmospheric Sciences, National Institute of Technology, Rourkela, Odisha 769008, India.*

Email: invenmmk@gmail.com

ABSTRACT

The study investigates the mechanism of the extremely heavy rainfall event during 7–10 August 2019 in Kerala. As the skill of WRF model for simulating the heavy rainfall strongly depends on the choice of cloud microphysics (CMP), sensitivity analysis is performed using cloud resolving WRF simulations with different CMP schemes to assess their performance. Total five sensitivity experiments are conducted by varying CMP schemes namely Thompson, Goddard, WSM6, Kessler and Purdue-Lin. Model results along with the fifth generation European Reanalysis (ERA5) data indicate that the heavy rainfall occurred in association with the monsoon depression, intensification of off-shore trough, and low-level jet (LLJ) phenomena and associated moisture transport and convergence. Further the analysis demonstrates that out of the five CMP schemes, Thompson scheme simulates large amounts of cloud, rain, and snow during the period of peak rainfall with relatively low amounts of ice. Moreover, Thompson indicates a high warming in the 4–6 km layer due to large snow production while Lin and Goddard configurations exhibit altitude shift in this pattern i.e., more heating in the upper troposphere (9– 15 km layer) due to producing more solid hydrometeor distributions and associated freezing processes. Among the CMP schemes, Thompson followed by Goddard better simulated the spatial and temporal distribution of rainfall as they produced the strongest convergence, CAPE and vertical motions compared to WSM6, Lin and Kessler schemes.

Keywords: Heavy rainfall, Kerala, Off-shore trough, Moisture transport, Cloud microphysics

Comprehensive analysis of the size-intensity relationship of TCs over the NIO

Yerni Srinivas Nekkali [a], Krishna Kishore Osuri[a], M. Mohapatra[b]

[a]Department of Earth and Atmospheric Sciences, NIT Rourkela.

[b]India Meteorological Department, New Delhi, India.

E-mail: yernisrinivasnekkali@gmail.com

ABSTRACT

Tropical cyclone (TC) size and intensity are crucial in determining the extent of destruction during landfall. This study investigates the relationships between key size metrics—radius of maximum wind (Rmax), radius of 34-knots wind (R34), and a new size parameter, TC fullness (TCF)—and intensity for North Indian Ocean (NIO) TCs from 2002 to 2021, using data from the Joint Typhoon Warning Center. The analysis reveals a stronger correlation between intensity and TCF (0.7) compared to R34 (0.5) and Rmax (0.6). However, size and intensity changes show weaker correlations (0.37–0.39), suggesting that size does not monotonically increase with intensity.

Four distinct groups of TCs were identified based on size-intensity relationships: (1) Group-1 TCs showed little to no size variation with intensity, where dry air intrusion outside the eyewall and low vertical wind shear limited rain-band development, maintaining intensity without increasing R34; (2) Group-2 TCs exhibited simultaneous increases in size and intensity, driven by strong surface fluxes and angular momentum transport in the primary eyewall region; (3) Group-3 TCs exhibited size increases with minimal intensity change, as broader surface fluxes, relative humidity, and vertical velocities favored secondary eyewall formation without significant strengthening of the inner core; and (4) Group-4 TCs had larger initial vortices that maintained or increased their size throughout their lifecycle due to sustained broad surface fluxes and strong convection in both the inner and outer cores. These findings provide insights into the complex interplay between size and intensity in NIO TCs.

Keywords: Tropical cyclones, Size, Intensity, North Indian Ocean

Skill of Downscaled and Bias-Corrected CMIP6 ModelSimulations in representing the Extreme Precipitation Indices Over India

Neha L. Hikare[a], Gopinadh Konda [a],

Jasti S. Chowdary [a] and C. Gnanaseelan[a] [a] *Indian Institute of Tropical MeteorologyE-Mail: neha.hikare@tropmet.res.in*

ABSTRACT

In the present study, the extreme indices such as RX1Day, RX5day, R99p, R95p, R20mm, R10mm, and R50mm for the Indian summer monsoon region are considered to examine the ExpertTeam on Climate Change Detection and Indices (ETCCDI) representation by Coupled Model Intercomparison Project Phase-6 (CMIP6) models simulation. The downscaled and bias corrected(DBC) rainfall data prepared from CMIP6 models for the historical period from, 1980 – 2014 is utilized. The performance of the MMM (multi model mean) after DBC and before DBC is examined using different statistics e.g., percentage mean bias, pattern correlation, and root meanssquare error. Findings demonstrate the relative performance of the MMM and individual models in representing the frequency and intensity of extreme rainfall events over India, which is largelyimproved after DBC, and are consistent with the observations. After DBC, MMM rainfall productshowed improved representation of regions with highest RX1Day, R99p, R95p, R20mm, and R10mm over Western Ghats, Northeast, and Central India. DBC rainfall product shows 83.18%, 94.36%, 83.85%, 64.37%, and 33.25% improvement in respective indices based on their magnitude and frequency. Further, the temporal variations of MMM shows relatively lower biasesover the regions like Western Ghats (1.6%, 0.59%, -0.17%, 6.32%, 11.11%), Northeast (2%, - 1.63%, -3.27%, -0.85%, 12.96%), and Central India (-6.76%, -2.99%, -4.04%, -15.06%, -8.71%).

The skill of the models in representing heavy rainfall days (R50mm) over India has been improvedsignificantly after DBC for La Nina-associated excess years compared to the El Nino-associated drought years. More particularly, the DBC product well captures extreme rainfall indices during excess and drought monsoon years. This study highlights the potential of the DBC product in examining the ETCCDI in future projections over India.

Keywords: Extreme Precipitation Indices; Indian Summer Monsoon; CMIP6; Downscaled and Bias-Correction.

A study of the Corellations among the Weather parameters and Air pollutants in six cities of West Bengal

Amitlal Bhattacharya[a], Priyadarshini Ghosh[b] and Rina Bhattacharya[c] [a]Department Of Physics, D.N.College, West Bengal 742201 [b]Department Of Physics, S.R.Fatepuria College, West Bengal 742133 [c]Department Of Physics, JIS University, Agarpara, West Bengal 700109 *E-Mail:* ghosh.priyadarshini441@gmail.com

ABSTRACT

Now a days, Air Pollution has become a looming threat to the Global environment and people's health. The Anthropogenic activities are overriding the naturally caused pollution. Particulate matters ($PM_{2.5}, PM_{10}$) , NO_2, SO_2, O_3, CO are considered as major pollutants of air. In this paper we are studying how the weather parameters are influencing the pollutant concentration level and their corellations. Six cities of West Bengal have been considered here. Those are Asansol, Darjeeling, Haldia, Kalyani, Kolkata and Siliguri. All of them have distinctive geographic feature and growing economic importance. As rapid urbanization are occurring, the atmospheric health and Air quality assessment of the places are of prime concern for better survuval. Study of the variation of the concentration level of the pollutants with the weather parameters (Temperature, Relative Humidity,Wind Speed and Direction) has been done for the years 2016- 2023. Covid-19 protocol Lockdown was implemented for the years 2020-2021. During this phase air quality was improved drastically. But, in order to understand the real status of the Air Quality, this study has been started from 2016 i.e from the Pre Lockdown era. The years have been studied vividly by dividing them in three segments i.e. Summer , Monsoon and Winter.

It has been found that the level of some pollutant becomes prevalent in summer, some in winter. But the Overall Air quality (measured by Air Quality Index, AQI) has been worsen in winter than that of Summer. The AQI value of Kolkata in summer'2016 is 75 ,but the value is 189 in winter. Similarly, Darjeeling in summer months of 2016 is showing AQI value of 61 but it had been risen to 73 in winter months of 2016. During this study it has been found that different weather Parameter affects differently the pollutant level. The extremely hot and stagnant air during heatwave increase the amount of Ozone (o_3) concentration. Humidity in the air traps the Particulate matter. It increases to a certain value and after that it ceases to increase. Not only that, there is also a significant correlation between the wind direction and pollutant distribution. Winds from some particular direction shows more Scavenging Effect than other direction. Also the concentration level of the pollutants fluctuates with the change in wind speed. Although the combined effect of all parameters on the pollutant levels is of great complex, but we have tried to study and correlate them individually.

Keywords: Weather parameter, Air Pollution, Scavenging effect, Air Quality Index (AQI)

Development of a buoy for monitoring air-water interactions in the creek byInternet of Coastal Things

Vikranth Teppala[a], Pratibha P Jadhav[b],
Prasad K Bhaskaran[a]

[a] *Department of Ocean Engineering andNaval Architecture, IIT Kharagpur*
[b] *Department of Civil Engineering, IIT BombayE-Mail: vikranth.teppala@kgpian.iitkgp.ac.in*

ABSTRACT

Topographic and bathymetric features are crucial in determining water levels in creek and estuarine environments. Tides, strong winds, monsoon depressions, and severe weather events can influence local water level changes. In this study, a buoy was developed to investigate the influenceof tides on local water levels and their impact on latent and sensible heat fluxes. The buoy has beendesigned with two buoyancy rings and attached to a metallic frame with a solar panel for continuous observations, the electronic components are installed in a waterproof enclosure and thesensors such as air temperature, relative humidity, water temperature, and pressure transducer interfaced to a microcontroller installed in the buoy. The buoy was integrated with the 4G cellularnetwork Wi-Fi module to upload the collected sensor data sets to the cloud-based server for real- time monitoring. The pressure transducer in the buoy is used to record the underwater pressure variability that occurred due to the tides. The air temperature, relative humidity, and water temperature sensors are used to estimate the latent and sensible heat fluxes by indirect calculationof fluxes by bulk formulas. The flood and ebb tide changes the local water levels and influences the water masses which further change that latent and sensible heat fluxes locally. The designed buoy was fabricated and deployed in Bhavanapadu Creek located in Srikakulam district, north coastal Andhra Pradesh to investigate the influence of tides on the latent and sensible heat fluxes.The water level data recorded by the buoy was validated with the ADCIRC model. The ebb tide, during the night, increases the air and surface water temperature in the deployed area which further increases the latent heat flux resulting in secondary cooling approximately for two hours. The estimated latent heat flux ranges from 20 to 150 w/m^2 and sensible heat flux varies between -10 to20 w/m^2 for a 15-day deployment in August 2024. The developed buoy is the best alternate solution for monitoring the localized variability in the creek and estuarine environments influencedby the tides.

Keywords: Internet of Coastal Things, tide, buoy, latent heat flux, sensible heat flux.

Impact of Ocean Stratification and Warming on the Intensification of Pre-Monsoon Tropical Cyclones over Northern Bay of Bengal

Arkaprava Ray[a], Sudeep Das[a], and Sourav Sil[a]

[a] School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar

E-Mail:ar31@iitbbs.ac.in

ABSTRACT

The Bay of Bengal experiences most of the severe cyclones typically during pre-monsoon and post-monsoon season. Anomalous warming of the ocean surface and subsurface has become an increasing threat responsible for the rapid intensification of several cyclones over the basin. One of such example is the cyclone Yaas which made the landfall as a Very Severe Cyclonic Storm inspite of forming above 14°N. The ocean played an indisputable role as the area with Sea Surface Temperature (SST) greater than 31°C expanded from 0.1 percent to 29 percent of the entire basin from 2007 to 2021. In addition to the spatial expansion, the region also experiences a consistent increasing trend of 0.09°C per year and 0.1°C per year in both the average and maximum SST values respectively. In 2021, such anomalous warming in ocean surface was primarily associated with prolonged Marine Heat Wave events during May over the northern basin. In the same year, argo profiles near the track also recorded the unusual warming and freshening in the subsurface ocean, which made the environment distinct from other cases and caused a rapid intensification of the cyclone Yaas. The weakening of western boundary current was become the fundamental factor for the extension of low salinity water over the region, which restricted the mixing and caused the upper ocean surface warmer. The associated anticyclonic eddy along the track extended the abnormal distribution of low saline water even up to the subsurface (~100m), which is vital in increasing the ocean heat content. Understanding the role of such precyclonic oceanic condition on the rapid intensification of tropical cyclones can be useful to improve our exixting weather prediction model for short-term forecast.

Keywords: Ocean Warming, Marine Heat Wave, Rapid Intensification, Tropical Cyclone, Western Boundary Current

Sensitivity of upper tropospheric ozone to its precursors during the Asian summer monsoon

Author1[a] (First name, surname), Author2[b],
and Author3[a,b], ..
[a] *Department, Institution*
[b] *Department, Institution*
E-Mail:

ABSTRACT

Ozone in the upper troposphere (UT) is critical for maintaining Earth's radiative balance. This study utilizes simulations from the CMIP6 to explore the dominant photochemical pathways influencing ozone production in the upper troposphere (UT) during the Asian summer monsoon. We emphasize the impact of ozone precursors—nitrogen oxides (NOx), volatile organic compounds (VOCs), and carbon monoxide (CO)-which are transported via convection to the Asian UT. Our results show that, in addition to direct convective ozone transport, the elevated levels of NOx and CO also contribute to enhancing the UT ozone concentrations in 2014 compared to 1850 levels. Analysis of the VOCs and NOx suggests that ozone formation in this region is primarily NOx-limited. Furthermore, CO concentrations in the UT are significantly higher than NMVOCs in the present-day compared to pre-industrial, reducing the relative importance of VOCs in UT ozone production. These findings enhance our understanding of the factors controlling ozone in the UT and their implications for future climate projections.

Keywords: Extreme weather events; Monsoons; Climate change; Weather Prediction; Disaster management (maximum 5 words)

Assessment of Long Term Climatological Data: Sunshine Hour, Trends and Anomaly in Southern India

Arti Choudhary[a], Bharat Ji Mehrotra[a], Manoj K Srivastava[a]
Pradeep Kumar[a] and Atul K Srivastava[b]

[a]*Department of Geophysics, Banaras Hindu University, Varanasi, India*
[b]*Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, New Delhi, India Email: choudharyarti12@gmail.com*

ABSTRACT

This study examines the long-term variation in sunshine hours (SSH) over the past three decades (1988-2018) across various regions of India, including the East Coast (Chennai, Bhubaneswar, Kolkata, Machilipatnam), the West Coast (Thiruvananthapuram, Goa, Mumbai), and Central Inland areas (Indore, Nagpur, Hyderabad).SSH is influenced by cloud cover extent and meteorological variations, particularly evident in pre-monsoon, monsoon, and post-monsoon seasons due to the Twomey effect. The analysis reveals a significant declining trend in SSH across the east coast, west coast, and central inland regions at a 95% confidence level, with Sen's slope values ranging from -1.61 to -2.72. Some cities show an insignificant decline with Sen's slope values between -0.29 and -1.21, while the post-monsoon season in central inland regions shows an insignificant positive Sen's slope of 0.50. Seasonal anomaly analysis supports the overall declining trend in SSH, except for the post-monsoon season in the central inland. These findings emphasize the need to consider climatic variables in solar radiation studies and develop sustainable strategies for solar energy viability.

Keywords: Sunshine hour, long-term variation, seasonal anomaly

Understanding the Long-Term Changes in Tropical Cyclone Activity in the North Indian Ocean

Vishnu B Bal[a], Krishnamohan K.S[a], and Vishnu S[b]

[a]School of Environmental Studies, Cochin University of Science and Technology, India

[b]School of Earth, Environmental and Sustainability Sciences, IISER, Trivandrum

E-mail vishnu.b.bal@gmail.com

ABSTRACT

Tropical Cyclones (TCs) play a significant role in driving extreme climate events in India, where one-fifth of world population lives. Despite their significance, there is limited understanding of their long-term changes and the factors influencing them, particularly in the North Indian Ocean (NIO). This study aims to investigate the long-term variations in TC activity and associated environmental factors in the NIO using historical event-based datasets and reanalysis datasets . TC tracking algorithms UZ (Zarzycki and Ullrich,2017) and OWZ (Tory et al. (2013), were employed to track TCs from ERA5 and the 20th Century Reanalysis. Both algorithms showed a reliable Probability of Detection with 74% for both algorithms and reasonable False Alarm ratios of 17% and 10% for OWZ and UZ algorithms, respectively relative to IBTrACS data instilling confidence for long-term analysis. Decadal-scale variability in TC genesis was observed during long-term analysis, with periods of increased TC genesis (1965 to 1975 and 2005 to 2015) and periods of reduced TC genesis (1945 to 1955 and 1985 to 1995). Our analysis identifies the impact of large- scale changes such as Pacific Decadal Oscillation (PDO) and Western Indian Ocean Warming in the observed long-term oscillations. In the decadal scale, the Pacific Decadal Oscillation significantly impacts the tropical cyclone genesis in the Bay of Bengal, while the warming of the Western Indian Ocean affects tropical cyclone genesis in the Arabian Sea, particularly in the recent decades.

Keywords: Tropical Cyclones; LPS Tracking Algorithms; Long-term variability; Indian Ocean Warming; Multidecadal oscillations

EFFECT OF ENSO ON CLIMATIC VARIABLES ON MALARIA BURDEN IN HBHI REGION OF INDIA

Shailendra Rai[a] , Shambhavi Krishna[b]

[a]M. N. Saha Centre of Space Studies, University of Allahabad, Prayagraj, UP, INDIA-211002

[b]K. Banerjee Centre of Atmospheric and Ocean Studies, University of Allahabad, Prayagraj, UP, INDIA-211002

E-Mail:shailendrarai@allduniv.ac.in

ABSTRACT

This study shows relationship of ENSO with ISMR on malaria burden in High Burden High Impact (HBHI) region as no efforts till date is made to discuss this considering climate change. An increase in malaria burden by 47.33% in El-Niño year and 50.44% increase in post El-Niño year predicts one year lag from high risk year enough for preparedness to minimise its impact. The correlation between '+ winter Ocean Niño Index (ONI)' and 'rainfall index' shows variability of Indian Summer Monsoon Rainfall (ISMR) with El-Nino Southern Oscillation (ENSO) due to geographical diversity. The correlation between rainfall index and malaria case, EIR andvector indices shows malaria transmission is heterogeneous depending on rainfall deficit or excess. A positive correlation between +winter ONI and malaria cases, Entomological Inoculation Rate (EIR) and vector indices indicates rise in malaria cases in the co-existing year in Chhattisgarh

and Jharkhand during El- Nino. Negative correlations found in Madhya Pradesh Bengal indicates the malaria outbreaks during La Niña.

Keywords: ENSO; ISMR; HBHI, Malaria, VECTRI, Climate Change

Study of Lightning Characteristics in association with Tropical Cyclones using Lightning Location Network(LLN)

Prajna Priyadatshini[1*], Hamza Varikoden[1] , Abhijeet Gangane[1],
V. Gopalkrishnan[1], S D Pawar[1],D R Pattanaik[2]

[1] *Indian Institute of Tropical Meteorology, Pune*
[2] *India Meteorological Department, New Delhi*
[*]*EMail:prajna.priyadarshini@tropmet.res.in*

ABSTRACT

Lightning Activity within tropical cyclones is an exciting and important phenomenon in scientific research. The physical mechanisms of lightning in tropical cyclones involve several complex processes related to atmospheric dynamics, thermodynamics, and electrical charge separation. Theinteraction between tropical cyclones and lightning characteristics is complex and vital for understanding storm dynamics and improving safety measures. As these systems develop and intensify, the presence of strong convective cells leads to increased electrical activity. The combined hazards of lightning and tropical cyclones create complex challenges for communities.Understanding these risks and implementing effective mitigation strategies is essential for enhancing safety, reducing economic losses, and fostering resilience in affected areas.For the present study, six pre-monsoon tropical cyclones (TCs) over the Bay of Bengal have beenconsidered, viz., Fani in 2019, Amphan in 2020, Yaas in 2021, Asani in 2022, Mocha in 2023 andRemal in 2024. The Lightning data is taken from the lightning location network (LLN) established by the Indian Institute of Tropical Meteorology Pune.The analysis reveals that the lightning counts are primarily clustered in the rainband regions (300kms-400kms from the center). The category-1 cyclones have shown more CG flash counts from the peak intensity period of the cyclone to landfall compared to category-5 cyclones. The lighting distribution within the TCs depends on the cyclone's category and the environmental factors like wind shear, moisture variables, instability, etc.

Keywords: Lightning, Peak Current, LLN, Tropical Cyclone

An Evaluation of Water Availability and Potential Evapotranspiration trends in Varanasi using CMIP6

R, Pandeya, A, Vermaa, and R, Bhatla[a]

a *Department of Geophysics, Institute of Science,*

Banaras Hindu University, Varanasi, 221005

E-Mail: ramapandeyphy@gmail.com

ABSTRACT

Using modelled data from the CMIP6 Multi-Model Ensemble (MME) and observational data from the India Meteorological Department (IMD), this study assesses spatial and temporal trends of Water Availability (WA) and Potential Evapotranspiration (PET) over the Varanasi region. T1 (1954–1984) and T2 (1985–2014) were the two time periods examined in order to evaluate the coherence and inconsistencies between observational and model data. In both datasets, the results show an important connection between PET and WA, with higher PET values correlated with more water availability in the area. While the CMIP6 model projected similar increases in the northern region, the IMD data spatially showed higher WA and PET in the southern sections of T1. The northern and northeastern regions of T2 displayed greater values for both datasets, despite the CMIP6 model's tendency to overestimate WA and PET. Although there were some overestimations and spatial shifts, the CMIP6 model did a good job of capturing the general hydrological dynamics of the area. The study emphasizes the significance of PET as a major factor influencing water availability and indicates that, while more work is required for localized accuracy, the CMIP6 model is a valuable tool for comprehending regional hydrological dynamics. These findings highlight the need for better model inputs and future projections with substantial implications for studies on the influence of climate change on water resources.

Keywords: Water Availability; Potential Evapotranspiration; CMIP6; Varanasi.

IoT-Based Human Discomfort Index Calculator using DHT11 Sensors

[a] Tammineni Sreelatha, [b] G. China Satyanarayana, [c] Sivaprasad Lebaka

[d] M. Sai Nihhaar, [e] A. H. V. S. Sathvik, [f] B.Venkata Krishna Mahesh

[a,b,c] *Department of Electronics and Communication Engineering, Koneru Lakshmaiah EducationFoundation, Vaddeswaram, Guntur District, Andhra Pradesh, 522502, India*

[d,e,f] *Student,Department of Electronics and Communication Engineering, Koneru LakshmaiahEducation Foundation, Vaddeswaram, Guntur District, Andhra Pradesh, 522502, India*

E-Mail: tamminenisreelatha@kluniversity.in

ABSTRACT

The Human Discomfort Index is a critical metric that combines air temperature and relative humidity to determine the perceived temperature, offering a more accurate measure of heat stressexperienced by individuals than temperature alone. This project aims to develop an IoT-based system for calculating the Human Discomfort Index using an Arduino development board and a DHT11 sensor. The DHT11 sensor provides temperature and humidity measurements, with an accuracy of ±5% for humidity and ±2°C for temperature, making it an accessible choice for such applications. The sensor data will be processed locally on the Arduino and displayed on an LCD screen or other visual output, enabling users to monitor environmental comfort in real time.This system is ideal for indoor environments such as homes, offices, or classrooms, where maintaining a comfortable climate is essential for well-being and productivity. The Human Discomfort Index can help individuals make informed decisions about adjusting ventilation, cooling, or heating systems based on real-time conditions. Although the DHT11 sensor offers a simple and cost-effective solution, its accuracy limitations may affect precision in more demanding applications. Nevertheless, this project demonstrates a practical approach to implementing an IoT-based Human Discomfort Index calculator, providing a foundation for future upgrades with more advanced sensors or additional features.

Keywords: Human Discomfort Index, IoT, DHT11 Sensor, Arduino, Temperature and HumidityMonitoring

Evaluating Snow Water Equivalent and Snowmelt Rates in Sikkim Himalayas under Climate Change

Shalini Dubey[1], Shruti Verma[1] and R. Bhatla[1,2]

[1] *Department of Geophysics, Institute of Science, Banaras Hindu University, Varanasi, India.*

[2] *DST-Mahamana Centre of Excellence in Climate Change Research, Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi, India.*

E-Mail: shalinidubey576@gmail.com

ABSTRACT

India, a mega biodiverse agrarian nation, is heavily influenced by the monsoon and the Himalayas. The glacial region of the Hindu Kush Karakoram Himalaya (HKH), known as the "water tower of Asia," stores vast amounts of water in the form of ice and snow, second only to the polar ice caps (Adnan et al., 2017). With global temperatures rising and glaciers receding at an accelerated rate, Sikkim has become the second most vulnerable Indian state to climate change due to its reliance on glaciers and stream power. This study focuses on the impact of climate change on snow water equivalent (SWE) and snowmelt rate in the Sikkim Himalayas from 1979 to 2017. It examines the temporal variation of melt rate and associated melt amounts through degree-day modeling. The results show an increase in the average decadal rate of SWE and Degree Day Factor (DDF) for the months of March to August in the Sikkim Himalayas over the period 1979-2017, with the exception of the 2009-2017 decade, indicating the impact of global warming. The average decadal temperature trend for the Sikkim Himalayas from March to August during 1979-2017 shows a significant increase, with a coefficient of determination of 0.91. This trend suggests an increase in humidity, cloudiness, and climate change due to the accelerated greenhouse effect in recent decades. The rate of snowmelt is crucial for flood forecasting, extreme weather events, agriculture, and optimal water resource management.

Keywords: Sikkim Himalaya, Snow Water Equivalent (SWE), Degree Day Modeling (DDM), climate change and impact.

EL NIÑO SOUTHERN OSCILLATION INFLUENCE ON MONSOON PATTERNS IN INDIA: A CLIMATE PREDICTION MODELING (CMIP6) STUDY

Lakshmi S[1a] and Neetu Tyagi[2b]

[a] *India Meteorological Department, Meteorological Training Institute*
[b] *India Meteorological Department, RMC-New Delhi*

E-Mail:lakshmiphy2@gmail.com

ABSTRACT

Monsoons are abundant seasonal rainfall caused by the consistent seasonal winds that switch their direction with astonishing frequency. The Indian subcontinent receives rainfall from two monsoons, namely the Southwest monsoon and the Northeast monsoon. While the majority of India benefits from the Southwest monsoon, during this season, the coastal community of Indian states encounters severe cyclonic storms causing floods and the lack of uniform during this season leads to drought. The study focuses on analyzing the inter-annual trend between El Nino Southern Oscillation – southwest monsoon rainfall as well as ENSO-North east monsoon rainfall for the years from 1971-2020. Projection of Southwest monsoon and Northeast monsoon extremities in the India till late Mid Century (2051-2075) was derived from Coupled model inter comparison project phase 6 - HIS, SSP 245,370 and 585 for scenarios of sea surface temperature. The bias- corrected sea surface temperature data from the models were used to calculate the Oceanic Nino Index for the historical period (1971-2020), which was then compared to the observed data. The same is also used for monsoon extremities validation and evaluation. The dependence of excess and deficit rainfall directly on the El Nino and La Nina events, respectively during the last five decades is evident from the obtained results. Even though a direct relationship exists between El Nino Southern Oscillation and monsoon rainfall, there are years in which the observed rainfall pattern cannot be explained satisfactorily based on El Nino Southern Oscillation alone. Thus, additional parameters are required to provide a proper explanation for the years during which exceptions occur.

Keywords**:** Northeast Monsoon, Southwest Monsoon, ENSO, Extreme events, SST, CMIP6

Analysis of Heavy Rainfall during Monsoon over Rajasthan

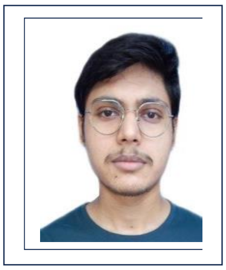
Himanshu Sharma, Radheshyam Sharma,Deepika Gupta
Meteorological Centre Jaipur, India Meteorological Department
sharma.himanshu10@imd.gov.in

ABSTRACT

Monsoons are abundant seasonal rainfall caused by the consistent seasonal winds that switch their direction with astonishing frequency. The Indian subcontinent receives rainfall from two monsoons, namely the Southwest monsoon and the Northeast monsoon. While the majority of India benefits from the Southwest monsoon, during this season, the coastal community of Indian states encounters severe cyclonic storms causing floods and the lack of uniform during this season leads to drought. The study focuses on analyzing the inter-annual trend between El Nino Southern Oscillation – southwest monsoon rainfall as well as ENSO-North east monsoon rainfall for the years from 1971-2020. Projection of Southwest monsoon and Northeast monsoon extremities in the India till late Mid Century (2051-2075) was derived from Coupled model inter comparison project phase 6 - HIS, SSP 245,370 and 585 for scenarios of sea surface temperature. The bias- corrected sea surface temperature data from the models were used to calculate the Oceanic Nino Index for the historical period (1971-2020), which was then compared to the observed data. The same is also used for monsoon extremities validation and evaluation. The dependence of excess and deficit rainfall directly on the El Nino and La Nina events, respectively during the last five decades is evident from the obtained results. Even though a direct relationship exists between El Nino Southern Oscillation and monsoon rainfall, there are years in which the observed rainfall pattern cannot be explained satisfactorily based on El Nino Southern Oscillation alone. Thus, additional parameters are required to provide a proper explanation for the years during which exceptions occur.

Keywords: Northeast Monsoon, Southwest Monsoon, ENSO, Extreme events, SST, CMIP6

ACCESSING THE IMPACT OF RADAR DATA ASSIMILATION ON TROPICAL CYCLONES



Sankhasubhra Chakraborty[a], Sandeep Pattnaik[a],
and
B.A.M. Kannan[b]

[a] *School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar, Argul, Jatni, Khordha, Odisha*
[b] *Regional Meteorological Centre, India Meteorological Department, Chennai 600006*
E-Mail: s23es09001@iitbbs.ac.in

ABSTRACT

The eastern coastal regions of India, specifically West Bengal, Odisha, Andhra Pradesh, and TamilNadu, are consistently vulnerable to severe tropical cyclone (TC) landfalls originating from the Bay of Bengal. It is extremely challenging to accurately forecast the TC structure, intensity, and rainfall, particularly during landfall hours, which greatly affects disaster preparedness and mitigation efforts. This study aims to address that deficiency by assimilating available radar data into the Advance Research Weather Research and Forecasting (ARW) model version 4.1. The Doppler Weather Radar (DWR) data has been collected from the India Meteorological Department(IMD) for the stations Vishakhapatnam and Chennai for the cyclone Hudhud (2014) and Vardah (2016). Two sets of experiments will be designed, i.e., CNTL (without assimilation) and RDA (with assimilation). We propose assimilating reflectivity (R_f) and Radial velocity (V_r) observations for these two cyclones with up to 72-hour forecast lead time. The results related to the forecast track, intensity, rainfall, and landfall location will be validated against available observations from IMD best track datasets as well as satellite and radar observations at different lead times. Furthermore, the evolution and decay of cyclone eyewall convective structure and associated rainfall will be rigorously validated with available satellite, reanalysis, and radar datasets with higher spatio-temporal resolutions.

Keywords: Tropical Cyclones; Radar Reflectivity; Eyewall; Doppler Weather Radar

Monitoring Agricultural Vulnerability in Delhi Using the Standardized Precipitation Index (SPI)

Shalini Saxena

Regional Meteorological Centre

India Meteorological Department, New Delhi-110049

E-Mail:saxenaorshalini9@gmail.com

ABSTRACT

This study examines the relationship between the Standardized Precipitation Index (SPI) and the Normalized Difference Vegetation Index (NDVI in Delhi, over a 30-year period from 1992 to 2022. The analysis reveals significant fluctuations in precipitation patterns, characterized by cyclical wet and dry periods without a consistent long-term trend. Southern region of Delhi particular, show notable variability in maximum SPI values, indicating increased exposure to extreme weather events, such as intense rainfall and drought. In January, a mix of positive and negative SPI values was observed, with positive values peakingat 0.3 and negative values dropping to -0.8, reflecting complex interactions between climatic conditions and vegetation health. Strong correlations were found between the precipitation patternsin South and South East Delhi (0.906), while moderate correlations were noted among other locations, suggesting shared climatic influences and regional weather patterns. The NDVI analysis from January 2001 to 2022 illustrates a gradual increase in vegetation health and density, with values rising from 0.15875 in 2001 to 0.2954 in 2022. This improvement in vegetation condition corresponds with consistently positive SPI values, reflecting above-average precipitation during this period. However, the correlation between NDVI and SPI was found to beweak (-0.0825), indicating that factors other than precipitation, such as urbanization or land use changes, also influence vegetation health. This research highlights the complexities of vegetation dynamics in urban environments and emphasizes the need for integrated strategies in water resource management and urban planning to mitigate the impacts of climate variability on vegetation health.

Keywords: Standardized Precipitation Index (SPI); Normalized Difference Vegetation Index (NDVI); Precipitation variability; Vegetation health; Urban environments; Climate variability

Performance of CMIP6 models to understand nature of evolution of drought and flood over India its six homogeneous regions

Akash Vishwakarma[a], Aashna Verma[a] Barunava Mandal[a],and R.Bhatla[a,b]

[a] *Department of Geophysics, Banaras Hindu University.*
[b] *DST- Mahamana Center of Excellence in Climate Change Research ,IESD,BHU*
E-Mail:akashvishwakarma500@gmail.com

ABSTRACT

Extreme Weather events are significantly more frequent or intense than the normal events as well as major cause of remarkable damage to our society and agriculture. Some extreme weather events such as heavy precipitation, very heavy precipitation, heat waves, cold waves, drought, flood, cyclones etc. have widespread adverse impacts on human and its belongings. As an agrarian country, extensive study of extreme weather events over India are very important, we consider drought and flood events because of it has devastating effect on agriculture. So, our center of attentions are drought and flood events that occur during Indian summer monsoon rainfall season (JJAS) over India and its six homogeneous regions viz. North west India (NWI), North central India (NCI), North east India (NEI), West Peninsular India (WPI), East Peninsular India (EPI), South Peninsular India (SoPI). In this study we use 14 historical simulations of sixth phase of Coupled Model Intercomparison Project (CMIP6) and two future emission scenarios Sheared socio-economic Pathways (SSPs) SSP2-4.5 and SSP5-8.5 and IMD observational precipitation data. The performance of CMIP6 models is determined by using different model evaluation metrics as correlation coefficient (CC), standard deviation (SD), root mean square error (RMSE), normalized root mean square error (NRMSE) and Interannual variability score (IVS). Drought and flood years are estimated using Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration index (SPEI).

Keywords: Extreme weather events; Indian summar Monsoon Rainfall; Standardized Precipitation Index; Standardized Precipiation Evapotranspiration Index; Coupled Model Intercomaparision Project.

MULTISCALE OCEAN PROCESSES AND CYCLONE INTENSIFICATION IN THE BAY OF BENGAL

Sourav Sil[a], Arkaprava Ray[a] and Hitesh Gupta[aa]
School of Earth, Ocean and Climate Sciences,
IIT Bhubaneswar
E-Mail: souravsil@iitbbs.ac.in

ABSTRACT

The Bay of Bengal (BoB) experience the tropical cyclone during pre-monsoon (April–May) and post-monsoon (October–November). The BoB is unique in terms of oceanic features like freshwater-induced stratification, warmer SST, eddies, and coastal trapped Kelvin waves with theirseasonal to interannual variability. The present study highlights the importance of those oceanic features on cyclone intensification. The westward tracks of the pre-monsoon cyclones, concurrentwith an increasing rate of warming in recent years, allowed tracks to cross the northeastward warmwestern boundary current and associated warm anti-cyclonic eddies (Amphan-2020 and Fani- 2019). The weaker western boundary current made the northern BoB fresher and more favorable for cyclone intensification (Yaas-2021). The extreme warming due to Marine Heat Wave events is responsible for cyclone intensification (Mocha-2023). During post-monsoon, the downwelling on the western BoB associated with coastally trapped Kelvin waves helps to maintain higher oceanheat content near the coast to provide the energy needed for the intensification of cyclones beforelandfall (Phailin-2013, Hudhud-2014, Titli-2018, and Gaja-2018). The low-saline freshwater influx advected by the southward East India coastal current also helps to maintain the warm temperature of the upper layer. Regional ocean modeling simulation showed that during negativeIOD and La-Niña years (1992, 1996, 2010, 2016), stronger coastally trapped downwelling KelvinWaves make the warmer subsurface favourable for more cyclone formation and intensification.

Keywords: Tropical Cyclones; Ocean Warming; Boundary Currents; Stratification; Coastally Trapped Kelvin Waves.

Assessing background environmental conditions influencing intense convective storms

[a] Achintya Paliwal, Martin Singh[b],and Vishal Dixit[c]

[a] *IITB-Monash Research Academy,
IIT Bombay, India*
[b] *School of Earth Atmosphere and Environment,
Monash University, Australia*[c] *Centre
for Climate Studies, IIT Bombay, India*

E-Mail:achpaliwal@gmail.com

ABSTRACT

Intense convective storms are characterized by lightning, hail, gust fronts, and heavy precipitation,which can result in fatalities and property damage. A significant amount of literature involving observations, theory and modelling exists on storm characterization for the mid-latitude regions but a similar characterization for the tropics is currently lacking. The CMIP5- climate models typically run at resolutions (~100km) that cannot resolve small-scale convective storms (~10km).Using a high-resolution ERA5 dataset in this study we identify background environmentalconditions (BECs) favouring the occurrence of intense convective storms over India. The acceptedindicators of intense convective storms in the mid-latitudes namely convective available potentialenergy (CAPE) and vertical wind shear show skill in capturing the storm severity. The severity over India is defined in terms of lightning, hail, straight line winds and precipitation and their co-occurrences. Using satellite, ground based observations and high resolution modelling datasets, itis found that CAPE and shear are insufficient discriminators for extreme precipitation over the Indian sub-continent. It is also found that co-occurrence of extreme precipitation and lightning take place in the high CAPE and high shear regime.

Keywords: Intense convective storm; CAPE; Shear; Extreme Precipitation

COST EFFECTIVE AND HIGH-PERFORMANCE AIR QUALITY MONITORING SYSTEM

Mamatha Bandaru[a], Nayan Balla [b], P Lekhan Aditya sai [b], Atmakuri Dhanush [b][a] *ECE, KLUniversity*, [b] *CSE, KLUniversity*

E-Mail:Mamatha.bandaru@gmail.com, 2400031211@kluniversity.in, 2400031189@kluniversity.in, 2400033102@kluniversity.in

ABSTRACT

Poor air quality is a global issue impacting both human health and ecosystems, withlarge quantities of pollutants causing significant environmental harm and health problems.To address this challenge, a cost-effective and high-performance air quality monitoring system has been developed. The system utilizes metal oxide sensors(MQ7, MQ135, MQ136) to detect and measure the concentrations of key pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), nitrogen dioxide (NO2), sulfur dioxide (SO2), hydrogen (H2), and particulate matter (PM),particularly in high-risk areas such as smoky zones, vehicular zones, and industrial emission sites.The system is built around a microcontroller and integrated with a cloud-based server, providing a comprehensive information platform equipped with a graphical user interface (GUI). This innovative approach ensures enhanced performance, delivering improved sensitivity, accuracy, and resolution for effective air quality monitoring.

Keywords:Air Quality; metal oxide sensor; carbon monoxide; cloud server; cloud server.

CHANGE IN WHEAT CROP YIELD FOR DIFFERENT RCPs IN THE CONTEXT OF CLIMATE CHANGE

Ajay Mohan[a], Prof. Shailendra Rai[ab], and
Prashant Narayan Vishwakarma[a],
a K. Banerjee Centre of Atmospheric and Ocean Studies (KBCAOS),
b M. N. Saha Centre of Space Studies (MNSCOSS)
University of Allahabad, Prayagraj
*Email:*ajay_phd2023@allduniv.ac.in

ABSTRACT

This study examines the potential impact of climate change on wheat production in the Prayagraj district using the Decision Support System for Agrotechnology Transfer (DSSAT) model. We analyzed various factors such as soil properties, crop genotype information, and daily weather data to forecast future wheat yields under different Representative Concentration Pathways (RCPs) - RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5. The simulation results revealed that the effect on wheat yields varies, with less severe RCPs indicating minimal reduction and the more intense scenarios predicting larger declines. Under RCP 2.6, the decrease in yield is expected to be around 5% by 2100. In contrast, RCP 8.5 projects a reduction in wheat yields by over 35%, highlighting significant risks associated with high emission trajectories. These findings underscore the necessity for specific adaptation strategies to sustain wheat productivity in the region. The DSSAT model, with its comprehensive parameters, is crucial for local agricultural planning as it offers insights into the potential future impacts of climate on crop yields, aiding in the formulation of effective mitigation and adaptation strategies in the Prayagraj district.

Keywords: Climate Change, RCPs, DSSAT-Simulation, Wheat Yield

ASSESSING THE INFLUENCE OF BIOPHYSICAL FACTORS ON THE TROPOSPHERIC METHANE CONCENTRATION: A CASE STUDY IN OIDSHA

Sudipta Manna[a], Argha Ghosh[a], Arnab Mandal[a], Rajashree Khatua[a], Araya Kumar Biswamohan Mohapatra[a]
[a] *Department of Agricultural Meteorology, Odisha University of Agriculture and Technology, Bhubaneswar-751003, India*

Email: sudiptamanna430@gamail.com

ABSTRACT

The eastern India has greater Global Warming Potential with increased greenhouse gases emissions due to extensive rice production, coal burning, rapid urbanization. In this study, the impact of biophysical factors on the tropospheric methane concentration over the eastern Indian state of Odisha was investigated. The Sentinel-5 Precursor (S-5P) satellite data, which was gathered from the open-source cloud computing platform Google Earth Engine (GEE), yielded the methane concentration (ppbv). The European Space Agency (ESA) launched the S-5P, outfitted with the Tropospheric Monitoring Instrument (TROPOMI), in October 2017 as a component of the Copernicus program. The cultivation of rice and other agricultural activities over Odisha was the primary cause of the methane concentration. Furthermore, the dynamics of a greenhouse depend on the soil. Methane concentration over Odisha was driven by the rice farming and other agricultural practices. Furthermore, the dynamics of greenhouse gases, which are influenced by land use and management, depend on soil. These variables have a significant effect on GHG exchanges as well as the cycling of carbon and nitrogen. Six biophysical factors including slope, surface temperature and water, vegetation condition, water content in vegetation were analysed to determine their influence on methane concentration. Slope and surface temperature were derived from the satellite derived Digital Elevation Model (DEM) and land surface temperature (LST).on the other hand, vegetation condition and water content in vegetation and water were represented by the satellite derived Normalised Difference Vegetation Index (NDVI) and Normalised Difference Water Index (NDWI). Simple correlation study was carried out between the methane concentration and the biophysical factors. The results revealed that the methane concentration decreased with increase in the slope and land surface temperature as indicated by the negative correlation coefficient values. Both the NDVI and NDWI exhibited positive agreement with the methane concentration. The study successfully showed the differential influence of the biophysical factors on the tropospheric methane concentration

Keywords: Methane, NDVI, NDWI, Slope, Odisha

Principal Component Analysis to study spatial variability in the ground truthdata derived air quality and case study estimates over North West part of India

Pratiksha Dubey, A.K. Mitra, P.C.S. Devara

India Meteorological Department, Lodhi Road, New Delhi, India

ABSTRACT

The development of a urbanized area in the day–to–day air quality conditions to which they are exposed during the last decade. Driven by the increasing awareness of the health aspects of air pollution exposure, especially by most sensitive sub–populations, short–term air pollution forecasts are being provided more and more by local authorities. The Air Quality Index (AQI) is a number usedby governmental agencies to characterize the quality of the air at a given location over the Indian region. The main objective of the present study is to utilize principal component Analysis (PCA) technique to reduce the dimensionality of the air pollution products and bring out the most impact based pollutants parameters based on their locations over Northwest India during 2018 to 2021 winter season. The Principal components have been computed using covariance of input data matrix. Only those components, having eigenvalues >1, were used to predict the AQI using principal component regression technique. It was found the performance of PCA was better in winter as studied through statistical error analysis. The values of normalized mean square error (NMSE) were found as 0.0067, 0.0092 for PCA and regression technique respectively. The other statistical parameters are also supporting the same result and The impact of crop residue burning during winter on air quality has also been investigated in this paper and a separate analysis will be reportedduring the conference.

An Assessment of the Impact of Indian Radiosonde/PILOT observations on the NWP Model Forecast: Study using FSOI method

Azad Singh, Rajpoot [a], Sumit Kumar [b], and John P. George [a,b]

National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences
A-50, Sector-62, Noida-201309, India E-Mail: asrajpoot@ncmrwf.gov.in

ABSTRACT

National Centre for Medium Range Weather Forecasting Unified Model (NCUM) NWP system is utilized for operational global NWP forecast at NCMRWF. Numerical Weather prediction is a crucial aspect of modern-day meteorology, impacting various sectors ranging from agriculture to disaster management. Advanced data assimilation techniques of Hybrid-4D-Var, is employed to utilize various observational data, including in situ measurements, satellite data, and radar observations, to generate the initial conditions (or analysis) for the model forecast. The primary objective of this study is to quantify the impact of Indian Radiosonde/PILOT observations on global NWP model forecasts using an adjoint-based FSOI system from June 2023 to June 2024. In this study all Indian Radiosonde(RS/RW) and PILOT observations were assimilated, RS/RW mostly reporting at 00UTC and 12UTC. Radiosonde(RS/RW) observation impact on 24hr global forecast error reduction are higher at 00UTC then 12UTC. It can be noticed from our variable- wise analysis that wind observation has largest contribution towards decreasing the forecast error followed by temperature and humidity. It is observed that Radiosonde temperature observations have no beneficial impact up to 850hPa from surface, but has beneficial impact at higher levels. Relative humidity, while also has relatively lesser impact. PILOT wind observations specifically contributes to the improved of 24hr forecasts between 900 hPa and 400 hPa.

Keywords: FSOI; NCUM; Hybrid 4D-Var; Radiosonde/PILOT

INVESTIGATING THE MONTHLY OZONE OSCILLATION USING SPACE BASED TECHNOLOGY: AN INSIGHT FROM EASTERN INDIA

Arnab Mandal[1a*], Argha Ghosh[1a], Sudipta Manna[1a] Araya Kumar Biswamohan Mohapatra[1a]
[a] Department of Agricultural Meteorology, Odisha University of Agriculture and Technology, Bhubaneswar-751003, India
*Email: mandalarnab110@gmail.com

ABSTRACT

People all around the world are affected by climate change, which threatens basic needs like food, water, health, land use, and the environment. Climate change, environmental damage, and human health are all intricately linked to greenhouse gas (GHG) emissions. Ozone (O_3), considered as a potential greenhouse gas, has a Global Warming Potential (GWP) of 65. The primary goal of this study is to evaluate the monthly and annual dynamics of ozone over the eastern states (Bihar, Chhattisgarh, Jharkhand, Odisha and West Bengal) of India during the period extending from February 2019 to February 2024 employing Sentinel-5P Tropospheric Monitoring Instrument (TROPOMI). In order to validate the ozone concentration obtained from the S-5P TROPOMI, the data from the reprocessed Aura Ozone Monitoring Instrument (OMI) Level-2 Ozone data product OMDOAO3 was used. An excellent positive agreement was determined between the TROPOMI and OMI observations considering the monthly mean values of all the years and over all the locations. The value of the correlation coefficient (r) was estimated as highly significant (0.99). There is a strong positive linear relationship between the two datasets as indicated by the value of coefficient of determination (R^2) as 0.978. Ozone concentration increased from 2019 and continued to rise up to 2022 followed by a subsequent decline in 2023 except in Bihar. Linear trend of annual mean ozone concentration revealed a non-significant rising trend. Ozone concentration was found to be the minimum during post-monsoon months and the maximum during pre-monsoon months indicating a seasonal oscillation. This study detected and quantified the spatial and temporal pattern of ozone content in the resent times which help the planners and policy makers to understand the trends, patterns, and changes and to develop effective mitigation strategies.

Keywords: Ozone, TROPOMI, OMI, Eastern India, monthly oscillation

RECENT ADVANCES IN IMPACT BASED FORECAST & RISK BASED WARNING APPROACH FOR UTTAR PRADESH

Atul Kumar Singh[1] , M.R.Ranalkar[1] , R.K.Jenamani[2] and M. Mohapatra[2] [1]MC Lucknow, India Meteorological Department
[2]DGM Office, Mausam Bhawan New Delhi, India Meteorological Department
E Mail: atul.singh88@imd.gov.in / physics.atul@gmail.com

ABSTRACT

Phenomenal improvement has been observed in Public Weather Service during recent few years with great benefit from the introduction of Conceptual Dynamic Multi-Hazard Impact Based Forecasting and Warning services by WMO resolution with the aim to bridge the gap between scientific community, different stakeholders and end user by improving last mile connectivity with inception of cross cutting component in the form of Community Centric Bottom- up Approach, which has proven to be a great initiative towards ‘TRANSLATING HAZARD INFORMATION INTO IMPACT SCENARIOS’. Uttar Pradesh, most populous state of the country, comprising of 75 districts & composed of 826 Development Blocks broadly classified into two meteorological subdivisions & nine agro-climatic zones. Each of these regions have varying weather & climatic features in terms of different spatio-temporal scales owing to their complex physiographic characteristics due to which this region is one of the most vulnerable part of the Indian subcontinent pertaining to various severe/disastrous hydrometeorological hazards that often result into high socio- economic impacts due to its peculiar geophysical settings along the vast IndoGangatic plains. This region is very often prone to furry of monsoon and the floods in Uttar Pradesh are acute and unique so far its extent, duration and magnitude are concerned with most of its eastern part is susceptible to flood damage. This study discusses about the opportunities offered by this approach in addressing the potential challenges during decision-making workflow in an operational context. The methodology may be classified into three principal aspects. The first & foremost input comes from the collection of detailed Meteorological/ Geophysical/ Physical/ Socio-Economic/ Hazard/ Exposure/ Vulnerability/ Impact & Risk data in order to create a consolidated Digital Data Repository in the form of Comprehensive Regional/District/City Profile Database for each Homogenious Region & Sublevel. The second part comes in the form of computation of numerical thresholds for different impact scenarios & preparation of Impact/Risk matrix accordingly based on two subjective approaches viz. Threshold Method (Elements: Meteorological Thresholds, Occurrence Probability & Expected Impact) aided/supported by Qualitative Combinational Method incorporating Generalised Conventional IBF. Final, but most vital part is the creation of suitable Risk/Response Matrix for different Impact/Risk scenarios to include exposure & vulnerability factors qualitatively and to quantify the uncertainties in the first two parts for proper Risk Assessment and Decisive Action by the concerned Disaster managers. The present approach goes one step further and comes up with a provisional qualitative cum quantitative Impact Based Warning products on zonal/regional/local basis classified on the basis of similar climatic/hazard/vulnerability profile with specified colour codes based upon the scale of exposure & vulnerability pertaining to the specific type of hazard/multi-hazard in this region depending upon the spatio-temporal scale of the hazard, which may ultimately result in better contingency planning with community centric bottom-up approach. This approach would also improve the objective evaluation of responsibilities of forecasters and decision makers by collaborative approach in EWS context. Additionally, IBF can further contribute towards Community Based Disaster Risk Reductions, Resilience & Response (CBDRRRR) mechanism through common situational awareness & behavioral recommendations (BRs) in order to achieve the prescribed seven Global Targets of Sendai Framework (2015-2030) with four (04) well defined Priorities for action towards Disaster Risk Reduction. In this study a recent case has been demonstrated to offer an insight about the present IBF & RBW approach with various sectoral applications in this region to trigger with further research and project developments with empirical justification for the added expense and time associated with the more detailed hazard warnings.

Keywords: MHIBF, RBW, CBDRRRR, WMO, Risk, Impact Matrix

Assessment of Near Real Time Blended rainfall product for an extreme rainfall event

Neha Rajput[a], K.AmarJyothi[a], and Preveen Kumar D. [a]
[a] *National Centre For Medium Range Weather Forecasting*
E-Mail: neha.rajput@nic.in

ABSTRACT

Blending Doppler weather Radar (DWR) data with satellite rainfall data (GSMaP_NOW and INSAT-3D/INSAT-3DR) enhances the ability to monitor, analyse and forecast the weather conditions. This study investigates the applicability of blended NRT Satellite Precipitation Products (SPPs) in near real-time monitoring of extreme rainfall events. Merging the DWR and satellite measurements ensures comprehensive coverage, addressing the limitations of each source. This study also shows the temporal variability of Near real-time (NRT) blended hourly rainfall product, operational at the National Centre For Medium Range Weather Forecasting (NCMRWF), against observations of extreme rainfall during the Michung cyclone. Comparison between the rainfall measurements from INSAT-3D, GSMaP_NOW and NRT Blended rainfall measurements have been made using various statistical parameters for the chosen event. This NRT product will be helpful in the identification of extremes and nowcasting product generation. Finally, the Blended-NRT product showed a high potential for monitoring extremes in near real-time at the operational level.

Keywords: Extreme weather events; Doppler weather Radar; Near Real Time; Rainfall; INSAT3D/3DR

Spatiotemporal Analysis of Heatwaves in India: Implications for Socioeconomic Development and Disaster Risk Management

Sonu Kumar, G.P. Singh

Department of Geophysics,

Institution of science, BHU

Email: sonubhu91@gmail.com

ABSTRACT

Global warming, coupled with rapid socioeconomic development, has heightened the risk of both regional and global disasters. In India, annual heatwaves (HWs) have resulted in significant fatalities and economic losses, with an alarming upward trend. This study examines the spatiotemporal dynamics of heatwaves in India from 1981 to 2023, utilizing gridded maximum temperature and specific humidity datasets. An innovative heatwave evaluation algorithm, which accounts for humidity's impact on human health and the unique characteristics of heatwaves in India, was applied to classify daily heatwave states into light, moderate, and severe levels. Our analysis reveals a significant increase in both frequency and duration of heatwaves across all levels, characterized by earlier onset and later termination. The study identifies substantial regional variations, with the highest heatwave frequency observed in the northwestern, northern central, and northeastern regions. These findings underscore the critical need for enhanced scientific and technological strategies to bolster national and regional disaster mitigation efforts and adapt to the challenges posed by extreme climate events.

Keywords: heatwave; frequency; onset and termination; heatwave level; regional difference

Assimilation of INSAT-3DR satellite radiance in NCMRWF global forecast system

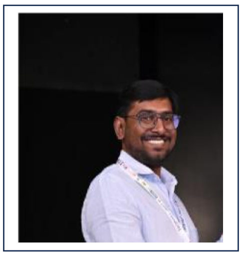
Sujata Pattanayak[a], Suryakanti Dutta[a], S. Indira Rani[a], and Ashish Routray[a]
[a]*National Centre for Medium Range Weather Forecasting*
A-50, Sector-62, NOIDA-201309, UP, India
Email: sujata.pattanayak@gov.in

ABSTRACT

This study illustrates an exhaustive analysis and assimilation of the third-generation Indian geostationary meteorological satellite INSAT-3DR radiance obsrvations in the NCMRWF Global Forecast System (NGFS). This advanced meteorological satellite carries 19-channel multi-spectral sounder payload. The sounder has 18 narrow spectral channels in the shortwave infrared, middle infrared, and longwave infrared regions and one channel in the visible region. In the present study the midwave water vapour channels are considered. The assimilation experiement was conducted for the whole month of April 2024 with the NGFS model to reveal the impact of the INSAT-3DR satellite data in global model. The statistical analysis in terms of frequency of assimilated observation, bias, root mean square error (RMSE), standard deviation, and scatter plot etc. are calculated. The RMSE shows an improvement of about 20%, 62% and 54%, respectively for lowlevel, mid-level and upper-level moisture channels. These RMSEs are calculated based on the bias corrected analysis with respect to the bias corrected background. This initial analysis suggests that the assimilation of INSAT-3DR observation will provide a positive impact on the global analysis field and, consequently, the model forecast. The daily as well as monthly statistics suggest that the analysis field with bias correction improved significantly over the background for all the assimilated channels. It is also noticed that the analysis field gives lesser error i.e varies from -2 to + 2° K.

Keywords: INSAT-3DR; Radiance; Global Forecast System; Assimilation; Statistical Skill Score

Modulation of tropical convection in response to diurnal ocean warming



Maheswar Pradhan[a], Suryachandra A. Rao[a],
[a] *Monsoon Mission, Indian Institute of Tropical Meteorology, Pune*
E-Mail: maheswar@tropmet.res.in

ABSTRACT

Simulation and prediction of diurnal variability of clouds and convection is one of the long-lasting challenges of using coupled climate models. On a diurnal scale, most of the climate models underestimate the diurnal amplitude of precipitation. Also, the precipitation in models occurs earlier than that in reality. In models, the diurnal variability of convection depends on several factors, such as land-sea breeze parameterization, boundary layer parameterization, convective parameterization schemes, cloud microphysics, etc. Although earlier studies have attempted to improve the diurnal variability of precipitation by modifying cloud and convection parameterization schemes, the improvement in the diurnal amplitude of precipitation is not encouraging enough. In this study, we explore a noble approach to improving the diurnal variability of convection through an improved representation of surface ocean diurnal variability. The study also reports the impact of diurnal ocean warming on the intra-daily development of clouds and convection. We have shown how diurnal warming can result in favorable conditions (convergence of moisture, increase in Convective Available Potential Energy, modulation in cloud top/bottom height/temperature) for the growth of cloud/convection through composite analysis. The presence of parameterization of diurnal ocean variability helps the coupled models reproduce the diurnal feedback between the ocean and atmospheric cloud and convective processes.

Keywords: Diurnal Ocean Warming; Diurnal Cloud and Convection; Monsoon Intra-Seasonal Oscillations

Changes in Pre-Monsoon Rainfall in India (1963-2022) and Its Regional Impacts

G Ch Satyanarayana[a], S. Hirali[a] and V Sambasivarao[a]

[a]*Center for Atmospheric Science, Department of Electronics and Communication Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur District, Andhra Pradesh, 522502, India*

E-mail: gcsatya@kluniversity.in

ABSTRACT

This study examines the variability of pre-monsoon rainfall (PMR) in India from March to May, covering the period from 1963 to 2022. The analysis is split into two periods (1963-1992 and 1993-2022) to assess changes in rainfall patterns over the last three decades. Using rainfall data from the India Meteorological Department and atmospheric parameters from ERA5 reanalysis, including sea surface temperature (SST), mean sea level pressure (MSLP), solar radiation, soil moisture, and wind components, the study reveals significant shifts in rainfall activity. Results indicate that the amount of rainfall and the number of rainy days (rainfall >2.5 mm/day) have increased over northeastern India, as well as along the east and southwest coasts, while central and southwestern regions have seen a decline in both metrics in recent decades. The SST analysis highlights a warming trend in the Indian Ocean, which correlates with enhanced moisture transport and increased PMR over India, particularly from the Arabian Sea and Bay of Bengal. Additionally, atmospheric analysis during high and low thunderstorm activity days (HTDS and LTDS) shows considerable variability in rainfall distribution, especially in Andhra Pradesh and Telangana. Northern and western Telangana experienced more rainfall, while southern regions remained drier. Key atmospheric factors such as wind patterns, cloud cover, and soil moisture levels contribute to the variability in rainfall. This study underscores the importance of understanding PMR variability, particularly in the context of climate change, as it has critical implications for agriculture, water management, and preparation for the monsoon season.

Keywords: Pre-monsoon rainfall, Climate variability, Thunderstorm activity, Atmospheric dynamics , Rainfall trends

Impact of high resolution GFS (6.5 km) model on the prediction of extreme rainfall event

B. Revanth Reddy[a], P. Mukhopadhyay[a] , and R. P. M. Krishna[a]
[a] *Indian Institute of Tropical Meteorology, Pune*
E-Mail:revanth.reddy@tropmet.res.in

ABSTRACT

An extremely heavy rainfall event occurred over Tamil Nadu on 18 December 2023 was observed as 95 cm, which is highest recorded during northeast monsoon over Tamil Nadu. The total amount received is equal to the 90 % of the total rainfall received in a year over Toothukudi district of Tamil Nadu state. The Numerical weather prediction models gained importance on the prediction of these extreme weather events for early detection of intensity and location. The modifications made in different physical parameterizations and new techniques in detecting the extreme events made remarkable changes in the model prediction. The improvements in the prediction of these extremes is found by increasing the resolution in operational weather prediction models. Currently the Global Forecast System (GFS) model used at 12.5 km failed to detect the above mentioned extreme heavy rainfall event. The indigenously developed High Resolution model at 6.5 km resolution is able to predict the heavy rainfall event with 7 days lead time.

Keywords: Extreme weather events; Weather Prediction; High Resolution.

Long Term Sea Surface Temperature and Salinity Dynamic in the Bay of Bengal

[a]Subham Maharana, [a]Uday Narayan Rana,
[b]Saikat Pramanik and [a]Samar Kumar Ghose.

[a]P. G. Department Of Atmospheric Science, Fakir Mohan University, Balasore,Odisha,756020
[b]Indian Institute of Tropical Meteorology, Pune- 411008
E-Mail: subham.maharana.109@gmail.com

ABSTRACT

Temperature and salinity, which govern seawater density, are key physical parameters in oceanography. Various physical processes, including air-sea heat and freshwater exchanges, as well as the three-dimensional movement of heat and salt through ocean currents and turbulence, play a role in determining sea surface temperature (SST) and sea surface salinity (SSS). Many complex processes affect the SST and SSS variability and co-variability along with the long term climate scale phenomena. The warming leads to increase evaporation, intensifying salinity in surface waters, while freshwater inputs from precipitation and river discharge can dilute salinity, creating complex interactions between SST and SSS. SST and SSS changes are mainly controlled by local weather conditions and the changes associated with turbulent heat and freshwater fluxes. The main objective of the work is to understand the SST and SSS covariability in different regions of Bay of Bengal (BoB). Here ECMWF reanalysis data (ORAS5) from 1961 to 2020 is used to find the long-term SST and SSS trend; along with its covariance in the BoB. The ocean dynamics is quite different in different part of BoB, so it is divided into three parts: northern BoB (18-24 °N,85-96 °E); south western BoB (04-18 °N, 85-96 °E) and central BoB (4-18 °N, 75-85 °E). The increasing SST trend is prominent in all three parts of BoB (northern BoB-0.013 °C/yr (19611990); south western BoB-0.017 °C/yr (1961-1990) and central BoB-0.017 °C/yr (1961-1990), whereas the SSS trend is not so reasonable in any of the region. However, we found a very decent correlation of SST and SSS in central BoB. Further, significant warming of ocean waters, combined with the processes of evaporation and the mixing of freshwater, plays a fundamental role in regulating the SST-SSS co-variability in the northern BoB.

Keywords: Sea Surface Temperature and Salinity; Climate Scale; SST Trend; Bay of Bengal; Evaporation and Mixing

Numerical Modeling of extremely long lasting cyclone Biparjoy: role of increasing ocean heatwaves

Lokesh Pandey[a], Ankur Gupta[a], and Akhilesh Mishra[a]

[a] *National Center for Medium Range Weather Forecasting (NCMRWF), Ministry of Earth Sciences, Noida, U.P., India.*
E-Mail: lkp.bhu@gmail.com

ABSTRACT

Extreme events like tropical cyclones are especially dangerous for people living in coastal areas. The Arabian Sea (AS) is one of the fastest-warming regions in the tropical oceans. In recent decades, unusual cyclonic activity has been observed in the AS, with cyclones becoming more intense and lasting longer. Recently, an extremely severe cyclonic storm Biparjoy formed over the AS and lasted for over 13 days (6^{th} - 19^{th} June 2023) which is highly unusual for small basins of the north Indian Ocean. It is noteworthy that Cyclone Biparjoy initially developed in a low vertical wind shear environment, but the shear increased suddenly after its formation. This indicates that factors beyond vertical wind shear significantly contributed to the cyclone's intensification. Marine Heatwave Index (MHW) reveals that sea surface temperatures (SST) in the AS were above the 90^{th} percentile threshold just before cyclogenesis. The analysis of Tropical Cyclone Heat Potential (TCHP), and upper ocean mixing parameters highlights the significant role that subsurface warming plays in sustaining the cyclone over the ocean. Models are important for filling in data gaps, especially in areas with little observational data. Using the state of the art NCMRWF NEMO ocean model, it has been shown that the model effectively simulates key variables influencing the development of Biparjoy, even in a 7-day forecast, although it has some significant limitations. This study shows that the realistic simulation and accurate forecasting of mixing related parameters in the upper ocean is important for capturing the dynamics of extremely rare cyclonic events in the India Ocean.

Keywords: Tropical cyclone; Arabian Sea; MHW; NCMRWF; NEMO

Interplay between South Asian High and Indian Summer Monsoon Rainfall: An analysis from observations and seasonal models

G. Sripathi[a], Krishna Kishore Osuri[a], Dandi. A. Ramu[b], A.S. Rao[c]
[a]*Department of Earth and Atmospheric Sciences, NIT Rourkela.*
[b]*Central University of Hyderabad, Hyderabad, Telangana, India*
[c]*Indian Institute of Tropical Meteorology, Pune, Maharashtra, India.*
E-mail: sripathigollapalli@gmail.com

ABSTRACT

This study examines the association between the South Asian High (SAH) and Indian Summer Monsoon Rainfall (ISMR) at different spatial and temporal scales from observations and seasonal models. This study has considered past-climate (1940–1980) and current-climate (1981–2020), to understand the changes in SAH and ISMR. Key findings suggest that the northwest-southeast ($\mathbf{I}_{NW-SE}$), north-south ($\mathbf{I}_{NS}$), and intensity ($\mathbf{I}_{INT}$) indices of the SAH are strongly correlated with ISMR, with correlation of ~0.67, ~0.60, and ~0.51, respectively, while the east-west ($\mathbf{I}_{EW}$) index shows a negative correlation of ~-0.52. Notably, these relationships are more pronounced in the past-climate than in the current-climate, except for the $\mathbf{I}_{INT}$ index. Specifically, the $\mathbf{I}_{NW-SE}$ and $\mathbf{I}_{NS}$ indices are closely linked with all-India, northwest India (NWI), and central India (CI) rainfall, while the $\mathbf{I}_{INT}$ index is associated with south peninsular India (SPI) rainfall. Increased rainfall over NWI and SPI in the current-climate is strongly connected to positive $\mathbf{I}_{NS}$ and $\mathbf{I}_{INT}$ indices, respectively. However, northeast India (NEI) rainfall shows no significant relation with SAH indices, though the $\mathbf{I}_{EW}$ index is notably linked to increased NEI rainfall during El Niño years. Additionally, there is a significant positive (negative) relationship between meridional (zonal) wind shear and SAH indices, except for the $\mathbf{I}_{EW}$ index, and positive SAH indices generally favour stronger ISMR due to positive moisture anomalies. This observed relationship has been checked in four seasonal models (CANCM4, NEMO, CANSIP, and CFSv2) initialised with May conditions for the 1982–2016 period. Note that the data period is not uniform in past- and current-climate periods, so this analysis is conducted for total data period. Most models capture the ISMR-SAH relationship, with slight variations in the correlation analysis. The positive rainfall anomalies associated with $\mathbf{I}_{NW-SE}$ years are strongly attributed to cold sea surface temperature (SST) anomalies over the equatorial eastern Pacific (La Niña) and positive vorticity from a strong cyclonic circulation over the monsoon region. Conversely, $\mathbf{I}_{EW}$ years show significant negative rainfall anomalies linked to El Niño patterns and negative vorticity anomalies over the monsoon region.

Keywords: South Asian High, East-west index, Northwest-Southeast index, Seasonal rainfall, Indian Summer Monsoon, Teleconnections, Homogeneous regions, wind shear

IoT-Based Real-Time Flood Monitoring and Early Warning System Using Water Level Sensors

P V Kishor Kumar Reddy , P D Yasasree, S A Kalam Azaad , M Nagesh and G Ch Satyanarayana

Department of Electronics and Communication Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur District, Andhra Pradesh, 522502, India

Email: 9704pvkkr@gmail.com

ABSTRACT

Floods are among the most destructive natural disasters, causing extensive damage to the environment and human life. Timely monitoring of river water levels is crucial for mitigating these impacts. This project presents an IoT-based Flood Monitoring and Alerting System that provides real-time detection, monitoring, and early warning alerts for potential floods. The system uses ultrasonic water level sensors and a NodeMCU ESP32 to collect and process data, which is then uploaded to the ThingSpeak IoT cloud for remote monitoring. The primary objective is to sense water levels in riverbeds and issue alerts when thresholds are exceeded, using both LED indicators and internet-based notifications. This system allows authorities and individuals to monitor river levels graphically from any location, enabling quick response and preparation. Incorporating IoT technology, this system integrates data from water level sensors with rain gauge measurements to provide a comprehensive flood forecasting model. Centralized data collection enables the prediction of flood severity and enhances the accuracy of alerts. Additionally, this project highlights the potential for combining IoT with Radar data for more robust flood monitoring in the future. By leveraging cloud computing and wireless sensor networks (WSN), this flood monitoring system offers a reliable solution for early warning. Future developments, including machine learning algorithms, will further enhance flood prediction by analyzing atmospheric conditions such as temperature, rainfall, and moisture levels. Ultimately, this system aims to reduce the risks and losses associated with floods through timely alerts and continuous monitoring, offering a practical solution for flood-prone regions.

Keywords: IoT, Rain gauge, Flood monitoring, weather predictions.

Trend analysis of rainfall characteristics using Mann-Kendall test in Marathwada region

Swapnali Mahude[a], Madhukar Jadhav[a], Pralhad Jaybhaye[a], Shantanu Dhawase[a], Ankush Chougule[a] and Anjali Kale[a]

[a] *Department of Agricultural Meteorology, VNMKV, Parbhani, Maharashtra, India-431402.*

E-Mail: mahudes07@gmail.com

ABSTRACT

Under changing climate, the Marathwada region of Maharashtra has been facing chronic water shortage regularly due to depleting ground water levels and erratic monsoon rainfall distribution. Therefore, present study was undertaken at Department of Agricultural Meteorology, VNMKV, Parbhani in 2021-22 and 30 years (1991 to 2020) rainfall data has been taken for computation. Mann-Kendall (MK) Test has been used for determination of taluka-wise trend of 8 districts. In general, in all 8 districts, annual rainfall trend was observed either decreasing or increasing nonsignificant. However, few talukas showed significantly increasing trend *viz*., Phulambari, Khultabad, Gangapur (Aurangabad); Vadavani and Shirur-Kasar (Beed); Renapur and ShirurAnantapal (Latur), Lohara and Washi (Osmanabad), Ardhapur, Loha, Mahur, Mudkhed, Naigaon-Khurd, Umari (Nanded), Manwat, Purna, Selu (Parbhnai), Aundha and Sengaon (Hingoli), and decreasing significantly in Udgir (Latur), Kalamb (Osmanabad), Deglur (Nanded), Gangakhed, Pathri and Jintur (Parbhani). During pre-monsoon season, significant increasing trend was observed in all talukas of all 8 districts, except very few talukas showed decreasing trend *viz.*, Jalna (Jalna), Ausa and Chakur (latur), Bhum, Kalamb, Juljapur and Umarga (Osmanabad) etc. During monsoon season only two talukas of Hingoli district (Basmat and Hingoli) showed significantly decreasing trend and some talukas of different district showed significantly increasing trend *viz.*, Phulambri (Aurangabad), Vadavani, Shirur-Kasar (Beed), Renapur (Latur), Lohara and Washi (Osmanabad) Dharamabad, Loha, Mahur, Mudkhed, Mukhed, Naigaon-Khurd and Umari (Nanded), Aundha and Sengaon (Hingoli). Post monsoon season showed non-significant trend in all talukas of Aurangabad, except in Phulambri, which showed significant rising trend. All talukas of Parbhani district showed significant increasing trend, and some talukas in remaining six districts showed significantly increasing trend, such as Vadavani and Shirur Kasar (Beed); Devani and Jalkat (Latur); Lohara and Washi (Osmanabad); Ardhapur, Loha, Kinwat, Naigaon-Khurd, Umari (Nanded), Aundha and Sengaon (Hingoli). During winter season, every taluka of all districts showed significantly increasing trend.

Keywords: Rainfall, Trends, Mann-Kendall test, Marathwada region

Impact of cumulus parameterization on precipitation at high spatial resolution: A case study of extreme rainfall event over central India

Parvathy Thankachy P[a], Saurabh Das[a]

[a] *Department of Astronomy Astrophysics and Space Engineering, Indian Institute of Technology Indore*
E-Mail: phd2301121011@iiti.ac.in

ABSTRACT

Although there have been great advancements in NWP models in recent times, accuracy and temporal matching in extreme weather events are still severely lacking. In this present work, a simulation study using various cumulus schemes, such as Kain-Fritsch (KF) and Betts-MillerJanjic (BMJ) have been tested over central India for 15-18 September, 2023 which recorded the highest rainfall in the last 30 years in a spell of three days. The simulation has been carried with 3 nested domains of 18 km, 6 km and 2 km resolution with feedback on. The results were validated against the IMD gridded rainfall data, GPM IMERGE and IMDAA reanalysis data set. The results indicate that simulation with KF turned on for the innermost domain was able to capture both the peaks of precipitation. Both cell by cell analysis and domain average analysis indicate that the KF in the innermost 2 km domain is able to capture the precipitation trend and magnitude better than the commonly used method of using the models with cumulus scheme turned off. Using a scale aware cumulus scheme could provide even better results.

Keywords: Extreme weather events; Cumulus Parameterization

Sensitivity of Microphysical Parameterizations in the Simulation of Thunderstorms Over Urban Region

Rajith K[a], Krishna Kishore Osuri[a], and Lakshman Kesireddy[a]
[a]*Department of Earth and Atmospheric Sciences,*
NIT Rourkela
E-Mail:rajithk98@gmail.com

ABSTRACT

Thunderstorms (TS) are destructive atmospheric events characterized by thunder, lightning, strong winds, and heavy precipitation, causing significant damage to agriculture, property, and human life. In India, thunderstorms are most prevalent during the monsoon season, especially severe in the pre-monsoon period. Despite their significance, modeling studies of TS in India are scarce. This study employs the Weather Research and Forecasting (WRF) model with various microphysical (MP) parameterizations to simulate TS events over the urban regions of Eastern India, aiming to evaluate their sensitivity. Five MP parameterizations- Ferrier, Milbrandt and Yau, Morrison, Thompson, and WSM6 were used in the WRF simulations. The model's performance was analyzed by focusing on rainfall characteristics, surface parameters, vertical velocity, and hydrometeor distribution. Ferrier underestimates rainfall, shows poor performance in simulating rain rates, while Milbrandt and WSM6 align closely with GPM observations. Thompson and Morrison exhibit moderate performance, with rain rates slightly lower than observed values. Milbrandt demonstrates the highest skill scores for rain rates across various thresholds, followed by Morrison and WSM6. Ferrier shows low skill scores, particularly at higher thresholds. Parameterizations tend to overestimate surface parameters- 2m temperature and wind speed at 10m while underestimating relative humidity at 2m compared to the METAR observation. Ferrier shows higher amounts of non-precipitating hydrometeors, mostly ice, leading to weak rainfall simulation. Milbrandt, Morrison and WSM6, which simulate higher amounts of precipitating hydrometeors, particularly graupel leading to better rainfall prediction. The profiles of graupel hydrometeor and diabatic heating highlights the role of graupel melting in improved rainfall predictions. These findings offer valuable insights for improving TS forecasts in urban regions, particularly in terms of prediction accuracy.

Keywords: Extreme weather events, thunderstorm, microphysics, numerical modeling, WRF

Analysing the diurnal and seasonal variation of particulate matter and its impact on the precipitation process

Dola Tharun[a], Bhishma Tyagi[a*], Balaji Kumar Seela[b]

[a]*Department of Earth and Atmospheric Sciences National Institute of Technology Rourkela*
[b]*Department of Atmospheric Sciences, Institute of Atmospheric Physics, National Central University, Zhongli District, Taoyuan City, 320317, Taiwan*
Email: tharundola@gmail.com

ABSTRACT

The daily and seasonal variation of $PM_{2.5}$ and PM_{10}, driven by human activities and meteorological factors, is critical in shaping local and regional air quality. Its interaction with atmospheric processes, especially cloud formation and precipitation, can suppress and enhance rainfall, with significant implications for regional weather patterns and climate. The present study focuses on Rourkela, an industrial capital of Odisha state. Rourkela is the third-largest urban agglomeration in Odisha after Bhubaneswar and Cuttack. For this study, one-year $PM_{2.5}$ and PM_{10} data was utilized, measured by an ambient air quality monitor installed at the NIT Rourkela. The disdrometer rainfall information, installed on the rooftop of the Department of Earth and Atmospheric Sciences, NIT Rourkela, is used to understand the impact of $PM_{2.5}$ and PM_{10} on precipitation processes. The disdrometer records the 22 classes of diameters of raindrops and 20 classes of velocities of raindrops, with a temporal resolution of one minute. The ERA 5 temperature, precipitation, cloud fraction, winds and AOD data were also used to understand the impact of air pollution on the precipitation processes.

Keywords: Air quality; Particulate matter; Aerosol Optical Depth; seasonal variation; diurnal variation; Disdrometer.

Evaluating the Indian Summer Monsoon variability during the end of the 21st century using CMIP6 projections

Karishma Dahiya[1], Nagaraju Chilukoti [1], and Raju Attada [2]

[1] Department of Earth and Atmospheric Sciences, NIT Rourkela, India
[2] Indian Institute of Science Education and Research, Mohali, India
E-Mail:kdahiya189@gmail.com

ABSTRACT

Large uncertainties exist in the Indian Summer Monsoon (ISM) rainfall projections in a warming climate scenario. The state of the ISM during the warm period is of concern from India's agriculture and economy perspective. In this study, we aim to evaluate the ISM state by the end of the 21st century with respect to the mid-Pliocene period which has very similar warming or temperature changes. To evaluate this, we have compared mid-Pliocene changes from the pre-industrial period with near future (2051-2080) and far future (2071-2100) changes from the historical period (1985-2014) using six models from the Coupled Model Intercomparison Project (CMIP) phase 6. The ensemble of the models simulated an increase in precipitation of nearly 21% and 29% in the near future and far future respectively. The precipitation changes in the near future changes are relatively less than the precipitation changes in past mid-Pliocene period (~29 %) while far future precipitation changes are similar to the past mid-Pliocene changes. From this analysis, we assume that the ensemble of CMIP6 models simulated similar intensification in ISM rainfall in the far future period for nearly similar warm temperature conditions. Further, we have evaluated the changes and similarities through thermo dynamical and dynamical factors. The change in global surface temperature in the near future and far future is simulated to be 2.83 ⁰C and 4.14 ⁰C respectively with corresponding changes in precipitable water is 9.54 kg/m^2 and 10.50 kg/m^2. The change in precipitable water is comparable in the far future and past mid-Pliocene. The regional scale Monsoon Hadley circulation over the Indian region is simulated to be strengthened in both past and future climates (near and far). In addition, large-scale wind circulation at 850 hPa is simulated to be stronger along the coast of Somalia in the near and far future and this intensity change magnitude is similar in the far future and mid-Pliocene. The findings of this research highlight the potential for significant changes in the Indian Summer Monsoon by the end of the 21st century which is mainly dependent on thermo dynamical change rather than the dynamical change.

Keywords: Indian Summer Monsoon Rainfall, CMIP6 models, mid-Pliocene, far future, near future.

Effect of microbial inoculants on soybean (*Glycine max. L*) root growth and development

Ankush Chougule[a], Pralhad Jaybhaye[a], Madhukar Jadhav[a], Swapnali Mahude[a], Shantanu Dhawase[a] and Anjali Kale[a]

[a]*Department of Agricultural Meteorology, College of Agriculture,VNMKV, Parbhani*
E-Mail: ankushchougule1522@gmail.com

ABSTRACT

Soybeans are an essential source of food, protein, oil worldwide, and nodules on their root systems play a critical role in nitrogen fixation. India spent USD 132.4 billion on crude imports. Soybean root comes under deep tap root system. A field experiment entitled "effect of microbial inoculants on soybean *(Glycine max. L)* root growth and development" was carried out during the *kharif* season 2024-2025 on research farm, Department of Agricultural Meteorology, College of Agriculture, Parbhani. The research field was laid out in spilt-plot design with five treatments (Mi_0- control, Mi_1- Biomix, Mi_2- Bacillus lichino phosphate, Mi_3-Bio NPK and Mi_4- Rhizophos) and three replications. The soybean crop (Var.- MAUS- 612) was sown on dated 22 Jun 2024 by dibbling with keeping space 45 × 5 cm. The root growth and development parameters (viz., nodules count, length, volume and fresh weight of root) per plant was taken by uprooting the plant (destructive sampling method) at pod full size (90 DAS) of soybean crop. The mean nodule count and root length was recorded 97 nodules and 28 cm respectively, which was found 4 to 29% and 11 to 19% more compare to control, respectively. The trend of volume and weight of root was not observed similar to root nodule count and root length. The mean root volume was recorded 8 ml and it was observed lower (-2 to -36%) compared to control in all microbial inoculants except higher (12%) in Mi_2. The mean root weight was recorded 7 gm and it was found 8 and 21% more in Mi_1 and Mi_2 respectively, and lower by -10 and -19% compared to control. Soil application of microbial inoculants are useful to increasing root nodule count and length, some times it is beneficial to get more root volume and weight.

Keywords: Soybean; Microbial Incoluents; Root growth; Nodule count.

Evaluation of Oceansat-3-Scatterometer-Derived Ocean Surface Winds over the Indian Ocean Using Observations from Buoys and ASCAT

Jharna Borah[a], Yerni Srinivas Nekkali[a], Kameshwari Nunna[a,b] and Krishna K Osuri[a]

[a]*Department of Earth and Atmospheric Science, NIT Rourkela*

[b]*Data and Information Management Group (DMG), INCOIS, Hyderabad*
E-Mail: jharnaborah7086@gmail.com

ABSTRACT

Ocean surface winds play a major role in the understanding of different oceanic dynamical processes from oceanic circulations to the generation of sea surface waves. As conventional wind observing systems are sparse and difficult to maintain, satellite scatterometers are widely used in numerical models as they can provide ocean surface winds under all weather conditions. However, it is important to validate the quality of scatterometer winds before its use in different applications such as ocean state analysis, improving the initial conditions of the models, etc. The present study describes the validation of ocean surface winds derived from the recently launched Oceansat-3 Scatterometer (O3SCAT) over the Indian Ocean using OMNI and RAMA buoy observations, along with other scatterometer winds such as Advanced Scatterometer (ASCAT) for the period of April, 2023 to March, 2024. Since the mission goal of O3SCAT is to provide wind speed measurements of 3–30 ms^{-1}, the winds within this range are only considered. The comparisons with OMNI buoy data available over the North Indian Ocean (NIO) show that the root mean square errors (RMSEs) for wind speed and direction are 2.13 ms^{-1} and 30.11°, respectively. While, for RAMA buoy data available over the Southern tropical Indian Ocean (SIO), the RMSEs are 1.48 ms^{-1} and 14.52°, respectively. The comparisons of O3SCAT and ASCAT winds demonstrate that the RMSEs are 1.93 ms^{-1} and 20.18°, respectively. In general, the matching between in-situ and satellite estimates indicate that errors of OMNI buoys exceed the scatterometer mission requirements (1.8 ms^{-1} and 20°) while RAMA buoys show good correlation. Furthermore, the accuracies of the O3SCAT are nearly consistent with ASCAT wind data. Further, analysis of the performance of O3SCAT in capturing cyclonic storms is depicted, which indicates its capability in capturing extreme weather events as well.
Keywords: Oceansat-3; Scatterometer; Buoys; Indian Ocean; Cyclone

Structure and Evolution of Mesoscale Convective Systems Over the Monsoon Zone: Insights From High-Resolution Observations and Model Simulations

Sachin M. Deshpande[1*], Manisha Tupsoundare[1], Zhe Feng[2],
Subrata K. Das[1], Medha Deshpande[1], and Harshad Hanmante
[1]*Indian Institute of Tropical Meteorology, Pune-8, India*
[2]*Pacific Northwest National Laboratory, Richland, USA*
Email: sachinmd@tropmet.res.in

ABSTRACT

Largest deep convective storms, known as mesoscale convective systems (MCSs), form when convection grows upscale and aggregates, combining with other storms to create a distinct mesoscale circulation. Because of their big size, extended duration, and increased precipitation, MCSs cause high-impact weather. During monsoon, synoptic systems pass across the monsoon zone, causing MCSs to form often. To gain a better understanding of convective organization in the monsoon zone, the structure and evolution of cloud and precipitation-related features of MCSs is explored for the first time using remote sensing data (radar & satellite) and model simulations. MCSs are identified and tracked during JJAS 2014-19 using an object-based cloud-tracking method applied to satellite IRTb and IMERG precipitation data. The statistical properties of tracked MCSs (n=2022) are studied in terms of land-ocean contrast, rainfall quantity, diurnal cycle, role of merging and splitting, and their shrot vs. long-lived evolutions. MCSs account for 40-60 % of total precipitation over land and 80% over the Bay of Bengal (BoB) during monsoon. This contrast between the land and ocean is due to BoB MCSs being larger, longer-lasting, and producing greater volumetric rain than land MCS. Stronger deep-layer wind shear and enhanced lower-free-tropospheric moisture prior to MCS initiation results in more MCS lifetime rainfall. Next, a storm classification is used to explore embedded storm structures for MCSs within the radar domain (n=65) using IMD S-band DWR data at Bhopal during JJAS 2015. The evolution of 3D structures of storms relative to the lifecycle phases of MCS, including top heights, convective core length, and convective/stratiform areas is investigated. MCS contains numerous precipitation features, mainly early in its formation when various convective clusters begin to join. The convective, stratiform, and anvil components of MCSs showed distinct vertical structures. To identify and track MCSs in convection-permitting WRF simulation (JJAS 2015), same cloud-tracking is applied to simulated reflectivity, IRTb, and precipitation. Rather than using simulation to outline specific MCS events, statistics of MCS is studied. Composite growth and freq. distribution of convective area, rain, and speed are consistent with observations, despite the model underestimating sum of observed MCSs. But, stratiform areas are undervalued. Simulated MCS features slowly increased from convective initiation to 1st half of MCS duration, which is consistent with observations. Similarities and differences of this comparison will be discussed.

Severe Heat Wave Characteristics and associated Thermal Discomfort conditions over India

Kesireddy Lakshman[a], Raghu Nadimpalli[b], Akhil Srivastava[b], Krishna Kishore Osuri[a], Raju Attada[c], Anant Parekh[d]

[a]Department of Earth and Atmospheric Sciences, National Institute of Technology Rourkela, India
[b]India Meteorological Department, New Delhi – 110 003, India
[c]Department of Earth and Environmental Sciences, Indian Institute of Science Education and Research Mohali, Punjab 140306, India
[d]Indian Institute of Tropical Meteorology, Pune, India
E-Mail: kesireddylakshman179@gmail.com

ABSTRACT

This study explores regional characteristics of heatwaves and thermal discomfort conditions during March-June for 1990-2020 over India. The Empirical Orthogonal Function (EOF) of maximum temperature (T_{max}) of India Meteorological Department (IMD) observational analysis identified north-central India (NCI) and southeast coast of India (SECI) as vulnerable regions to heatwaves. Normalized-T_{max} anomaly is used to identify heat waves from IMD analysis, Indian Monsoon Data Assimilation and Analysis (IMDAA), and ECMWF Reanalysis v5 (ERA5). Results highlight that IMDAA with 202-days (181-days) overestimates heat waves duration by ~3.5-11% while ERA5 with 132-days (89-days) underestimates by ~32-45% compared to IMD with 195-days (163-days) in NCI (SECI) respectively. The slight overestimation (underestimation) of T_{max} in IMDAA (ERA5) compared to IMD could be one of the reasons for the bias in respective heatwave days. The average length of heatwave is 7.8, 7.5, and 7.76 days (8.15, 7.72, and 6.1 days) over NCI (SECI) in IMD, IMDAA, and ERA5, respectively. Composite analysis reveals a negative soil-moisture anomaly (SMA) in IMDAA favors the intensification of heatwaves, and is consistent with that of European Space Agency Climate Change Initiative (ESACCI), unlike ERA5 in both the regions. The mid-level anticyclone over northwest India is stronger during NCI heat waves than SECI. Advecting the heat, stronger (~10m/s) north-westerlies at 850 hPa abates sea breeze in the coastal region, aiding for longer duration of heatwaves in the SECI region. The high heat-stress is more frequent in SECI than NCI region, and common during May-June (May only) as seen in IMDAA (ERA5). Relative humidity played a major role in the maintenance of high heat-stress over SECI in-spite of less 2m temperature than NCI region.

Keywords: Heatwaves, Pre-monsoon, South East Coast of India, North Central India

Characterizing rain-type classification and convective clustering in RADAR observations and model simulations over the monsoon core zone

Sachin M. Deshpande[1*], Harshad Hanmante[1], Subrata K. Das[1], Medha Deshpande[1] and Manisha Tupsoundare[1]
[(1)] *Indian Institute of Tropical Meteorology, Pune-8, India*
**Email: sachinmd@tropmet.res.in*

ABSTRACT

Deep convection and the degree of convective organization play an important role in the global circulation regarding moisture fluxes, energy, and momentum transport. During the monsoon, deep moist convection is frequent, and it produces widespread and heavy precipitation over Central India. Given its significance, a polarimetric C-band (CPol) radar was installed at the Atmospheric Research Testbed (ART) Facility of IITM at Silkheda in the monsoon core zone. The high-resolution CPOL radar observations (6 min, 1 km) allow us to investigate evolution of convective clustering during the life cycle of convective entities and use this as an observational basis to assess how convective clustering is represented in a numerical model. The CPol radar measurements from two-day heavy rain events in June to September 2022 are used to categorize 3D radar echoes as convective, stratiform, mixed, isolated convective core, and isolated convective fringe. Clustering metrics are then applied to radar-identified convective echoes to determine the degree of convective aggregation/clustering as well as their spatial distribution within the radar domain. Convective clustering occurs in two different phases, lasting approximately 24 hours before (Phase 1) and after (Phase 2) peak rain rate. Convective clustering is accompanied by an increase in convective elements in phase 1, but phase 2 demonstrates the preponderance of a broad stratiform area as well as a decrease in convective elements. Composite evolution reveals that small convective objects are blended into fewer and larger objects that are more clustered, indicating that convective aggregation is taking place. A phase lag is observed between the isolated convective core, convective, and stratiform echoes. Next, the WRF model is used to perform a convection-permitting simulation for a severe rain event on August 20-22, 2022. Similar techniques were applited to simulated reflectivity to investigate rain-type categorization and convective clustering, and the findings were compared to radar data. In general, the reflectivity CFADs for different rain types below 5 km show a decent comparison between radar and WRF, but the frequency distribution is much wider and the WRF reflectivity values are weaker above 5 km. The degree of convective clustering in the model is evaluated against radar-based clustering by applying organization indices (e.g., SCAI, I_{org}) to the WRF simulation. The microphysical characteristics and other variables from the simulation (e.g. vertical velocity) are utilized to explain the observed similarities and differences between the radar and WRF comparisons, and details will be provided at the conference.

Implementation of CO2 Conversion to Oxygen in Automotive Systems for Cleaner Emissions

[a]Dr. N V K Ramesh, [b]Sekuboyina Eswar vadan, [c]Dinakar sasi nuvvala

[a] *Department of Electronics and Communication Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur District, Andhra Pradesh, 522502, India*

[b,c] *Student,Department of Electronics and Communication Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur District, Andhra Pradesh, 522502, India*

E-Mail: nvkr@kluniversity.in

ABSTRACT

This paper explores innovative methods for converting CO2-polluted air into pure O2 within automotive systems. With rising concerns over air quality and climate change, the integration of CO2 reduction technologies in vehicles is essential. The proposed system utilizes advanced catalytic converters and photochemical processes to facilitate the transformation of carbon dioxide into oxygen. By leveraging renewable energy sources, such as solar or wind power, the system can operate efficiently, minimizing its environmental footprint. Additionally, we examine the role of nanomaterials in enhancing the reaction rates and overall efficiency of these processes. This approach not only aims to improve air quality but also contributes to sustainable automotive practices. The feasibility and potential impact of implementing this technology in mainstream vehicles are discussed, highlighting the benefits for urban environments. Overall, the study presents a pathway towards cleaner automotive emissions and a healthier atmosphere.

Keywords: CO2 Reduction, Catalytic Conversion, Arduino, Nanomaterials, Sustainable Automotive Technology

https://shivacement.com/

Shiva Cement is a well-positioned player in the cement value chain and is presently a part of the prestigious JSW Group. Having started our operations in Odisha in 1985, we are today expanding our capacities to cater to the emerging opportunities in the eastern India markets. We are enabled by robust raw material reserves, proximity to the market, and a strong focus on sustainable growth.

We have enhanced our production capacity to 4,000 TPD this year. Our objectives and strategies for the future are aligned with our goal of being the market leader in India's eastern area.

We have looked at expanding our operations further, using the experience of our parent firm, JSW Cement. Our manufacturing facility is strategically located at the geographical border of three eastern states of India, namely Odisha, Chhattisgarh, and Jharkhand, having proximity to the raw materials that we require for our operations, including limestone, clay, laterite, iron fines, slag, gypsum, and fly ash. It is also well-connected to our key markets by road and railways. We believe that this shall enable our manufacturing facility to act as a feeder to the eastern plants of JSW Cement, providing us with a competitive advantage.

Our journey:
1985: Shiva Cement comes into existence
1986: Commercial manufacturing commences
1998: Reach 300 TPD clinker production capacity
2017: Acquired by JSW Cement
2017 to till date: Enriching the lives of nearby communities by enhancing: Education, Health, Sustainable Livelihoods & Rural development
2020: Commenced work for building the new Clinkerization plant
2023: Inauguration of Clinkerization plant

Investigation of diurnal and seasonal variations in atmospheric boundary layer over a tropical coastal urban station

Angel Anita, Christy [a] and Manoj, M.G[a]

[a] *Advanced Centre for Atmospheric Radar Research (ACARR), Cochin University of Science and Technology, Cochin, Kerala*

E-Mail: angelanitachristy@cusat.ac.in

ABSTRACT

The atmospheric boundary layer (ABL) is primarily characterized by its diurnal variability, which is crucial in exchanging heat, momentum, moisture, and chemical components between the surface and the free atmosphere. Diurnal variation is typically pronounced, especially over land during periods of peak surface temperatures and in the absence of upper-level clouds. However, only a few studies have explored the diurnal variation of ABL height, mainly due to the lack of measurements with sufficient temporal resolution. This study investigates the diurnal fluctuations and seasonal variation in ABL height using a VHF radar at Cochin, Kerala covering six years from 2018 to 2023. The ABL height was estimated through the normalized standard deviation method (NSDM) derived from VHF radar data, utilizing profiles of signal-to-noise ratio, horizontal wind speed, and direction. This method connects the intensity of turbulence within the ABL. The study focused exclusively on days with clear or partly clear skies. In the preliminary analysis, 48 such days were identified across all seasons. Of these, 7 days had 24-h profiles and 41 days had 14-hour profiles. The ABL depth shows significant spatial and temporal variability, as it is influenced by factors such as topography, solar radiation, surface roughness, and other surface forcings. Given the increasing frequency of localized extreme weather events, this study aims to establish a short-term climatology of the diurnal and seasonal evolution of the ABL over a tropical site with complex terrain and a land-sea interface. The results are expected to reveal the structure and dynamics of ABL which has direct implications in studies related to atmospheric turbulence, air pollution and local extreme weather events.

Keywords: Atmospheric boundary layer; 205 MHz radar; Diurnal variations; Seasonal changes

Remote Sensing Insights into NDVI and Rainfall in Semi-Arid Maharashtra

[a]Satwik Panda, [b]K K Dakhore, [b]Y E Kadam, [c]Rahul Nigam, [b]B. S. Bhalerao, [b]R. B. Mane, [a]Vishwadip Bharne, and [a]A U Dabhade

[a]Department of Agricultural Meteorology, VNMKV, Parbhani431 401
[b]AICRPAM,VNMKV,Parbhani,431 401
[c]EPSA, Space Application Center, ISRO, Ahmedabad 380 015
Email: satwikpanda.7@gmail.com

ABSTRACT

This study investigates the relationship between rainfall (RF) and the Normalized Difference Vegetation Index (NDVI) across various regions, including Ch. Sambhajinagar, Jalna, Beed, Latur, Dharashiv, Nanded, Parbhani, and Hingoli, from 2014 to 2020. By analyzing monthly data from June to October, results show considerable variability in both rainfall and NDVI across the studied years and regions. Ch. Sambhajinagar experienced significant rainfall peaks in 2020, while NDVI values fluctuated, reflecting vegetation health during critical growth periods. Notably, NDVI values improved with better Standardized Precipitation Index (SPI) values in Ch. Sambhajinagar, particularly in August. However, severe droughts in 2015 and 2017 led to significant declines in NDVI. A strong correlation between SPI and NDVI was observed, especially in July and August, indicating that improved rainfall conditions contribute to enhanced vegetation health. Parabhani and Hingoli districts demonstrated moderate relationships with rainfall, with notable spikes in NDVI linked to increase SPI in August. Regression analysis revealed that SPI in August had the strongest predictive power for NDVI, with each unit increase in SPI associated with a 0.4-0.6 increase in NDVI, highlighting the critical role of this month for vegetation growth. Overall, the multilinear analysis underscores a clear relationship between NDVI and rainfall, particularly during the monsoon months of July and August. Adequate rainfall, as indicated by positive SPI values, correlates strongly with improved vegetation health in semi-arid Maharashtra. This analysis emphasizes the necessity of monitoring rainfall patterns to effectively predict and manage vegetation health, which is crucial for agricultural sustainability in the region.

Keywords: Standardized Precipitation Index (SPI), NDVI (Normalized Difference Vegetation Index), Remote Sensing, Semi-Arid Regions, Drought Impact

Assessment of remote sensing derived drought Indicators over Maharashtra

[a]Vishwadip Bharne, [b]K K Dakhore, [b]Y E Kadam, [c]Rahul Nigam, [b]B. S. Bhalerao, [b]R. B. Mane, [a]Satwik Panda and [a]A U Dabhade

[a]Department of Agricultural Meteorology, VNMKV, Parbhani 431 401
[b]AICRPAM,VNMKV,Parbhani,431 401
[c]EPSA, Space Application Center, ISRO, Ahmedabad 380 015
Email: vishwadipbharne16@gmail.com

ABSTRACT

This study analyzes rainfall deviations and drought indicators in Maharashtra during the kharif seasons of 2022 and 2023, utilizing remote sensing data. By employing Short Wave Infrared (SWIR)-based Land Surface Water Index (LSWI), Near Infrared-based Normalized Difference Vegetation Index (NDVI), and their corresponding Vegetation Condition Index (VCI), monitored seasonal agricultural drought and assessed their responses to rainfall deviations. In 2022, the strongest correlation between India Meteorological Department (IMD) and satellite rainfall data occurred in early August. Severe negative rainfall deviations were observed in June and early July, while the second fortnight of July showed the highest positive deviations. However, districts like Pune, Ratnagiri, and Satara maintained low constant deviations throughout the season. Conversely, 2023 experienced significant rainfall deficits, marked by weak correlations between IMD and satellite data and persistent negative deviations. Some areas exhibited positive anomalies by September, but negative deviations predominated, particularly in October. Regional disparities in vegetation health were pronounced, with districts like Dhule and Parbhani facing early negative rainfall deviations in 2022. Dhule experienced reduced vegetation despite stable LSWI VCI, while Parbhani showed improved NDVI following rainfall. In 2023, areas such as Nashik and Nagpur suffered from negative NDVI and LSWI deviations, though districts like Thane and Palghar demonstrated improved water conditions despite lower NDVI. By late September, Solapur and Akola exhibited strong vegetation health. Overall, the analysis highlights the intricate relationship between rainfall variability and drought indicators, revealing diverse impacts on vegetation and water conditions across Maharashtra. These findings underscore the necessity for targeted interventions to support affected regions and mitigate the effects of drought.

Keywords: Land Surface Water Index, NDVI, VCI, Satellite Data, Rainfall Deviation

Assessment of seasonal soil moisture dynamics using satellite dataover Marathwada

[a]A U Dabhade, [b]K K Dakhore, [b]Y E Kadam, [c] Rahul Nigam,

[a] Vishwadip Bharne, [a]Satwik Panda and [b]B. S. Bhalerao, [b]R. B. Mane

[a] *Department of Agricultural Meteorology, VNMKV, Parbhani 431 401*
[b]*AICRPAM, VNMKV,Parbhani,431 401*
EPSA, Space Application Center, ISRO, Ahmedabad 380 015

ashwinid1201@gmail.com

ABSTRACT

This study investigates seasonal soil moisture dynamics in the Marathwada region from 2015 to2023, utilizing satellite data to assess spatial and temporal variations in soil moisture and theirimplications for agriculture. Focusing on three zones—high, moderate, and low soil moisture variability—the research identifies distinct challenges and opportunities for farming. High- variability zones, such as Naigaon and Mudkhed, experienced a notable increase in variability,with standard deviations rising from 0.22 in 2020 to 0.36 in 2023, largely due to erratic rainfalland poor water retention, necessitating improved irrigation and resilient crop varieties. Moderate- variability regions like Aurangabad and Beed exhibited greater stability, benefiting fromconsistent rainfall and better management practices, although fluctuations remain. In contrast,low-variability zones, including Ashti and Nanded, enjoyed stable conditions conducive to traditional farming. The analysis highlights significant seasonal dynamics, particularly during the monsoon (June to September), when high-variability zones saw rapid moisture increases followedby sharp declines, while low-variability zones retained moisture more effectively. Post-monsoon,high- variability areas dried out quickly, emphasizing the need for effective moisture management. Additionally, the study evaluates satellite-based soil moisture measurements from the SoilMoisture Active Passive (SMAP) satellite, validated against in-situ observations in Parbhani from 2020 to 2024. While satellite estimates generally underestimated soil moisture, correlations withground measurements improved over time, with a correlation coefficient rising from -0.48 in 2020to 0.69 in 2021. The Mean Absolute Error (MAE) decreased from 6.1 in 2020 to 1.3 in 2023,indicating improved accuracy. Ultimately, the study underscores the reliability of satellite soilmoisture estimates and highlights the importance of enhancing sustainability in Marathwada.

Keywords: Soil Moisture Dynamics, Satellite Data, Drought Assessment, Variability Zones,Climate Resilience

X-BAND POLARIMETRIC WEATHER RADAR NETWORK OVER MUMBAI: NETWORK SET-UP AND PRELIMINARY RESULTS

Subrata Kumar Das[a], Sunil Khadgarai[a], Chiranjeevi Guttula[a], Chandramuni Survase[a], AdtiyaJaiswal[a], Amol Dhole[a], Prashant Kshirsagar[a], Yogesh Kolte[a], Sachin Deshpande[a]

and G. Pandithurai[a]

[a] *Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune-411008E-Mail: subrata@tropmet.res.in*

ABSTRACT

Rapid urbanization has led to increased instances of heavy rainfall and flash floods in metropolitan cities, highlighting the need for advanced monitoring systems. Traditional rainfall observation methods, such as rain gauges, are limited in providing the high-resolution data required for effective urban hydrological applications. In response to this, the Indian Institute of Tropical Meteorology (IITM) has implemented an advanced network of four X-band dual-polarization Doppler weather radars across the Mumbai metropolitan region, aimed at delivering high- resolution weather measurements.

These radars are strategically located in Panvel, Kalyan Dombivli, Vasai Virar, and Vile Parle, with an approximate separation of 30 km between them, ensuring optimal cross-range resolution and facilitating measurements closer to the ground. The data from these four radars are merged into a common format to create a radar MOSAIC, providing comprehensive insights into precipitation estimation and wind retrieval over the region.

This is the first of its kind which is planned for both operational and scientific research utilizing anetwork of Doppler weather radars. The details of the scientific and operational objectives of the Mumbai's urban radar network will be discussed during the conference.

Keywords: Weather radar; Precipitation; Urban Flooding; MOSAIC

Characteristics of high frequency gravity waves and its impact on tropopause variability: A direct observations and simulations over Western Ghats region

Pooja Purushotham[ab], Sanjay Kumar Mehta[b], A. Aravindhavel[a], P.Prasad[a], Thara Prabhakaran[a],

N.Koushik[c],Y. Jaya Rao[a], P. Murugavel[a] and Sachin K Philip

[a] *Indian Institute of Tropical Meteorology (IITM), Ministry of Earth Sciences, Dr. Homi Bhabha Road, Pune 411008, India*
[b] *Atmospheric Observations and Modelling Laboratory, Department of Physics, SRM Institute of Science and Technology (SRM IST), Kattankulathur, Tamil Nadu 603203, India*
[c]*Space Physics Laboratory, Vikram Sarabhai Space Centre,Thiruvananthapuram 695022, India*
E-Mail: pooja.purushotham@tropmet.res.in; pp2335@srmist.edu.in

ABSTRACT

High frequency gravity waves play a pivotal role in atmospheric dynamics, influencing weather patterns and altering the energy exchange process between lower and higher altitude. The lack of direct measurements and complex representation resulting significant uncertain in numerical models. In this present study the Characteristics of high frequency gravity waves and its impact on tropopause variability is studied from direct observations and simulations over the Western Ghats region during a CAIPEEX coordinated CABLE field experiment. The persistent of Gravity wave (GW) is observed due to the orographic excitation wind during night-time stable environment. The westerly low-level jet of > 10ms-1 act as a source of orographic excitation at complex topography of Western Ghats Mountain region during monsoon season. These GW waves ranging from the ABL to Tropopause for a period of ~14 hr from ~18:00 to 07:00 IST. Based on wind profile radar and GPSRO measurements the vertical wavelength is observed vary between ~1.5 – 4km from ABL to tropopause region. The peak-to-peak variability of cold point tropopause temperature (CPT-T) and Potential energy indicates these high frequency GWs modulating the tropopause variability.

Keywords: Gravity Waves; tropopause; Western Ghats; Potential Energy, CPT

Anthropogenic Source Dependency Between CO_2 And CH_4: A Study Using Multi-Source Data

Pranav U[a,b] (Pranav, U),

Mahalakshmi D.V. [b], Mahesh Pathakoti [b],and Girish Gopinath[a]

[a] *Climate variability and aquatic ecosystems,*
Kerala University of Fisheries and Ocean Studies (KUFOS)
[b] *Earth and Climate Science Area, National Remote Sensing Centre(NRSC), Hyderabad*
E-Mail:pranavu288@gmail.com@gmail.com

ABSTRACT

The escalating levels of greenhouse gases (GHGs), driven predominantly by human activities, represent a major challenge in the context of global climate change, as highlighted by the Intergovernmental Panel on Climate Change (IPCC) and the World Meteorological Organization (WMO). This study focuses on the source dependency of GHGs—methane (CH_4), carbon dioxide(CO_2), and examines their spatial relationships with Land Use/Land Cover (LULC) changes in identified hotspot regions. Utilizing satellite-derived concentration data in combination with the Emissions Database for Global Atmospheric Research (EDGAR), we performed a comprehensive analysis of the spatial distribution patterns of these gases. The analysis revealed a notable increasein CH_4, which has risen by approximately 150 ppb over the past 15 years, corresponding to an annual trend of 9.72 ppb. CO_2 concentrations have also shown a significant upward trajectory, increasing at a rate of 2.43 ppm per year. In contrast, CO exhibited considerable variations in the Indo-Gangetic Plain (IGP) region, with fluctuations ranging from 100 to 150 ppb, indicating its role as a dependent partner alongside CO_2 and CH4. Through ratio analysis, high-emission source regions were identified, which displayed substantial deviations from the average emissions of thestudy area. Correlating these regions with LULC changes, particularly within 100, 200, and 300 km radii, we observed a significant increase in settlement areas and a predominance of agriculturalland within the 300 km radius, with a corresponding decrease in other land classes. These findingshighlight the critical need for localized monitoring and targeted mitigation strategies, in alignment with IPCC's global climate objectives. The research contributes to a deeper understanding of the interactions between human activities, GHG emissions, and LULC changes, providing actionable insights for policymakers to develop effective climate response strategies.

Keywords: Anthropogenic CO_2 and CH4, EDGAR, source dependency, LULC changes.

Long-term observations of stratospheric water vapour Using SABER measurements: Implications for climate

Dilna Damodaran[a,b] (Dilna, Damodaran),
KandulaV Subrahmanyam[b], and Girish Gopinath[a],

[a] *Climate variability and aquatic ecosystems, Kerala University of Fisheries and Ocean Studies (KUFOS)*
[b] *Earth and Climate Science Area, National Remote Sensing Centre(NRSC), Hyderabad*
E-Mail:dilnaskpm@gmail.com

ABSTRACT

Water vapor is the most prevalent greenhouse gases in the atmosphere, exhibiting significant variability and plays a vital role in regulating Earth's climate. This study analyzes changes in stratospheric water vapor (SWV) from January 2002 to December 2023 using data from Sounding Atmospheric Broadband Emission Radiometry (SABER), focusing on global, tropical, and regional trends. Our methodology included calculating latitudinal and longitudinal averages to derive the global mean SWV, followed by time series analysis to identify trends over the study period. We also examined seasonal variations in H2O concentrations and assessed the impacts of El Niño and La Niña events on SWV distribution. Our findings shows that the global mean SWV concentration averaged between 3 and 5 ppmv, rising from approximately 4.8 ppmv (2002-2012) to about 5.0 ppmv (2013-2023), particularly at an altitude of 30 km. Significant seasonal peaks were observed, including a notable spike following the 2022 Hunga Tonga eruption. Linear trend analysis revealed a remarkable increase in SWV, peaking at 0.8 ppmv/decade in the tropical region around 22 km, with a global maximum of roughly 0.5 ppmv/decade at 45 km. During El Niño events, water vapor concentrations increased at higher altitudes while extending toward the equator, whereas La Niña conditions led to a more even distribution of water vapor. Regions such as Africa and South America displayed the highest trends, exceeding 1.0 ppmv/decade in Africa. Overall, this research highlights the complex dynamics of SWV and its implications for climate, emphasizing the need for ongoing monitoring.

Keywords: Climate change; El Nino

Evaluating the decadal prediction skill of the Indian summer monsoon rainfall in the DCPP models

Mudit [a], and Suneet Dwivedi [a]

[a]*K Banerjee Centre of Atmospheric and Ocean Studiesand M N Saha Centre of Space Studies,*
University of Allahabad, Prayagraj, UP 211002E-Mail: mudit@allduniv.ac.in

ABSTRACT

Understanding the decadal variability and predictability of the Indian Summer Monsoon Rainfall (ISMR) is essential for effectively managing agricultural productivity, water resources, and disaster management in the South Asia. This study evaluates the prediction skill of the ISMR in

the Decadal Climate Prediction Project (DCPP) models of CMIP6. Our findings reveal

significant improvements in capturing decadal predictability of the ISMR in the initialized hindcasts of DCPP models compared to the uninitialized runs of CMIP6, thus demonstrating the potential of DCPP forecasting techniques. The results suggest that proper initia ization improves decadal predictability of the ISMR. The fact that the ISMR is predictable on a decadal time scale

helps in integrating decadal predictions into climate adaptation strategies for mitigating

monsoon-related risks in the future.

Keywords: Decadal Prediction; Indian Summer Monsoon Rainfall; DCPP; Predictability

Influence of meteorological parameters on lightning events over the Indian region

Manendra Singh Nag[a], S Pattnaik[a],

[a] *School of Earth, Ocean and Climate Sciences, Indian Institute of Technology, Bhubaneswar*
E-Mail: 23cl06008@iitbbs.ac.in

ABSTRACT

This study utilises long-term lightning and weather datasets to investigate the complex interactions between lightning occurrences and various meteorological factors. The natural phenomena, lightning, an electrical discharge phenomenon mainly observed in thunderstorms, pose a significant threat to life and property, especially with increasing occurrences due to climate change. The global lightning distribution is heavily influenced by convection processes, with land regions, particularly the tropics, experiencing the highest lightning frequencies due to their lower heat capacities than oceans. Many areas in India have been observed to have experienced increased lightning events in the past few years.

Our proposed study focuses on cloud-to-ground (CG) and cloud-to-cloud (CC) lightning events by examining climatological trends and regional lightning distribution across India's meteorological zones. The research identifies the influence of critical factors such as solar heating, aerosols, monsoons, cyclones, and land processes on lightning activity. We will examine regional and seasonal variations over four homogenous regions of India, i.e. central India, northwest, south peninsular and northeast, during the pre-monsoon and post-monsoon seasons. Efforts will be made to elucidate insights into its relationship with meteorological dynamics and suggest pathways for improved lightning forecasts and mitigation strategies.

Keywords: Lightning; Monsoons; Cyclones; Aerosols; Mitigation.

An assessment of the impact of cyclones on the ocean surface using satellite and in-situ observations

Prasenjit Dey[a], Sudeep Das[a], Sourav Sil[a] and Sandeep Pattnaik[a]

[a] *School of Earth, Ocean and Climate Sciences, IIT Bhubaneswar*

E-Mail: 23cl06003@iitbbs.ac.in

ABSTRACT

The Bay of Bengal experiences cyclones in the pre-monsoon and post-monsoon. This study presents (i) the validation of the GHRSST and the scatterometer (ASCAT) winds in the Bay of Bengal and (ii) a comparative assessment of the impact of the cyclone on the upper oceans during pre- and post-monsoon during 2019 – 2022. Our study indicates a high correlation of winds with available RAMA and OMNI buoys. The GHRSST is highly correlated with in-situ observations and the reanalysis products. Analyses were done for four pre-monsoons (Fani-2019, Amphan- 2020, Yaas-2021, and Asani-2022), and three post-monsoon cyclones (Bulbul 2019, Nivar-2020, Sitrang-2022). In recent times, cyclogenesis has occurred in the warmer part of the basin. The cyclone-induced cooling is comparatively less in the salinity stratified post-monsoon as compared to the thermally stratified pre-monsoon. The impact analysis on both duration and the stages showed that the cyclone induced upwelling depends on the pre-existing features of the ocean like currents and eddies. The study highlights the usefulness of satellite and in-situ observations on studies of extreme events like cyclones in the Bay of Bengal.

Keywords: Cyclones; Monsoons; Scatterometers; In-situ observations; Winds

Effect of climate change on the clustering and waiting time between the extreme precipitation events over India

Suneet Dwivedi[a]

[a]K Banerjee Centre of Atmospheric and Ocean Studies and M N Saha Centre of Space Studies, University of Allahabad, Prayagraj, UP 211002

E-Mail: suneetdwivedi@gmail.com

ABSTRACT

The temporal distribution of the Indian summer monsoon precipitation events is analysed in terms of waiting time between events and clustering of events. It is demonstrated that the waiting time between extreme precipitation events are power-law distributed with long-range dependence. The results indicate that there is a finite probability of recurrence of rarer extreme events within a season. The analysis also reveals that the effect of climate change on the waiting time distribution between rainfall events over different parts of India is non-uniform. The extremal index analysis of extreme precipitation events suggests that there is a strong tendency of clustering of the precipitation extremes over India. Except few densely populated regions of India, there will an overall reduction in the tendency of clustering of extreme precipitation events in a warming environment. The information related to the temporal volatility of extreme precipitation events over India in a warming environment is useful for urban planners, policy makers and other stakeholders.

Keywords: Extreme weather events; Waiting time; Clustering; Indian Monsoon; Climate change

Theoretical Understanding and Numerical Simulation of Tropical WavesUsing Reduced Gravity ENSO Model

Pramit Majumder[a], Vinu Valsala [b], Jagabandhu Panda[a]

[a] *Department of Earth and Atmospheric Sciences, NIT Rourkela*
[b] *DESK, Indian Institute of Tropical Meteorology, Pune*

EMail:pramit.nitr@gmail.com

ABSTRACT

The study focuses on the theoretical understanding and numerical simulation of tropical waves, particularly Kelvin, Rossby, and Mixed Rossby-Gravity (MRG) waves, using a reduced gravity ENSO model. Tropical waves, especially Kelvin waves, play a critical role in driving tropical weather systems, affecting global climate patterns. The model used in this study is based on a linear ocean model, which simulates first baroclinic mode waves in response to wind stress anomalies. The study examines the behaviour of these waves under ideal conditions, without landmass interference, and then explores wave dynamics when accounting for the Rossby radius of deformation. The simulation demonstrates that Kelvin waves propagate eastward with the highest velocity, reaching the eastern boundary of the model domain within approximately 100 days, while Rossby waves, with one-third the velocity, propagate westward. MRG waves, generated by meridional wind stress, are also examined, revealing unique propagation patterns. The Hovmöller diagrams generated from the simulations confirm the theoretical velocities and behaviour of the waves, with Kelvin and Rossby wave speeds of ~1.94 m/s and ~0.61 m/s, respectively. The analysis also includes the effects of wave interaction with geographical features,highlighting partial wave penetration and reflection. Errors in the model, particularly in the estimation of group velocity, and the effect of wind stress placement are discussed. Future works may involve in improving the model's accuracy by incorporating ocean-atmosphere interactions and verifying theoretical values for energy reflection of equatorial waves at boundaries.

Keywords: Tropical waves, Kelvin waves, Rossby waves, shallow-water equation, numerical simulation.

Long-Term Trends of UV Index, $PM_{2.5}$, and Aerosol Optical Depth (AOD) Over Northern India: Insights from Satellite Observations

Vikram Bhati[a], Abhishek Saxena[a]
[a]*Department of Physics , Sangam University*
E-Mail: vikram.bhati@sangamuniversity.ac.in

ABSTRACT

This study examines long-term trends in the UV Index, $PM_{2.5}$ concentrations, and Aerosol OpticalDepth (AOD) over the northern region of India using satellite-based measurements. The northernpart of India, characterized by its diverse geography and rapid industrialization, has been experiencing significant environmental changes. Satellite data spanning multiple decades were analyzed to assess the variations and correlations among these key atmospheric parameters. The UV Index trends reveal both seasonal and spatial fluctuations influenced by atmospheric pollutants. $PM_{2.5}$ concentrations have shown a steady increase, particularly in urban and industrialareas, contributing to severe air quality degradation. The AOD, which reflects the extent of aerosols in the atmosphere, also demonstrates a rising trend, particularly during winter and post- monsoon months, coinciding with increased emissions from vehicular traffic, biomass burning, and agricultural residue burning. The interplay between elevated $PM_{2.5}$ and AOD levels appears to contribute to the attenuation of the UV Index in heavily polluted regions. This research underscores the need for comprehensive air quality management and mitigation policies to curb the rising health risks associated with these environmental trends in northern India.

Keywords: Aerosol Optical Depth (AOD), Air Quality, UV Index, $PM_{2.5}$ concentrations, and Forcasting

Impact of ocean warming and enso on the marine heat waves

Arpan Bhattacharjee[a], Sourav Sil[a],and Nirupam Karmakar[a].

[a]*School of Earth Ocean & Climate Science,IIT Bhubaneswar*

E-Mail: 23CL06004@iitbbs.ac.in

ABSTRACT

The Marine Heatwaves (MHWs) are extreme warmer (threshold of 90th percentile over climatology) condition of the Sea Surface Temperature (SST) for more than five days. This studyfocuses on the impact of the ocean warming and ENSO events on the MHWs in the Bay of Bengal(BoB). Our analysis with OISST and ORAS5 shows a distinct upward trend, and these extreme events are lasting longer, happening more often, and becoming more intense over time. After removing the large scale warming of the ocean (detrending) from the SST data, a few notable changes in the analysis of Marine Heatwaves (MHWs) emerged. When accounting for the long- term warming trend, there were indeed significant MHWs in the past that were previously maskedby the overall increase in temperature. For more recent years, the detrended data shows a slight decrease in the daily intensity of MHWs compared to the original dataset. The recent MHWs are less extreme in their deviations from the average compared to earlier periods. Interestingly, the daily intensity of MHWs during El Niño years remain almost unchanged when comparing the detrended and original data. This suggests that the strong climatic signals associated with El Niñoevents are significant enough to dominate the MHW characteristics, even after removing the long-term warming trend.

Keywords: Global Ocean warming; MHW; ENSO; Bay of Bengal.

Can the 'internal' variability due to land-atmosphere feedbacks affect monsoon droughts?

Subhadeep Halder[a], Paul A. Dirmeyer[b] and S. Bhowmick[a]

[a]*Department of Geophysics, Institute of Science Banaras Hindu University, Varanasi 221005, India*
[b]*Department of Atmospheric, Oceanic and Earth Sciences Centre for Ocean-Land-Atmosphere Studies George Mason University, Fairfax, Virginia 22030, USA. E-mail: subhadeeph@bhu.ac.in*

ABSTRACT

Accurate prediction of the Indian Summer Monsoon Rainfall (ISMR) seasonal extremes, namely droughts and floods are extremely important but also highly challenging. About a half of the interannual variability of the ISMR is determined by 'external' slowly varying boundary conditions such as SST whereas the remaining half is determined by 'internal' non-linear feedbacks of the coupled climate system where other slowly varying land surface anomalies namely soil moisture play a significant role. The objective of the present study is to analyze and quantify the role of this 'internal' variability due to coupled land-atmosphere feedbacks on the droughts. For that purpose, ensembles of seasonal coupled hindcast simulations performed with the NCEP Climate Forecast System version 2 (CFSv2) operational model and long AMIP type simulations performed with the NCAR Community Earth System Model (CESM v1 & v2) are evaluated. Hindcast simulations with the CFSv2 are made in each of the 28 years (1982-2009) initialized on the 1st of April, May and June and ending at the end of September. With the CESM model, two sets of simulations are made wherein the land-atmosphere feedbacks are allowed or switched off and the land initial conditions are perturbed. Analyses suggest that the 'internal' variabilities generated due to such feedbacks may be partly responsible for droughts in certain years. However, biases in the representation of land-atmosphere feedbacks in the models tend to subdue the simulated interannual variability. The authors gratefully acknowledge the financial support from the Science and Engineering Research Board, Govt. of India to conduct this research. The first author also gratefully acknowledges the financial support received under the National Monsoon Mission (Phase I), Ministry of Earth Sciences, Govt. of India and a Seed Grant under IoE scheme of BHU to conduct this research. Availability of computing resources on the Param Shivay Supercomputer at IIT-BHU is also thankfully acknowledged.

Keywords: Land-atmosphere feedback, monsoon, internal variability, non-linear processes, droughts

Flood Risk and Vulnerability: A Comprehensive Studyalong the Vashishti River in Chiplun, Maharashtra

Abantika Kar[a], Dr. S. D. Pardeshi[b]

[a] *Indian Institute of Remote Sensing, Dehradun*
[b] *Department of Geography, Savitribai Phule Pune UniversityE-Mail:* abantikakar.munu@gmail.com

ABSTRACT

Flooding is a recurrent and destructive natural hazard, especially in regions like the Vashishti Riverbasin in Chiplun, Maharashtra, where small to medium-scale floods occur every 3 to 5 years. Thisstudy assesses flood risk and vulnerability in the region using advanced geospatial tools such as Geographic Information Systems (GIS) and the Analytical Hierarchy Process (AHP). By incorporating multiple factors—including elevation, slope, drainage density, land use, topographic wetness index, proximity to rivers, and soil type—this research constructs a comprehensive flood-risk zonation map. The study assigns relative importance to each factor through AHP to identify flood-prone zones. Results indicate that 12.20% of the Vashishti River basin is at high risk of flooding, with the most vulnerable areas concentrated around Chiplun town and neighboring villages. Urbanization, deforestation, and inadequate drainage systems are key contributors to increased flood susceptibility in these regions. The findings stress the necessity for targeted flood management strategies, including improving infrastructure, enhancing flood forecasting systems, and promoting sustainable land-use practices. The methodology used in this study provides a robust framework for flood risk assessment, offering significant potential for application in other regions prone to similar flooding challenges. By integrating geospatial data and multi-criteria decision-making tools, this research contributes valuable insights into flood risk dynamics and supports the formulation of proactive flood mitigation strategies.

Keywords: Flood Risk, GIS, Analytical Hierarchy Process (AHP), Vashishti River Basin, Chiplun Flooding

Integrating Climatic Factors for Enhanced Land Use/Land Cover Prediction Using Machine Learning: A Case Study for Gandhinagar

Krishna Kakad[a], Swati Priya[ab]

[a] *DA-IICT, Gandhinagar, Gujarat*
[b]Member, Indian Meteorological Society *E-Mail:krishnakakad779@gmail.com*

ABSTRACT

Precise forecasting of future land use and land cover (LULC) is essential for sustainable planning and resource management, especially in swiftly urbanizing areas. The present case study demonstrates the potential of machine learning in integrating climatic factors for more accurate land use and land cover prediction in the face of climate change. Weather elements, particularly precipitation and temperature, play a crucial role in the LULC forecast procedure. The use of machine learning methods, specifically a random forest (RF) Classifier and support vector machine (SVM), along with the incorporation of weather elements, ensures a high level of precision in the LULC forecast by utilizing the LULC data and associated climatic factors from prior years. Incorporating weather factors aims to improve the predictive precision, as precipitation and heat variations can significantly impact land use changes, especially in farming, bodies of water, and plant life.

The research entails preparing multi-year raster datasets for LULC, precipitation, and temperature, then combining features to integrate changes in land cover and climate patterns. The model underwent training using land use and land cover (LULC) information from 2022- 24 for the Gandhinagar district in Gujarat and the weather conditions for LULC prediction for 2025.

Assessment measures like correctness, exactness, and memory were employed to evaluate model efficiency, indicating the model's capability to anticipate future land use with enhanced accuracy. The anticipated land use and land cover (LULC) for 2025 were depicted using raster outputs, offering valuable information for urban planners and environmental supervisors. This method underscores the practical value of incorporating ecological elements for a more robust LULC modeling, ultimately aiding in more knowledgeable and practical decision-making in land management and climate adaptation strategies.

Keywords: LULC, Model efficiency, Machine Learning, Random Forest Classifier, SVM (Support Vector Machine).

Satellite-Based Total Column Water Vapour Observation Assimilation and itsImportance in the Seamless Prediction of Precipitation over a Monsoon Domain

Meenakshi K J[a,b] (Meenakshi, K J), Gibies George[a], Ankur Gupta[a], S. Indira Rani[a] and John P George[a]

[a] *National Centre for Medium Range Weather Forecasting*

[b]*Department of Atmospheric Sciences,School of Marine Sciences,*

Cochin University of Science And Technology, Kochi

E-Mail: meenakshikj28@gmail.com

ABSTRACT

This study addresses the role of the atmospheric initial state of the horizontal distribution of moisture availability in predicting the precipitation associated with the Indian Summer Monsoon system. The total column water vapour (TCWV) observations from the Copernicus sentinel 3 ocean and land colour instrument (OLCI) over the land are assimilated to get a more realistic initial state of atmospheric moisture content in the sensitivity experiment of observing system experiment (OSE), along with all other observations including conventional and satellite observations, whichare operationally used. The control run of the OSE uses all observations except the TCWV observation to get an identical twin set of analysis. Both control and experiment analysis of a period of one month in the OSE assimilation during June 2023 is further used to initialize long forecast identical twin experiment using a stand-alone atmosphere model (nearly one week lead time) and ocean-atmosphere coupled model (nearly one season lead time).

The assimilation of the new information resulted in the enhancement of moisture and thereby precipitation over the Amazon region in South America, Tropical West Africa and tropical Southeast Asia. However, the distribution of latent heat flux and vertical integrated moisture transport suggest that the response of the new observation in the analysis varies from one locationto another. Further the assimilation of satellite based total column water vapour is useful for the improvement of prediction in many of the cases where the model underestimates the precipitation, in all timescales from medium range (daily mean) to seasonal scale (monthly mean).

The impact of moisture redistribution in the model varies according to location. Identical twin forecast experiments are conducted in various time scales. In all the forecasts, it is observed that the underestimated locations of precipitation have been improved in the sensitivity run comparedto the control run. Improvement in the horizontal distribution of moisture in the atmosphere of initial state, resulted in the improvement of precipitation forecast irrespective of timescale, over the locations where it is underestimated otherwise.

Keywords: Total column water vapour, Ocean and land colour instrument, Observing system experiment, Assimilation, Precipitation.

Impact of Urbanization on simulation of Sea Breeze over Chennai, India: A Numerical Study of Thermal and Surface Drag Effects

K K Amal[a, b], V Yesubabu[a,*], Raghavendra Raju N[c], Govindan Kutty[b]

[a] *Weather and Climate Research Group (WCRG), National Atmospheric Research Laboratory, Gadanki-517112, Andhra Pradesh, India*

.[b]*Department of Earth and Space Sciences, Indian Institute of Space Science and Technology, Valiamala, India*

[c]*India Meteorological Department, Ministry of Earth Sciences, Govt. of India*

E-Mail:1600amalkk@gmail.com

ABSTRACT

Chennai, a metropolitan city located on the southeast coast of India, has experienced significant land surface changes due to rapid urbanization over recent decades. This horizontal expansion of the city and vertical rise in the building heights altered the thermal properties and surface roughness significantly in the recent years. However, its impact on metrological phenomena has not been explored fully yet using the numerical weather prediction (NWP) models. This study aims to investigate the impact of urbanization on sea breeze (SB) formation and its characteristics, including onset and cessation times, duration, intensity, vertical structure, and inland penetration. To achieve this, we carried out sensitive study by conducting several simulations using Weather Research and Forecasting (WRF) model without and with varying degree of urbanization. Further we explored how the surface drag modulates the SB by utilizing the WUDAPT land use land cover (LULC) data. In total, five experiments are conducted for 2 different SB cases. Before presenting the analysis of SB dynamics, we evaluated the results with available surface AWS datasets, which suggest that the WRF model utilizing WUDAPT LULC configuration provides the best results compared to that of USGS and MODIS. The primary results of SB analysis indicate that the urban cover effects the direction of SB onset winds. As the urban cover increases, due to enhancements in thermal inertia, drives the wind strongly towards inland leading to a dominant zonal SB wind at onset time. The experiments with WUDAP clearly indicate that the increased surface roughness over urban region have a negative impact on the propagation of SB. Our results also reveal that this decrease in the inland penetration of SB is mainly due to the reduction in the SB intensity and its duration over the urban areas.

Keywords: Land Use, WRF model, Urbanization, Sea Breeze and Surface drag

Future projection of marine heatwaves over the tropical Indian ocean using HIGHRESMIP models

Shivam Kesharwani[a], Alok Mishra[a], and Suneet Dwivedi[a]

[a]*K Banerjee Center of Atmospheric and Ocean Studies and M N Saha Center of Space Studies, University of Allahabad, Prayagraj, UP 211002, India*

Email:28shivam5@gmail.com

ABSTRACT

The accurate future projections of marine extremes are essential for climate adaptation strategies, particularly in vulnerable regions like the Tropical Indian Ocean (TIO). The precision of these projections relies heavily on the performance of Global Climate Models (GCMs) in simulating historical climate patterns. Enhancing model resolution is a key strategy for improving the representation of regional climate phenomena. This study leverages on the High-Resolution Model Intercomparison Project (HighResMIP) model simulations under the Coupled Model Intercomparison Project Phase 6 (CMIP6) developed as part of the PRIMAVERA project to assess near future (i.e. up to 2050) projections of Marine Heatwaves (MHWs) over the TIO. The quality of these projections is examined with increase in the horizontal resolution. The results indicate a significant increase in MHWs, with variability across models, regions, and seasons. The refinement of ocean grid leads to a prominent improvement on the quality of MHW projections. However, in certain areas, it is also found that the inter-model differences are comparable or even larger than the improvements due to horizontal resolution.

Keywords: Tropical Indian Ocean, SST, Marine Heatwaves (MHWs), HighResMIP, CMIP6

Night Light Data as a Proxy for Assesing Air Pollution in Urban Landscapes: Potential of Remote Sensing Technology

Lakshmi kanchana, Asuri[1], Anisha, J[2], Mahalakshmi D.V[1], Mahesh Pathakoti[1], Abheendra Bandary[3]

[1]Earth and Climate Science Area, National Remote Sensing Centre, Indian Space Research Organization, Hyderabad, India-500037

[2]National Institute of Technology, Karnataka, Surathkal-575025,

E- Mail:kanchi84brecw@gmail.com/kanchana_l@nrsc.gov.in

[3]School of Earth Ocean and Climate Science, Indian Institute of Technology Bhubaneshwar, Khordha, 752050, India

E-Mail: a23es09002@iitbbs.ac.in

ABSTRACT

The goal of this study is to demonstrate how data from the TROPOspheric Monitoring Instrument (TROPOMI) onboard Sentinel-5 Precursor (Sentinel-SP) can be effectively utilized and interpreted to enhance our understanding of air quality for India cities. In view of this, the spatio-temporal variability of the atmospheric column amounts of four trace gases namely XCO, XNO_2, XSO_2, and XHCHO were analysed over various cities across India (Hyderabad, Delhi, Chandigarh, Kolkata, and Guwahati) during the years 2019 to 2023. The pollutants *X*CO and XNO_2 are predominantly concentrated in the central areas of cities, with levels gradually decreasing towards the outskirts. This pattern suggests that major contribution from vehicular and fossil fuel combustion, along with unregulated development activities. Other contributing sources are industrial emissions, residential emissions, and biomass burning. An increase in pollutant concentrations during the winter season has been observed in Delhi, Chandigarh, and Kolkata, likely due to the haze effect. This study further utilised the data from ERA5, MOPITT and VIIRS daily datasets. Further, TROPOMI and MOPITT sensors demonstrated good agreement in *X*CO retrievals over the selected study regions, providing consistent and reliable results. The results of the study revealed that pollutant concentrations frequently exceed permissible limits and have been steadily increasing, driven by urban development and seasonal variations, wind speed and direction. Thus the city level pollution dynamics is further evidenced the by the night-time lights from the VIIRS Lunar Night-time Lights data.

Keywords: air quality, pollutants, haze effect, TROPOMI, MOPITT

Climatological analysis of spatial patterns inter-annual variability and trends of convection from 1980-2020 over West Bengal

Anup Mahato and A.N.V. Satyanarayana

Centre for Ocean, River, Atmosphere and Land Science
Indian Institute of Technology Kharagpur, India

Email- anuprock1988@gmail.com

ABSTRACT

This study investigates the climatological variations of convective parameters over West Bengal India, during the pre-monsoon season (March-May) from 1980 to 2020 using high (0.25° x 0.25°) horizontal resolution of ECMWF reanalysis (ERA-5) and hourly time interval data. We analyse the spatial patterns of inter-annual variability as well as spatial trends employing Mann Kendall test of Convective Available Potential Energy (CAPE), Convective Inhibition (CIN), CAPE/CIN ratio, K-index. The climatological analysis reveals the existence of three distinct zones with unique convective characteristics potential over West Bengal. The coastal zone-1 (21.5°N-23°N, 87°E- 89°E) exhibits a consistently favourable environment for convection with high CAPE (2000-2500 Jkg-1), low CIN (350-450 Jkg-1), and high CAPE/CIN ratios (4 - 6) with consistent low spatial patterns of inter-annual variability. The central zone-2 (23°N-26°N, 86°E-89°E) shows an inconsistent convective environment with moderate CAPE (1000-2000 Jkg-1) and CIN (250-350 Jkg-1) values with moderate spatial patterns of inter-annual variability. The northern zone-3 (26°N-27°N, 88°E-90°E) presents less favourable but occasional convective conditions with lower CAPE (500-1000 Jkg-1) and CIN (200-250 Jkg-1) values with highly varying spatial patterns of inter-annual variability. The K-index (22-25) is sufficient to produce a convective environment in zone-1 compared to zones 2 and 3. Zone-1 exhibits spatial trend analysis generally shows positive trends for CAPE and K-index, and negative trends for CIN, the temporal trend analysis of CAPE/CIN ratio shows a decreasing trend with 95% confidence ($p < 0.05$). These climatological signatures signify the zone-1 is hotspot region of thunderstorms followed by zone-2.

Keywords: CAPE, CIN, Inter-annual variability, Thunderstorms

Impact of Air-pollution on outdoor human thermal comfort during the last demi-decade over the megacity of Hyderabad

Peri Subrahmanya Hari Prasad and A.N.V. Satyanarayana

Centre for Ocean, River, Atmosphere and Land Science Indian Institute of Technology Kharagpur, India

Email- pshari19@gmail.com

ABSTRACT

Air pollution's impact on human health has become an alarming issue in recent times. Rapid urbanization and changes in the landscape have a two-way impact: increasing land surface temperature and air pollution. Recent studies have reported a significant impact of urbanization on outdoor thermal comfort and urban health. Very few studies have been attempted to include air pollution effects on outdoor thermal comfort. In the present study, a new index - meteorology and environment comfort (MEC) is estimated during the last demi-decade to assess thermal comfort by including the air pollution over the metropolitan city of Hyderabad (17.3850 N, 78.4867 E). In the study, air pollution data of PM2.5, PM10, O3, SO2, and NO2 and meteorological data of air temperature, relative humidity and precipitation obtained by the Central Pollution and Control Board (CPCB), India, over five different zones in Hyderabad are used. The discomfort levels are categorized into 6 categories: extreme heat discomfort, thermal discomfort, general thermal comfort, comfort, general cold comfort, and cold discomfort.

The results depicted that extreme heat discomfort during 2018 and 2019. Interestingly, during COVID-19 (2020-21), the hours of extreme heat discomfort decreased over Hyderabad due to the reduction in air pollution levels. During 2022-23, there has been an increase in extreme heat discomfort hours. The industrial and urban location, Bollara (17.5433 N, 78.3514 E), has shown an increase in the percentage of extreme heat discomfort hours during the study period of 50.38% (2018), 31.78% (2019), 26.79% (2020), 20.84% (2021), 43.5% (2022), 49.2% (2023) respectively.

Whereas significant contrast in the percentage of extreme heat discomfort hours is noticed over highly vegetated zones like the Central University of Hyderabad (17.4567 N, 78.3264 E), showed 40.78% (2018), 28.12% (2019), 12.52% (2020), 13.84% (2021), 12.5% (2022), 14.25% (2023),

respectively. Thus, a clear difference in the impact of vegetated lands and highly urban areas on MEC is observed. The study reveals that outdoor thermal comfort will significantly change with the inclusion of air pollution in addition to urbanization. Thus, there is a great need to improve air quality and thermal comfort in urbanized areas to improve human health and well-being.

.

Keywords: Air Pollution; Monsoons; Outdoor Thermal Comfort; ; meteorology and environment comfort (MEC) ; Urban Health

Climatology and Spatio-Temporal Trend of Aerosol and its Potential Sources over Indo- Gangetic Plain

Rohit Kumar Singh and A.N.V. Satyanarayana

Centre for Ocean, River, Atmosphere and Land Sciences
Indian Institute of Technology Kharagpur

Kharagpur-721 302
India

ABSTRACT

Rapid urbanization and industrialization lead to significant changes in land use and land cover (LULC), particularly in agricultural activities over the Indo-Gangetic Plain (IGP), which in turn impacts the distribution of aerosol loading. In the present study, climatological and spatio- temporal trends of aerosol optical depth (AOD) and the influence of metrological factors and aerosol sources are investigated over the IGP region. Climatological analysis of the AOD over the upper, central, and lower IGP regions was conducted using satellite-based aerosol data. LULC analysis over the IGP region during the study period showed a significant increase in crop land and built-up area, mainly replacing the deep vegetation. This signifies the rapid urbanization burden during agricultural cycles ultimately affecting the aerosol loading over the region. Seasonal trend analysis revealed significant seasonal variation of AOD has been noticed in different regions of IGP. The key factors driving the variation in AOD across the IGP are identified. The analysis reveals characteristic changes in the aerosol loading and the spatial and temporal variation over the different regions of IGP. The findings from this study are expected to provide useful insights for urban planning, land use management, and air quality improvement.

Keywords: Aerosol, Indo-Gangetic Plain, Land Use Land Cover

Absence of Depressions During Contrasting Summer Monsoons: A Comparative Study of 2002 and 2010 Using RegCM5

Rambilli Loknadh[a], Nagaraju Chilukoti[a], Nimmakanti Mahendra[a]

[a]*Department of Earth and Atmospheric Sciences , National Institute of Technology , Rourkela*

*E-Mail:*rambilliloknadh012@gmail.com

ABSTRACT

Monsoon depressions contribute anomalously to the rainfall over India during the summer season. These depressions are integral to the Indian summer monsoon (ISM). However, in the recent decade, no depression has been reported during contrasting summer monsoons in 2002 and 2010. In this study, we have examined ocean-atmospheric local and remote conditions caused by the absence of depressions during these contrasting monsoon years using RegCM5 with CLM4.5. It is found that anomalous subsidence over the ISM region associated with El Niño and cold sea surface temperature (SST) anomalies over the Bay of Bengal (BoB) in the summer of 2002 is mainly responsible for reduced relative humidity in the lower troposphere. In addition, weak low-level relative vorticity over the BoB cannot promote the formation of depressions during the summer of 2002. In the case of summer 2010, La Nina-like conditions prevailed in the Pacific, the tropical Indian Ocean was warmer than normal, and relative humidity was high in the ISM region. However low-level vorticity anomalies are negative over the head BoB and could not promote the conversion of monsoon lows to depressions.

This weak monsoon circulation is mainly due to the extension of easterly wind anomalies from a western Pacific anticyclone. Thus this study suggests that the manifestation of both local and large-scale circulation variations contribute towards the growth of low-pressure systems to depressions.

Keywords: El Niño; La Nina; low-pressure systems; Monsoon depressions; RegCM5; Large- scale circulation

Unraveling the Impacts of Warming on Primary Production in the Bay of Bengal: Insights from CMIP6 Models

Abhishek Kushwaha[a],Vivek Kumar Pandey[a]

[a]K Banerjee Center of Atmospheric and Ocean Studies, University of Allahabad, Prayagraj, UP 211002, India
Email:abhishekup70au@gmail.com

ABSTRACT

The Bay of Bengal (BoB) is experiencing significant warming due to climate change, which poses a potential threat to marine ecosystems and primary productivity. This study investigates the impacts of ocean warming on primary production over the BoB using climate models from the Coupled Model Intercomparison Project Phase 6 (CMIP6). We analyze historical and future climate scenarios, including SSP245 and SSP585, to assess changes in sea surface temperature (SST) and its relation with phytoplankton productivity, a critical component of the marine food web. The study identifies trends in SST rise and its consequent effects on phytoplankton biomass over the 21st century. Results reveal that increasing SST leads to a reduction in primary production, with notable regional and seasonal variations. Significant model-to-model differences are observed, where models showing stronger warming tend to exhibit weaker reductions in primary production, while those with weaker warming show stronger reductions.

Keywords: SST, Bay of Bengal, CMIP6, Phytoplankton

Assessing Climate Change Impacts on Precipitation Patterns in the Indo-Gangetic Plain: An Observational and HighResMIP Model Perspective on Extremes and Intraseasonal Variability

Alok Kumar Mishra[a], Suneet Dwivedi[a] , and Mudit[a]

[a] *K Banerjee Center of Atmospheric and Ocean Studies and M N Saha Center of Space Studies,University of Allahabad, Prayagraj, UP 211002, India*

E-Mail:alokmishra006@gmail.com

ABSTRACT

The Indo-Gangetic Plain (IGP) is a region of immense agricultural and economic importance. Inthe face of a changing climate, understanding its vulnerabilities is crucial to safeguarding its future and to ensure a resilient future. This study examines the impact of climate change on the spatiotemporal variability across different spatial and temporal scales over IGP using long-term precipitation data (1901-2022) from the India Meteorological Department and the Global Precipitation Climatology Centre. A special focus is put on extremes, seasonal fluctuations, and intraseasonal variability. Our results highlight significant shifts in the intensity and frequency of extreme precipitation events, alongside changes in the timing and magnitude of intraseasonal variability in the recent decades, particularly during the monsoon season. Near future (i.e. up to 2050) changes are also exmined using HighResMIP models developed as part of the PRIMAVERA project which show the precipitation extremes are likely to experience weakeningwith more irregular rainfall patterns in the future, exacerbating risks to agriculture, water resources, and livelihoods. These findings underscore the urgency of climate adaptation strategies to mitigate the growing impacts of climate variability in this vital region.

Keywords: ISMR, Extreme weather events; Climate change; HighResMIP

Challenges in the utilization of automatic weather station for operational use and weather forecasting

B Sudarsan Patro[a,b], Prashant P. Bartakke[a]

[a] *E & Tc Engineering, COEP Technological University, Pune*
[b] *India Meteorological Department*
E-Mail:sudarsan.patro@imd.gov.in, ppb.extc@coeptech.ac.in

ABSTRACT

Climate change has led to a rise in extreme weather events, which require robust ground-based verification. Automatic Weather Stations (AWS) are crucial in confirming such events, including cloudbursts defined as 100 mm or more of rainfall within 1 hour, and validating weather forecasts. Despite their usefulness, the deployment of AWS for operational weather forecasting faces multiple challenges that can affect data quality and forecasting accuracy. One major issue is the uneven distribution of AWS, with many located in urban areas and along major roadways, leaving rural and remote regions underrepresented. This spatial disparity creates data gaps, especially in areas susceptible to extreme weather. Such gaps hinder the collection of localized data necessary for understanding microclimates and localized phenomena, reducing the effectiveness of weather predictions in these regions. Additionally, the placement of AWS in flat and open terrains may not reflect the weather patterns of areas with diverse topography, leading to inaccurate measurements of precipitation, temperature, and other parameters. The sensor height (usually 2-10 meters above ground) can also cause errors, as local environmental features like buildings and vegetation can skew results. Technical issues like sensor inaccuracies, calibration challenges, and limited deployment due to high costs further complicate their operational use. Maintenance is another critical factor, as harsh environmental conditions and difficult access can lead to sensor malfunctions or data loss. Addressing these challenges requires improving AWS distribution, enhancing technology, and ensuring consistent maintenance and calibration. Doing so will enable AWS to provide more accurate and reliable data, ultimately strengthening its role in weather forecasting and helping to mitigate the impacts of extreme weather events.

Keywords: Climate Change; Extreme Weather Events; Automatic Weather Stations (AWS); Weather Forecast Validation; Geographical Data Gaps; Sensor Calibration and Maintenance; Disaster management

Comparative Analysis of Deep Learning and Empirical Methods for Enhancing Thunderstorm Detection in Northeast India UsingINSAT-3D/3DR Data

Rekha B, Gogoi[a], Abhishek, Chaari[b], P Subhash, Singh[a] Arundhati Kundu [a], Shyam S, Kundu[a], K K, Sarma[a], S P, Aggarwal[a]

[a] *North Eastern Space Applications Centre, Dept of Space, Meghalaya*

[b] *Space applications Centre, Ahmedabad*

E-Mail:rekha.bharali@nesac.gov.in

ABSTRACT

The Northeast Region (NER) of India poses significant challenges for thunderstorm prediction dueto the complex interaction between atmospheric conditions and local uneven topography. This study compares two different approaches for identifying thunderstorm potential locations: a traditional empirical method and modern deep learning models, UNET and Mask R-CNN. This study uses different band (TIR1, TIR2, MIR, WV, VIS) of INSAT-3D/3DR satellites. The empirical method involves cloud identification using dynamic thresholding, bi-spectral variance, and brightness temperature difference (BTD); filtering with a "split-window" technique to removecirrus clouds; and convective cloud detection through BTD (water vapor (WV) and thermal infrared (TIR1)) thresholding. The deep learning models that are trained on 9,000 satellite imagesfrom the INSAT-3D/3DR (infrared and water vapor channels) offer a data-driven approach to cloud segmentation. The satellite images consist of both thunderstorm and non-thunderstorm scenarios. The data processing has been done using python module where cloud masks are generated in TIFF and JSON formats using cloud detection thresholding techniques. The results showed that both deep learning models performed well, with UNET achieving an IoU (Intersection over Union) score of 0.86 and Mask R-CNN achieving 0.89. A notable difference between the models is in their outputs: UNET provides generalized cloud segmentation, whereas Mask R-CNN excels in segmenting clouds with a focus on structural variations. All approaches effectively identified potential thunderstorm zones; however, the empirical method demonstrated a significant advantage by detecting deep moist convection zones, which are crucial for evaluating thunderstorm intensity. To improve the deep learning model, an additional branch has been incorporated to identify deep convection, highlighting opportunities for enhancement in these models. While deep learning techniques are both effective and efficient, their performance could be further improved by integrating additional physical variables such as temperature, humidity, and pressure. This would enable the algorithms to better distinguish between general clouds and deep convective zones.

Keyword: Thunderstorm, INSAT 3D/3DR, Deep Learning, Deep Learning

Investigation on the local and remote factors influencing the frequency of fog occurrences over the Gangetic plains of India

Lt Cdr Beena Jain

Naval Met Office, Meenambakkam, Chennai

E-Mail:bnjn138@gmail.com

ABSTRACT

Fog is a localized weather phenomenon which affects our life in various ways and means and also our daily activities. It affects public health, roadways, airways as well as economy. Fog generally occur in winter season in northern parts of India and sometime it becomes very dense. Fog formation depends on so many surface parameter such as moisture, minimum temperature, surface winds and dew point temperature. The advection fog occurs in the forward sector whereas the radiation fog occurs mainly in the rear sector of a synoptic scale weather system known as “Western Disturbances” that affect India during winter. Conditions favorable for radiation fog are high relative humidity, light wind, cloud free sky and stable inversion layer.

Occurrence of dense fog during late in the night or early in the morning over northern parts of India is very common in winter. These fog occurrences many times remain so prolonged over the region that it can be easily detected in satellite visible picture Jenamani (2012). Wind speed and direction in lower levels, relative humidity, movement of effective western disturbances or westerly trough in middle tropospheric levels, vertical wind, soil moisture, dew point depression and minimum temperature are the key parameters to forecast the fog (Charan singh 2010).

Various authors have attempted to study various aspects of fog occurrences but there has not been any in-depth micro-climatic trend analysis of different fog climatological characteristics on the basis of its various visibility intensity using standard longer period visibility data. An attempt has been made in this study, by analyzing the synoptic hour and daily weather data recorded from weather stations of New Delhi, Lucknow and Patna and the global remote factors data for the main winter months of December, January and February for more than 35 -years period, to prepare different micro-climatological characteristics of fog. This study also discusses how various phenomenon like El-Nino, La-Nina, IOD and NAO influence in the occurrence of fog formation. The objective of this study is to find out the climatology of different intensities and the identification of trends in different intensities of fog over the Gangetic plains of India along with the role of remote factors such as NAO, ENSO and IOD on the fog events over the study region and it also includes the relationship between the local factors such as temperature, humidity, rainfall etc. and fog occurrences over the study region.

Aerosols over Chennai Metropolitan Area

Arkadeb, Banerjee[a], V. R. Durai[a],

[a] *Regional Meteorological Center*,
India Meteorological Department, Chennai-600006,
E-Mail: arka354deb@gmail.com

ABSTRACT

The study region, Chennai Metropolitan Area (CMA) in Tamil Nadu of India, encompasses 1189 sq. km. surrounding the core city of Chennai. The coastal city primarily experience dry climate. The accelerated growth of urban areas, transportation and industrial operations have led to a severe decline in air quality. Therefore, it is essential to conduct detailed spatial and temporal studies of air pollution to better understand how exposure varies over time and across different locations, which can enhance awareness of the duration of exposure and the potential risks associated with it. Aerosol particles scatter and absorb sunlight, impacting the atmospheric radiation balance by altering how light interacts with the Earth's surface. Our present research summarizes the spatio-temporal distributions of AOD, based on MODIS (Terra and Aqua) observations. Aerosols over the CMA are analysed using MODIS optical properties for 2021- 2023. Study compares AOD retrievals between MODIS-Terra and MODIS-Aqua, revealing discrepancies in accuracy. It is found that during the months of winter (DJF), summer (MAM) and post-monsoon (ON), the AE value remains greater than 1, showing the dominance of fine- mode particles. The distinct characteristics of aerosols are markedly procured from MODIS observations for CMA, deployed to ascertain the various types of aerosols employing threshold limits based on certain aerosol parameters. Aerosol classification is performed on different temporal scale and explained with possible conclusion. The results underscore the link between wind patterns and aerosol transport. Present study contributes to a deeper understanding of atmospheric dynamics with maritime interactions.

Keywords: MODIS; Aerosols; Transport; Retrieval; Chennai

Enhancing Beach Safety with an Innovative AI-Based Approach for Rip Current and Person Detection

Harshit Gautam[1], Surisetty V V Arun Kumar[*,2], Girish B[3], Venkateswarlu[3], C V Naidu[3], Sanjib K Deb[2], Deepak Putrevu[2] and Rashmi Sharma[2]
[1]*Silver Oak University, Ahmedabad, Gujarat*
[2]*Space Applications Centre, (ISRO) Ahmedabad, Gujarat*
[3]*Department of Meteorology & Oceanography, Andhra University, Visakhapatnam, AndhraPradesh*
*Email: * arunkumar@sac.isro.gov.in*

ABSTRACT

Rip currents are a leading cause of coastal drownings worldwide, presenting a critical safety challenge for beachgoers and rescue teams. Existing detection methods, such as manual observation by lifeguards or traditional sensor systems, are inherently limited by human oversight, response delays, and geographic scope. This research proposes a state-of-the-art, real-time solution for the automated detection of both humans and rip currents using the YOLOv8n object detection model. Our primary aim is to significantly improve beach safety by identifying at-risk individuals caught in rip currents andtriggering immediate alerts, thereby reducing the time needed for life-saving interventions. TheYOLOv8n architecture, selected for its superior computational efficiency and fast inference capabilities, was trained on a unique dataset designed specifically for coastal surveillance applications.This dataset includes a broad range of images capturing both human figures and rip currents, collectedfrom aerial, high resolution satellite imagery and ground-level sources such as CCTVs. Using the Roboflow® platform, we performed extensive pre-processing, including data augmentation,normalization, and resizing, to ensure that the model is well-equipped to generalize across diverse beach environments and lighting conditions. The combined dataset approach enables the model to concurrently detect humans and hazardous rip currents, offering a unified solution that addresses two critical beach safety concerns. The model's performance was rigorously evaluated on 1338 test images comprising 3854 instances, yielding a precision of 0.795, a recall of 0.644, a mean average precision (mAP@50) of 0.717, and a mAP@50-95 of 0.385. For human detection across 779 images (3205 instances), the model achieved a precision of 0.767, a recall of 0.560, and a mAP@50-95 of 0.414. Ripcurrent detection across 563 images (649 instances) demonstrated a higher precision of 0.823, with a recall of 0.727 and a mAP@50-95 of 0.356. These results underscore the model's robust capacity to detect both human subjects and rip currents under challenging real-world conditions, thus enabling more effective interventions. This research presents a significant advancement in the integration of AI-basedobject detection for public safety applications. By providing continuous, automated monitoring of beachenvironments, this system offers the potential to drastically reduce beach drownings, helps in boostingtourism industry.

Keywords: Rip currents, Artificial intelligence, Yolo, object detection

Water hyacinth in rivers and mosquito menace in a changing climate scenario: Spatio-temporal analysis using remote sensing and geospatial technology

Ila Agnihotri[a], Pratip Shil[a], and Nayana Deshpande[b]
[a]*BDM, ICMR-National Institute of Virology, Pune*
[b] *STCVP, Indian Institute of Tropical Meteorology, Pune*
E-Mail:ilaagni@gmail.com

ABSTRACT

A swarm of mosquitoes swirling like a tornado was witnessed by the citizens of Pune, India on February 8, 2024 over the localities near *Mula-Mutha* River. This unusual event was followed bymosquito menace and Pune municipal corporation (PMC) took immediate steps to control mosquitoes and growth of water hyacinth in rivers. PMC asserted that the growth of water hyacinthas a main reason. The study focuses on monitoring water hyacinth using high resolution satellite imageries (Sentinel-2) and associating it with climate variations.

The objective of the research was to identify water hyacinth growth in rivers, spatio-temporal variations, and identification of locations of concern on rivers of Pune comprising *Pawana, Mulaand Mula-Mutha* rivers. Retrospective Earth observation data from Sentinel-2 Satellite images from 1 October 2023 to 30 April 2024 were analyzed for water hyacinth area. Sen's slope estimation for assessing assessing seasonal climate variations. Correlation was established with fortnightly temperature (Tmax, Tmin).

Fortnight wise analysis reveals that there were altogether 28 locations of WH growth with 4 on *Pawana R.*, 14 on *Mula R.* and 10 on *Mula-Mutha R.* having average area under water hyacinth as 734.5 Th. m^2 per fortnight. The average growth rate was found to be 4.4 Th. m^2/day, with *Mula R.*had 0.8 Th. m^2/day, *Pawana R.* had 0 Th. m^2/day) and *Mula-Mutha R.* had 3.6 Th. m^2/day. Amongall fortnights, highest growth rate was observed in February first fortnight (18.4 Th. m^2/day), the time when mosquito outbreak was reported. Positive correlation with temperature, mainly with Tmax was found (more than 0.5) for all rivers and individual rivers. Long term temperature data(1969-2022) reveals that significant warming trend during winter months (DJF). The anomalous rising temperature in winter months especially December may have contributed to unusual accelerated growth of WH in rivers.

Keywords: Seasonal climate variations; Mosquitoes; Water hyacinth; Climate change; GeospatialTechnology

Early warning system for extreme weatherin the climate change context

Satyabrata Datta,

Regional Meteorological Centre,
Kolkata
E-Mail: satya_imd@yahoo.co.in

ABSTRACT

Early weather system for Extreme Weather in the Climate Change Context primarily depends on the Forecasting skills of the principal weather agency. The impact of the extreme weather accompanied with the disaster risk reduction in regard to saving of life and properties is an exercise of interdisciplinary approach. These factors are being dealt by the agencies other than weather department. The extreme weather e.g. Extreme Temperature, Extreme Precipitation, Extreme Storms have their impact, mitigation and preparedness differently. In case of extreme temperature impact is on the human health, agriculture/livestock, livelihood mainly. Hence for preparedness and mitigation respective agencies needs to take action in coordination well in advance based on the farecast given by the weather agency.

In case of extreme precipitation irrigation & waterways, geological department , water commission, general administration etc. Needs to assess the vulnerability and contingency plan for preparedness and mitigation should be chalked out. It is very much location specific assessment and preparedness for risk reduction and mitigation.

In case of extreme storm like Cyclone, weather agency is to address the general public along with all government agencies about the intensity, track, area of land fall and time of land fall of the system with a sufficient lead time and subsequently update it with hourly or three hourly bulletin. The bathemetry of the coastal area and structure there needs to be taken carefullyfor impact assessment and preparedness.

Standard Operating Practice(SOP) may be prepared for System Specific and Location Specific disasters for mitigation, preparedness and response action that will effectively fulfill the objective of Early Warning System.

Keywords: Extreme Weather Systems; Climate change; Impact assessment; Disaster risk reduction; Standard Operating Practice

Characteristics of Size-Resolved Aerosols and New Particle Formation in a Rural Region of Central India

Jeni Victor N*, Yang Lian, Anil Kumar V, Sachin Philip Kakkanattu, Uday Shau, Padmakumari B and Pandithurai G

Indian Institute of Tropical Meteorology, Pune, India

**Email:n.jeni@tropmet.res.in*

ABSTRACT

Atmospheric new particle formation (NPF), driven by gas-to-particle conversion, is a frequent phenomenon in the troposphere, influencing air quality, weather patterns, and climate. In this study, we present the first comprehensive characterization of NPF events at the Atmospheric Research Testbed (ART), located in a rural background region of central India (23.5°N, 77.65°E,

~450 m above mean sea level), surrounded by dense vegetation. Using eight months of continuous measurements of particle number size distributions, cloud condensation nuclei (CCN), and black carbon (BC), we observed that out of 210 days of monitoring, 69 days (32%) exhibited typical NPF events, 40 days showed particle burst events, and 10 days were classified as undefined. Thisstudy also distinguishes between polluted-NPF and clean-NPF events based on BC concentrations.Notably, most burst events coincided with elevated BC mass concentrations, likely due to crop- burning activities prevalent in the post-monsoon season (October to December). During this period, background aerosol concentrations in the accumulation mode were higher than in other seasons. Additionally, the impact of surface atmospheric variations and cloud cover on NPF event days was examined, offering new insights into their interactions. Seasonal patterns of NPF eventsand their potential precursors in this rural setting are also discussed.

Keywords: Aerosol, Size segregation, new particle formation, rural environment, Central India

Is cloud turbulence different from standard turbulence?

Nikitabahen N. Makwana[a] , Bipin Kumar[a], and Rama Govindarajan[b]

[a] *Indian Institute of Tropical Meteorology, Ministry of Earth Sciences,*
Dr. Homi Bhabha Road, Pashan, Pune 411008, India

[b] *International Centre for Theoretical Sciences, Tata Institute of*
Fundamental Research, Bengaluru 560089, India

E-Mail: makwana.nikita@tropmet.res.in

ABSTRACT

A turbulent cloud is a complex mixture of air, water vapor, liquid water droplets, and aerosol particles. The availability of aerosol particles in regions of local supersaturation leads to condensation, forming growing cloud droplets. Cloud turbulence differs from other fluid turbulence due to the impact of phase change. This study explores the growth of droplets in background turbulence, focusing on how phase change influences turbulence [1-2]. In regions where condensation occurs, the surrounding air warms due to the expulsion of latent heat. In turbulent clouds, the temperature rise is rapid and uneven. We perform three-dimensional direct numerical simulations (DNS) of decaying turbulence, both with and without phase change, in a periodic box[4]. The turbulent flow is set up in a supersaturated environment with uniform vapor concentration and at constant temperature, after which monodisperse droplets are introduced in a random distribution, which act as sites for phase changes. Inertia expels droplets from vortical regions and so phase change is shown to occur thereafter preferentially outside these regions[3]. We show that colder temperatures and moisture are therefore found preferentially in vortical regions, giving rise to small scale turbulence dure to baroclinic torque. Phase change too is a rapid process, so the efficacy depends on the ratio of the time scales.

Keywords : Cloud turbulence; 3D-DNS; Phase change; Vortex formation

Impact on coastal inundation and storm surges due to land use/land cover (LULC) Changes on East Coast of India: Climate change perspective

Vyshnavi Sai Yalla[a] and A.N.V. Satyanarayana[a*]
[a]*Centre for Ocean, River, Atmosphere and Land Sciences,*
IIT Kharagpur, Kharagpur
E-Mail: anvsatya@coral.iitkgp.ac.in

ABSTRACT

Storm surges caused by atmospheric pressure changes and strong winds associated pose a significant risk to coastal regions. The interaction between storm surges and land use/land cover (LULC) patterns is crucial in determining the extent of coastal inundation. The present study explores the interaction between storm surges, and varying LULC in a climate change perspective. As climate change intensifies, rising sea levels and increased storm intensity exacerbate storm surge risks. Urbanization, deforestation, and changes in land cover significantly influence coastalresilience and susceptibility. To comprehend the influence of LULC incorporation in a coupled hydrodynamic model (ADCIRC+SWAN), to examine the impact of a highly intense storm knownas Amphan, which made landfall in the Sundarbans region of the West Bengal coast. Three landuse scenarios were tested in the model to examine which land use class has the maximumand minimum reduction potential for storm surge inundation. The influence of climate change impact as a result of global warming on the coastal inundation is evaluated by enhancing the intensity of the Amphan cyclone in terms of winds in the present study. Analysis reveals that varying LULC and the high intensity of winds show a significant effect in increasing coastal flooding up by to 30%. The study suggests the need for effective land management and conservation efforts to enhance coastal resilience in the face of a changing climate.

Keywords: Storm Surge; LULC; ADCIRC+SWAN; Climate Change

Investigating the dynamic and microphysical preocesss in observed convection through range-height indicator scans of C-band polarimetric radar

Kumar Abhijeet [a,b], Sachin M. Deshpande[b], and G. Pandithurai[b]

[a] *Atmospheric Research Testbed-Central India, Bhopal, India.*
[b] *India Institute of Tropical Meteorology, Pune, India.*
E-Mail: abhijeetkrbhu11@gmail.com

ABSTRACT

During the monsoon, deep moist convection is frequent over Central India, and it produces widespread and heavy precipitation over the region. Given its significance, a polarimetric C-band (CPol) radar was installed at the Atmospheric Research Testbed (ART) Facility of IITM at Silkheda in the monsoon core zone. The CPol radar was operational during the monsoon season of 2022 and 2023 in the plan position indicator (PPI) scan followed by a range height indicator (RHI) scan, and it collected unique observatios of various types of rain-bearing systems, such as low-pressure systems, depressions, stratiform and convective rain types, etc. Compared to PPI scan, the RHI scan data provide much higher vertical resolution and hence would reveal insight into dynamic and microphysical processes in observed convection. In this study, the RHI scan data during 2022-2024 are explored to investigate the evolution of the finescale vertical structure of an isolated cells and organized convective systems. Collected measurements from additional equipment at the ART facility, such as the radiosonde, radiometer, and disdrometer, are also utilized. Details on the horizontal and vertical structures of selected cases of convection types, as well as their polarimetric fingerprints, will be presented at the conference.

Keywords: Polarimetric radar; Monsoon; Extreme rainfall; Rain microphysics

Impact of Western Disturbances on Thunderstorms and Hailstorms in Maharashtra

Jismy Poulose[a], Shambu Ravindren[a], Sushma Nair[a] and Nitha Sasidharan[a]

[a] *India Meteorological Department*
Colaba, Mumbai
Email: jismy.poulose@imd.gov.in

ABSTRACT

The Western Disturbance (WD) has a wide range of effects on pre-monsoon thunderstorms (TSs) and hailstorms (HSs) over the Maharashtra region. The recent observation of disastrous weathers shows that the passage of WD often resulted in TSs and HSs over the region. The interaction of the upper-level trough of WD with lower-level winds from the Arabian Sea and easterly/southeasterly winds from the Bay of Bengal results in TSs/HSs. The severity of TSs/HSs is expected to be influenced by the vertical and aerial extension of the WD trough and its embedded cyclonic circulation (Sankar and Babu, 2020). This study examines the vertical cross-section of WD winds and their characteristics to understand the interaction processes and its thermodynamics, highlighting the role of WD in determining the severity of thunderstorms and hailstorms in terms of precipitation amount, thunder intensity, and lightning severity in the region. The hailstorm events in 2023 over the Maharashtra region is considered for this case study. The study reveals that severe hailstorms occurred when the WD trough extended deeper, from 850 hPa to 200 hPa and when the horizontal extension of the WD trough reached till the Arabian Sea. With the help of the 200 hPa trough, there was convective lifting of moisture which crossed the freezing level and resulted in heavy hailstorms. The characteristics of TSs/HSs also changed from dry severe thunderstorms with light hailstorms to wet severe thunderstorms with heavy rainfall and hailstorms, depending on the phases of the WD, its vertical tilt, and its horizontal extension toward the Arabian Sea.

Keywords: western disturbances, hailstorms

Evaluating the Impact of Microwave Imager Radiance Data Using4D-Var Assimilation in NCUM-R Model Simulations of Tropical Cyclones over the Bay of Bengal

Shivaji Singh Patel[1,2] ,A. Routray[1], K. C. Gouda[2],Rajeev Bhatla[3] and V. S. Prasad[1]

[1]National Centre for Medium-Range Weather Forecasting (NCMRWF), Ministry of Earth Sciences (MoES), A-50, Sector-62, Noida, UP 201309, India

[2]CSIR Fourth Paradigm Institute (CSIR-4PI), NAL Belur Campus, Bangalore

[3]Department of Geophysics, Banaras Hindu University (BHU), Varanasi, Uttar Pradesh, 221005

E-Mail: shivaji.ncmrwf@gmail.com

ABSTRACT

An attempt was made to investigate the effects of assimilation of Microwave Imager (MI) radianceobservations on simulation of Tropical Cyclones (TCs) using the high resolution NCUM-4DVAR assimilation technique over Bay of Bengal. Assimilation of GTS observations (CTL) and satelliteMI radiance (SSMIS) (assimilation of GTS plus GMI and SSMIS) were the two sets of numerical experiments that were conducted. It has been observed that integrating MI radiation can well represent storm structure, trajectory, and intensity. The analysis of temperature and geopotential height increases shown that the SAT experiment may successfully alter the core region of TCs and systematically adjust the position in the model's first approximation. With the axisymmetric eye of TCs, the SAT accurately simulates the strength of large-scale moisture transport from the underlying marine surface as well as the helicity around storms. While the evolution of storm intensity is quite effectively recorded in the SAT experiment, the premature intensification of TCsis reproduced by CTL. The CTL simulations clearly show that the energy cycle can be disrupted by dry air penetrating the inner core of the TC, resulting in a decrease in storm intensity. In CTL simulations, the intensity of TC is hindered by the -ve value of diabatic heating that appears aroundthe storm's center as altitude increases. This aspect made it very evident that CTL simulations are not accurately capturing the intensity and vertical organization of the TCs. In comparison to CTL,the track forecast of storms is significantly better in SAT simulations. In SAT simulations, the rainfall forecasting accuracy has also somewhat improved. The model's ability to anticipate stormstructure, velocity, severity, and precipitation was improved overall by the integration of MI radiances.

Keywords: Microwave Imager, 4DVAR Assimilation, NCUM regional Model, Tropical cyclone

Study of Long Term Rainfall Trends over Different Regions of India

Soumalya Roy[a] , Sahadat Sarkar[b]

[a] *Department of Geography, Nowrosjee Wadia College, Pune*
[b] *FRD, Indian Institute of Tropical Meteorology, Pune E-Mail:*
soumalyaroy.802@gmail.com

ABSTRACT

This study explores long-term rainfall trends across India, analyzing data from 1871 to 2016 for rainfall. The study uncovers significant climate variability, with notable regional differences in rainfall patterns. A general decline in annual rainfall is observed, particularly during June and July, the critical monsoon months. However, some regions, such as North-West and Peninsular India, show slight increases in rainfall over the years, while other regions like North-East India and West- Central India experience pronounced declines. In addition to regional trends, the study investigates the impact of large-scale climate phenomena on rainfall variability. The El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) are identified as key drivers of rainfall anomalies. Their influence adds complexity to India's rainfall patterns, amplifying or diminishing seasonal rains depending on their phase and strength. These climate drivers further complicate the country's already variable monsoon behavior, presenting additional challenges for water resource management. The study employs rigorous statistical analysis to unravel these complex climate dynamics, providing a clearer understanding of how different regions are responding to global climate trends. Given the importance of rainfall to agriculture, water resources, and biodiversity in India, these findings underscore the urgency of developing adaptive strategies. The study highlights the necessity for region-specific policy interventions that address local climate realities while considering the broader, large-scale climate systems at play. Ultimately, the study aims to assist policymakers in creating informed, long-term strategies to mitigate the impacts of changing rainfall patterns, ensuring sustainable development in the face of ongoing climate change.

Keywords: Indian Monsoon, Rainfall Trends, Climate Variability, ENSO, IOD

Ocean heat content analysis in the Arabian Sea

A. Nayan[a] and C. Shaji[a]

[a] *Centre for Ocean, River, Atmosphere and Land Science,Indian Institute of Technology Kharagpur*
E-Mail:aayushnayanofficial@gmail.com

ABSTRACT

Ocean heat content (OHC) is a crucial weather and climate change indicator. In the ocean, most ofthe heat gain occurs in the upper 700 meters, while changes in the interior happen more slowly. Most extreme weather events, such as tropical lows, depressions, and cyclones, depend on the OHC. The 27°C isotherm is the depth at which the ocean stores sufficient heat, a critical thresholdfor the formation of cyclones. Using the depth of the 27°C isotherm, we computed OHC in the Arabian Sea (AS) over 30 years. We compared it with other OHC computations, including the depths of 26°C, 25°C, and 20°C isotherms. There is a strong correlation between the deepening ofthe 27°C isotherm and cyclone intensity. This study provides a comprehensive knowledge of the evolution of the upper thermal structure in the AS by comparing the variability of isotherm depthswith fixed depth layers in the ocean. Such comparisons help 1) understand the mechanics behind the strengthening of tropical storms in the AS and identify patterns in ocean heat storage, 2) betterunderstand the cyclone prediction models and early warning systems, and 3) provide significant light on how maritime processes fuel climatic extremes.

Keywords: Ocean Heat Content, 27°C Isotherm, Tropical Cyclones, Arabian Sea, Thermal Structure

Estimation of glacier ice velocity using SENTINEL-1A Synthetic Aperture Radar (SAR) data over eastern parts of Sikkim (Mangan district).

Shubhendu Karmakar[a,b], Atanu Bhattacharya[b,c]

[a] *Regional Meteorological Centre, Kolkata, Alipore, Kolkata*
[b] *Department of Earth Sciences & Remote Sensing, JIS University, Kolkata*
[c] *Centre for Data Science, JIS Institute of Advanced Studies & Research, JIS University, Kolkata*
E-Mail: shubhendu.karmakar1997@gmail.com

ABSTRACT

Synthetic Aperture Radar (SAR) imagery is an effective tool for glacier monitoring, providing valuable data on snowlines, surface flow velocity (both retreat and advance), mass balance (whether positive or negative), and volume changes. One of the key advantages of SAR is its ability to capture data in any weather conditions, utilizing both intensity and phase information. Systematic SAR-based studies can be conducted to assess glacier changes and trends using archived satellite datasets over several decades.

When measuring glacier velocity with SAR data, two main approaches are commonly used: the interferometric approach and the offset tracking approach. The interferometric method, known as Interferometric Synthetic Aperture Radar (InSAR), is highly sensitive to subtle displacements in the glacier's surface, but its effectiveness is often limited by coherence loss due to the 12-day interval between acquisitions and the rapid movement of glaciers. In contrast, the offset tracking technique measures feature displacement between two SAR images by applying patch intensity cross-correlation optimization (Strozzi et al., 2002). This method is widely used for estimating glacier motion. Glacier movement has significant environmental and ecological impacts, as changes in surface ice dynamics can influence the overall health of the glacier.

In this study, glacier-ice flow velocity over the eastern parts of the Mangan district is estimated using the image-to-image offset tracking technique with eight SAR images, from Sentinel-1A data collected for the year 2024. Elevation data for the study area is obtained from the Shuttle Radar Topography Mission (SRTM) with a spatial resolution of 90 meters. The aim is to produce a time series of surface velocity for glaciers located in the study area.

Keywords: Climate change, Glacier mass balance, ERA5 land reanalysis data, Optical stereo satellite images.

Weather events in the Arabian Sea

S. Lahane[a] and C. Shaji[a]

[a]*Centre for Ocean, River, Atmosphere and Land Sciences,Indian Institute of Technology, Kharagpur, India*
E-Mail: shreyashlahane2001@gmail.com

ABSTRACT

Sea surface height anomaly (SSHA) indicates the difference between the average ocean surface height over a long period and the actual height observed by a satellite. The SSHA is a crucial indicator for identifying unusual patterns in the ocean, locating heat-stored regions in the ocean, identifying areas at risk of sea level rise, and protecting ocean fisheries. This study focused on understanding the correlation between the SSHA and extreme weather events, such as cyclones and intense rainfall, in the Arabian Sea (AS) over the past thirty years. To assess relationships andinterdependency, we applied statistical tools to examine the temporal and spatial patterns of SSHA.We compared them with historical data on cyclonic activity and precipitation extremes.

Keywords: Arabian Sea, Sea Surface Height Anomaly, Extreme Weather Events, Cyclones, Intense Rainfall.

Contrasting features of the marine heat waves over the Arabian Sea and Bay of Bengal

Alankita Nag[a], Debadatta Swain[a], and Sandeep K K[a]

[a] *School of Earth, Ocean and Climate Sciences, IIT Bhubaneswar*
E-Mail: 23CL05002@iitbbs.ac.in

ABSTRACT

Climate change significantly impacts marine ecosystems, particularly through rising sea surface temperatures (SST), leading to extremes called marine heat waves (MHWs). These are prolonged episodes of anomalous increase in the SST exceeding the 90th percentile for at least five consecutive days, with a gap of two days in between considered as a single event (Hobday et al., 2016; Oliver et al., 2018). The Northern Indian Ocean, a hotspot for marine primary productivity, is experiencing a 1 °C rise in SST, exceeding the global increase of 0.7 °C (Gnanaseelan et al., 2017; Roxy et al., 2016). While studies have characterized MHWs separately in the Arabian Sea (AS) and Bay of Bengal (BOB) and explored their variability (Chatterjee et al., 2022; Chakraborty et al., 2023; Gupta et al., 2024; Liang et al., 2024), a comprehensive basin-wide inter-comparison of these events and their contrasting spatio-temporal variability under climate change over the AS and BOB is not addressed well. A comparative study of the factors influencing MHWs in the AS and BOB is essential for accurate predictions of future events and climate projections. Our results have shown that AS and BOB is experiencing a rapid increase of MHW events in the recent decades. It was observed that BOB is more prone to frequent MHW events than the AS, with an increasing trend of 0.48 events/decade in the BOB and 0.092 MHW events/decade in the AS. On the other hand, AS is experiencing more intense and longer duration MHW events than the BOB. Our future goal is to investigate the factors driving these spatio-temporal variability, particularly in relation to the longest prevailing MHW events in both regions, and to analyze the subsequent chlorophyll-a changes resulting from these extremes.

Keywords: Marine heat waves; Arabian Sea; Bay of Bengal; Chlorophyll-a

Unconventional genesis of tropical cyclone Asna in August 2024: analysis of formation, intensification and dissipation

Avijnan Das, Sanjeev Kumar Singh, Yogesh Kant and D. Mitra

Marine and Atmospheric Sciences Group, Indian Institute of Remote SensingISRO, Dehradun-248001
E-Mail: avijnan2016@gmail.com

ABSTRACT

A Tropical Cyclone (TC) is a warm-core, non-frontal low-pressure system that typically forms over the ocean, characterized by organized surface circulation. However, TC Asna represents an unusual case, as its low-pressure system developed over land in central India. This rare occurrenceincluded a westward movement toward the Arabian Sea in August 2024, a period typically markedby weakened southwestern monsoon winds.

The study investigates the thermodynamic and dynamics processes involved in the formation, intensification and dissipation of TC Asna, utilizing observational and high-resolution numerical weather prediction (NWP) model datasets. It employs a three-dimensional spatiotemporal analysis of various atmospheric variables throughout the cyclone's development. This approach aims to enhance understanding of turbulent fluxes of momentum, heat, and moisture between land, atmosphere and the ocean, as well as the influence of dynamic controls such as the Tropical UpperAtmospheric Trough (TUTT), Monsoon Trough, and Equatorial Waves on tropical cyclogenesis.

Results indicate that these turbulent fluxes were significantly enhanced during the cyclone's passage. Notably, the Monsoon Trough shifted westward over central and western India, coupled with increased moisture from previously saturated soil, generating sufficient vorticity for the development of a land depression. This depression subsequently moved westward, influenced by easterly winds, ultimately intensifying into a Cyclonic Storm upon reaching the Arabian Sea due to heightened moisture supply and reduced vertical wind shear. Further research is essential to deepen understanding of the roles of these fluxes in TC intensification and propagation.

Keywords: Tropical Cyclone; Asna; NWP, Turbulent Flux; Monsoon Trough

Urbanization over Indian Cities and its Role in Modulating the Local Environment: Application of AI/ML and Numerical Modeling

Jagabandhu Panda

Department of Earth and Atmospheric Sciences, National Institute of Technology Rourkela

E-Mail:jagabandhu@gmail.com

ABSTRACT

Urbanization in Indian cities is striding at an incomparable and irreversible rate and is mostly driven by the population migration, which eventually imparts a significant pressure on the local environment, weather and climate in many ways. Therefore, the study on urban meteorology, climatology, and extreme weather is quite important in the current scenario as the country is evolving towards becoming an advanced economy. In this context, urban growth dynamics and future projection over Indian cities are carried out using satellite datasets, relevant spatial metrics, urban density gradient analysis and by applying machine learning (ML) and deep learning (DL) techniques. A heterogeneous urban growth pattern and sprawling for different cities is noticed with dominance of infill or outlying or sprawling or dispersive or aggregation type. A substantial anthropogenic activities is realized through night light and population density analysis. The ML/DL-based study indicates higher growth in Kochi and greater projected rate over Mumbai. While associating the variability of geophysical parameters, local meteorology and environment with the urban growth trends, their correspondence is strongly realized mostly when large-scale stronghold is absent. In several instances a strong association of urbanization with urban heat island (UHI) at the surface, aerosol and particulate matter variability, near-surface temperature, and rainfall is observed. DL-model-based projections also reveal that the projected urban growth will also govern reasonably the future trends of temperature and rainfall over urban areas. The urban-induced land use changes when accounted within Weather Research and Forecasting (WRF) model to study the impacts, it is realized that the urbanization can modulate the local weather as well. The modulations include UHI effects, rainfall patterns and intensity during thunderstorms and convective rain events, wind patterns, fluxes, moisture variability and atmospheric boundary layer characteristics. Such modulations would impact the quality of life over urban areas, which includes water and electricity consumptions, daily activities, health, etc. Therefore, urban meteorology, extreme weather, and associated climatology study is quite an important area of research would help providing inputs for disaster management and policy making.

Keywords: Urbanization; ML; DL; Meteorology; Local environment; UHI; WRF; Temperature; Rainfall

Mixing layer and cloud base height from Lidar Ceilometer and Space based observations over a Western Ghat region

Aathira K P[a], Abhinav B Roy[b], and Pramitha M[a]

[a] *School of Earth, Environment and Sustainability Sciences, IISER Thiruvananthapuram*
[b] *Earth and Environmental Sciences, IISER Bhopal*
Email: aathirakp23@iisertvm.ac.in;
pramitha@iisertvm.ac.in

ABSTRACT

Attenuated backscatter profiles from the Lidar Ceilometer, CL61, is used to calculate the planetary mixing layer height and cloud base height over IISER Thiruvananthapuram. The Wavelet Covariance Transform (WCT) method and gradient method is used to identify the mixing layer height. The variations in mixing layer from 6:30 am to 6:30 pm IST is analysed and then proceeds to study the seasonal variations from September 2023 to August 2024. The mixing layer grows after sunrise and reaches a peak of 1.8 km during noon and becomes stable around 2 pm. The mixing layer height obtained from Ceilometer is compared with ERA-5 reanalysis and COSMIC-2 satellite data. ERA-5 tends to underestimate the mixing layer height in September, October, November and December while COSMIC-2 overestimates the mixing layer height in these months. Results need to be analysed further.

The cloud base height is calculated from CL61 using WCT and relative frequency of occurrence of different levels of clouds are analysed monthly from September 2023 to August 2024. According to the altitude of the cloud base, it is categorized as low level (< 2 km), middle level (2 km – 5 km) and high level (> 5 km). The relative frequency of middle and high level clouds are fairly consistent, while the occurrence of low level clouds are highly varying. The cloud base heights are compared with that available from ERA-5 reanalysis and Aqua-MODIS satellite. Only few cloud base height estimates from ERA-5 and Aqua-MODIS are significantly close to ceilometer estimates, suggesting the importance of ground based observations in improving the climate models.

Keywords: Mixing layer height; Cloud base height; Ceilometer; WCT; Gradient method

Characterization and trends in Hadley Cell expansion using reanalysis

Aathira K P[a] and Pramitha M[a]

[a] *School of Earth, Environment and Sustainability Sciences, IISER Thiruvananthapuram*
aathirakp23@iisertvm.ac.in; pramitha@iisertvm.ac.in

ABSTRACT

Hadley cell is a thermally driven meridional circulation with the ascending branch in the tropics and descending branch in the mid-latitudes. Previous studies show an expansion of the cell polewards but these studies have not agreed on the magnitude of expansion. The expansion of the poleward edge of the hadley cell indicates a shift in the subtropical dry zones poleward. The present study is an attempt to characterize the Hadley cell and study the trend in its expansion using MERRA-2 reanalysis data from 1980 to 2024.The cell edge is characterised using the meridional mass stream function (MSF). The surface pressure is temporally averaged for a month, while the meridional wind is averaged temporally and zonally to calculate MSF as a function of latitude and pressure for each month. The latitude where the MSF becomes 0 kg/s at 500 hPa is assigned as the poleward edge of the cell. The edge of the Northern hemispheric cell varies between 25 to 40 degree latitude and the edge of the Southern hemispheric cell varies between 25 to 35 degree latitude. The seasonal variation of the cell edge is also analysed. The long-term trend in the cell edge is studied using the LOTUS multivariate linear regression model using the natural variables like 11 year solar cycle, ENSO and QBO as the predictors. The Hadley cell shows an expanding trend. The results are in agreement with the previous studies.

Keywords: Hadley Cell; MERRA-2; MSF; Long-term trend

Hail growth detection and early warning from dual polarimetric signatures

J.S. Thomas[a], P. Murugavel[a], Aravindhavel[a], Thara Prabhakaran[a]

[a]*Indian Institute of Tropical Meteorology (IITM), Ministry of Earth Sciences, Dr. Homi Bhabha Road, Pune 411008, India*

E-Mail: josin.thomas@tropmet.res.in

ABSTRACT

Hailstorms pose significant threats to agriculture, infrastructure, and public safety, demanding accurate detection and forecasting skill. The complexity of hail detection arises from rapid storm development, variable size-intensity and the difficulty to classify and isolate the hail hydrometeors. The present study explores the detection of hailstorms using dual-polarization radar, specifically focusing on the differential reflectivity (ZDR), specific differential phase (KDP) and cross-correlation ratio (RhoHV) signatures obtained from IITM C-band dual- polarimetric radar over the western ghats region. The early development of an isolated case with positive ZDR values extending 500m above the freezing point is selected for this study. To avoid false alarms a threshold of ZDR > 2.5 dB and ZH 25 dBZ is applied. The identified cases exceed

> 40 dBZ with lead time from 20 to 50 minutes indicating the growth of hydrometeors. Other polarimetric parameters such as specific differential phase and cross-correlation ratio are used to identify the rain and hail signatures. The increment of KDP values with high ZDR columns above freezing point further ascertain the presence of hail from dual polarimetric signatures. Finally, a hydrometeor classification algorithm is applied to identify the microphysical properties and hail signatures. This study offers a useful lead time to detect hailstorms for an operational DWR network.

Keywords: Hydrometeor classification, ZDR columns, Hailstorm, C-band RADAR

ROLE OF ARABIAN SEA HIGH SALINITY WATER MASS ON POST-MONSOON HYPOXIA IN THE BAY OF BENGAL

K. S. Sreejith[1], C. Shaji[2]
[1]*National Institute of Oceanography, Goa, India*
[2]*Indian Institute of Technology, Kharagpur, India*
E-Mail:sreejithk@nio.res.in

ABSTRACT

During October, there is an Oxygen Minimum Zone (OMZ) off the Godavari River Discharge (GRD) region of the Bay of Bengal (BB). This study investigates the role of Arabian Sea High Salinity Water (ASHSW) in supplying oxygen to this region. In contrast to the presence of usual OMZ at the intermediate depth in the BB, the observed subsurface (40-200 m) hypoxia at the GRD area primarily occurs as a combination of several mechanisms such as the nutrient enrichment from the GRD, elevated primary productivity, and subsequent organic matter decomposition, andcoastal upwelling. The Biogeochemical-Argo floats, and World Ocean Atlas 2018 (WOA18) reveal a clear shoaling and intensification of the OMZ during the post-monsoon season. Our studysuggests that the advection of ASHSW, after its formation in the northern Arabian Sea (AS) duringwinter, is critical in non-intensifying this subsurface OMZ off the GRD region. The ASHSW brings about 2 $ml.l^{-1}$ of dissolved oxygen into the BB by October and is one of the significant contributors of oxygen at subsurface layers, especially during post-monsoon when winds are weak.Moreover, any variations in the formation processes or spreading of ASHSW can adversely affect the observed post-monsoon hypoxia near the GRD mouth region. Understanding the formation and spreading of ASHSW is vital for predicting the possible impacts of river runoff variations onthe coastal environment and the well-being of BB's marine ecosystem.

Keywords: Arabian Sea High Salinity Water, Oxygen Minimum Zone, Godavari River Discharge,Bay of Bengal, Post-monsoon

Identification of the Southwest Monsoon Current Variability and the Associated High-Salinity Core

Salini Nayak ,Dipanjan Dey

School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar
E-Mail: 23cl05019@iitbbs.ac.in

ABSTRACT

Seasonal monsoon winds exert great influence on the Northern part of Indian ocean, which results in reversal of ocean currents. Among these is the Southwest Monsoon Current (SMC), which is the most pronounced current to flow into the Bay of Bengal from Arabian Sea in summer. This plays a crucial role in maintaining salinity across these two northern Indian ocean basins. The present study focuses on examining the variability of SMC from 1993 to 2023 and its influence on salinity dynamics, especially the formation and variability of the High-Salinity Core (HSC) in the BoB. Using both reanalysis and observational data sets, we investigate the mechanisms that cause anomalous high and low HSC events and their relation to local and remote forcings. The study further examines how interannual salinity and temperature influence regional climate patterns, providing insight into the physical processes driving salinity changes in the BoB's subsurface layers. Our findings show a strong agreement between the Global Ocean Physics Reanalysis (GLORYS12V1) NEMO model simulations and the real-world datasets from OSCAR, ARMOR3D L4, and RAMA buoys. Notably, the monthly mean transport analysis reveals peak meridional volume transport during July, ranging from 12 to 14 Sv. The analysis of meridional volume transport anomalies from 1993 to 2023 reveals significant year-to-year variability, particularly in anomalous years. The analysis of wind stress curl, sea surface height, and thermocline depth is currently being carried out to identify the mechanisms driving these anomalies and their impact on regional ocean dynamics.

Keywords: Southwest Monsoon Current (SMC), High Salinity Core (HSC), Interannual Variability, Indian Ocean Circulation

Identifying Ocean Surface Microplastic Pathways in the Global Ocean

Josephine Veronica Chaganti, Dipanjan Dey

School of Earth Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar
E-Mail: 23cl05009@iitbbs.ac.institution

ABSTRACT

Microplastics(<5mm in size) have become the ubiquitous and alarmingly increasing pollutant in the oceanic waters. Their concentrations are under sampled outside North Atlantic and North Pacific Gyres. To address this problem, a new methodology was invented to detect and image ocean microplastics using the Cyclone Global Navigation Satellite System(CYGNSS) by measuring the reduction in surface roughness. However, the validation of the results from satellite derived microplastic (MP) concentration still remains an unanswered question. Studying their transport mechanisms also remains a challenge because of their high spatio-temporal variability.

Keeping these complexities in mind, this study aims to validate the satellite derived product with the available in situ data and analyze the transport mechanisms. Our findings show a good agreement between CYGNSS-derived microplastic concentrations and in situ measurements. Seasonal analysis reveals elevated microplastic concentrations during summer months and a decline in winter across both hemispheres. Notably, the head of the Bay of Bengal experiences peak microplastic influx post-monsoon, attributed to increased river runoff. The analysis of ocean currents, winds and stokes drift is being carried out to identify the marine surface microplastic transport mechanisms and will be discussed in the conference. We hope that our findings contribute to better understanding of the transport mechanisms and global assessment of microplastic distribution and aid for mitigation strategies.

Keywords: Microplastics, CYGNSS, transport mechanisms.

The urban heat and pollution island of Hyderabad:Implications for sutainability of Indian cities

Yengula Rashmitha[a] and Jayanarayanan Kuttippurath[a]

[a]CORAL, Indian Institute of Technology Kharagpur,
721302 West Bengal.

E-Mail: yenugularashmitha729@gmail.com

ABSTRACT

Urbanization is a growing challenge, contributing to various climatic issues, due to significant landuse and land cover (LULC) changes. These changes are particularly evident within cities and theirsuburban fringes, which are rapidly being transformed into urban areas. This study focuses on theunplanned and excessive urbanization in Hyderabad and its impact over the last 20 years,particularly on LULC changes and their effects on urban heat and pollution. Two key phenomena—Surface Urban Heat Island (SUHI) and Urban Aerosol Pollution Island (UAPI)— are highlighted, representing the difference in heat and pollution levels between urban and surrounding rural areas. The analysis reveals that the shift from forested areas to cropland and built-up regions is intensifying both SUHI and UAPI effects. The findings indicate a potential mitigation strategy: increasing urban vegetation. Areas with vegetation consistently recorded lower Land Surface Temperatures (LST), remaining below 30°C, even in built-up surroundings. This suggests that proper vegetation planning could help mitigate the adverse effects of urbanization. The study further considers key climatic factors, including temperature, humidity and rainfall, to identify areas within the city where plant growth would be most effective. Recognizing that different urban zones require tailored approaches, the study categorizes the areaof the city based on road types—national highways, state highways and residential roads. Each category demands a specific vegetation strategy to optimize plant growth and mitigate SUHI and UAPI effects. By addressing LULC changes with a targeted vegetation approach through nature based solutions, there remains potential for reducing urban heat and pollution in rapidly growing cities like Hyderabad.

Keywords: LULC; SUHI; UAPI; Nature based solutions

Can Air Pollution Change the Raindrop Size Distributions? A case study for Pre-monsoon Thunderstorms over an Industrial Station

Pritam Meher [1], Balaji Kumar Seela [2], Bhishma Tyagi [1]

[1] *Department of Earth and Atmospheric Science, National Institute of Technology Rourkela, Rourkela 769008, Odisha, India*

[2] *Institute of Atmospheric Physics, Department of Atmospheric Sciences, National Central University, Taoyuan City 320317, Taiwan*

E-Mail:pritammehermax39@gmail.com

ABSTRACT

Precise quantitative precipitation estimation and forecasting depend on an understanding of raindrop size distribution (RSD). The present study examines the microphysical characteristics of RSD in both polluted and non-polluted contexts at an industrial tropical Indian station, Rourkela, Odisha. This study examined the impact of pollution on precipitation using pre-monsoon in-situ (disdrometer) and reanalysis (ERA5) data for the years 2018–2021. The air quality index (AQI) value over the Rourkela region was provided by the Central Pollution Control Board (CPCB), Government of India. This value was used to determine the day of polluted rains. Convective rainfall was found to have higher concentrations and larger mean diameters when precipitation on days with and without pollution was separated into stratiform and convective types. The RSD empirical relations (Z-R, $\mu - \lambda$, D_m-R, N_w-R) also showed a noteworthy difference between the polluted and non-polluted rainfall days. The results disclosed that non-polluted rainfall has higher concentration of small-diameter raindrops, whereas polluted day rain has higher concentrations of midsize and large-diameter raindrops.

Keywords: Raindrop size distribution; Air quality Index; Normalized intercept parameter; Disdrometer; Precipitation.

Identification of extreme weather event using machinelearning and artificial intelligence approaches over theHimalayan region of Uttarakhand

Yasti Panchbhaiya[1], Alok. Sagar Gautam[1], Aman Deep Vishwkarma[1], Karan Singh[1], Sanjeev Kumar[1]

[1]Himalayan Atmospheric and Space Physics Research Laboratory, Department of Physics, Hemvati Nandan Bahuguna Garhwal University (A Central University), Srinagar Garhwal, Uttarakhand -24746, India

E-mail: phyalok@gmail.com, panchbhaiyayasti@gmail.com

ABSTRACT

This study conducts a comprehensive examination of extreme weather phenomena in Uttarakhand, India, addressing the challenges arising from its intricate topography and irregular distribution of rain gauges. Weather data encompassing temperature, precipitation, wind speed, humidity, and atmospheric pressure play a crucial role in weather prediction and the training of machine learning models. Decision trees, random forests, and neural networks are employed to identify patterns associated with extreme weather events, with a particular emphasis on the unprecedented June 2013 rainfall event in the Western Himalayas (Kanga et al., 2022). Emphasizing the hydrological implications of such events, the study underscores the significance of precise rainfall predictions derived from satellite observations. Machine learning techniques, including neural networks and Support Vector Machines (SVM), are utilized to analyze various weather parameters and propose an artificial intelligence-based approach to predicting storm characteristics. Specifically, the Gated Recurrent Unit (GRU) model is employed to forecast storm characteristics such as wind speed, pressure, humidity, temperature, and wave height, with evaluation metrics attesting to its efficacy. The study highlights the effectiveness of the GRU model and SVM classifier in predicting storm characteristics, indicating the growing utilization of machine learning and deep learning models in forecasting extreme weather events (Frifra et al., 2022). It further explores the broader application of artificial intelligence in meteorological studies, emphasizing the continuous evolution and impact of cutting-edge technologies in enhancing predictions and understanding meteorological phenomena.

Keywords: Metrological Parameters, Deep learning, Machine learning, Gated recurrent unit, Support vector machines, Decision making

Diagnostic analysis of extreme rainfall events due to monsoondepression

Goriparthi Pavani[a] , Dr. Jyoti Bhate[a],and Dr. Amit Kesarkar[a]

[a] *Department of Space, National Atmospheric Research Laboratory,Gadanki, Pakala, Andhra Pradesh 517112*

E-Mail: pavanigoriparthi24@gmail.com

ABSTRACT

India has witnessed a notable increase in the frequency and intensity of extreme rainfall events during the monsoon season in recent years, driven largely by climate change. The 2024 monsoon season was characterized by a series of significant depressions, which resulted in extreme rainfallacross the country, leading to severe flooding and widespread destruction in various regions. Thisstudy investigates the extreme precipitation triggered by a monsoon depression in 2024 over Vijayawada region, utilizing high resolution reanalysis and satellite data. High resolution simulations were generated using WRF model in cyclic mode from August 29, 2024 00 UTC to September 03, 2024 00 UTC at a grid resolutions of 12km, 4km and 1.33km in a nested configuration. The study explores the atmospheric and oceanic conditions and their dynamics thatled to the unprecedented rainfall exceeding 245.5mm over Vijayawada and neighbouring districtsleading to the flooding during early 1st September 2024. The results indicate that warmer sea surface temperature and an increased moisture convergence in the Bay of Bengal, which led to thedevelopment of depression on August 31 2024. As the depression moved inland, the presence of high windspeeds with the associated monsoon trough allowed efficient transport of moist air, resulting in pronounced moisture convergence over Vijayawada region, thereby amplying the precipitation potential. Overall, the combination of warmer sea surface temperature that intensified atmospheric moisture levels, effective moisture convergence and strong windspeeds led to the extreme precipitation observed over the Vijayawada region. The findings of this study illustrates the complex relations between oceanic conditions in Bay of Bengal and atmospheric dynamics, offering valuable insights for enhancing the forecasting and disaster preparedness in the region.

Keywords: Extreme rainfall event; Monsoon depression; Monsoon trough; high resolution reanalysis; satellite data;

Impact of Climate change on Tourism – A case study of Visakhapatnam

Bharati S. Sabade [a], S. Sudhavalli [a]

[a] *Cyclone Warning Centre, Visakhapatnam, India Meteorological Department bharatisabade@gmail.com*

ABSTRACT

One of the most important components in the sustenance of tourism cities is the Climate of the city. The relationship between the two is intricate due to the complex nature of climate and how its various elements interact to create specific conditions relevant to tourism. Under the Climate Change scenario, the coastal cities are predicted to be more susceptible to marine heat waves, rise in sea level, rise in frequency and period of heat waves, rise in specific humidity and severe cyclones, posing risks to infrastructure and future viability. Hence, Climate Researchers have sought to address this complexity by integrating key climate and tourism factors into a single, interpretable index such as Tourism Climate Index (TCI) by Mieczkowski (1985), Climate- Tourism-Information-Scheme (Matazarakis, 2007), HCI (Holiday Climate Index)-Urban by Scott et. al (2015).

In this study, long term statistical period (1991-2020) of daily mean data of meteorological variables such as temperature, humidity, cloud amount, rainfall and wind are used to determine the tourism climate suitability of Visakhapatnam (17.7N/83.3E), a coastal city, in India. To prepare tourism calendar for this city, HCI-urban was used. Inter-decadal analysis is done to see the increase/decrease in the days under different categories. The results show that the period 1 Jan to 5 Feb and 29 November to 31 December comes under the category of ideal period while remaining days of February & November and 1-10 March comes under excellent category. This weather-climatic information will guide the tourist to plan their vacations and also help tourism industry to deal with ever increasing footfall of national and international tourists. Additional detailed information about extreme events is given through the use of frequencies of classes and amounts of threshold values. This calendar can be further modified using three hourly data to classify the categories at different times in a day.

Keywords: Climate change; Tourism, Holiday Climate Index

Extraction of Atmospheric Gravity waves from COSMIC GPSRO profiles and Identification of their Source Using GROGRAT model

Arun Jo Mathew.[a*], M. Pramitha[a]

[a] *Indian Institute of Science Education and Research, IISER Thiruvananthapuram, Kerala, India*

*Email: *arunjomathew19@iisertvm.ac.in, pramitha@iisertvm.ac.in*

ABSTRACT

Atmospheric Gravity Waves are buoyancy-driven waves, with gravity and buoyancy serving as the restoring forces. These waves play a crucial role in connecting different layers of the atmosphere and are considered as a sub-grid process which are parameterized in global atmospheric models[1]. This parameterization helps in understanding the coupling process betweendifferent layers of the atmosphere. Nevertheless, there is a need to enhance the parameterization of gravity waves by integrating the latest insights and understanding into current models. Being small scale waves, global estimation of GWs is difficult as well as understanding their sourcesare essential for their parameterization. Present study utilises Global Positioning System Radio Occultation (GPSRO) dataset compiled by COSMIC 2 satellite for the year 2020 to find gravity wave parameters three dimensionally (altitudes, latitudes, longitudes). Inorder to extract GWs from GPSRO the methodology used involves grouping three temperature profiles into triples satisfying the predefined spatial and temporal constraints[2]. The distance constraint is met by utilising 3-degree bins of latitude (from -55° to 55°) and longitude, and profile pairs are selected such that the time difference is less than 20 mins. Stockwell Transform (S Transform) technique is employed to find the phase difference between each triplets. Results obtained from the analysisshed light on the global variation of GW parameters. Thus, estimated GW parameters (Zonal wavelength, meridional wavelength, ground based frequency) are used to identify their sources using the ray tracing model, Gravity-wave Regional Or Global RAy Tracer (GROGRAT). Three dimensionally varying background atmospheres for GROGRAT are developed using the outputs obtained from CESM SD-WACCM simulations. Hence identified the sources of the GWs at tropics, mid latitude region. The significance of the present study lies in extracting the GWs from COSMIC satellite and hence identifying their sources, which can be used to find the source spectra of the GWs at different regions over the globe, which can be the first step towards parameterisation of GWs.

Analysis of thunderstorm prediction using artificial intelligence / machine learning techniques

Menaka Gandhi . J [1]

[1] *Regional Meteorological Centre Chennai,*
India Meteorological Department

E-Mail:menakagandhi88@gmail.com

ABSTRACT

Thunderstorm is a hazardous storm that occurs due to cumulonimbus cloud. The basic conditions for thunderstorm are unstable air, sufficient moisture and force to raise the air upwards. There are different types of thunderstorms namely single cell, multi cell and super cell. Severe thunderstorm lead to strong winds, flash flooding, lightning and tornadoes. Climate change plays a vital role that can influence the intensity of the thunderstorm. These hazardous conditions affect the life and property. To overcome such risks, Artificial intelligence and Machine learning (AI/ML) techniques can be applied to predict the lightning and the development of thunderstorm. The time of day is a crucial actor for the intensity of the thunderstorm. The dataset used must reveal that thunderstorm is also a significant weather phenomenon. AI tool is trained with the historical weather data and predicts the future event of thunderstorm. Such predictions are used for disaster preparedness. Some advantages are the computation power is lesser and can be executed in the smaller systems. In this paper, the different types of AI/ML algorithms are analysed that can contribute in predicting the occurrences of thunderstorm using numerical weather prediction (NWP) data. The accuracy rate of different types of AI/ML techniques are compared. Those techniques are used for the prediction of thunderstorm to save lives by issuing timing warnings to the public about such hazardous events.

Keywords: Artificial Intelligence, Machine Learning, Climate Change, Prediction, Accuracy.

BSISO effect on extreme events over Indian region during El Nino and La Nina years

Bhavya Shivhare[a], Dr. Kiranmayi Landu[a]

[a] *School of Earth, Ocean and Climate Science, Indian Institution of Technology, Bhubaneswar*

E-Mail: 23CL06001@iitbbs.ac.in

ABSTRACT

The Boreal summer intraseasonal oscillation (BSISO) of the Asian summer monsoon (ASM) is one of the most prominent sources of short-term climate variability in the global monsoon system. The BSISO is characterized by its distinct northward movement of convective activity from the equatorial regions towards the northern parts of the Indian Ocean and Asia, this movement affects the monsoon dynamics in South Asia and Southeast Asia. However, significant research gaps remain in understanding the mechanisms through which BSISO influences the frequency and intensity of these extreme events. Additionally, existing climate models often inadequately incorporate BSISO dynamics, limiting their effectiveness in predicting extreme weather. The analysis of our research reveals that BSISO significantly modulates extreme weather events in India during both El Niño and La Niña years. During El Niño years, periods of enhanced BSISO activity were associated with an increase in the frequency and intensity of heavy rainfall events, particularly in the eastern and northeastern regions of India.

Keywords: BSISO; ASM; Extreme events; EL Nino; La Nina

A broad analysis to understand the climatic impacts due to vegetation using LAI, EVI and PAR as a key variable

Yatendra, Singh[1], Mukunda Dev, Behera[2]
[1,2]*Centre for Ocean River Atmosphere and Land Sciences, Indian Institute of Technology Kharagpur, West Bengal-721302*
E-Mail: yatendra7017@gmail.com

E-0127

ABSTRACT

This study focuses on the relationships between key vegetation indices—Leaf Area Index (LAI), Enhanced Vegetation Index (EVI), and Photosynthetically Active Radiation (PAR)—and environmental factors such as temperature, precipitation, and soil moisture across the Indian subcontinent. The Indian subcontinent experiences diverse climatic conditions and ecosystems, making it an ideal region to examine how vegetation responds to varying environmental drivers. Using MODIS satellite data for LAI, EVI, and PAR, alongside ERA5 reanalysis data for temperature, precipitation, and soil moisture, this research aims to uncover the spatial and temporaldynamics of vegetation across different vegetation types.

The study will analyze these variables from 2001 - 2023, allowing for an assessment of long-termtrends and potential shifts in vegetation health and productivity due to climate change and variability. MODIS-derived vegetation indices (LAI and EVI) provide robust measures of plant canopy structure and greenness, while PAR represents the light available for photosynthesis. By integrating ERA5 climate data, this study investigates how changes in temperature, precipitation,and soil moisture influence vegetation performance, particularly in response to rising temperatures,changing precipitation patterns, and soil moisture dynamics.

The findings of this research will contribute to a deeper understanding of how different vegetationtypes in the Indian subcontinent respond to environmental and climatic variables. This knowledgeis critical for monitoring ecosystem health, predicting future vegetation dynamics under climate change scenarios, and developing effective land-use and ecological management strategies. Additionally, the insights gained from this study will inform sustainable agricultural practices, forest conservation efforts, and climate resilience planning in the region, which is highly vulnerable to climate-induced stressors. Ultimately, this research provides a comprehensive framework for understanding vegetation-environment interactions in one of the world's most biodiverse and ecologically significant regions.

Keywords: Leaf Area Index; Enhanced Vegetation Index; Climate change; Photosynthetically Active Radiation

Machine learning approaches for analyzingextreme weather events in the Garhwal Himalaya region

Aman Deep Vishwkarma[1*,] Alok. Sagar Gautam[1], Yasti Panchbhaiya[1], Sanjeev Kumar[1], Karan Singh[1],

[1]Himalayan Atmospheric and Space Physics Research Laboratory, Department of Physics, Hemvati Nandan Bahuguna Garhwal University(A Central University), Srinagar Garhwal, Uttarakhand -24746, India

*E-mail: *amandeep212241@gmail.com,*

ABSTRAC T

This review study focuses on various machine learning approaches for analysing extreme weather events in Uttarakhand, India, based on meteorological data and aerosol properties. Unforgettable major extreme weather events have been reported in Uttarakhand, such as the Kedarnath flash flood in 2013, and the Chamoli incident in 2020 (Pandey 2021; Naithani et al., 2011). We aim to acquire a comprehensive understanding of the incidents and attributes of extreme weather events in the central Himalayan Region. We employ cutting-edge methodologies, including Random Forest, Support Vector Machines (SVM), Artificial Neural Networks (ANN), and General Regression Neural Networks (GRNN), specifically, we implemented a Random Forest model to predict rainfall events in the Srinagar Garhwal region, utilizing parameters such as temperature, humidity, wind direction, and wind speed. This model serves as an early warning system for environmental management and disaster preparedness. The model's efficacy was assessed throughrigorous evaluation metrics, including the Mean Absolute Error (MAE), Coefficient of Determination (R2), and Root Mean Square Error (RMSE). The Srinagar rainfall model, with 100trees, demonstrated a delicate balance between complexity and performance, excelling with RMSE2.74, MAE 1.39, and R2 0.57. However, increasing the number of trees to 1500 reduced the performance and increased the errors (RMSE 3.02, MAE 1.54 & R2 0.46). In future work, we planto incorporate more ground-based and satellite meteorological data, including parameters such assolar radiation, pressure, dew points, and higher data resolution (1 minute) to enhance model efficiency. Additionally, we aim to apply SVM, ANN, and GRNN to further study extreme weather events over Uttarakhand. This interdisciplinary approach provides valuable insights into extreme weather patterns in Uttarakhand, contributing significantly to the understanding of extreme weather events in the central Himalayan Region. It supports efforts for sustainable environmental management and disaster resilience.

Keywords: Metrological Parameters, Central Himalayan Region, Random Forest Model, RMSE, MAE, FFNN, Learning models

Investigating the characteristics ofdrop size distribution in Urban precipitation extremes using Doppler Weather Radar and Laser Precipitation Monitor

Nandana V* [1,2,3], Kandula V Subrahmanyam[2], M.V. Ramana[2], V. Babu rao[4] , and K. NagaRatna [4]

(1)IASc-INSA_NASI Summer Research Fellow-2024
(2) Earth and Climate Sciences Area (ECSA), National remote Sensing Centre (NRSC), ISRO, Hyderabad
(3)Cochin University of Science and Technology, Kochi, Kerala
(4)India Meteorological Department, Hyderabad
E-mail:nandanav574@gmail.com

ABSTRACT

Raindrop size distribution (DSD) is a crucial parameter for understanding cloud and microphysical processes. Urbanization exacerbates the strain on local environments in the context of both global and regional climate shifts. Therefore, understanding the connections between urbanization, present local environmental changes, and accelerating climate change is essential. Thus, the present study is to understanding the microphysical processes of urban precipitation extreme event using Doppler Weather Radar (DWR) and Laser Precipitation Monitor (LPM). A heavy rainfall event took place on 10^{th} May 2024 in Hyderabad. The spatial patterns of convective precipitating systems were using DWR measurements. At 18:12 hrs on 10^{th} may 2024, the precipitating tops were observed to be around below 10 km. Further, studied the temporal evolution of total number concentration (N_T), liquid water content (LWC), rain rate (R), reflectivity factor (Z), median drop diameter (D_m), and normalized number concentration (N_w) derived form 1-min LPM observation over the study region. The peak values in all parameters correspond to the mature stage of the thunderstorm, characterized by maximum rainfall intensity, larger raindrop sizes, and high liquid water content. High reflectivity values (>40 dBZ) and intense rain rates (>100 mm/hr) are typical signatures of severe thunderstorms. The presence of larger raindrops (Dm around 4 mm) and high LWC values (near 6 gm/m3) further confirms the occurrence of a significant thunderstorm event with heavy precipitation. In addition, investigated the dominant microphysical processes governing precipitation, including convection, vapor deposition, weak shallow convection, deposition-aggregation-riming, warm rain collision-coalescence, and convection with graupel or hail using D_m and N_w, which provided the major microphysical processes in the typical urban heavy rainfall event for the first time.

Keywords: Drop size distribution; Doppler weather radar; Laser precipitation monitor

Spatial heterogeneity in sources of ionic species in rainwater during the summer monsoon period over the Indo-Gangetic Plain

D.S. Bisht[1], A.K. Srivastava[1], S. Rajabhoj[2], K. Ram[3], V. Singh[1], S. Payra[4], S. Tiwari[1], M.K. Srivastava[5], S. Singh[6]

[1]Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, New Delhi

[2]Department of Energy and Environment, TERI, New Delhi

[3]Institute of Environment and Sustainable Development, BHU, Varanasi

[4]Birla Institute of Technology, Mesra, Ranchi

[5]Department of Geophysics, Banaras Hindu University, Varanasi

[6]Central Institute of Mining and Fuel Research, Dhanbad

E-Mail:deewanbisht@gmail.com

ABSTRACT

The present study is conducted to understand the rainwater chemistry over the Indo-Gangetic Plain (IGP) at three different stations, namely Jaipur (a representative urban station dominated bydust), Varanasi (a representative urban station dominated by anthropogenic emissions), andDhanbad (a representative urban station dominated by industries and coal mines) during the Southwest summer monsoon period from June to September in 2018. The rainwater samples were analyzed for the following parameters- pH, conductivity, anions (F^-, Cl^-, NO_2^-, NO_3^-, SO_4^{2-}), and cations (Ca^{2+}, Mg^{2+}, NH_4^+, K^+, Na^+). The mean pH and conductivity shows a significant heterogeneity in rainwater samples with alkaline nature at Jaipur (7.09 and 43.46 µS/cm) and Varanasi (7.31, and 55.42 µS/cm) whereas acidic nature at Dhanbad (5.10 and 31.98 µS/cm). The ionic compositions of rainwater were found to be drastically different at all the threestations, which are also reflected in the neutralization of rain water samples. Neutralization factors of the Ca^{2+}, NH_4^+ and Mg^{2+} ions were calculated for rainwater samples at the three stations, which were 3.10, 1.41 and 0.40 for Jaipur, 2.65, 1.14, and 0.84 for Varanasi and 0.61, 0.91 and 0.13, respectively for Dhanbad. Results suggest that Ca^{2+} was the major neutralizing species in rainwater at Jaipur and Varanasi but not at Dhanbad. Principal component analysis (PCA) was applied to identify the possible sources of rainwater constituents, and the threefactors were obtained explaining crustal dust, biomass burning, fossil fuel combustion, agricultural emissions, and coal burning as possible sources of observed ions in rainwater.Further, the air mass back-trajectory clusters were computed by using the HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model to escalate the terrestrial influence on the chemistry of the region. Results suggest the contribution from both local and regional constituents that influenced the monsoonal rainwater chemistry over the IGP.

Keywords: Rainwater chemistry; Indo-Gangetic Plains; Neutralization factor; Principal component analysis.

Indication of milder winters in past decades over several parts of India and adjoining

Ishita,Srivastava[a], MD Behera[b]

[a] *Environmental Science and Engineering,*
[b] *Centre for Ocean, River, Atmosphere and Land*

Sciences,Indian Institute Of Technology Kharagpur

E-Mail:ishitasrivastava652@gmail.com

ABSTRACT

This study investigates the spatiotemporal dynamics of 2-meter air temperature across the Indian subcontinent, employing ERA5 reanalysis data from 2001 to 2023. A rigorous assessment of temperature trends, anomalies, and extreme values—maximum, minimum, and mean—provides critical insights into the evolving thermal landscape of this climatically heterogeneous region. Theanalysis elucidates distinct seasonal temperature patterns, with mean temperatures varying from 276 K in January to 294 K in July. Maximum temperatures peak in June and July, reaching an extreme of 294.56 K in July 2021, while minimum temperatures are recorded at approximately 276.65 K in January 2012. A noticeable warming pattern, particularly in maximum temperatures, suggests significant regional climate shifts, emphasizing the intensifying impacts of climate change across key geographical zones.Significant anomalies in maximum temperatures were identified, notably a peak anomaly of 1.833 in March 2010 and a prominent anomaly of 2.453 in February 2006, indicating a typical warming events. The analysis reveals an increase in maximumtemperatures and a concomitant reduction in the diurnal temperature range (DTR), while minimumtemperatures exhibit a more gradual rise. These anomalies reflect substantial deviations from historical norms, offering detailed perspectives into the region's climatic variability and their implications for extreme weather phenomena, such as heatwaves, influenced by global climatic oscillations like El Nino. This research underscores the imperative of monitoring these temperature dynamics for effective regional climate adaptation strategies, agricultural resilience, and water resource management, thereby highlighting the Indian subcontinent's vulnerability to the impact of global warming.

Keywords: ERA5 Reanalysis; Temperature Anomalies; Indian Subcontinent; Climate Trends; Temperature Extremes

Thunderstorm prediction for Indian region using gradient boost machine learning techniques

Arpita Dhamija[a], A. Jayakumar[a],

[a]*National Centre for Medium Range Weather Forecasting*
E-Mail:arpita.dhamija@nic.in

ABSTRACT

Thunderstorm prediction presents a significant challenge in Numerical Weather Prediction due tocomplexities associated with resolving convective systems and their microphysics. In this study, we explore the feasibility of utilizing machine learning techniques benefitted for thunderstorm prediction over tropical regions. The study focuses on predictor variables as indicators for the occurrence of thunderstorm systems with a focus on tropical regions covering monsoon and pre- monsoon season of 2021-2023. Decision tree based ensemble machine learning techniques, XGBoost are used to uncover important features enhancing predictability for lightning trained withECMWF reanalysis datasets (ERA5). Shapley value analysis is then applied to determine which large scale variables are important predictors and to establish their relationship with the predictand.

Considering the influence of lifting forces, moisture and instability for setting up a deep convective system, important large scale variables such as dewpoint temperature, geopotential, vertical velocities, relative and specific humidity at pressure levels are taken as predictands in the ML model to train these features for generating novel relationships. A difference between important parameters for predictions in both seasons is seen along with changing dynamics for different Indian regions.

Keywords: Machine learning, Thunderstorms, Tropics

Are monsoon months thirster? - analysis of evapotranspiration trends of current century overindia and adjoining countries

Ritikesh Maurya[a], Mukund Dev Behera[b],and Swadhin Kumar Behera[c]

[a] *School of Water Resources, IIT Kharagpur*

[b] *Center for Ocean, River, Atmosphere and Land Sciences, IIT Kharagpur*

[c] *Applications Laboratory, Japan Agency forMarine-Earth Science and Technology, Yokohama236-0001, Japan*

E-Mail: ritikesh999@gmail.com

ABSTRACT

The Indian subcontinent, with its diverse climatic zones and substantial agricultural reliance, is a critical region for studying evapotranspiration (ET) patterns. ET is a key part of the water cycle, influencing hydrological processes, agricultural productivity, and ecosystem dynamics. Given theregion's susceptibility to monsoonal variations and climate change, understanding ET trends is vital for water resource management. The study used Google Earth Engine (GEE) to process large-scale satellite data and perform statistical calculations, including monthly mean ET, variance, andstandard deviation. The MOD16A2GF.061 Gap-Filled 8-Day 500m ET product was used to analyze monthly mean ET data from 2000 to 2023 and corresponding ET anomalies from 2001 to2023. The analysis focused on trends and extreme values in monthly ET. Monthly mean ET revealsa seasonal pattern, with higher ET during monsoon months (June–September), peaking in July andAugust, and lower ET during the dry season (November–February). Notably, 2020 had the highestmean ET across several months, particularly in May and June, with a maximum of 215.82 mm inAugust. In contrast, the lowest ET was recorded in 2000, with values as low as 77.97 mm in April. Anomaly data from 2001–2023 highlights both increasing and decreasing trends across months. ET anomalies increased significantly during the monsoon, while some dry season months (e.g., January) showed fluctuations with occasional decreases. In 2020, significant positive anomalies indicated a wetter-than-average year, while 2001 and 2004 showed lower-than-average ET,particularly in March and April. This study emphasizes the need to monitor ET trends for sustainable water management, particularly in the context of climate change.

Keywords: Evapotranspiration, Climate change, monthly ET trends, ET anomaly, Google Earth Engine.

Why *Chromolaena odorata* Prefers a Stable Climate with Minimal Temperature Variation? - Species Distribution Modeling of an Invasive Plant Species

Manisha Rani, Sahu[a] , Merin, Menachery[a], Mukunda Dev, Behera[a],
Soumit Kumar, Behera[b], Sudam, Sahu[c], and S. K. Barik[d]

[a]*Centre for Ocean, River, Atmosphere andLand Sciences, IIT, Kharagpur*
[b] *National Botanical Research Institute (NBRI)*
[c]*North Orissa University*
[d]*North-Eastern Hill University*

E-Mail: barshamanisha905@gmail.com

ABSTRACT

Invasive species, such as *C. odorata*, pose significant environmental challenges due to their potential to spread rapidly and disrupt ecosystems. Predicting the future distribution of such species is crucial for effective management. This study investigates the potential distribution of *C.odorata* in the Similipal Biosphere Reserve under current and future climate scenarios. We used Maxent modeling with presence only data to predict the species' distribution under two socioeconomic pathways (SSP245 & SSP585) using the CMCC ESM2 General Circulation Modelfor 2030 and 2050. Species occurrence data were obtained from field, while bioclimatic variableswere sourced from the WorldClim database. Model performance was evaluated using the Area Under the Curve (AUC) and Receiver Operating Characteristic (ROC) metrics. Results revealed that environmental factors such as mean diurnal range (BIO2), isothermality (BIO3), precipitation of the coldest quarter (BIO19), and mean temperature of the wettest quarter (BIO8) were the key drivers of *C. odorata* distribution.

The model predicts an increase in the species' suitable habitat in future climate scenarios, with SSP245 showing a greater expansion by 2050. This highlights that the *C. odorata* is more likely to thrive in areas with minimal temperature fluctuations and high precipitation, particularly underwarm and humid conditions. As climate change progresses, the species is likely to expand its range, posing an increased threat to ecosystems in the SBR. Understanding these patterns is crucial for developing management strategies aimed at mitigating the invasive spread of *C. odorata* and protecting biodiversity.

Keywords: *C. odorata*, Species Distribution Modelling (SDM), Maxent, Similipal Biosphere Reserve

Assessing seasonal and inter-annual variability of gross primary productivity in the Indian subcontinent(2000–2023) using MODIS data

Vikramjeet Singh[a], Mukunda Dev Behera[a],
and Swadhin K. Behera[b]

[a]*Centre for Ocean, River, Atmosphere and Land Sciences, Indian Institute of Technology Kharagpur, Kharagpur 721302, India*
[b] *Applications Laboratory, Japan Agency for Marine-Earth Science and Technology, Yokohama 236-0001, Japan*
E-Mail: vikramjeet365@gmail.com

ABSTRACT

Understanding the seasonal and inter-annual variations in vegetation productivity is critical for assessing ecosystem responses to environmental changes. This study analyzes Gross Primary Productivity (GPP) across the Indian subcontinent from January 2000 to December 2023 using theMOD17A2HGF.061: Terra Gross Primary Productivity 8-Day Global 500m dataset. The GPP values, measured in kgC/m², were downloaded from Google Earth Engine and analyzed in Python. The results reveal significant seasonal patterns, with the highest mean GPP recorded in August (264.58 kgC/m²), corresponding to the monsoon season, and the lowest in April (119.50 kgC/m²), likely reflecting pre-monsoon dry conditions. Maximum GPP values ranged from 694.25 kgC/m²to 1113.33 kgC/m², with the highest values occurring during peak growing seasons, whileminimum GPP was consistently 0 kgC/m², indicating periods or regions of no productivity. GPP anomalies highlight substantial inter-annual variability, with the largest positive anomaly in February (+37.19 kgC/m²) and the largest negative anomaly in January (-36.82 kgC/m²). These fluctuations suggest that climatic and environmental factors play a significant role in driving productivity changes in the region.

This analysis provides a comprehensive view of the spatio-temporal dynamics of GPP in the Indiansubcontinent, contributing to a deeper understanding of ecosystem productivity and its sensitivityto climate variability.

Keywords: Gross Primary Productivity (GPP); Indian subcontinent; Inter-annual variability; Monsoon effects; MODIS

Trends in convective cloud fraction and lightning frequency alongwest coast of India

Ashish Shaji [a] , Manoj M.G [a]

[a] *Advaned Centre for Atmospheric Radar Research, Cochin University of Scienceand Technology, cochin-22, Kerala.*

E-Mail: ashishshaji.acarr@cusat.ac.in

ABSTRACT

It is widely recognized that a warming planet could lead to more lightning strikes that might inflictsevere damage to life and properties. Although the west coast of India (WCI), one of the most densely populated areas, witnessed climatologically less lightning activity during the monsoon season of June through October, a significant increasing trend in lightning flash counts is observedin the southern part of the west peninsula compared to its northern counterpart. By analysing a long record of 26 years (1998-2023) of lightning data from TRMM OTD/LIS sensors, a significantincrease in lightning activity associated with deep convective clouds over the southern WCI is observed while witnessing a negligible decreasing trend in the northern WCI in the recent years (2017-2023). The more the convective fraction, the greater are the graupel, snow ice and cloud icepath. Although, it is earlier reported that the WCI is becoming more convective during the monsoon season, our results emphasize that the southern WCI requires greater caution as the lightning strikes increases with an increase in surface air temperature and SST providing ample fuel for deep convection in an unstable environment, as evidenced by enhanced moist static energy.The results ring the bell of a changing climate which calls for early preparedness and disaster prevention in view of exposure and vulnerability of individuals and communities.

Keywords: Lightning, deep convection, West coast of India, TRMM, LIS.

Influence of Subtropical and Tropical Jet Streams on Indian Summer Monsoon Rainfall

Rona Maria Sunil[a] , and Manjoj M.G[b],

[a, b]*Advanced Centre for Atmospheric Radar Research, Cochin University of Science and Technology*
E-Mail: ronamariasunil123@gmail.com

ABSTRACT

The Subtropical Jet Stream (STJ) and Tropical Easterly Jet (TEJ) are key atmospheric components influencing the Indian Summer Monsoon (ISM). This study investigates the relationship between the positional dynamics of these jets and rainfall patterns over the Indian region during the period from 2000 to 2023. Utilizing ERA5 reanalysis data and IMD rainfall observations, the zonal and meridional wind fields at 200 hPa are examined in conjunction with daily rainfall records to analyze the effects of jet stream variability on monsoon progression.

A Tropical Easterly Jet Index (TEJI) was developed by area-averaging the TEJ at 200 hPa at its core location, revealing a strong correlation with rainfall intensity. Results indicate that when the STJ in both the hemisphere is positioned equatorward (20S -30N), the TEJ weakens and shifts southward. Conversely, as the STJ migrates poleward, the TEJ strengthens and moves northward extending to central India, with a significant correlation between TEJ intensity and rainfall patterns. This shift has been linked to variations in monsoonal rainfall intensity and the northward advancement of the ISM. Further analysis of these dynamics reveals that the poleward displacement of the STJ enhances TEJ strength, influencing rainfall distribution across the Indian subcontinent. These findings provide crucial insights into how upper tropospheric wind patterns modulate monsoonal rainfall, contributing to a deeper understanding of atmospheric circulation in the region.

Keywords: Monsoon; Subtropical jets; TEJ; Rainfall;

Early Detection of Severe Storms using Differential Reflectivity from Dual Polarimetric Radar for Nowcasting

Aravindhavel[1], P.Murugavel[1], J.S. Thomas [1], Thara Prabhakaran[1], P.Prasad[1] and Pooja Purushotham[1]

[1] *Indian Institute of Tropical Meteorology (IITM), Ministry of Earth Sciences, Dr. Homi Bhabha Road, Pune 411008, India*

E-Mail: aravindhavel@tropmet.res.in

ABSTRACT

A Severe Storm weather disaster is associated with strong updrafts, abundant water droplets, intense rainfall that pose significant threat on flash-foods. The early warning on the rapid development of severe storm is crucial for minimizing the potential damages. The present study suggests the differential reflectivity (ZDR) from dual polarimetric radar is potential tool for early detection of severe storm for nowcasting. In this study, a severe storm case has been illustrated from IITM C-band dual polarimetric radar over the Western Ghats region. An algorithm of early detection of high ZDR columns was used based on the max reflectivity, positive ZDR values extended 0.5 km above the freezing point with ZDR $\geq$ 1.5 dB. The detected columns were preceded with high ZH > 40 dBZ with lead time maxima about 0-30 min indicating the potential development of severe storm. The positive correlation of ZDR column strength with ZH indicates the probability of increase of storm development. The early detection of ZDR signatures clearly indicates the storm cell updraft and its rapid development, which offers the forecasters on timely warning on weather hazards.

Keywords: Radar; Severe Storm; ZDR columns; max reflectivity , Western Ghats.

Multi-weather hazard resilience and early warnings with satellite-powered insights and impact monitoring for changing climate

Dr. Rajasekhar Meka
SDSC SHAR ISRO
E-mail: rajasekhar.meka@shar.gov.in

ABSTRACT

The intensification of multi-weather hazards, including cyclones, floods, droughts, and heatwaves, driven by anthropogenic climate change, presents escalating risks to both human systems and natural ecosystems. Developing robust resilience frameworks and implementing advanced early warning systems are imperative to mitigate these risks. Satellite-based remote sensing technologies provide an unparalleled capability for high-resolution, spatiotemporal monitoring of atmospheric, hydrological, and terrestrial processes. These systems enable the detection and prediction of hazard dynamics, identification of vulnerable regions, and analysis of long-term climatic perturbations. By integrating satellite-derived datasets with predictive modeling techniques, such as machine learning and dynamic simulations, and incorporating in situ observations, it is possible to generate actionable early warnings with enhanced precision and lead time. Moreover, satellite-enabled post-event impact assessments facilitate comprehensive evaluations of hazard-induced damages, informing adaptive management strategies, disaster recovery frameworks, and long-term policy interventions. This synthesis of satellite technology and data-driven analytics represents a critical advancement in climate resilience, offering scalable solutions to address the growing challenges of a warming planet.

The Recent Trends In The Indian Summer Monsoon Rainfall

Ramesh Kumar Yadav
Indian Institute of Tropical Meteorology, Pashan, Pune 411008, India
E-Mail: yadav@tropmet.res.in

ABSTRACT

India gets maximum rain during the summer months of June through September, called Indian summer monsoon rainfall (ISMR). The increasing/decreasing trend of ISMR affects millions of agriculture-dependent people in India. The spatial deviation of long-term ISMR trends indicates the monsoon circulation shift and should be minutely observed. The current study has observed that the ISMR has statistically significantly increased/decreased in western/eastern India in the last four decades. The significance of these trends is checked by evaluating the incomplete beta function used as a *p*-Value calculator for the Student *t*-test. In the meantime, the Indian Ocean has become more active due to its recent warming. The warming of the equatorial Indian Ocean has increased the in-situ convection south of the equatorial Indian Ocean, whose subsidising Hadley's branches has increased the upper- tropospheric geopotential height (GPH) in northern Europe and southern Africa. The north Europe GPH is associated with the Eurasian wave having massive ridges over eastern Europeand east Asia sandwiched with a trough east of the Caspian Sea. The penetration of thistrough towards the Indian landmass has created favourable conditions for deep convection. Besides, the southern African GPH increases the cross-equatorial flow, which interacts with the mid-tropospheric trough over the Arabian Sea, increasing the moisture flow/convergence over western India. The interaction of the cross-equatorial flow with the upper-tropospheric penetrated trough through the Indian landmass increases the moist static energy, whichresults in heavy rainfall over west India and causes a shift of monsoon westward. This teleconnection could further be examined in the seasonal forecast models.

Keywords: Indian summer rainfall · Eurasian wave · Mid-tropospheric trough · Upper-troposphere trough · Cross-equatorial flow · Trend analysis · Equatorial convection

National Inventory of Air Pollutants, Heavy Metals & GHGs for Optimizing Climate/Chemistry Modelling

Saroj Kumar Sahu[a], Ashirbad Mishra[a], Pallavi Sahoo[a], Poonam Mangaraj[b], Marianne T. Lund[c], G Beig[d], Sachin S.Gunthe[e]

[a] *Department of Environmental Science, Berhampur University, India*

[b]*Research Institute for Humanity and Nature, Kyoto, Japan*

[c]*CICERO Center for International Climate Research, Oslo, Norway*

[d]*National Institute of Advanced Studies, IISc-Campus, Bangalore,India*

[e]*Dept. of Civil Engineering, Indian Institute of Technology Madras, Chennai, India*

E-Mail: sks.evs@buodisha.edu.in

ABSTRACT

In recent decades, air pollution has been a global concern and is one of the leading causes of mortality. Air pollution is considered as the fifth leading cause for mortality across the globe. Elevated emission of air pollutants is not limited to urban areas and drives the air quality across the Indian sub-continent as well as across the globe with adverse health impacts. Ammonia (NH_3),a reactive nitrogen species, acts as a precursor to the particulate matter and increases the air toxicity. This indirect greenhouse gas can modify atmospheric chemistry largely. Similarly, methane (CH_4) is another potent GHGs where livestock is the largest contributor due to prevailinglifestyle in India. Hazardous pollutants like Mercury (Hg) have also emerged as a pressing challenge in recent times with expanding industrial and many unattended sectors in India but underreported. The present findings highlights development of a comprehensive high-resolution gridded (0.1° x 0.1°) national inventory of particulate pollutants ($PM_{2.5}$, PM_{10}), NH_3, CH_4, Hg, for India using IPCC methodology tire 2/3 bottom-up approach. This study developed inventory of above pollutants by considering as many as 25 types of sources dominating at the best possible resolutionactivity data over the Indian sub-continent. The estimated annual emission of $PM_{2.5}$, PM_{10} NH_3, CH_4 (Livestock), Hg are calculated to be 15.8 Tg/yr (2020), 8.3 Tg/yr (2020), 10.54 Tg/yr (2022),~13 Tg/yr (2023) and 459.4 t/yr (2019) respectively. As air pollution is also linked with monsoonrecent times. The developed new surface dataset over India will redefine the spatial emission hotspots pattern and will help to optimize the regional climate and chemistry modelling studies inthe country.

Keywords: Air Pollution; Emission Inventory; Ammonia: Methane Climate; Mercury

El Niño To La Niña Transition And Influence On The Surface Air Temperature And Rainfall Over India

Jasti S. Chowdary

Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune-411008, India

Email: jasti@tropmet.res.in

ABSTRACT

The El Niño and Southern Oscillation (ENSO) teleconnections provide valuable predictive information for surface air temperature and rainfall over India. During the developing and mature phase of El Niño (DJF), weakened Walker circulation triggers an anomalous anticyclone in the southeast Tropical Indian Ocean (TIO). This anticyclone forces oceanic downwelling Rossby waves, which then propagate westward and warm the southwest TIO by deepening the thermocline. The southwest Indian Ocean warming drives an asymmetrical pattern of anomalous winds over the TIO in the following spring, with north-easterlies to north and northwesterlies to south of the equator. After the onset of the southwest monsoon in May and June, these anomalous northeasterly winds warm the NIO by reducing the latent heat flux. This NIO warming excites the atmospheric Kelvin waves in the troposphere, which propagates to the western Pacific and induce anomalous anticyclone over western North Pacific (WNP) during post El Niño summers. Both TIO SST warming and atmospheric circulation changes induced by preceding El Nino, found to cause prominent spring surface air temperature warming and increased number of heatwaves over India. Further, ocean-atmospheric interactions in the Indo-Western Pacific during El Niño to La Niña transition phase alters the summer rainfall patterns over India. Mechanisms to how the El Niño to La Niña transition phase impacts climate over India is discussed in detail.

Understanding the variability of Shallow Meridional Overturning Circulation and its regional impact

Anant Parekh[a] Rahul Pai[a,b], Subrota Halder[a]
Jasti S. Chowdary[a], C. Gnanaseelan[a]
[a] Indian Institute of Tropical Meteorology, Pune-411008
[b] Savitribai Phule Pune University

ABSTRACT

This study investigates the variability of the Shallow Meridional Overturning Circulation (SMOC) and its association to climate variability over the last century, using Ocean reanalysis data and model simulations. At interannual timescale, strong (weak) SMOC years were associated with enhanced (weakened) southward transport and subduction in the South Indian Ocean (SIO). A detailed analysis revealed that the interannual SMOC variations were closely linked to zonal wind anomalies south of 10°S, which in turn showed a significant relationship with the Southern Oscillation Index. The ocean model simulations further confirmed the role of local zonal wind variability that primarily drives SMOC variations. In addition to this, it is found that the variability of SMOC is maximum during boreal winter. The power spectrum of winter SMOC exhibited a robust signal with periodicity of 5-7 years (intra-decadal timescale) significant at 95% confidence level. The intra-decadal SMOC variations were driven by zonal wind anomalies between 10°S and 20°S which displayed strong association with the Southern Annular Mode. The study also explores the impact of SMOC variability, at interannual as well as intra-decadal timescales, on the upper ocean heat content (OHC200) and sea level. At both timescales, the strong SMOC years transported excess heat southward, leading to a reduction in OHC200 and sea level over the south western Indian Ocean. Additionally, the study highlights the role of meridional heat transport (MHT) variability influences regional climate, particularly rainfall over Southern Africa at intra-decadal timescale. The mechanism of MHT driving the rainfall over Southern Africa is established for the first time.

Fidelity of coupled hindcast simulations in representing intraseasonal biases over South Asia .

Nagarjuna Rao. D [a], Mohan, T. S [a]., Ankur Gupta [a], Kondapalli Niranjan Kumar [a], Akhilesh Mishra [a], Imranali M Momin [a], Saji Mohandas [a], Ashis K Mitra[b] and V. S Prasad [a]*

[a] *NCMRWF,Noida*
[*]*NCMRWF,Noida*
[b]*UNEP Consultant || TERI SAS Professor of Practice*

E-Mail: dgnrao@ncmrwf.gov.in

ABSTRACT

This study examines the efficacy of the National Center for Medium-Range Weather Forecasting (NCMRWF) global coupled unified model (CNCUM) hindcasts in depicting seasonal biases, focusing specifically on the Indian summer monsoon (ISM). Using 23 years (1993-2015) of coupled hindcasts driven by the UK Met Office GloSea5 seasonal prediction system, we analyze the representation of biases in the model's mean state and sub-seasonal variability. High-resolution observations from the Tropical Rainfall Measuring Mission Microwave Imager (TMI) SST and rainfall, along with GPCP rainfall data, are used for validation. The results indicate that while the CNCUM hindcasts satisfactorily portray key aspects of boreal summer monsoons over the Indian subcontinent and surrounding oceanic regions, systematic biases persist. Notably, there is a significant wet bias (~6-8 mm/day) during July and August over the western Indian Ocean, and dry biases are observed across most parts of the Indian subcontinent. The annual cycles of SST and rainfall over the equatorial Indian Ocean are relatively weak compared to other monsoon regions. Additionally, the model exhibits a leading nature of SST anomalies (~5-7 days) during active-break monsoon periods, which is encouraging, but also reveals inconsistencies in the SST- rainfall relationship over the Bay of Bengal. A novel contribution of this study is the identification of a strong association between rainfall biases and free tropospheric (700-400 hPa) moisture distribution. This finding highlights the need for a deeper understanding of moist processes within the CNCUM modelling system. By highlighting both the strengths and caveats in the model's performance, this research provides valuable insights and suggests pathways for future model development and improvement.

Keywords: Intraseasonal biases, coupled processes, free-tropospheric moisture; Sea Surface Temperature, Mixed layer thickness

Two Decades of Primary Productivity of the Bay of Bengal through MODIS

Vishwanath Boopathi and Sourav Sil

SEOCS, IIT Bhubaneshwar, Argul, Odisha, India, 752050
E-Mail: vishwanathboopathi@gmail.com

ABSTRACT

This study presents the results of the estimated net primary productivity (PP) using the Eppley- VGPM algorithm for the Bay of Bengal (BoB) using the MODIS-Aqua data from 2003-2023. The temporal and spatial variability and the influence of IOD on PP were studied. Over the BoB, highPP was observed over the coastal region, reaching > 2000 mg C m^{-2} d^{-1}. The PP decreases from January, reaching a minimum during March, and again increases with the onset of the southwest monsoon, peaking in July, followed by a decreasing trend. Further, the basin was divided into threeregions, viz., the northern BoB, the western and eastern BoB, for time series analysis. All the regions showed high seasonality in PP, with maximum productivity in July. On average, of all theregions, northern BoB was found to have higher productivity, ranging between ~700 – 1700 mg Cm^{-2} d^{-1}, followed by western BoB (400 – 1400 mg C m^{-2} d^{-1}) and eastern BoB (500 – 700 mg C m^{-2} d^{-1}). All the regions show a very gentle increase in productivity. The correlation between the Indian Ocean Dipole (IOD) index and productivity was studied to understand the influence of IODon PP. Insignificant correlations were observed but the northern BoB showed increased productivity during certain PIOD years. This study indicates that the primary productivity of the BoB is highly seasonal and controlled by the influx of nutrients through rivers and other physical and biogeochemical processes. Maximum productivity in July and an insignificant correlation between the IOD index and productivity show that primary productivity is influenced more by theIndian monsoon than the IOD.

Keywords: Net primary productivity; Bay of Bengal; Modis-Aqua; Indian Ocean Dipole; Eppley-VGPM.

Teleconnection between Arctic Oscillation and Winter Precipitation over the Indian region

S.D Sanap

Climate Research and Services, IMD Pune
E-Mail: sd.sanap@imd.gov.in

ABSTRACT

Winter precipitation over the Indian region plays a crucial role in maintaining glaciers in the mountainous areas. The associated atmospheric conditions positively impact various sectors, such as agriculture, water resources, power generation, and tourism. Therefore, understanding the variability and teleconnections of winter precipitation is essential. This study focuses on exploring the dynamic linkages between Arctic Oscillations (AO) and winter precipitation variability across the Indian region using reanalysis and observational data. The analysis uncovers a dipole pattern in precipitation between the western Himalayas and central India, which is primarily connected to the positive (negative) phase of the AO. The positive (negative) AO phase is linked to a Rossby wave with wavenumber 2, dominated by the quasi-barotropic Euro-Atlantic and Siberian High (Ural-Siberian High and the high over Northwest Pacific). This is accompanied by a wave train pattern that extends across Europe, subtropical North Africa, and West Asia. This wave train pattern leads to the strengthening (or weakening and southward movement) of the Middle East jet stream and induces anticyclonic (or cyclonic) circulation over the Arabian Sea during the positive (negative) AO phase. The precipitation dipole between the western Himalayas and central India primarily results from moisture transport driven by the outflow of anticyclonic (cyclonic) circulation over the northern Arabian Sea, which is associated with the positive (negative) AO phase and its related atmospheric dynamics.

Keywords: Winter Precipitation, Arctic Oscillation, Winter Extremes, Teleconnection

Extreme weather events in Monsoon 2024

Sunanda moka1[a], Prayek. S2[b], Sagar K3[c]

[a] *India Meteorological Department*
DWR, India Meteorological Department
MC Amaravati, India Meteorological Department
E-Mail: sunnu1887@gmail.com

ABSTRACT

Southwest **Monsoon** Season June – September. August 2024 witnessed Extremely very heavy rainfall events mainly Gujarat, Saurashtra & Kutch, Assam & Meghalaya, Tripura, East Rajasthan, Gangetic West Bengal, Uttar Khand and Konkan& Goa, very heavy rainfall events in west coast, over many parts of Central India, Tamil Nadu, Puducherry & Karaikal and heavy rainfall events were observed in many parts of India. Out of total 1926 occasions, 105 were extremely heavy rainfall, 526 were very heavy rainfall and 1295 were heavy rainfall catogories in this month. There are six low pressure systems formed, two from land during 3 to 5 August, one over Arabian sea from 22 to 24 August, one well marked low pressure area over Bay of Bengal from 25 to 28 August, one Depression over Bay of Bengal from 29 to 2nd September, one land Deep Depression from 2 to 5 August and one Cyclonic storm 'ASNA' over Bay of Bengal from 16 -2nd September. In Last seven years there is no cyclone formation in August month was seen, no. of low-pressure days Are more and three systems were formed in 2024 and two Depressions are formed. Over all August month given ample amount of Rainfall throughout India. Due to these systems Monsoon related Heavy rains and floods & landslide damage 112 deaths, Due to Lightning 65 deaths from different parts India is reported.

Keywords: Extremely Heavy Rains, Cyclonic storm, Deep Depression, Floods and Landslides

Trends in aerosol characteristics over India: Implication to climate forcing

Atul Kumar Srivastava*
[a] *Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, New Delhi, India*
*[*Corresponding Author's E-mail:* atul@tropmet.res.in *]*

ABSTRACT

Atmospheric aerosol, the tiny suspended particulate matter originated from various natural and anthropogenic sources is one of the most visible aspects of air pollution, and has vast effect span in the areas of air quality, health, radiation, cloud microphysics and climate change. The Indian summer monsoon region, comprises the Indo-Gangetic Basin (IGB) in the northern part of India, is dominated by the enhanced loading of anthropogenic aerosol pollution and thus considered as one of the global hotspots. It is one such region, where heterogeneity in aerosol optical and microphysical properties over a wide range of spatial and temporal scales continuesto hinder in improving the estimates of aerosol-induced climate forcing. Rapid increase in population and urbanization has resulted in excessive fossil fuel combustion and biomass burning leading to high anthropogenic aerosol loading over this region. The large increase in anthropogenic aerosols over the IGB is hypothesized to cause considerable changes in regional monsoonal circulation and also the global climate system apart from the aerosol-induced negative health impacts.

Keywords: Aerosol, anthopogenic, natural, biomass, dust.

Role of positive outlier cloud-to-ground lightning strokes in initiating forest fires in India

Trisanu Banik[1a],
Dipanjana De[2b],and
Anirban Guha 3[b]

[a] *India Meteorological Department, Mausam Bhawan, New Delhi, India*
[b] *Department of Physics, Tripura University, India*
E-Mail: baniktrisanu@gmail.com

ABSTRACT

A surge in lightning strikes in India and globally due to climate change is a major emerging issue associated with disaster management and mitigation. Lightning strikes are the leading natural cause of wildfires worldwide. Discharges away from the main thunderstorm activity pose a significant danger to India's vulnerable and isolated forest reserve zones. Positive discharges have long stroke durations, making a substantial number of those discharges long-continuing currents (LCC). This study merges data from World Wide Lightning Location Network (WWLLN) and Earth Networks Total Lightning Network (ENTLN) sources. Using the DBSCAN algorithm and other AI/ML python packages, we extracted the Positive Outlier Strokes (POSs) from the clusters on the studied vegetation zones of the Indian subcontinent, particularly over the dry seasons in 2021. These specific discharges have an increased potential for disaster as they occur in areas with limited precipitation probabilities and prolonged ignition periods. Data analysis indicates that the daily POS count is aligned with the spreading of the daily thunderstorm activity. Additionally, the higher the number of outliers, the larger the scattering, leading to an increased impact of outliers on the POS count. The knowledge of the outlier count can estimate the positive polarity proportion amongst the outliers. Daily outlier count also has a good correlation with daily intense discharges. Daily spatial visualization of POS discharges and their close correlation with the total daily outlier count can help relay immediate alerts of a probable lightning-ignited wildfire (LIW) to the foresters and the public of the surrounding area. This will lead to the faster mitigation of wildfires even before the satellite sensors pick up signals from fire events.

Keywords: clustering; WWLLN; ENTLN; AI/ML; wildfires; outliers; positive-discharges; disaster-mitigation.

SIMULATION OF CLOUDBURST EVENT OVER KERALA

Prabhath H Kurup1[a], Abhilash S2[b]

[a] *Advanced Center for Atmospheric Radar Research (ACARR),Cochin university of Science and technology (CUSAT)*

E-Mail: prabhathhkurup94@gmail.com

ABSTRACT

The Cloudburst is an extreme weather event capable of producing torrential rainfall in a small area in a short time. A heavy rainfall event where the rainfall rate exceeds 100 mm/h is termed as a classical Cloudburst. Cloudburst generally occurs during the monsoon season due to strong convection associated with orographic forcing over the western Ghats and Himalayan region which causes widespread damage to property and loss of lives. So it is crucial to predict such events to help authorities to take preventive measures. We use the numerical mesoscale model Weather Research Forecast model (WRF) to simulate the cloudburst of Kerala on 8th August 2019, to capture and understand the underlying dynamical and thermodynamical characteristics of this event. The WRF model was initialized with NCEP GDAS with two domains, the outer domain spans from 10°S to 30°N latitude, 55°E to 95°E longitude. The inner domain spans from 5°N to 15°N latitude, 70°E to 80°E longitude. We used a multi-physics ensemble with two sets of resolutions 15km, 5km and 9 km, 3km for sensitivity study and to examine the performance of the individual schemes and ensemble. The results show that the ensemble forecast performed better than the individual ensemble members. There is a significant difference in performance of schemes with resolution,but the ensemble mean doesn't show much change with resolution. The simulated hydrometeor structure of the cloud system from the experiment is compared with cloud hydrometeors derived from ERA-5 data sets.To understand the dependence of schemes on resolution, further in-depth studies are required.

Keywords: Extreme weather events; Extreme weather events; Monsoons; Numerical Weather Prediction; WRF

Recent two decades witness an uptick in monsoon depressionsover the northern Arabian Sea

Nagaraju Chilukoti[a], Mahendra Nimmakanti [a],
and J. S. Chowdary[b]
[a] *Department of Earth & Atmospheric Sciences, NIT Rourkela*
[b] *Indian Institute of Tropical Meteorology*
E-Mail: chilukotin@nitrkl.ac.in

ABSTRACT

The present study, for the first time, reports a significant increase in the frequency of Monsoon depressions (MDs) over the northern Arabian Sea in the past four decades. The analysis reveals that increased frequency of MDs due to the substantial variations in both dynamic and thermodynamic parameters across the observation array. Notably, there has been a noteworthy upswing in the Genesis Potential Parameter (GPP) within the northern Arabian Sea sector of the region, shedding light on the increased likelihood of MDs forming in this area during recent monsoon seasons in contrast to the decreasing MDs in Bay of Bengal. However, this finding strongly underscores the increased risk of the emergence and expansion of MDs in the Arabian Sea region over the past two decades, because of rising mid-tropospheric moisture, dynamical instability, augmented relative vorticity at 850 hPa, and weakened shear between upper and lower tropospheric winds. Therefore, it provides absolute assurance of their occurrence with the increasing dynamical process of its formation seems to be due to a combination of barotropic and dynamical instability. The evidence points to a heightened potential for MDs development in this area. Certainly, this is one of the significant contributors to the increased rainfall over northwestern India (NWI) in recent decades.

Keywords: Monsoon Depression, Arabian Sea Warming, Dynamics, Genesis Potential Parameter.

Spatial-Temporal Deep Learning for Glacial Lake Outburst Flood Prediction: A ConvLSTM Approach

Leepakshi Singh Banswal[a], Vinay Anand Tikkiwal[b], and Arun Kumar[a]

[a] *Department of Computer Science & Engineering, National Institute of Technology, Rourkela, India*
[b] *Department of Electronics and Communication Engineering, Jaypee Institute of Information Technology, Noida, India*
E-Mail: : 223cs2124@nitrkl.ac.in

ABSTRACT

Glacial lake outburst floods (GLOFs) pose an increasing threat due to accelerated glacier melt driven by climate change. This research work seeks to improve GLOF forecasting by utilising Convolutional Long Short-Term Memory (ConvLSTM) networks to predict future changes in glacial lake areas. ConvLSTM models, which capture both spatial and temporal patterns in data, are applied to the historical satellite data and climatic factors such as temperature and precipitation. The approach involves two phases: First, ConvLSTM is used to forecast future glacial lake area proportions, analysing interactions between climatic variables and lake expansion. Second, the time-series data from ConvLSTM is trained as a secondary neural network to estimate the probability of a GLOF within a specific timeframe. This dual-model strategy combines spatial- temporal forecasting with hazard probability estimation to enhance the predictive accuracy of GLOFs. By integrating deep learning models for spatial-temporal and hazard prediction, this research offers a more reliable GLOF forecasting system, improving early-warning capabilities and aiding disaster preparedness. The results support decision-makers in evacuating, reinforcing infrastructure, and minimising socio-economic impacts in glacier-dependent regions.

Keywords: GLOFs; ConvLSTM; Deep Learning; Early Warning Systems; Climate Change

Air Quality Warning and Integrated decision Support system for Emissions (AIRWISE): Enhancing Air Quality management in Megacities

Sachin D. Ghude[1]*, Gaurav Govardhan[1,2], Rajesh Kumar[3], Prafull P. Yadav[1,4], Rajmal Jat[1], Sreyashi Debnath[1,4], Gayatri Kalita[1], Chinmay Jena[5], Shubhangi Ingle[1], Preeti Gunwani[5], Pooja V. Pawar[1], Rupal Ambulkar[1], Sumit Kumar[1,4], Santosh Kulkarni[6], Akshay Kulkarni[6], Manoj Khare[6], Akshara Kaginalkar[6], V.K. Soni[5], Narendra Nigam[5], Kamaljit Ray[7], S.D. Atri[8], Ravi Nanjundiah[9,10], M Rajeevan[11,12].

[1]Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune, India
[2]National Center for Medium Range Weather Forecasting, Ministry of Earth Sciences, Noida, UP, India
[3]National Center for Atmospheric Research, Boulder, Colorado, USA
[4]Dept. of Atmospheric and Space Sciences, Savitribai Phule Pune University, Pune, India
[5]India Meteorological Department, Ministry of Earth Sciences, New Delhi, India
[6]Centre for Development of Advanced Computing, Pune, Maharashtra, India
[7]Ministry of Earth Sciences, New Delhi, India
[8]Commission for Air Quality Management, New Delhi, India
[9]Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science, Bengaluru, India.
[10]Divecha Centre for Climate Change, Indian Institute of Science, Bengaluru, India.
[11]National Centre for Earth Science Studies, Thiruvananthapuram, Kerala, India.
[12]Atria University, Bengaluru, India.

ABSTRACT

Air pollution poses a significant environmental risk to large cities worldwide, including New Delhi, India's capital. Occurrence of frequent episodes of elevated levels of air pollution during October to March in Delhi and National Capital Tertiary (Delhi-NCT) chokes its ~32 million residents every year. Current air quality models lack the ability to accurately predict severe air pollution events in Delhi-NCT, rendering decision-makers helpless in their efforts to safeguard public health. To address this shortcoming, a new initiative with a very high-resolution Air Quality Early Warning System (AQEWS) was developed and made operational in 2018. Subsequently, a Decision Support System (DSS) was incorporated into the architecture in 2021, enabling dynamical high resolution source attribution data and various emission reduction scenarios from a single model forecast. The newly developed system, Air Quality Warning and Integrated decision Support system for Emissions (AIRWISE), assimilates near real-time satellite aerosol optical depth (AOD) retrievals, satellite bases fire information, surface data from 320 air quality monitoring stations, and high-resolution emissions from anthropogenic and natural sources, resulting in an extensive modeling framework with dynamical downscaling. This framework exhibits remarkable prediction skills, accurately forecasting very poor air quality episodes up to 3 days in advance at a city-scale to street-level resolution achieving an accuracy of 83% in predicting these pollution events downscaled to a very high resolution of 400 metres. The AQEWS stands as the first operational air quality forecasting system in the world to operate on such a high-resolution with inclusion of chemical data assimilation. Products based on AQEWS have been made publicly available to provide air quality forecasts 3 days in advance, real-time observations of air quality, daily and hourly near real-time forecast verification, and contribution of non-local fire emissions to air quality in Delhi-NCT. The Commission of Air Quality Management (CAQM) utilises the forecast for the effective implementation of the multi-stage Graded Response Action Plan (GRAP), which imposes graded restrictions on pollution sources in Delhi-NTC region. This paper presents an overview of the high-resolution Air Quality Early Warning System (AQEWS) and a Decision Support System (DSS), synthesis of modeling experiments, verification of forecasts, and challenges associated with accurately capturing episodes of exceptionally high air pollution levels.

MACHINE LEARNING-BASED IMPROVEMENTS TO IMDAA REANALYSIS FOR MAXIMUM AND MINIMUM TEMPERATURES

Harvir Singh[a,b]*, Anumeha Dube[a], Prashant K Srivastava[b],, Raghavendra Ashrit[a] , VS Prasad[a]
[a] *National Centre for Medium-Range Weather Forecasting, Ministry of Earth Sciences, India*
[b]*Insititute of Environmental and Sustainable Development, Banaras Hindu University, India*
E-Mail: **harvir_ncmrwf@gmail.com**

ABSTRACT

The Indian Monsoon Data Assimilation and Analysis (IMDAA) is a high-resolution regional reanalysis of the Indian subcontinent, marking the first initiative of its kind for India. Developed through a collaboration between the National Centre for Medium Range Weather Forecasting, the Met Office (UK), and the India Meteorological Department, this effort is part of the National Monsoon Mission under the Ministry of Earth Sciences, Government of India. The reanalysis covers the period from 1979 to 2020, coinciding with the modern satellite era. Recent global surface temperature trends have revealed a notable rise in extreme heat events, underscoring the critical need for accurate predictive models. In India, the average temperature has increased by 0.85°C from 1901 to 2015, contributing to a 27% increase in mortality and a 24% rise in heatwaves, making them the country's second most deadly natural disaster.

This study leverages advanced machine learning (ML) techniques—specifically support vector machines (SVM), random forests (RF), gradient boosting (GB), and multiple linear regression (MLR)—to model and forecast maximum and minimum temperatures across different regions of India. The models were trained using temperature data, while the predictors included 6-hourly rainfall, cloud cover, relative humidity, and wind speed at 10 meters from the pre-monsoon months (March, April, May, and June, or MAMJ) for 1979– 2018, and tested on data from 2019–2020. Our analysis of heatwave patterns from 2000 to 2022 shows a significant increase, particularly for extreme events, which have become more frequent, especially between 2010 and 2020. Factors like climate change and rapid urbanization have further intensified these trends. Traditional numerical weather prediction (NWP) models have struggled to forecast such extreme events accurately.

We applied ML techniques to correct biases in the IMDAA reanalysis of maximum and minimum temperatures to improve prediction accuracy. The GBM and SVM models performed strongly, significantly reducing root mean squared errors (RMSE). Gradient Boosting proved effective for forecasting maximum temperatures, while SVM excelled at predicting minimum temperatures—except in Hyderabad, where Random Forest outperformed other methods for both temperature extremes. The overall improvement in RMSE across all stations ranged from 15% to 65% for maximum temperatures and 15% to 80% for minimum temperatures, although some challenges persisted compared to other methods.

Keywords: Extreme weather events; Machine Learning; Reanalysis

Rainfall Shifts in a Changing Climate over Ladakh

Richa Singh, R. Bhatla

Department of Geophysics, Institute of Science Banaras Hindu University, Varanasi, India.

Email: richa.envt@bhu.ac.in

ABSTRACT

Ladakh is particularly vulnerable to shifting climatic trends because of its chilly desert environment and delicate ecosystem, which are geographically linked to the Western Himalayas. More rain events have been occurring in the area recently, which has impacted the agriculture and could lead to landslides and flash floods. In order to shed light on climatic trends, this study covers 90 years from 1932 to 2021 in Ladakh, statistically quantifying variations in the rainfall pattern on tricadal (30-year periods) and decadal (10-year periods) bases. The gridded dataset of rainfall has been taken from India Meteorological Department (IMD) for this study, which was then processed to estimate variations in rainfall in Ladakh during the pre-monsoon, monsoon, post-monsoon, and winter seasons. Non-parametric tests, such as the Mann-Kendall (MK) and Sen's slope tests, were used to determine the trends. Both Ordinary Least Squares (OLS) regression techniques and the MK sequential test, which takes into account overlapping time segments, were used. In this study, rainfall variation was estimated using the Precipitation Concentration Index (PCI). Rainfall trends over the past 90 years are better understood according to this study, which shows that some seasons have received more rainfall while others have seen less. Rainfall was consistent and highly concentrated, according to PCI values, indicating the possibility of extreme weather. Rainfall fluctuations were found using decadal analysis, most likely as a result of larger climatic cycles. This information could help build early warning systems and infrastructure that can withstand major weather events. The tricadal study showed long-term patterns, with T1 (1932–1961) experiencing higher pre-monsoon rainfall and T2 (1962–1991) and T3 (1992–2021) experiencing lower monsoon and post-monsoon rainfall. Agriculture, ecological services, and the management of water resources can all benefit from this study.

Keywords: Ladakh, Rainfall Variability, Mann-Kendall Sequential Test, Gridded Data, Climate Change

Sub Seasonal Variability of Summer Monsoon Rainfall in Coupled Climate Models (CCMs) Simulation

P. Parth Sarthi
Department of Environmental Science, School of Earth, Biological and Environmental Science, Central University of South Bihar, Gaya, Bihar 824236, India

Email: ppsarthi@cub.ac.in

ABSTRACT

The Indian Summer Monsoon Rainfall (ISMR) and associated wind circulation in the simulation of the Coupled Climate Models (CCMs) of CMIP6 is evaluated in the control experiment. of CCMs, namely BCC-CSM2-MR and BCC-ESM1 of the Beijing Climate Center, China, and MPI-ESM1-2-HR and MPI-ESM1-2-LR of Max Planck Institute (MPI) Germany, since they had better performed in Coupled Model Intercomparison Project phase 5 (CMIP5). Under the historical experiment (control experiment) for the period of 1979 to 2014, the simulated wind circulation, relative humidity, and rainfall are evaluated on the sub-seasonal scales during the Indian summer monsoon season (i.e. June-July-August- September). The simulated wind and relative humidity at pressure levels of 1000, 850, 700 and 200 hPa are considered for the evaluation. To validate, the zonal wind (u component), meridional wind (v component) and relative humidity, the reanalysed data (0.25° × 0.25°) at the pressure levels of 1000, 850, 700 and 200 hPa are taken from ERA5 of the European Centre for Medium-Range Weather Forecasting (ECMWF). The seasonal and monthly mean wind and relative humidity are vertically averaged from the levels of 1000 to 700 hPa, while monthly mean wind at the level of 200 hPa is considered for upper level analysis. The India Meteorological Department (IMD) observed rainfall (0.25° x 0.25°) is used to validate the model's simulated rainfall. The evaluations show that the CMIP6 model BCC-CSM2-MR performs well in reproducing relative humidity over the Arabian Sea and the Bay of Bengal. The model BCC-CSM2-MR and BCC-ESM1 perform well in simulating JJAS rainfall in comparison to observed rainfall of IMD.

Keywords: CMIP6 models, control experiment, ISMR, Zonal and meridional wind, Relative humidity

Unravelling the causes of heatwaves over Southwest India

Ganaraj Dala1[1], Tinesh Pathania[1], Akash Koppa[2], Vittal Hari[1]

[1]Department of Environmental Science and Engineering, Indian Institute of Technology(ISM) Dhanbad, Jharkhand, India

[2]Laboratory of Catchment Hydrology and Geomorphology,Civil and Environmental Engineering, EPFL Valais Wallis, Sion, Switzerland

E-Mail: 21mt0147@ese.iitism.ac.in

ABSTRACT

Climatic extreme events like heatwaves will have severe impacts on mankind and the whole society as the heatwave intensity, duration and frequency is going to increase due to global warming. Local communities faced severe impacts in the form of human mortality, biodiversity and ecosystem degradation, crop losses due to heatwaves. There is a need to study the casual mechanism behind the heatwaves so that we will be able to predict the occurrence of heatwaves well in advance. Our study helps us to understand the physical mechanism of heatwaves over Western Ghats (World Heritage site declared by the UNESCO and ecologically sensitive and rich biodiversity hotspot). Daily maximum temperature dataset is used for analysis purpose provided by the Indian Meteorological Department (IMD). Climate indices namely TX90P (Number of days greater than 90^{th} percentile) is used to quantify the heatwaves over the region. The Pacific walker circulation is weakened by the climatic modes like (El Nino Southern Oscillation) ENSO helping to create high pressure system leading to adiabatic compression and causing warming of air leading to temperature rise. Also, after the climate shift in the pacific ocean around 1979, ENSO became prominent leading to stronger connection between heatwaves and ENSO in Southwest India. The Hadley circulation is strengthened due to Indian Ocean Dipole (IOD) causing subsidence and descending motion of air favouring conditions for heatwaves to occur. The clear understanding of physical mechanism will help us to predict heatwaves accurately in the near future and help in planning adaptation and mitigation strategies over the Southwest India.

Keywords: Heatwaves; ENSO; IOD; Walker Circulation; Hadley Circulation

An Interactive Web-GIS based Decision Support System (DSS) for Heat Wave

Iyyappan M[a], Anshul Chauhan[a],
M Mohapatra[a], Kuldeep Srivastava[a],
Suman Gurjar[a], Sankar Nath[a], Akhil Srivastava[a] and Naresh Kumar[a],

[a] *India Meteorological Department, Ministry of Earth Sciences, New Delhi - 110003*
E-Mail: muthuiyyappan@gmail.com ; iyyappan.m@imd.gov.in

ABSTRACT

India Meteorological Department (IMD) measure various metrological parameters like Temperature, Relative humidity, pressure, wind direction and speed, etc., using a vast nationwide network of surface observatories to provide information on heat wave conditions. Quantitatively, different thresholds are used to define the heat waves. The heat wave conditions are classified based on the temperature thresholds over a region in terms of actual temperature and its departure from the climatological normal. Also, it provides temperature and humidity-based heat index (feel like temperature) and warm night temperature, hot and dry winds etc., to assess the impact of heat wave/temperature. The percentile information on the temperature helps to assess the extreme behaviours of the temperature and heat waves. Above all, the impact-based forecast and risk-based warning are provided based on the operations and multi-model ensemble framework. To enable the forecaster in the above objective, a Web-GIS-based Decision Support System (DSS) has been developed for the forecasters and users. A web-based GIS module for heat waves with open-source tools, including jQuery, AngularJS, JavaScript API, OpenLayers, and GeoServer, has been indigenously developed by IMD. It provides information about past, current, and forecast heat wave-related information. Users can visualise heat-related geospatial datasets in a geographical framework with multiple user access anytime and anywhere. The application is helpful for forecasters and decision-makers to issue warnings about heat wave conditions and raise public awareness about understanding heat waves and temperature-related products. DSS played a major role in issuing the forecast for the heat wave conditions over the nation, and it improved the accuracy of warnings to the public during 2023 and 2024. The current status, a gap areas and future scope of the DSS have been analysed and presented.

Keywords: Heat wave, Temperature, Web-GIS, DSS, Geospatial Techniques, Geoserver

UNRAVELLING THE MICROPHYSICAL FEATURES RAINFALL OVER 8 STATIONS OF INDIA AS REVEALED FROM THE DISDROMETER NETWORK

Kaustav Chakravarty(a), Rohit Patil(a), Gargi Rakshit(b), Ambuj Jha(a), and Harikrishna Devisetty(a)
a Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune, India
b India Meteorological Department, Ministry of Earth Sciences, New Delhi, India
E-Mail: kaustav@tropmet.res.in

ABSTRACT

Indian Institute of Tropical Meteorology (IITM), Pune has built up the testbed for rainfall microphysics for understanding the characteristics features of raindrop size distribution as observed over 8 different regions of India which differ contrastingly with respect to their geographical and climatic variations. The regions include New Delhi, Mumbai. Kolkata, Chennai, Kochi, Pune, Mahabaleshwar and Bhopal– thereby covering the coastal, orographic and plain regions of Indian sub-continent where 8 Joss-Waldvogel Disdrometer are been in operation continuously. The raindrop size distribution (DSD) data for the month of March-May during 2021- 2023 have been used in this study. With the present system in operation, the study tried to highlight the variation of DSD as observed over these 8 stations specially during these pre-monsoon period when the regions experience the rainfall accompanying with severe thunderstorm. The initial analysis reveals that the majority of this rainfall occurs during the afternoon hours for almost all these stations with a contrasting diurnal variation with each other. The impact of strong surface heating and evaporation plays an important role for this contrasting diurnal pattern of rainfall distribution. Similarly, it has also been found that the raindrops of diameter 2.8 mm are dominant for the New Delhi rainfall with respect to all the other stations during these pre-monsoon periods. The morphology of the prevailing clouds is also considered to be one of the important factors for these heterogenous microphysical features of DSD. In line of that it has been observed that the maritime and continental clouds provide their strong impact on the variation of surface DSD where maritime cloud contains smaller concentration of larger droplets and continental clouds contains "tenfold"-larger concentrations of respectively smaller droplets. The paper also tried to address the microphysical features of rainfall simultaneously over Kochi, Bhopal and Kolkata – which lies along the track of Indian summer monsoon. More details related to these studies will be highlighted in the Conference.

Keywords: Raindrop size distribution, Thunderstorm rainfall

Impact of Western Ghats orography on the simulation of extreme precipitation over Kerala, India during 14–17 August 2018

V. Yesubabu[1], Biyo Thomas[2], C.V. Srinivas[3], Ghouse Basha[1], Ravi Kumar Kunchala[2]

[1] *Weather and Climate Research Group (WCRG), National Atmospheric Research Laboratory, Gadanki- 517 112, Andhra Pradesh, India.*

[2] *Centre for Atmospheric Sciences, Indian Institute of Technology Delhi, New Delhi, India*

[3] *Environmental Assessment Division, Indira Gandhi Centre for Atomic Research, Kalpakkam – 603102, Tamilnadu, India, a CI of Homi Bhabha National Institute, Mumbai*
E-Mail:

ABSTRACT

The state of Kerala, located in southwest peninsular India, has experienced a series of extremely heavy rainfall events in recent years, resulting in severe flooding and landslides. Among these events, an episode of extremely heavy rainfall (50 to 480 mm/day) during 14–17 August 2018 led to devastating floods along the southwest coast of India. In this study, we have chosen this event as a case study to analyze the role of orography using a high-resolution (1-km) cloud-resolving WRF model configuration. Our results of the mountain sensitivity experiments indicate that as mountain height increases, the simulated low-level wind decelerates quickly. This flow blocking is also manifested in parameters such as reduced upper-air wind intensity, increased dynamical convergence, and increased vertical velocities at the Western Ghat (WG) mountain barriers. These factors lead to variations in moist instability and cloud microphysical processes, influencing the horizontal and vertical distribution of mixed-phase hydrometeors. Additionally, the results suggest that large-scale variations in mountain orography in numerical simulations can affect the simulated magnitude and direction of moisture transport, which may have played a role in determining the magnitude and distribution of simulated rainfall over Kerala.

Keywords: Heavy rainfall events, Kerala, Western Ghats, Orography and WRF-ARW model

Heatwave Predictions and Decision Support System for Advisory

Palash Sinha, Sahidul Islam, Sumita Kedia, Manoj Khare*
Centre for Development of Advanced Computing (C-DAC), Pune
**Corresponding Author (email id: manojk@cdac.in)*

ABSTRACT

Heatwaves (HW), often referred to as the "Silent Killer," have recently intensified in terms of frequency, duration, and size, significantly impacting the environment, public health, and various sectors, particularly in urban areas. This study rigorously evaluates the performance of the Weather Research and Forecasting (WRF) model in simulating a severe heatwave event over India, focusing on the northwest region during 23-28 May 2020. Using a 1.5 km spatial resolution, WRF simulations were compared with ERA5 reanalysis data, with initial and boundary conditions sourced from the National Centers for Environmental Prediction-Global Forecasting System (NCEP-GFS). The results show that the WRF model exhibits strong skill in predicting maximum temperatures, heat fluxes, and planetary boundary layers. However, the model presents a consistent warm bias, particularly in minimum temperature forecasts, and an eastward bias in HW location. Additionally, the model tends to overestimate the diurnal temperature range (DTR) and the rate of temperature change, especially during heatwave phases. Sensible and latent heat fluxes (SHF and LHF) were also assessed, revealing discrepancies, with WRF underestimating LHF and overestimating SHF in HW regions. In addition, several statistical metrics have been applied to evaluate the model performance to capture the spatiotemporal pattern of the heatwave. Further, categorical skill scores emphasize the model's robust performance in forecasting extreme temperatures, although its skill diminishes in longer forecast periods. These findings highlight both the strengths and limitations of the WRF model in predicting extreme heat events and underscore the necessity for model improvements in bias correction and surface-atmosphere interactions to enhance HW prediction accuracy. In parallel with the scientific developments, an automated system has been developed to streamline the research process, accelerating model execution, and reducing the time required to deliver advisories for weather extremes to stakeholders. This automated system facilitates quicker policy planning and improves societal response to extreme weather events, particularly in urban settings where the impact of heatwaves is most severe.

Keywords: Heatwave, extremes, WRF, Automated-system, DSS

INDIAN SUMMER MONSOON ANTI-CYCLONE DYNAMICS, AEROSOLS, AND POLLUTION PATHWAYS: A CLIMATE PERSPECTIVE

M. VENKAT RATNAM
National Atmospheric Research Laboratory (NARL),
Gadanki-517112, India
E-Mail: vratnam@narl.gov.in

ABSTRACT

The Indian Summer Monsoon (ISM) circulation is one of the most dynamic systems among different monsoon circulations across the world. ISM is characterized by the low-level jet in the lower troposphere, the tropical easterly jet (TEJ), and the Asian Summer Monsoon Anticyclone (ASMA) in the upper troposphere and lower stratosphere (UTLS) region. High cloud cover with deep convective systems is commonly observed during ISM. Any changes in these elements will finally be reflected in the monsoon precipitation. ASMA is one of the important systems that persist for more than three months during the ISM season, extending from the Middle East to the Pacific. This anticyclone is characterized by a large, high-pressure system that forms over the northern Indian subcontinent and the Tibetan Plateau. Any pollutant entering into this ASMA will be trapped and persist for a long time, affecting the background through radiative forcing. The way ASMA varies, similar changes will be reflected in the chemical composition that includes aerosols and trace gases. Thus, the foremost objective is to understand ASMA variability itself. We used several reanalysis datasets to understand the variability of ASMA and to investigate how monsoon activity influences the ASMA. Huge differences among different reanalysis datasets are noticed in reproducing the dynamical changes of monsoon circulation including ASMA. Unusual behavior in ASMA is observed during El Niño conditions and during active and break monsoons. Next, aerosol and trace gas behavior within ASMA are investigated using long-term satellite measurements. Large asymmetry in the aerosol and trace gases distribution within ASMA is noticed. Long-term trends show increased pollutants in the ASMA, attributed to increased convection in global warming scenarios. Special experiments like Balloon Measurements Campaigns of Asian Tropopause Aerosol Layer (BATAL) campaigns are conducted over different locations in India to obtain physical, optical, and chemical properties of aerosol within and outside of ASMA. The role of vertical and long-range transport of these pollutants into ASMA is also investigated. Finally, the radiative forcing due to ATAL is estimated using both in situ and satellite measurements. An overview of these investigations will be presented during the workshop.

Keywords: Monsoon dynamics; Convection; Aerosol and Trace gases; Climate

Comparative Analysis of Aerosol trends over India and China: A Two-Decade Study (2001-2023)

LS Ritika[1], Sushant Das[2],

[a] *Department of Earth and Atmospheric Sciences,National Institute of Technology, Rourkela' Odisha, India*
E-Mail:423AS2042@nitrkl.ac.in

ABSTRACT

Aerosols significantly influence the radiation budget, impacting regional climate impacts. India and China, two rapidly developing nations, experience significant pollution due to industrialization, urbanization, vehicular emissions, and natural dust from desert sources. This study uses data from the Moderate-resolution Imaging Spectroradiometer (MODIS) on Terra to examine annual and seasonal variations in aerosol optical depth (AOD) trends over South Asia from 2001 to 2023. The spatial trends show a dipole pattern, increasing AOD over India and decreasing AOD over China. Eastern and Central India show rising aerosol levels, while South and Central East China show a decline. Seasonal trends also reflect this pattern, with variations inaerosol changes across seasons, highlighting specific aerosol species' dominance. Quantitative data from Modern-Era Retrospective Analysis for Research and Application (MERRA-2) indicates a substantial increase in sulfate aerosols over India, particularly during post-monsoon and monsoon seasons. The study highlights significant changes in aerosol composition over the past two decades, providing insights for policymakers to target emission hotspots. My gratitude goes to Prof. Sushant Das for letting me work on the project under his guidance. I am thankful that he supported me at every turn, gave me advice, urged me to complete the task to the best of my ability,and motivated me to learn more about this subject. Also deserving of my gratitude is our HOD, Prof. Naresh Krishna Vissa, sir, who has guided and inspired me at every turn. I am grateful to myseniors for their assistance and guidance during this project.

Keywords: Aerosol, Dipole, Trends, India, China

Land Cover Changes and Urbanization: Impact on Urban Climate

A.N.V. Satyanarayana,
Centre for Ocean, River, Atmosphere and Land Sciences
Indian Institute of Technology Kharagpur
Kharagpur – 721302, India

ABSTRACT

Cities provide improved lifestyles with advanced infrastructure, job opportunities, and economic development that lead to the accumulation of the earth's population in major global cities. Global cities occupy only 3% of the area of the Earth's land, but about half of the global population lives in cities and utilize about 60% to 80% of the total energy consumption and are also responsible for 70% of the carbon emission. The global cities are thus abruptly growing in both horizontal and vertical directions to meet the socioeconomic demand. The pressure of the growing population has forced significant modifications in land use land cover (LULC) to modify into artificial urban surfaces which affect the surface dynamics. Due to these altered properties, the land surface temperature (LST) of the urban surface is higher than that of the natural surface and thus generates an urban heat island (UHI), which influences atmospheric temperature, humidity level, more frequent heat waves, and extreme variability of precipitation patterns with a higher risk of urban flooding or drought and other climatic activities on a regional scale. It is essential to understand the variation of surface energy exchanges over the urban and rural domains to understand the boundary layer dynamics over the fast-developing cities and quantitatively investigate the influence of heat fluxes on the occurrence and modifications to the weather extremes, and precipitation changes. These human-made changes led to the increased urbanized regions of highly polluted air and densely constructed infrastructures. India is a developing tropical country with many cities proliferating. The Indian metropolitan cities are encountering significant UHI effects due to the changes in the LULC distribution. Rapid urbanization causes potential changes in the urban landscape, resulting in significant changes in outdoor thermal comfort that develop poor health conditions and liveability of urban residents. The effect of urban heating on cities in different regions of India will be different as Indian climatic conditions range from extremely hot deserts in the west to heavy-raining northeast regions and from severely cold regions in the north to hot semi-arid regions in the south. It is essential to understand the influence of urban land-cover expansion over Indian cities to ascertain its implications for urban climate in India. The local changes in the urban climate can affect regional climate which in turn influence the global climate.

HELICAL PARADIGM OF TROPICAL CYCLONES LIFE CYCLE

Amit Kesarkar[a], Arpita Munsi[a], and Jyoti Bhate[a]
[a] *National Atmospheric Research Laboratory, Gadanki, Tirupati District, Andhra Pradesh 517112*
E-Mail:amit@narl.gov.in

ABSTRACT

Tropical cyclones (TCs) are the most violent disasters, causing loss of life and being responsible for socio-economic damage. Substantial progress has been made in forecasting the tracks and movement of tropical cyclones; however, forecasting rapid changes in the intensity of the tropical still needs to be improved. Our previous investigations have shown that the helical organization of TC emerges as self-sustaining when primary tangential and secondary overturning circulation starts intensifying mutually. The local maxima in helicity time series are commensurate with the changes in tropical cyclones' stages. Feedback between helicity and ocean surface fluxes control the life cycle of tropical cyclones. Further, Increased helicity density above 200 × 10 −2 ms −2, irrespective of intensity, caused a decrease in heat and moisture flux trends. Thus, the helical organization of tropical cyclones is controlled by atmospheric deep shear and exchanges of moisture and heat fluxes from underlying oceans.

In the present work, we have formulated a helical paradigm of tropical cyclones that describes the helical organization of tropical cyclones during their different life cycle stages, i.e., during genesis and intensification (stagnation, rapid intensification, rapid dissipation). This paradigm has been validated for 10 tropical cyclones over the North Indian Ocean. The relationships between the prognostic variation of shear, energy dissipation, and ocean fluxes, with integral helicity gradient, have been used to derive the criterion for the intensification stages of tropical cyclones. Our results indicated that the patterns in the prognostic variation of the integral helicity gradient parameter commensurate with the tropical cyclone intensification processes. We argue that it can be considered a parameter for the prognostic prediction of tropical cyclone intensification processes.

Keywords: Extreme weather events; Tropical Cyclone; Intensification; Weather Prediction; Helical organization

Rossby Wave Breaking events exacerbate the heatwave conditions over the Indian region

Biyo, Thomas[a], Ravi Kumar Kunchala[a], Bhupendra Bahadur Singh[b], Kondapalli Niranjan Kumar[c], Viswanadhapalli Yesubabu[d]

[a] *Centre for Atmospheric Sciences, Indian Institute of Technology Delhi,110016, India*

[b]*Centre for Climate Change Research, Indian Institute of Tropical Meteorology, Ministry of Earth Sciences, Pune, 411 008, India.*

[c]*National Centre for Medium Range Weather Forecasting, Ministry of Earth Sciences, Noida, 201309, India*

[d]*Weather and Climate Research Group (WCRG), National Atmospheric Research Laboratory, Gadanki 517*

E-Mail: Biyo.Thomas@cas.iitd.ac.in

ABSTRACT

In India, heatwaves present a substantial risk, resulting in an elevated mortality rate when compared to other natural hazards, particularly in the northern regions of the country. Many studies emphasized the significance of upper-level blocking patterns and stationary anticyclonic circulations in conjunction with Rossby Waves as pivotal factors in regulating heatwave events. While several studies have emphasized the influence of upper-level synoptic Rossby Wave Breaking (RWB) events on heatwaves, there is a dearth of research that explicitly examines the role of RWB on heatwaves, but extensively studied its potential influence on rainfall patterns. To bridge this knowledge gap, the present study endeavors to examine the relationship between pre-monsoon (March to May) Rossby Wave Breaking (RWB) events and heatwave events over 43 years, from 1979 to 2021. We utilized a Potential vorticity contour searching algorithm and 90th percentile heatwave criteria to detect upper-level RWB events and heatwaves respectively. Our findings indicate that 38% of the heatwaves are found to coincide with the occurrence of the RWB events which constitutes 40% of the total RWB events detected during the March-May months. Further analyses indicate that temperature anomalies are increasing during the RWB days lasting 3-4 days at the peak of breaking events, correlating strongly with the maximum day of breaking. Moreover, our analysis revealed that the Rossby wave train, typically breaks and becomes stationary over the Indian region during the RWB events. The ridges near the extended troughs exhibit strong and persistent anticyclonic circulations leading to warm dry conditions over the regions predominantly attributable to the diabetic hating and adiabatic heating followed by horizontal temperature advection causing heatwave events with intense temperature and duration. Overall, this study will provide insight into the role of RWB events on the heatwaves over the Indian region.

Keywords: Rossby Wave Breaking; heatwaves; Potential vorticity; heat budget; climatology

KEY FACTORS INFLUENCING THE CLOUD CONDENSATION NUCLEI IN RURAL AREAS

1[a] (Ravi Kiran, Varaha), Jayasri Tamada[a],
and M.Venkat Ratnam[a]
[a]*National Atmospheric Research Laboratory (NARL), Gadanki*
E-Mail: ravikiranv@narl.gov.in

ABSTRACT

The detailed knowledge on cloud condensation nuclei (CCN) characteristics of aerosols is fundamental to the understanding of cloud formation, cloud modifications, cloud-radiation interactions and precipitation physics. The characteristics of aerosols that make them CCN are largely unknown, as they depend on various factors such as aerosol size, composition, ambient humidity, etc. Over the Indian region, CCN studies have been reported from a variety oflocations including urban, coastal and high-altitude sites. However, to the best of our knowledge,such investgations does not exisits over rural locations. For the time time, multi-instrument lon- term data have been used to understand the key factors influenceing the CCN over rural location Gadanki. The total CCN concentration (N_{CCN}) was found the highest during pre-monsoon season, followed by winter, post-monsoon, and monsoon. Diurnal variations in N_{CCN} showed bi- modal distribution with a relatively weak peak at around 08 IST and a substantial rise at about 20IST. However, a systematic increase in N_{CCN} was observed during the daytime in all the seasons except for the monsoon. Comparison with other locations suggests the CCN concentrations over Gadanki lies between those of polluted urban, coastal, and high-altitude stations. To understand the factors that influence the CCN concentrations, a set of aerosols, gases and meteorological parameters obtained from a suite of collocated instruments have been analyzed. Bio-mass buring seems to influence the CCN activity during the pre-monsoon months of February to March. Day time variations in CCN are associated with the gas concentrations (O_3, SO_2, NH_3), temperature, solar radiation suggestes the possible role of chemical transformations. Statistical frame work based on Multiple Linear Regression analaysis is adopted to quantify the influencing factors of CCN which indicates the deterministic role of meteorology. Size resolved CCN measurements are necessary to know the deterministic role of size and composition.

Keywords: Aerosols, Cloud Condensation Nuclei, Bio-mass burning, fossil-fuel combustion;

National Institute of Technology Rourkela
Rourkela 769008, Odisha

CONTACT IMS

Room No. 605, VI Floor, Satellite Meteorological Building
Mausam Bhavan Complex, Lodi Road, New Delhi-110 003
Ph No: 011-49967783
Email ID: imetsociety@gmail.com : web : http://imetsociety.org/