DST – Mahamana Centre of Excellence in Climate Change

(2017-2023)

विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF SCIENCE & TECHNOLOGY

काशी हिन्दू विश्वविद्यालय
BANARAS HINDU UNIVERSITY

Azadi Ka Amrit Mahotsav

काशी हिन्दू विश्वविद्यालय BANARAS HINDU UNIVERSITY

विज्ञान एवं प्रौद्योगिकी विभाग DEPARTMENT OF SCIENCE & TECHNOLOGY

An Initiative of National Mission on Strategic Knowledge for Climate Change Department of Science and Technology under the National Action Plan for Climate Change, Government of India

DST-Mahamana Centre of Excellence in Climate Change Research

Institute of Environment and Sustainable Development

Banaras Hindu University

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विज्ञान और इंजीनियरी अनुसंधान बोर्ड
(विज्ञान और प्रौद्योगिकी विभाग, भारत सरकार का एक सांविधिक निकाय)
SCIENCE & ENGINEERING RESEARCH BOARD
(A Statutory body of Department of Science and Technology, Govt. of India)

Foreword

Climate change stands as an undeniable concern for the world, raising a critical question over the survival of humanity. The unequivocal rise in global temperatures due to anthropogenic emissions has caused irreversible changes across natural ecosystems, leading to rising extreme weather events, sea-level rise, agricultural losses etc. Standing at the threshold of being one of the most vulnerable countries facing multi-faceted challenges due to climate change, India has immense potential to reduce these adverse impacts. While new advances in research are paving the way for effective adaptation strategies to reduce concerns over food and water security, a paradigm shift has occurred at each level of governance to build climate resilience across the country. Under the aegis of the National Action Plan on Climate Change (NAPCC), the Department of Science and Technology-coordinated Centre of Excellences are taking leaps in strengthening climate knowledge-based resilience and capacity building.

I am delighted to know that the DST-Mahamana Centre of Excellence in Climate Change Research (DST-MCECCR), Institute of Environment and Sustainable Development, Banaras Hindu University, has been performing remarkable work in climate change impact assessment in the agriculture, water, and health sectors with an interdisciplinary approach as well as capacity building for stakeholders. I congratulate the team of DST-MCECCR for their efforts and this report, which is an outcome of all the initiatives taken by the Centre to advance climate research, build climate resilience, and enable policymakers to make informed decision for society.

Dr. Akhilesh Gupta
Secretary
Science & Engineering Research Board

सत्यमेव जयते

डा. अनिता गुप्ता

Dr. Anita Gupta

सलाहकार एवं प्रमुख वैज्ञानिक 'जी'
जलवायु परिवर्तन एंव स्वच्छ ऊर्जा
विज्ञान और प्रौद्योगिकी विभाग
भारत सरकार

SCIENTIST 'G' ADVISOR & HEAD,
Climate Change & Clean Energy (C&E)
Department of Science & Technology
Government of India

Foreword

Recent scientific evidences have stated the rising global temperatures are changing the climatic patterns. Unprecedented rise in extreme events have given rise to an increased vulnerability and severe damage to life and property across the globe. Climate change has emerged as a global concern and India stands no different in experiencing its impacts. While the challenges of climate change remain high with increasing threat to food and water security, India is advancing in climate action as much emphasis is being given to climate research and capacity building for adequate mitigation and adaptation initiatives.

The Department of Science and Technology is spearheading two national missions under the National Action Plan for Climate Change i.e., National Mission on Strategic Knowledge for Climate Change (NMSKCC) and National Mission for Sustaining Himalayan Ecosystem (NMSHE). Under these missions, the Centre of Excellences have contributed in strengthening the knowledge base in understanding the key climatic processes & have carried out impacts assessment on important sectors such as agriculture, water, health, biodiversity, natural ecosystems etc. They have also aided in building national capacity to reduce the adverse impact of climate change on the country.

I am pleased to know the DST-Mahamana Centre of Excellence in Climate Change Research (DST-MCECCR), Institute of Environment and Sustainable Development, Banaras Hindu University efforts and initiatives in strengthening the climate resilience agriculture, water and health sector as well as their outreach programs for capacity building. I congratulate DST-MCECCR for this outcome report highlighting the impact assessment research and capacity building initiatives.

(Dr. Anita Gupta)

Place: New Delhi
Dated: 08.11.2023

Room No.8, S&T Block-I, Technology Bhavan, New Mehrauli Road, New Delhi-110016

Acknowledgement

This report is prepared to summarize the qualitative and quantitative outcome of research and development initiatives undertaken by DST Mahamana Centre of Excellence in Climate Change Research since its establishment in 2017. The Centre is extremely thankful to all the Co-PIs, research fellows and administrative staff for their contribution and support in curating the research achievements as well as far-reaching capacity building programs. The Centre gratefully acknowledges the Climate Change Programme, Department of Science and Technology, New Delhi, for financial support (DST/CCP/ CoE/80/2017(G)).

(R K Mall)
Coordinator/Principal Investigator
DST-MCECCR

Executive Summary

DST-Mahamana Centre of Excellence in Climate Change research is envisioned to do state of the research in climate impact assessments in agriculture, water, aerosol and health sector. The Centre also strives to develop state of the art infrastructure facilities along with the application of advanced tools and techniques to facilitate interdisciplinary, transformational and usable climate change research. The three thematic research groups of the Centre have an interdisciplinary approach as the output of simulation modeling from one sector (climate, water, agriculture, and health) are being utilized as an input to another sector to assess the impact of changing climate besides addressing various socio-economic challenges. The Centre has successfully simulated Indian Summer Monsoon (ISMR) variability and extreme weather events such heat waves, flood, and drought etc., by dynamically downscaling global climate model data for the generation of accurate regional climate information and reliable future climate projections. In the recent decades, a spatio-temporal shift in heatwave and extreme rainfall events over India and a decline in diurnal temperature range (DTR) in the parts Indo-Gangetic plain, north-east, and central Indian region has been reported by the researchers. Artificial Intelligence (AI) & Machine learning (ML) based methods are being deployed for big data analysis in climate research.

Three-dimensional climatology of South Asian aerosols and aerosol sub-types was explored and mineral dust, smoke, and urban aerosols were found to be most dominating aerosols at <1 Km. AI and ML-based methods have been developed to fill a major data gap in air pollution impact studies for high-resolution estimates of surface $PM_{2.5}$. Assessing the severe impact of climate change on health, researchers have found large increase in daily mortality associated with extreme temperature and low DTR over central IGP. Also, 1°C rise in Tmax was associated with an increase in diarrhea and skin-disease whereas, a unit decline showed an increase in cold & flu cases among children. Researchers have found that exposure to black carbon can lead to premature mortality. Studies on assessing impact of climate change on agriculture using crop simulation models have reported a decline in the wheat, rice, tomato, potato, sorghum, and pigeon pea yield and a decrease in sugar content in sugarcane crop in future scenarios. Along with impact assessment, the Centre is working towards developing suitable adaptation strategies for enhancing crop productivity and climate resilience. Double transplantation (DT) in rice along with organic addition emerged as an innovative adaptation practices found shifting of sowing dates by a week later than usual will result in better potato yield in West Bengal and a week early would result in better Sorghum yield in Karnataka. Study on understanding the farmers' perception to climate change found that more than 60% of the farmers agreed that alterations in temperature and precipitation reduce the production as well as the revenue and opted for passive adaptation strategies to cope up with the adversities of climate change.

In water resources studies, Gomti, Gandak, Mahi, Teesta, Kosi, and Varuna have shown increased susceptibility to flood and drought events which is likely to increase in the future. Multicriteria decision-making methods and Advanced AI & and ML techniques-based delineation of groundwater potential zones and future water table projections of Varuna river show moderate groundwater potentiality and water table declination in the near future. The river basin tends to have low potentiality in groundwater reserves and more groundwater table decline due to rapid urbanization in the catchment area. Also, the non-carcinogenic health risk assessment of groundwater of the river basin showed that children are more susceptible to fluoride and nitrate contamination in this region. Committed to application-based and policy-oriented research for the benefit of the end users, the Centre has developed a prototype of irrigation scheduling for Android phones using geospatial technology for Varanasi which will be extended to other districts of India. Also, a hyperspectral-based crop stage estimator prototype has been developed that will facilitate a better estimation and understanding of crop stages through the Leaf Area Index, etc. For Climate Services to Society the Centre under Gramin Krishi Mausm Seva (GKMS) Scheme, issues location and crop-specific weather-based 3-day agromet advisories for the benefit of the farming community of eastern UP region, twice a week in collaboration with IMD, ISRO and Ministry of Agriculture & Farmers Welfare, Govt. of India through different media and messaging services.

The Centre has published more than 171 research papers with a cumulative impact factor of 602 in high-impact peer-reviewed journals during 2017-2023. Apart from the research, the center has also organized 12 training/ workshops (trained 545 students), 23 capacity building programs and regular visits and lectures of distinguished scientists which has trained cumulatively around 835 students, researchers, scientists and more than 800 farmers of the country. 96 master dissertation and 21 PhDs have been awarded with 32 PhDs ongoing within the Centre. The Centre's work has been represented at International and national platforms in around 134 conferences and seminars with 354 DST-MCECCR personnel participation. 50 foreign deputations and 62 national & international awards/recognitions have been awarded to the Centre. DST-MCECCR Lecture Series has been initiated for knowledge and capacity building of students by inviting lectures from distinguished scientists. In the future, the Centre will be addressing the challenges of climate change with a focus on application of artificial intelligence in climate analytics, local/regional climate information generation, health-climate-air pollution impacts, multi-model approach for crop yield predictions, climate model statistical/dynamical downscaling at a higher resolution, and vulnerability assessment etc. All of the above research and development initiatives at the Centre will be instrumental developing climate resilient mitigation and adaptation strategies by the Government.

(R K Mall)
Coordinator/Principal Investigator
DST-MCECCR

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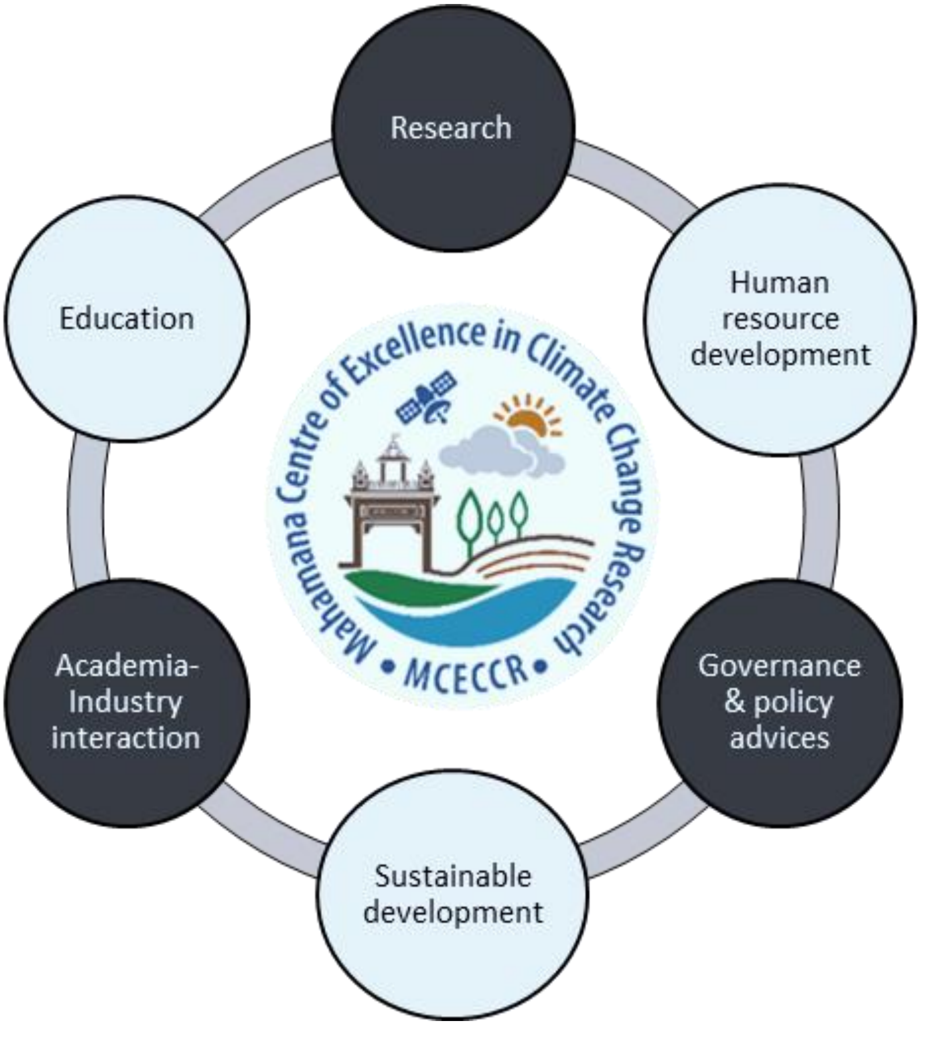
DST MAHAMANA CENTRE OF
EXCELLENCE IN CLIMATE
CHANGE RESEARCH
IESD - BHU

1. Introduction

The Department of Science & Technology established DST Mahamana Centre of Excellence in Climate Change Research (DST-MCECCR) at Banaras Hindu University in May 2017. The Centre was established under National Mission on Strategic Knowledge for Climate Change (NMSKCC), which is one of the important missions under the National Action Plan on Climate Change (NAPCC). The Centre aims to provide strategic knowledge on key climate changing processes, their impacts, associated risks and vulnerabilities to build resilience and to facilitate framing of adequate adaptation and mitigation measures by policy makers. The activity of the Centre can be broadly sub-grouped into six major sectors as shown below:



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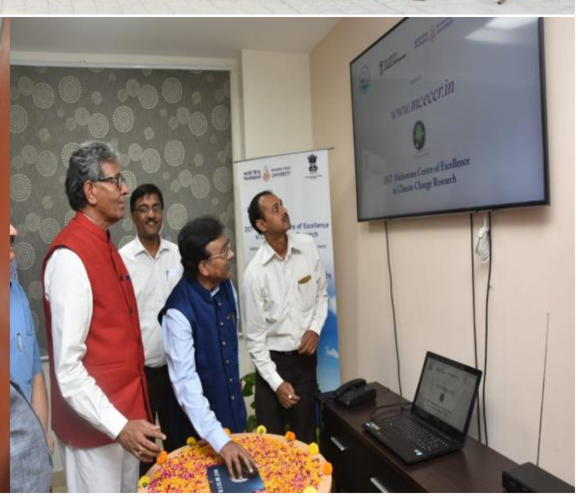

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DST-Mahamana Centre of Excellence
in Climate Change Research


PUSH


Expert Committee
Prof. TALAT AHMAD
Dr. ANITA GUPTA
Dr. SUSHEELA NEGI

2. Objectives and Features

Mission

DST-MCECCR is envisioned to do state-of-the-art research in the climate change impact studies on agriculture, water, aerosol, and health. It aims to generate evidence at the regional level to aid government and policymakers in planning for adaptation and mitigation measures towards climate change scenarios. The research objectives of the Centre have been divided into three thematic areas-

i. Climate modeling

To understand model performance with respect to parameterization and validation of various climate models and constraining uncertainty (in coordination with other DST-CoE on climate modeling in India).

ii. Impact and vulnerability assessment

a. To standardize the sector-specific impact assessment models for agriculture, water, and health.

b. To quantify the impacts and vulnerability in water, agriculture, and health sectors due to climate variability and change.

iii. Socio-economic assessment

a. To identify the associated socio-economic implications.

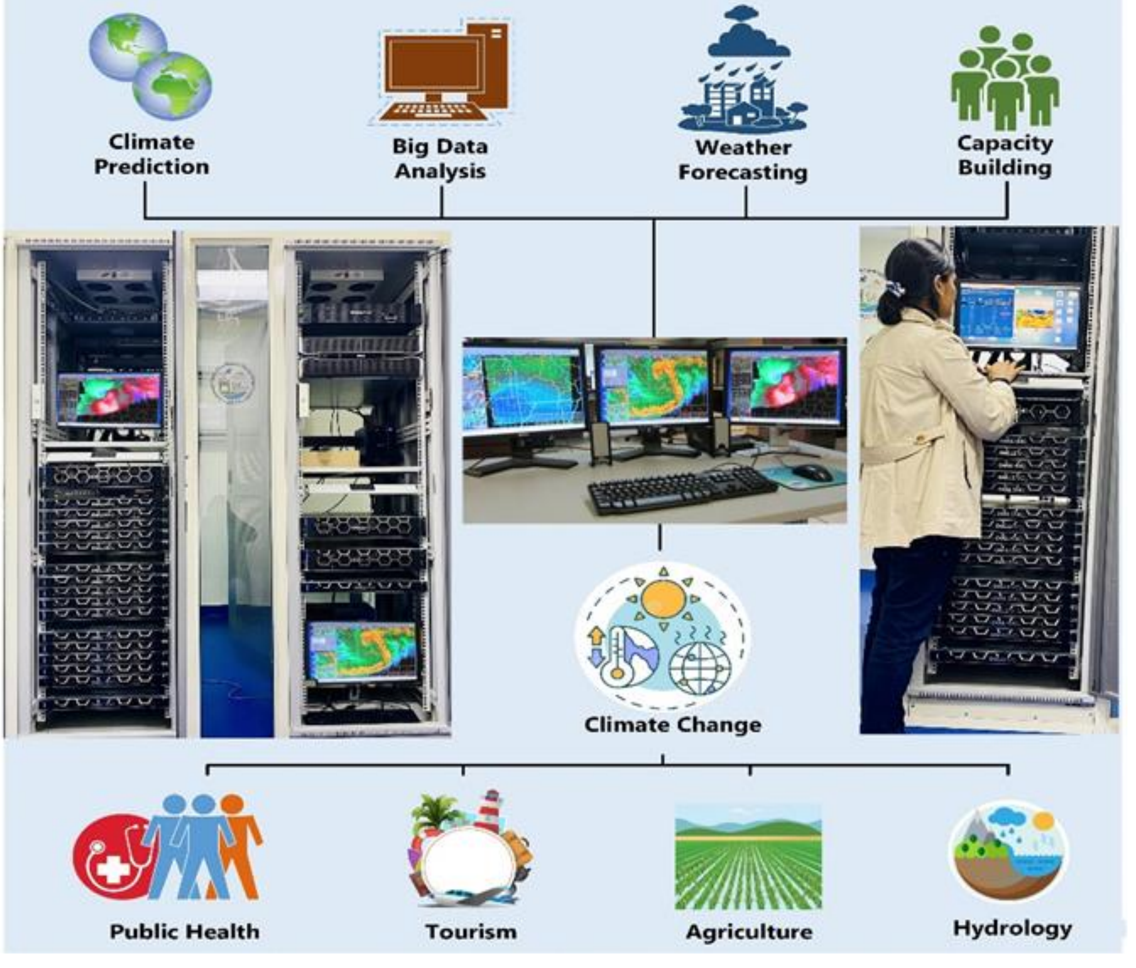
b. To develop infrastructure facilities for climate research and a coherent multi-disciplinary problem-driven research group, manpower by strengthening teaching and training to build long-term scientific capacity and serve R&D needs.

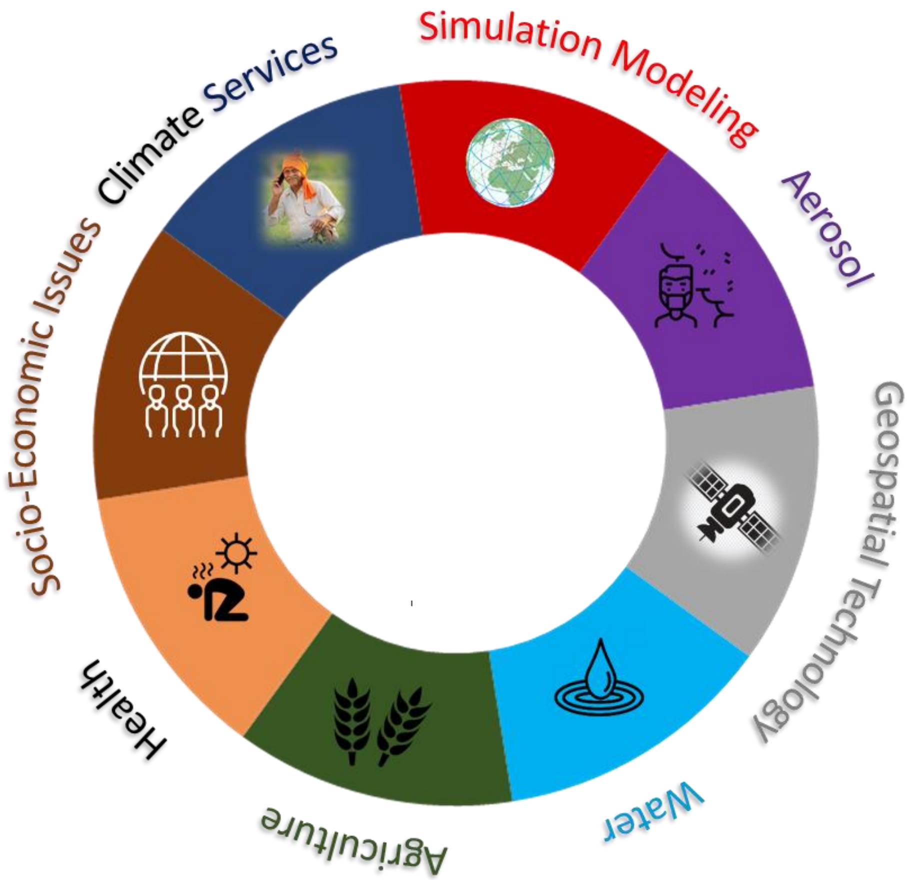
The three thematic groups have an interdisciplinary approach as the output of simulation modeling from one sector (climate, water, agriculture, and health) will be utilized as input to another sector to assess the impact of changing climate besides addressing recent fundamental socio-economic challenges. These outputs can serve as datasets for improving the simulations, particularly at the local and regional scale, that will improve the understanding of the present and future scenarios. The final effort is to converge these outcomes in an appropriate policy framework inclined towards the suitable adaptation and mitigation measures targeted at local and regional levels. Further, the proposed outreach activities, such as lecture series, short-term internships, training, and workshops, would strengthen manpower and capacity building.

Salient Features

The Centre is a visionary initiative of DST, Government of India. The primary goal of the centre is to provide strategic knowledge for understanding key climate-changing processes, their impacts, associated risks, and vulnerabilities in agriculture, water, health, and socio-economic sectors. The Centre is working to develop infrastructure facilities for simulation modeling to facilitate cutting-edge multi-disciplinary research for past, present, and future climate studies.

With advanced research, the Centre is committed to a holistic approach to building climate resilience at every level of society and so is actively organizing capacity-building programs for students, government professionals, and farmers. Providing climate knowledge and understanding the stakeholder's perception is another approach to climate research to facilitate people-centric policy recommendations. The Centre is also dedicated to devising appropriate disaster mitigation and adaptation strategies.


Climate Prediction
Big Data Analysis
Weather Forecasting
Capacity Building
Climate Change
Public Health
Tourism
Agriculture
Hydrology



The High-Performance Computing (HPC) Laboratory of DST-MCECCR has been functional since April 2019. Modeling weather and climate is a challenge, and it requires a powerful HPC facility that can cater to the most complex research workloads. With the facility of High-Performance Computing, the Centre thrives to achieve state-of-the-art on climate change and allied sciences. The HPC aids in accurate simulation modeling to deal with the short-term weather forecasts as well as the long-term climate predictions which could be used directly by the scientists to prepare advisories for agriculture and health sectors as well as future projection studies. The simulated high-resolution outputs are used in assessing interannual variability and regional spatiotemporal changes of extreme weather events like intense precipitation, drought, heat waves, etc., over different levels such as different agro-climatic zones, meteorological sub-divisions, and sub-regions over the Indian subcontinent.

The Centre aims to work along building climate resilience through research and training on different interlinkages of climate extremes, air pollution, water security, adaptation-based agriculture, sustainable practices using high resolution advanced datasets, new techniques with a focus on AI/ML and involvement of stakeholders in research and its implementation at the ground level. The Centre will be an aid in capacity building of society and particularly the local farming communities who suffer most due to unpredictable weather patterns.

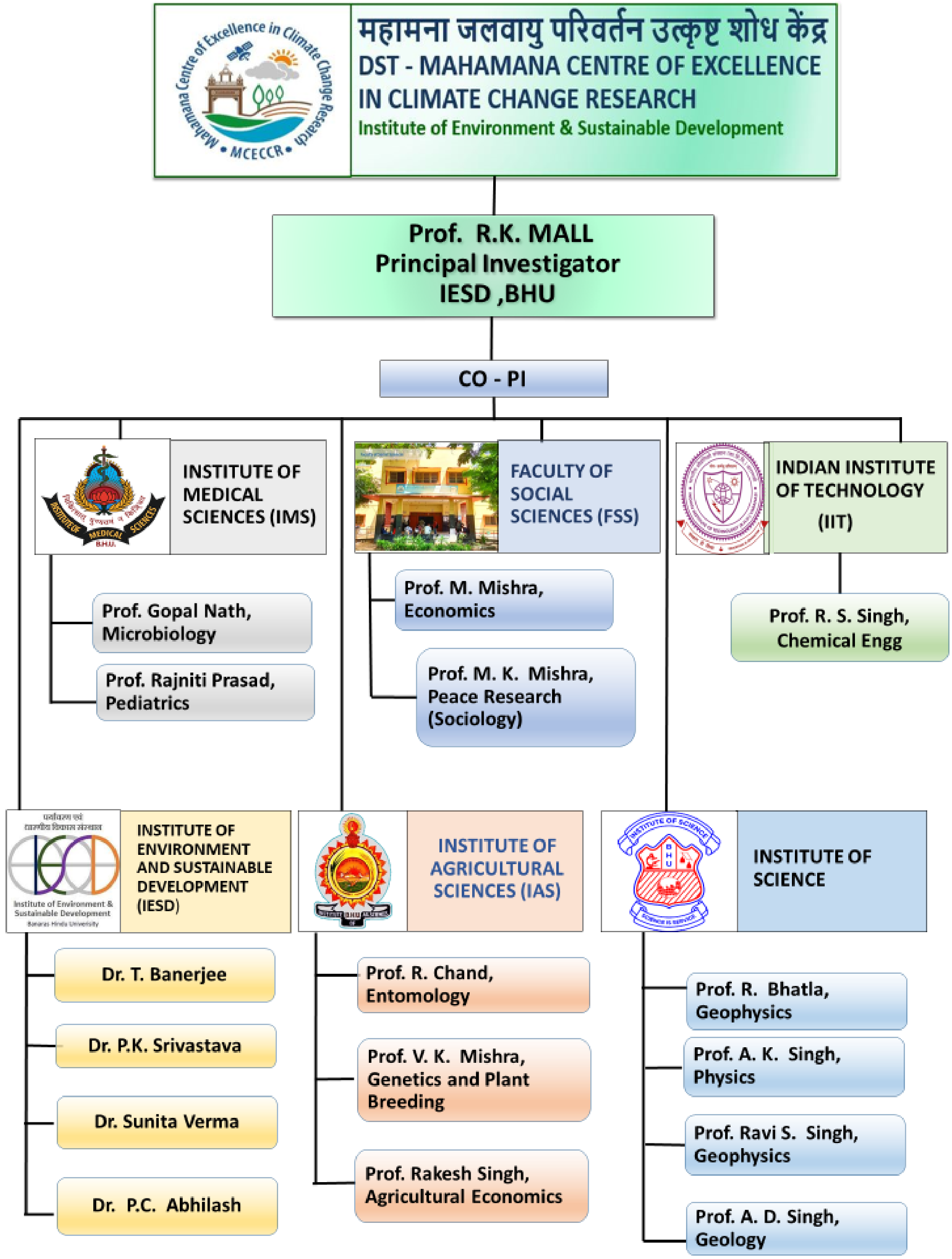

G.S.Singh


Meeting of the Expert Committee
of
DST Climate Change Programme
Organized by
CLIMATE CHANGE & CLEAN ENERGY DIVISION
Department of Science & Technology
Government of India
October 16 –17th, 2023
Hosted by
Banaras Hindu University, Varanasi


Dr. ANITA GUPTA


Organized by
Prof. TALAT AHMAD

3. Organogram of the Centre



OUR CREATIVE AND MOTIVATED RESEARCH FELLOWS

4. Core Areas of Research

i. Climate Simulation Modeling

a. Downscaling

The process of downscaling is crucial for collecting precise climate and weather data. Traditionally, a regional climate model (RCM) is integrated with the initial and lateral boundary conditions from a general circulation model (GCM) to dynamically downscale the climate projections. However, dynamical downscaling simulations are often associated with bias. The sources of bias include future emission scenarios, internal climate variability, and model uncertainty, which hinder the application of climate projections in impact assessment studies. Three key processes are involved in a dynamically downscaled simulation: choosing the GCM simulation (which may include the historical and/or future scenario) that will serve as the boundary conditions for downscaling; configuring the RCM; and finally, executing the RCM and archiving its output. The statistical downscaling approach, though recent, is also worth exploring to generate high-resolution regional climate data.

b. Evaluation of climate models

Climate/weather models at local, regional, or even global scales are being simulated to understand the synoptic conditions of the atmosphere. Rapid change in climate patterns is anticipated due to an increase in greenhouse gases/aerosols emitted into the atmosphere predominantly from human activities. The drivers of these emissions are the burning of fossil fuels, industrial processes, livestock farming, and waste incineration, among others (IPCC 2021*).

Observational data on precipitation, temperature, humidity, and other atmospheric parameters are required to understand the complex interactions and patterns of weather and climate. In the context of climate change scenarios, model simulations are a persuasive tool to understand future climate and how anthropogenically derived greenhouse gases and aerosols may affect it. Prognostic climate modeling predicts future climate, such as global warming trends using current or historical data. The timescale for projection basically includes interannual/inter-seasonal, tricadal/decadal variability, and 21st-century scenarios.

ii. Impacts of Climate Change and Vulnerability Assessment

a. Climatic impacts and vulnerability assessment in the agriculture sector

Climate change is one of the important challenges to the agriculture sector. Global food demand is projected to increase by at least 60% in 2050. Without adaptation to climate change, it will not be possible to achieve food security for all to tackle hunger, malnutrition, and poverty owing to densely populated regions with high vulnerability to the impacts of climate change. The crop yield is likely to be declining in most of the prominent varieties due to the erratic behavior of the climate.

Crop diseases appear at different growth stages of the crop, which become very prominent and coincide with high relative humidity, rainfall, and temperature. Development of new climate-resilient varieties and strengthened monitoring and surveillance of the crops are essentially required. The crop model, a decision support system, has been proven to be an effective tool for proper management practices and predicting yield under possible impacts of climate change.

*IPCC 2021: Allan, R. P., Hawkins, E., Bellouin, N., & Collins, B. 2021. IPCC, 2021: summary for Policymakers.

b. Climatic impacts and vulnerability assessment in the health sector

Environmental consequences of climate change, such as extreme heat waves, rising sea levels, changes in precipitation resulting in cyclones, floods and droughts, intense hurricanes, and degraded air quality, affect directly and indirectly the physical, social, and psychological health of human beings. According to a recent UN report the health risks related to climate change are rising worldwide. Climate change, especially the heat waves and other extreme events, will bring new and emerging health issues. In particular, children, women, and elderly falling in lower socio-economic status (SES), people with pre-existing medical conditions, and residents in areas with weak health infrastructure – mostly in developing countries – are among the most vulnerable populations.

c. Climatic impacts and vulnerability assessment in the water sector

National Water Mission under the National Action Plan on Climate Change (NAPCC*) has been implemented to promote citizen and state water conservation and resource management actions (NWM, 2009*). The shortage is identified to have affected the hydrological well-being of the basins apart from the reduction in per capita water availability. The non-perennial river basins are facing a serious shortage of water resources, and some of the pockets in the Indian region are on the threshold of a very serious groundwater crisis, which needs mitigation both in the fields and in the policy framework of the country.

d. Geospatial technology

Access and analyses of satellite images are gradually becoming a cost-effective input source for flood prediction under various circumstances. Remote sensing, as well as Earth Observation (EO) data from multiple platforms, are providing wide-ranging datasets that are useful for gathering direct information on the Earth's surface, water, and energy fluxes and the creation of spatially distributed parameters appropriate for hydrological budget and modeling.

Committed to application-based and policy-oriented research for the benefit of the end users, the Centre has developed a prototype of irrigation scheduling for Android phones using geospatial technology for Varanasi, which will be extended to other districts in India. Also, a hyperspectral-based crop stage estimator prototype has been developed to better estimate and understand crop stages through the Leaf Area Index, etc.

e. Socio-economic Issues

Climate change has directly or indirectly affected the physical form of nature, society, economy, agriculture, water, and health. This fact necessitates implementing appropriate strategies to strengthen resilience according to the problem of climate change. It is also necessary to divert resources, techniques, and adaptation and mitigation strategies in the appropriate direction. Hence, policymakers must prioritize or designate certain key areas to allocate resources effectively. Climate vulnerability assessment is an important option for identifying priority regions for adaptation and mitigation. It brings together empirical research, regional knowledge, and stakeholder involvement to overarching the aspects of vulnerability assessment.

f. Community-based management

For Climate Services to Society, the Centre under Gramin Krishi Mausam Seva (GKMS) Scheme issue's location and crop-specific weather-based 3-day agromet advisories for the benefit of the farming community of eastern UP region twice a week in collaboration with IMD, ISRO, and Ministry of Agriculture & Farmers Welfare, Govt. of India through different media and messaging services.

*Source:
National Action Plan on Climate Change (NAPCC), Government of India. 2008. Available at https://moef.gov.in/wp-content/uploads/2018/04/Pg0152.pdf (dated 6th of April, 2023).
National Water Mission (NWM) 2009 National Water Mission under National Action Plan on Climate Change, comprehensive Mission Document, Available at the official website: http://wrmin.nic.in

5. Research Achievement Highlights

A. Climate Variability and Change

a. Climate Simulation and Modeling

Human activity contributes to climate change by causing modifications in the levels of greenhouse gases, cloudiness, and aerosols in the Earth's atmosphere. Extremes of climate are a key expression of climate variability, and this assessment includes new data that permit improved insights into the changes in extreme events including heat waves, floods, droughts, cold waves, cyclones, etc. A number of seasonal and long-term (for past and future) analyses can be described through a pattern of climate variability.

i. Empirical findings

Singh & Mall, 2023 evaluated the future **heat wave projections** that have been quantified in terms of changes in frequency, intensity, and duration over India for the mid-term (2041-2060) and long-term period (2081-2099) under **RCP 4.5 and RCP 8.5 scenario**. Future projections showed a four-to-seven-fold increase in heatwave frequency with an average of 20 events/yr to 35 events/yr for the **mid-term and long-term future** under the RCP 4.5 scenario, and five-to-ten-fold increase under RCP 8.5 scenario with 25 events/yr to 70 events/yr. Similarly, the **maximum intensity** was projected to rise by 54°C to 59°C in the long-term future for RCP 4.5 and RCP 8.5 scenarios, and duration would rise to 18 to 22 days and 22 days to 51 days for the same period. Northwestern, central, and south-central India recorded the highest heat wave events, emerging as future **heat wave hotspots** over India (Fig 1).

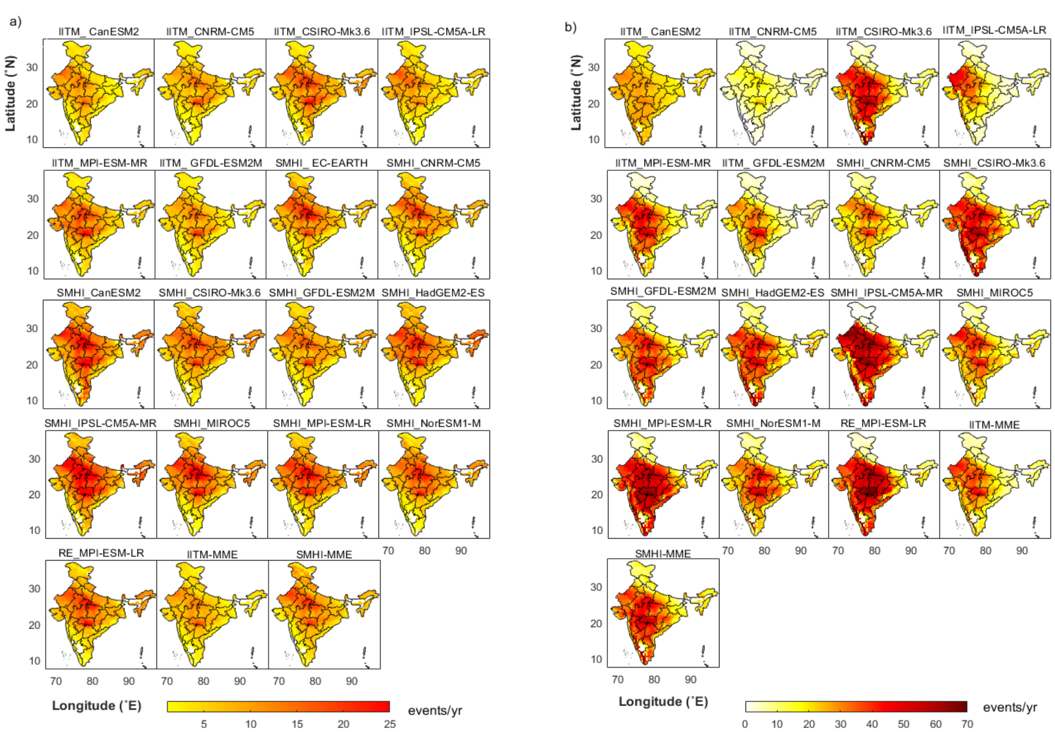


Fig. 1 Spatial distribution of CORDEX-RCM simulated average number of heat wave events/year using during Mar- Jun for a) mid-term (2041-2060) and b) long-term (2081-2099) future under RCP 8.5 scenario (Singh & Mall, 2023).

Bhatla et al., 2023 found the relationship between **Indian summer monsoon (ISM) rainfall** and the **Atlantic Multidecadal Oscillation (AMO)** on a monthly and seasonal basis with respect to the quasi-biennial oscillation (QBO) during the period 1953–2016 (Fig. 2 & 3). The study showed a direct positive association between ISM rainfall and the AMO for the full-time series during the pre-monsoon (March-May) and winter (January-February) seasons, primarily through a **Rossby wave** train from the North Atlantic across South Asia. This strengthens the ISM by increasing the temperature gradient between the Indian Ocean and Eurasia which reinforces the Indian summer monsoon. The strongest association was during the pre-monsoon season and especially during April. (Bhatla et al., 2023).

Verma et al., 2022 evaluated the daily modulating behaviors of Indian summer monsoon rainfall (ISMR) over eight important sub-zones of India (Fig. 4). Moderate to severe drought variability portrays a diversity over regional scale viz. **Northwest India, North central India, Eastern Ghats** of the Southern peninsular region, and Northeast India while the occurrence of moderate to severe flood is dominated towards the Himalaya region (26°N-35°N; 70°E-80°E), Western peninsular region and Western Ghats (Verma et al., 2022).

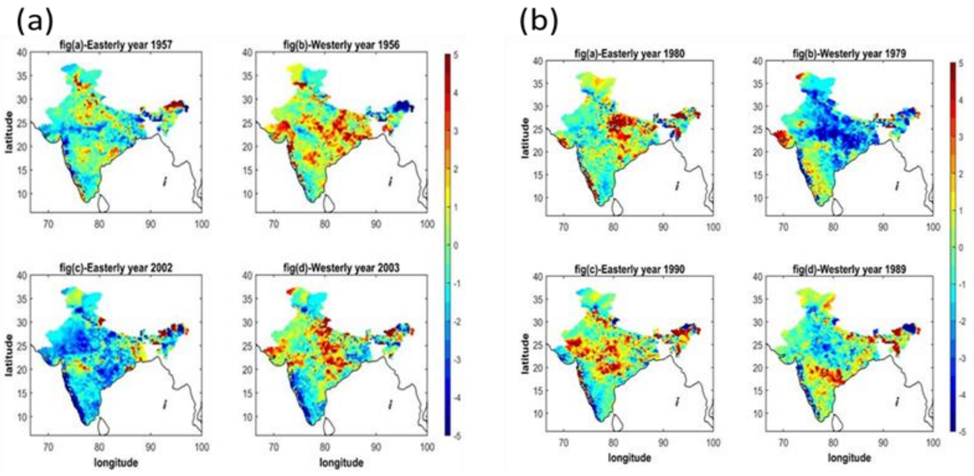


Fig. 2 (a) Spatial plot of mean JJAS rainfall anomaly for westerly years 1956 and 2003 and easterly years 1957 and 2002 of JFM during the positive cycle of the AMO. (b) Spatial plot of mean JJAS rainfall anomaly for westerly years 1979 and 1989 and easterly years 1980 and 1990 of JFM during the negative cycle of the AMO (Bhatla et al., 2023).

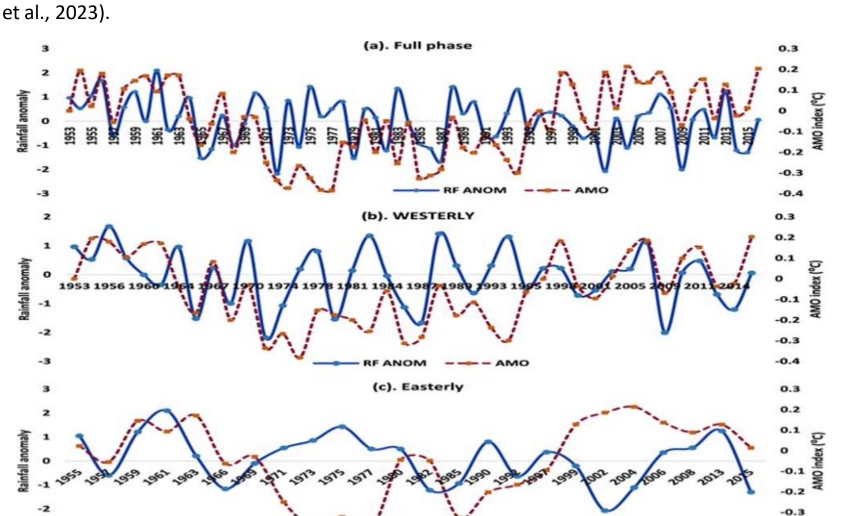


Fig. 3 Time series of the standardized all-India summer monsoon rainfall anomalies (blue line) and AMO anomalies (orange line) during JFM for the period 1953–2016: (a) full time series, (b) QBO westerly phase, and (c) QBO easterly phase.

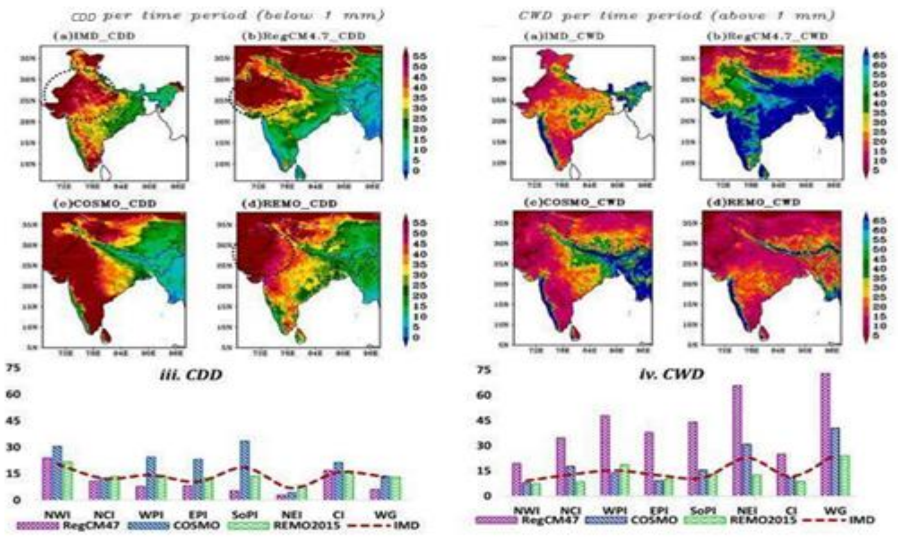


Fig. 4 Climatological spatial-temporal distribution of mean consecutive dry days (CDDs) and consecutive wet days (CWDs) observed by (a) IMD and simulated by (b)RegCM47, (c) COSMO and (d) REMO Climate RCM for the period 1981–2015 (Verma et al., 2022).

ii. Global/ Regional Climate model findings

Bhatla et al., 2020 evaluated the performance of **Conformal-Cubic Atmospheric Model (CCAM)** simulations downscaled from six global climate models (GCMs) and Max Plank's Regional Model (REMO2009 (MPI)) obtained from the South-Asia Coordinated Regional Climate Downscaling Experiment (CORDEX) for analyzing the summer monsoon maximum temperature (Tmax) over different **Agro-Climatic Zones (ACZs) in India** (Fig. 5 & 6). Two bias correction methods, i.e., linear scaling (LS) and distribution mapping (DM), had been used to correct RCM output bias. The model performance using **DM correction** was better than the LS method. The model simulations were compared with the two sets of observed data obtained from the India Meteorology Department (IMD) and Climate Research Unit (CRU) for the period from 1981 to 2005 (Bhatla et al., 2020). It was evident that distributions of all uncorrected or raw model simulations were quite different from the observation. Concurrently, both the bias correction methods could be able to improve the RCM model skill when compared with the IMD data; however, the improvement was lesser when compared with the IMD than the CRU data. All the CCAM models were overestimating the observation (**IMD & CRU**) over the **West Himalayan region and Eastern Himalayan** region except REMO. The CCAM (GFDL) and REMO2009 (MPI) were the best-performing models over India and its ACZ after bias correction (DM).

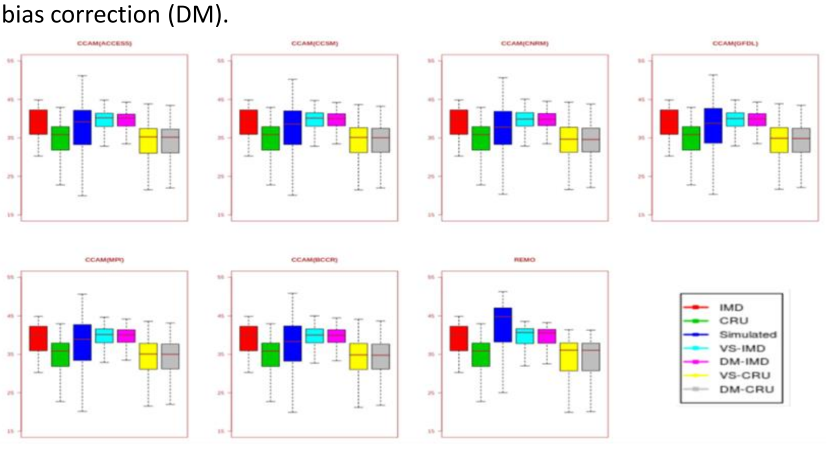


Fig. 5 The boxplot of observed (IMD and CRU), model-simulated (raw), and bias-corrected model simulation of seasonal maximum temperature (unit in °C) using VS and DM method computed against IMD and CRU, respectively, over India during 1981–2005 (Bhatla et al., 2020).

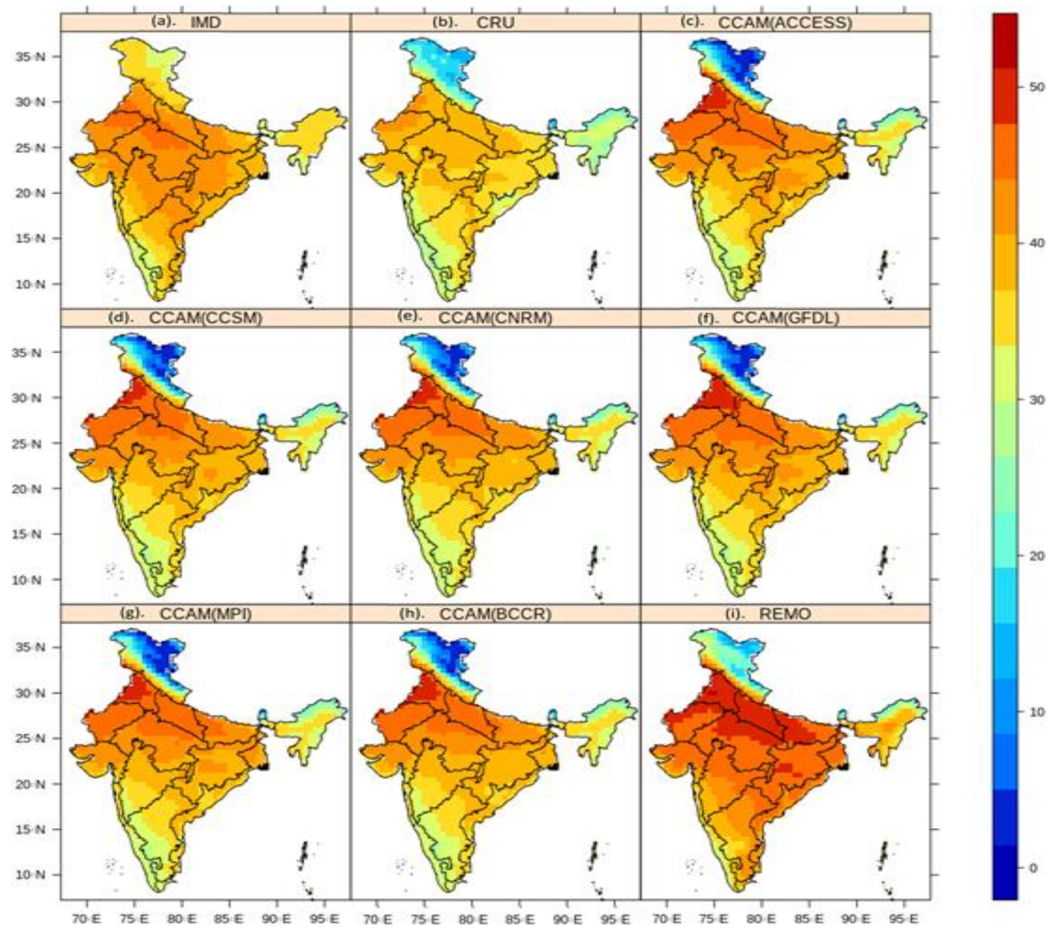


Fig. 6 Observed (IMD & CRU) and model simulated seasonal maximum temperature (Tmax) for summer monsoon season.

Pant et al., 2022 revealed the efficacy of the **regional climate model RegCM4** in depicting the onset**,** active, and break phases of the Indian summer monsoon (ISM) used for the period 1981-2008 (Fig. 7 & 8). A relationship between the sea surface temperature (SST) changes over the **Niño-3.4 region** and the ISM over all India and the **monsoon core region (MCR)** was established where a strong dependency in the rainfall variation over the MCR with the SST variation was observed than all India rainfall. The model performed better in simulating the onset and break phases (dry days) than the active phases (Pant et al., 2022). The limited skill of the RegCM4 model in representing the active phase was due to the model simulated low temperature and weak pressure gradient over the MCR. This prevents convection and gives rise to small and weak active phases over the region.

Bhatla et al., 2020 evaluated the performance and validation of the **regional climate model (RegCM-4.3)** simulation of Indian summer monsoon rainfall (ISMR) over the different homogeneous regions of India (Fig. 9). The **Grell CPSs** simulation of monsoon rainfall was reasonably good over northwest India. Over north-central India, predictability/simulation of **Kuo and Grell** were the best performing parameterize scheme of RegCM-4.3. The western and eastern peninsular parts of India's simulation of **Emanuel and Mix99** schemes were better, respectively. The southern peninsular region and Western Ghats showed the **Tiedtke scheme** as the best-simulated scheme of RegCM-4.3 (Bhatla et al., 2020). The overall diversification of simulation, depending upon the topographical difference of the Indian subcontinent, causes the regionalized difference in simulating monsoon rainfall over the Indian subcontinent.

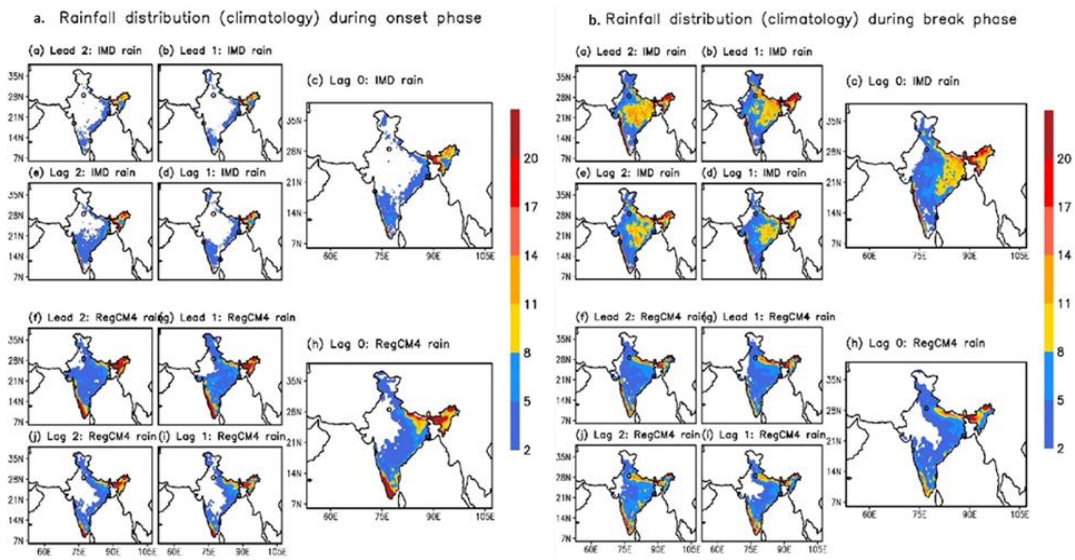


Fig. 7 Spatial distribution of IMD (a-e) and RegCM simulated (f-j) rainfall climatology (mm/day) during a) onset phase b) break phase (Pant et al., 2022).

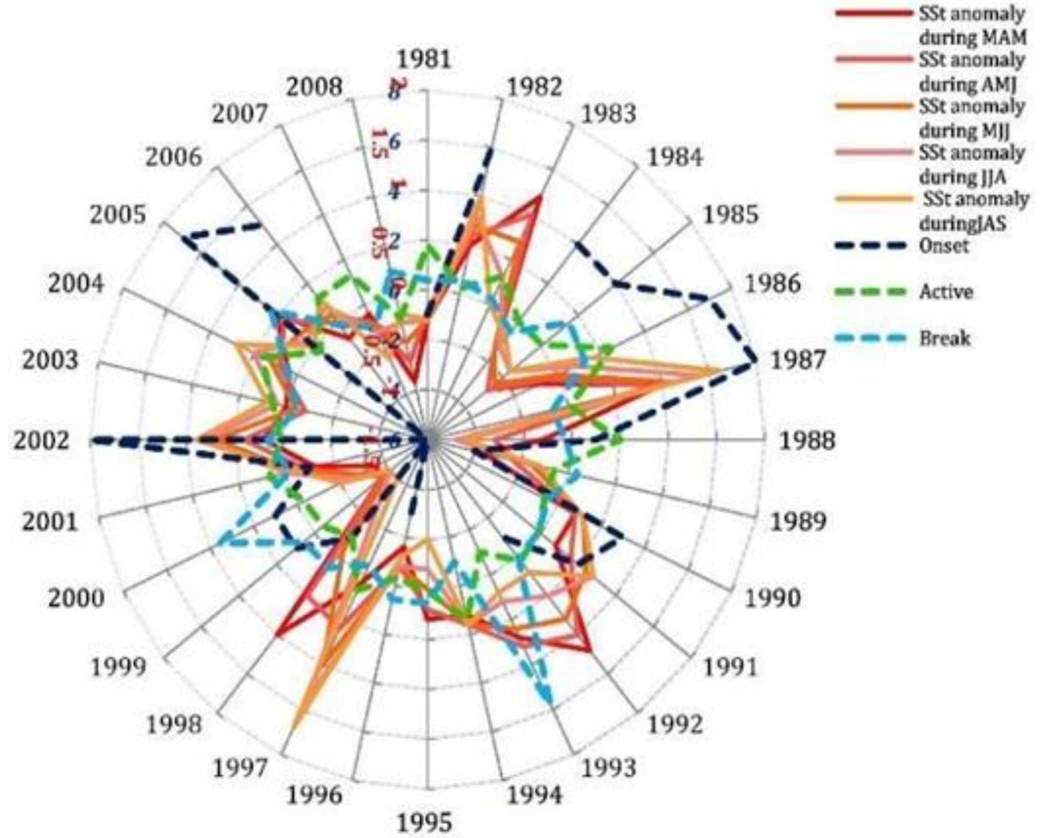


Fig. 8 Dependency of RegCM4 performance during different monsoon phases i.e., onset, active and break on SST anomaly over Niño-3.4 region (Pant et al., 2022).

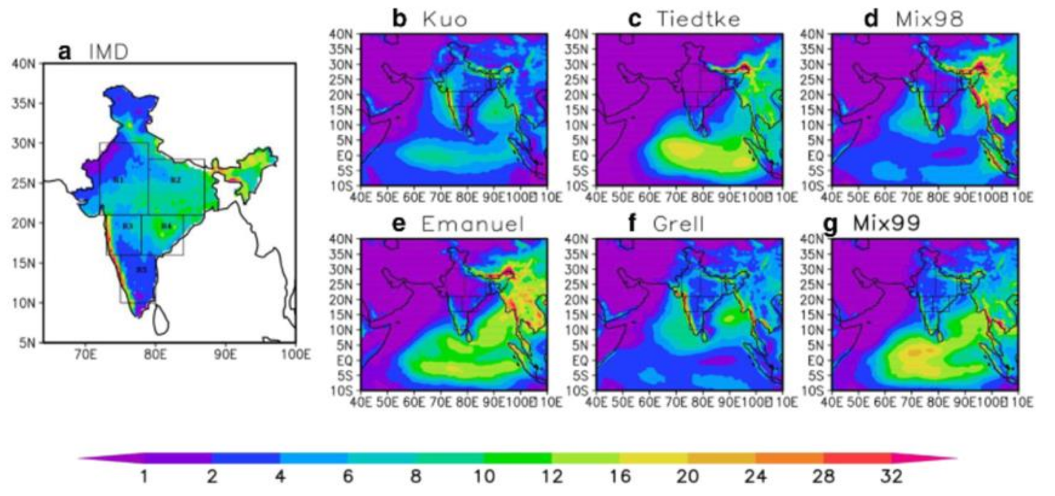


Fig. 9 Indian summer monsoon rainfall (mm/day) over India and its homogeneous regions during period 1986-2010.

Verma et al., 2021 analyzed the **sensitivity experiments** in selecting the best convective **parameterized schemes** in simulating the surface air temperature during the summer monsoon season (June–September) over India and its five sub-regions such as Northwest India, Northcentral India, West Peninsular India, Eastern Peninsular India, and Southern Peninsular India (Fig 10). The model showed the tendency of overestimation of surface air temperature mainly in four **cumulus parameterization schemes (CPSs)**, that is, Tiedtke, Emanuel, Mix98, and Mix99 of RegCM4.3 during the JJAS, where Grell and Kuo CPSs showed better agreement with the IMD data (Verma et al., 2021).

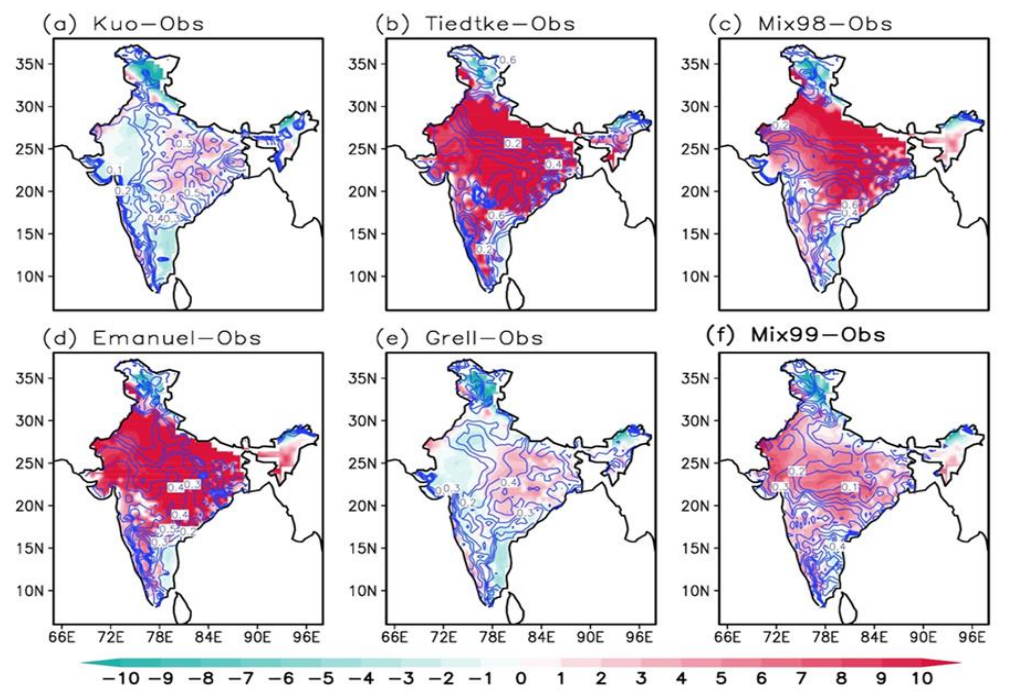


Fig. 10 The spatial mean bias (shaded) and correlation coefficient (contour) of surface air temperature (°C) climatology in RegCM4.3 simulations from the observation (obs) (IMD 0.5˚ x 0.5˚ gridded dataset) (a) Kuo-obs, (b) Tiedtke-obs, (c) Mix98-obs, (d) Emanuel-obs, (e) Grell-obs, and (f) Mix99-obs consider for the 25-year time period (1986-2010) during the monsoon season (Verma et al., 2021).

Pant et al., 2022 explored the performance of a **regional climate model (RegCM4.6)** in simulating an **extreme rainfall** event over Mumbai in India (Fig. 11). Various sensitivity experiments were performed to simulate extreme rainfall events with three core **Cumulus Parameterization Schemes** (CPSs), namely Grell, Emanuel, and Tiedtke along with their six different combinations. The CPSs EL_GO performed well in simulating extreme rainfall events. The spatiotemporal distribution of rainfall and associated thermodynamic and dynamics aspects were captured satisfactorily (Pant et al., 2022).

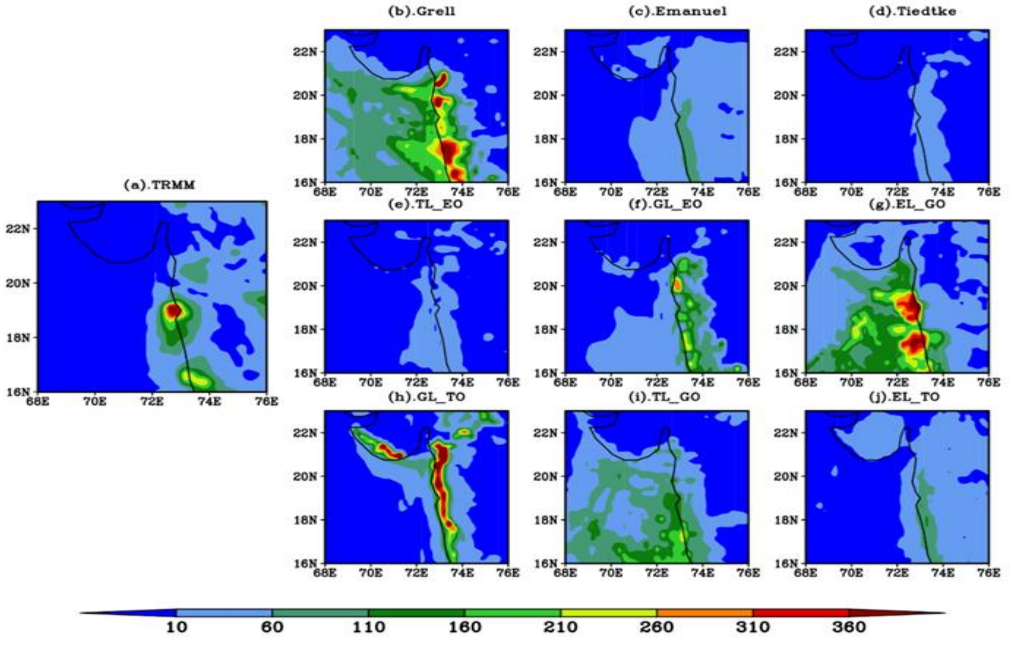


Fig. 11 Spatiotemporal distribution of accumulated rainfall (mm) within 24 hours on 26th July 2005 (160N-230N & 680E-760E) (Pant et al., 2022).

Ghosh et al., 2023 examined the ability of the **regional atmospheric model, RegCM4.7,** with 25 km resolution, to replicate the key features of Northward propagating summer **monsoon intra-seasonal oscillations (MISOs)** in the Indian Ocean region (Fig 12). The model was forced distantly at the boundaries by atmospheric observations (ERA-Interim, 0.75˚) and forced locally by observed sea-surface temperature (SST) over the period of 1979–2016. The MISO exhibited spatial structures and northward propagation characteristics broadly similar to observed MISO when confined to the 25–90-day period band (Ghosh et al., 2023).

Jaiswal et al., 2022 studied the **Bias-correction** methods namely **linear scaling** (SCL), **local intensity scaling** (LOCI), and **empirical quantile mapping** (EQM) (Fig. 13) to correct monsoon rainfall simulations from 7 RCMs over different **agro-climatic zones (ACZs)** in India from 1970 to 2005. The corrected rainfall data were compared to the observations obtained from India Meteorological Department. The SCL method was found to be more effective, followed by EQM, while LOCI was less effective in correcting errors (Jaiswal et al., 2022).

Chaturvedi et al. used **Deep-learning-based methods**, namely **Long Short-Term Memory Network (LSTM), Deep Neural Network (DNN), and Recurrent Neural Network (RNN)** for downscaling of **CMIP6 NorESM2-MM** (1.25^o x 1.25^o resolution) **Global Climate Model (GCM)** maximum temperature (Tmax) at a regional scale of 0.5^o x 0.5^o spatial resolution for the period 1991-2010 over the IGP (Fig. 14). The LSTM method was found to perform better than DNN and RNN in downscaling **GCM dataset** when evaluated against observed maximum temperature data from India Meteorological Department (IMD) in terms of RMSE (0.9 to 2.4), MAE (0 to 1), R^2 (0.98) along with spatiotemporal variability (Chaturvedi et al., Under Review).

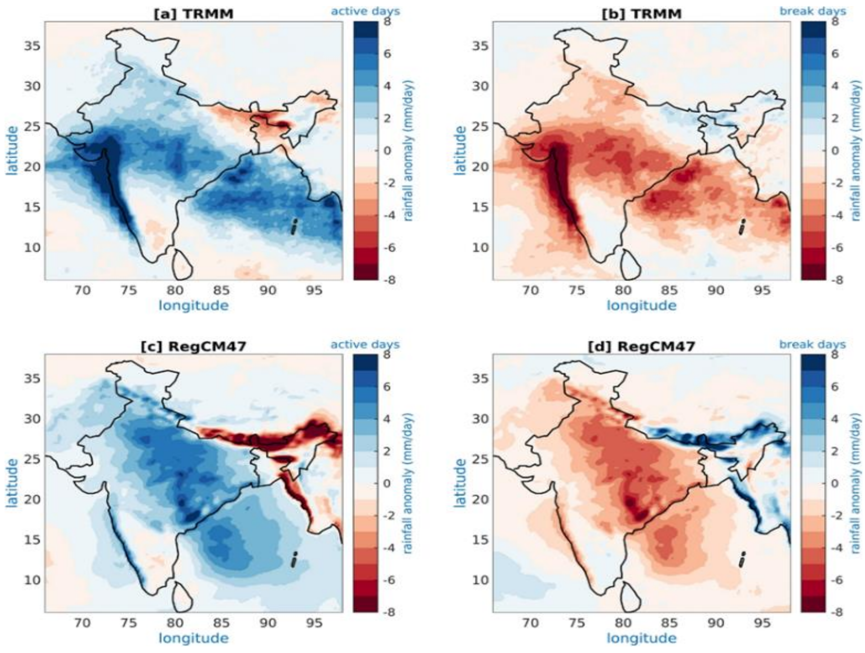


Fig. 12 Spatial patterns of active and break phases of the summer monsoon in TRMM observation (a, b) and RegCM4.7 simulations (c, d) using 25–90 days filtered rainfall. The positive anomalies (blue) represent wet conditions (active phase) and the negative anomalies (red) represent the dry conditions (break phase) during the MISO (Ghosh et al., 2023).

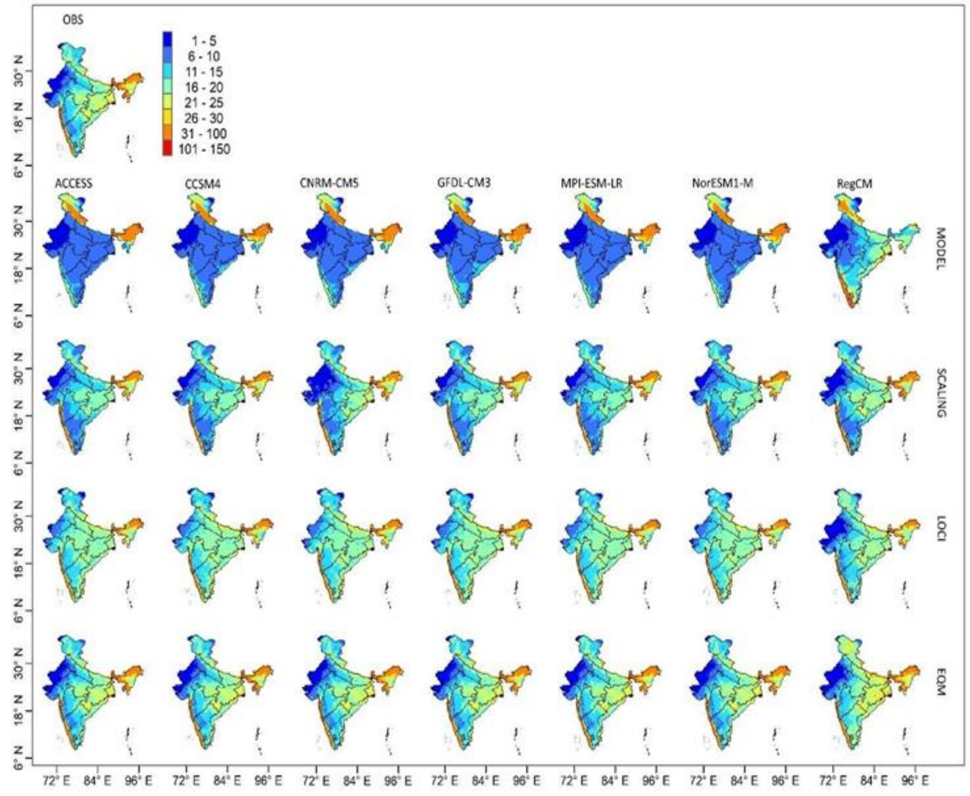


Fig. 13 Rainfall distribution at 95th percentile for period (1970-2005) from IMD observed (top row with legend showing rainfall at 95th percentile), uncorrected (second row) and subsequent row with bias corrected by method (Scaling, LOCI & EQM) (Jaiswal et al., 2022).

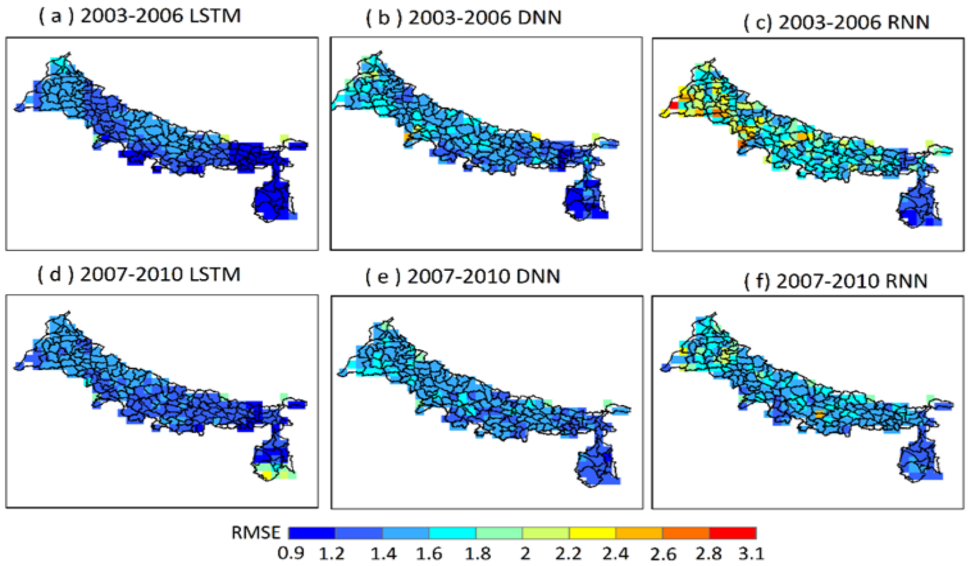


Fig. 14 Distribution maps of RMSEs (Root mean square error) for the downscaled daily maximum temperature based on the LSTM, DNN and RNN methods of Indo-Gangetic plain (India) for the calibration set (2003-2006; upper row) and validation set (2007-2010; lower row). The model is trained from observed data (period 1991-2002) (Chaturvedi et al., Under Review).

b. Extreme Weather Events

Singh et al., 2021 analyzed that **Heat waves** have raised public and scientific interest in exploring the potential adverse effects of climate-related events on human health. Long-term climatological trends of **Heat Wave (HW) and Severe Heat Wave (SHW**) events were analyzed from March-July for the period 1951-2016 over different meteorological subdivisions of India. It showed a significant increasing trend in three prominent heat wave-prone regions and found a spatiotemporal shift in the occurrence of HW events with a significant increasing trend in three prominent heat wave prone regions, i.e., north-western, central, and south-central India, the highest being in West Madhya Pradesh (0.80 events/year). A significant decreasing trend was observed over an eastern region that was Gangetic West Bengal (−0.13 events/year) (Fig 15a). SHW events showed a **southward expansion** and a spatial surge during the last two decades (Fig 15b) (Singh et al., 2021).

Furthermore, Singh et al., 2021 analyzed the performance of eight **ensemble dynamical downscaled models** from **CORDEX-SA** in simulating HW over India (March–June) from 1971 to 2005 (Fig 16). The analysis shows that both **RCMs** were capable of successfully simulating heat wave events in the northwestern, central, and south-central regions where the events are most pronounced according to the observation (IMD and IITM criteria). LMDZ4 and GFDL-ESM2M (RegCM 4.1.1 ensemble) were the best-performing models (ensemble) in reproducing the heat wave frequency and spatial variability (Singh et al., 2021).

Mall et al., 2021 investigated the seasonal, annual, and decadal changes in the spatiotemporal trend in DTR and air temperatures (Tmax and Tmin) during 1951–2016 and solar radiation (Srad) during 1984–2016 over 14 different agro-climatic zones (ACZs) in India. The changes in the DTR trend between two time periods: 1951–2016 and 1991–2016 (recent period) are also evaluated. A decreasing trend in **Diurnal temperature (DTR)** (- 0.02°C /decade) was observed primarily because of the relatively faster increase in Tmin (0.21 °C/decade) relative to the Tmax (0.18 °C /decade) and the Srad (0.20 °C/decade) (Fig 17). In recent decades, a significant **declining trend in DTR** was noted in parts of Gangetic Plain, WD, and CPH (Mall et al., 2021). The study observed an overall increasing trend of DTR during 1951–2016, and a decreasing trend during the recent period 1991–2016 across the different agro-climatic zones (Fig 18).

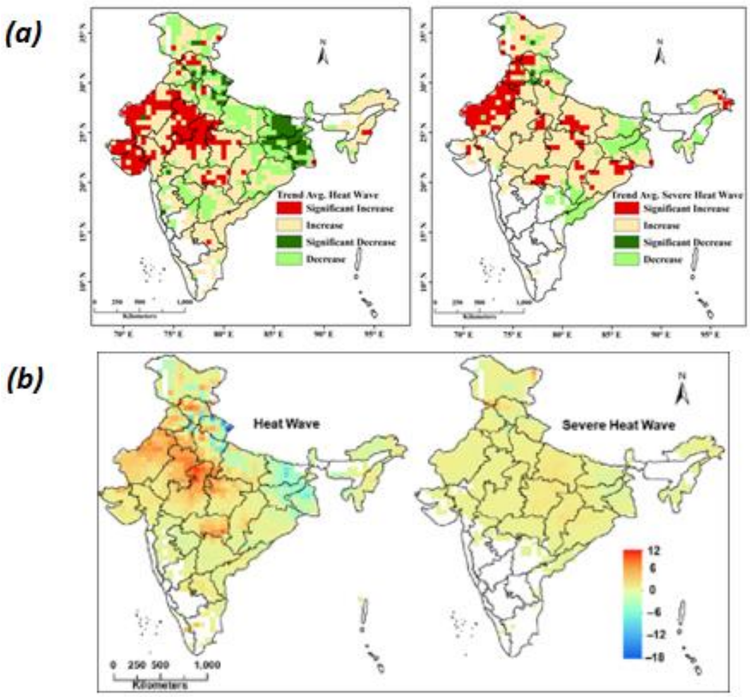


Fig.15 (a) Long term trend in Seasonal Heat Wave and Severe Heat Wave events during 1951-2016 (March-July), (b) Difference in heat wave and severe heat wave events from 1951–1980 to 1981–2016 (March–July) (Singh et al., 2021).

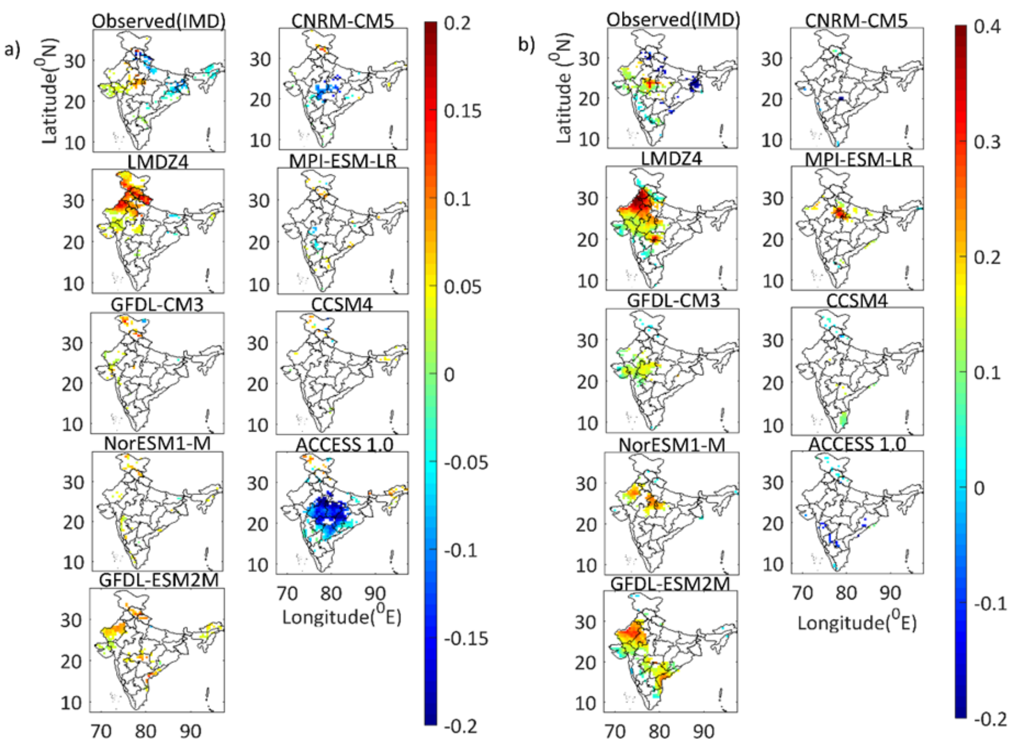


Fig. 16 Trend of observed and CORDEX-RCM simulated total number of heat wave events/year using (a) IMD criteria and (b) IITM criteria during Mar-Jun (1971- 2005). The trends which are statistically significant at the 10% significance level are only shown (Singh et al., 2021).

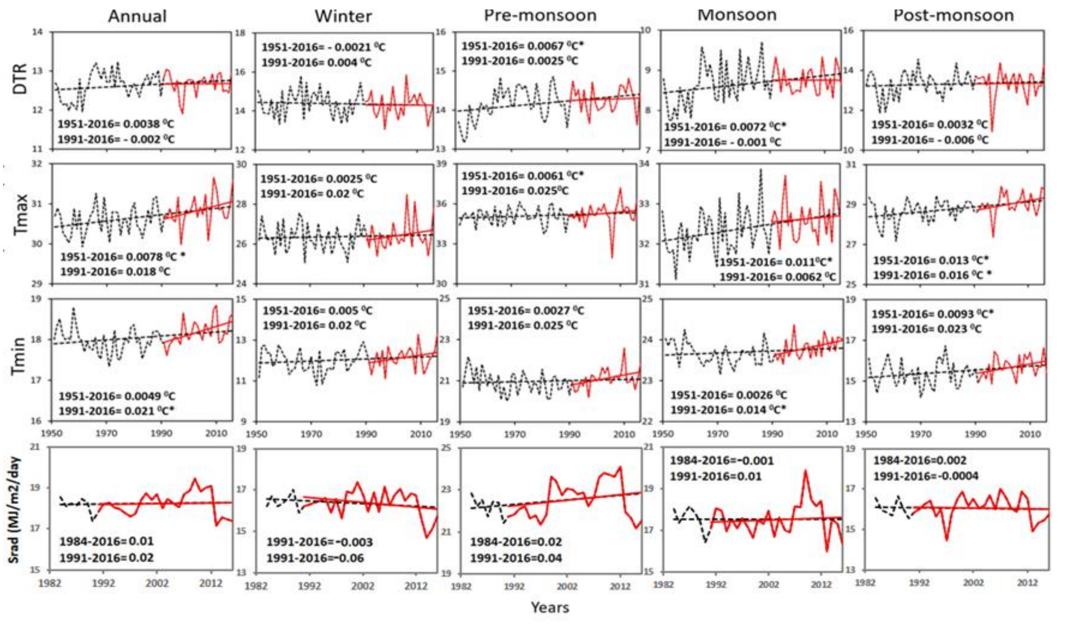


Fig. 17 Annual and seasonal variation of spatially averaged DTR, Tmax, Tmin, and Srad over India with a linear time trend (Mall et al., 2021).

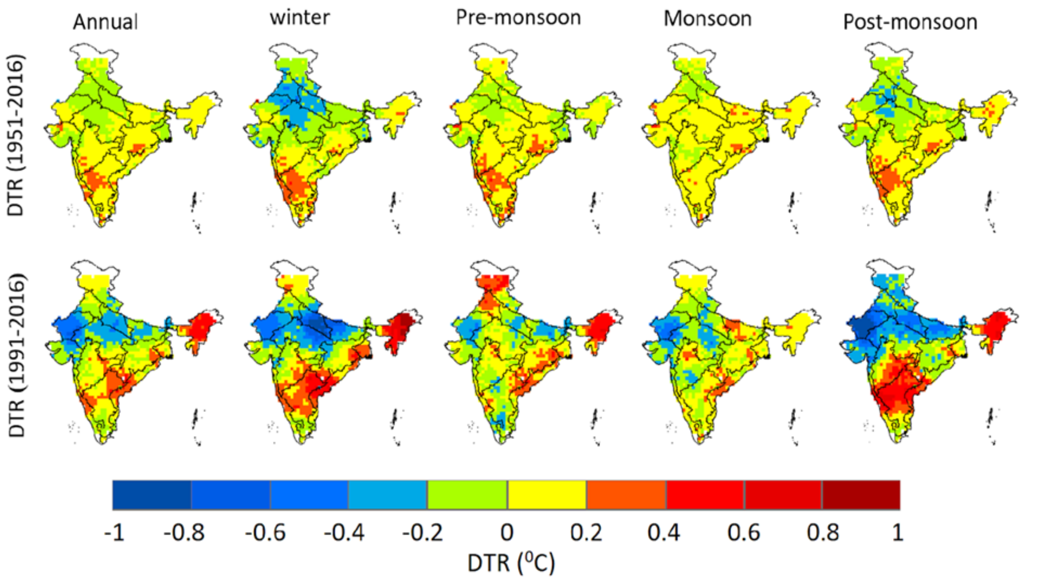


Fig. 18 Decadal trends of DTR over the different Agro-climatic zones of India during the period 1951-2016 and 1991-2016 (Mall et al., 2021).

Singh et al., 2023 assessed the probable future **spatiotemporal changes** in the **Tmax, Tmin, and DTR** and their **long-term warming trend** from 2006-2099 under two **RCPs scenarios** over different Agro-climatic zones of India (Fig. 19). In future projections, a reduction in DTR (-0.01 to -0.20 °C/ decade) was reported partly, linked to the substantial increase in Tmin (0.20 to 0.71 °C/ decade) than Tmax (0.31 to 0.60 °C/ decade), that was stronger in far twenty-first-century future under **RCP8.5** (Fig 19). The decline in DTR was consistent over northern India (up to 3 °C) surrounding the Indo-Gangetic Plain (IGP), western dry region (WD), and part of central India, with the highest decline observed in winter and pre-monsoon seasons (Singh et al., 2023). However, a decline in DTR was also anticipated over the plateau, coastal, and eastern Himalayas region. Change in land use and land cover (LULC) pattern also complimented the findings on the decline in DTR.

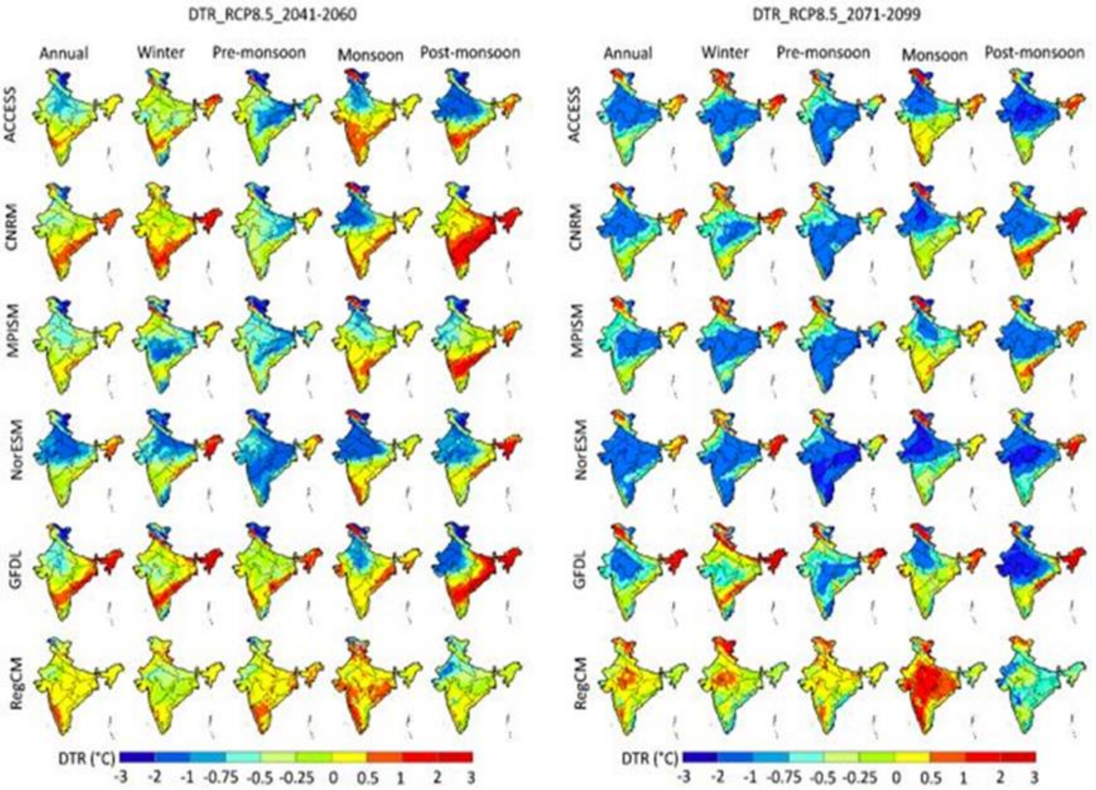


Fig. 19 Change in annual and seasonal DTR (°C) under RCP8.5 mid-century (2041–2060) and far-century (2071–2099) period for different model experiments (RCMs) (Singh et al., 2023).

Kumar et al., 2021 explored a possible connection **of quasi-resonant amplification (QRA)** to the recent (August 2018) **Kerala heavy rains**. It resulted in severe floods and claimed more than 400 mortalities (Fig. 21 & 22). June month over India witnessed a great delay in **ART (Atmospheric Residence Times)** in near, mid, and far-future scenarios of **RCP 4.5 and 8.5** and this delay was concentrated in the regions of the Western Ghats and the **core monsoon region** of India. Remarkable delay in residence times over India during June was shown to have an association with QRA evidenced by the higher magnitudes of amplitudes at wave numbers six and seven from the 19 **global climate models** of **CMIP5** under the **RCP4.5 and RCP8.5** scenarios (Kumar et al., 2021).

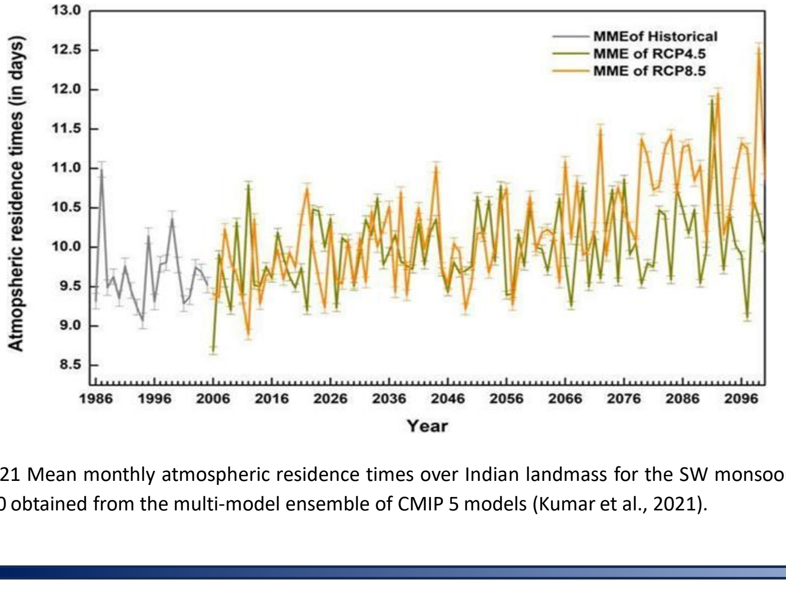


Fig. 21 Mean monthly atmospheric residence times over Indian landmass for the SW monsoon from 1986 to 2100 obtained from the multi-model ensemble of CMIP 5 models (Kumar et al., 2021).

Maurya et al., 2023 analyzed the **epochal variation** of basic **meteorological parameters** and **surface energy fluxes** in monsoonal drought and flood episodes from 1961 to 2020 (Fig. 23 & 24). The southern Arabian Sea (AS), southern peninsular India, and the Bay of Bengal were found to experience a decrease in rainfall during the past three decades of monsoonal drought events while an increase in rainfall over the **Indian Ocean** (IO) has been observed by a change in the amount of cloud cover and surface energy fluxes (Maurya et al., 2023a).

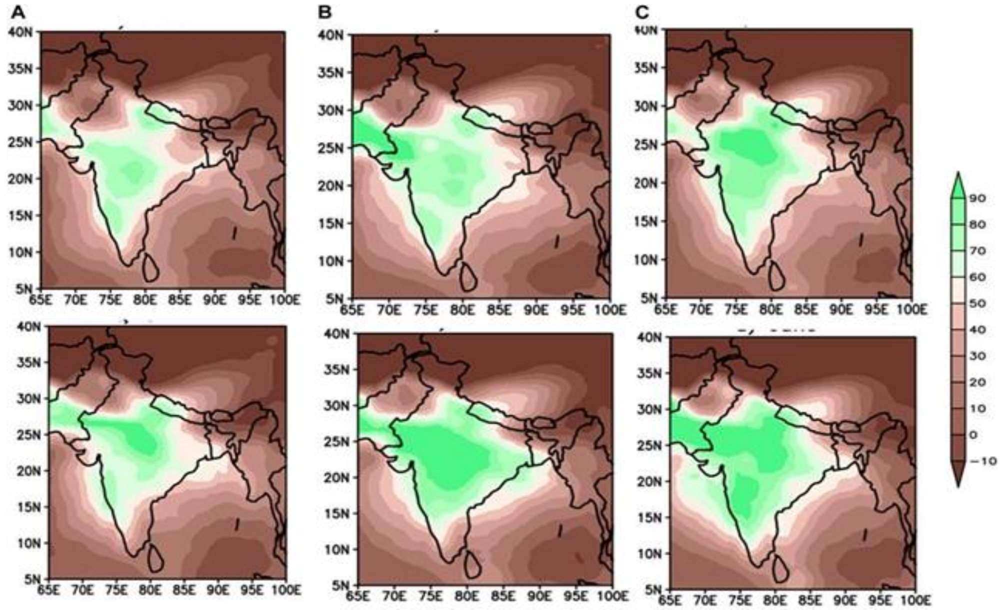


Fig. 22 Anomalies in ART for June over India for the periods (A) 2016–2035, (B) 2046–2065 and (C) 2080–2099 under RCP 4.5 (top panel) and 8.5 (bottom panel) emission scenarios (Kumar et al., 2021).

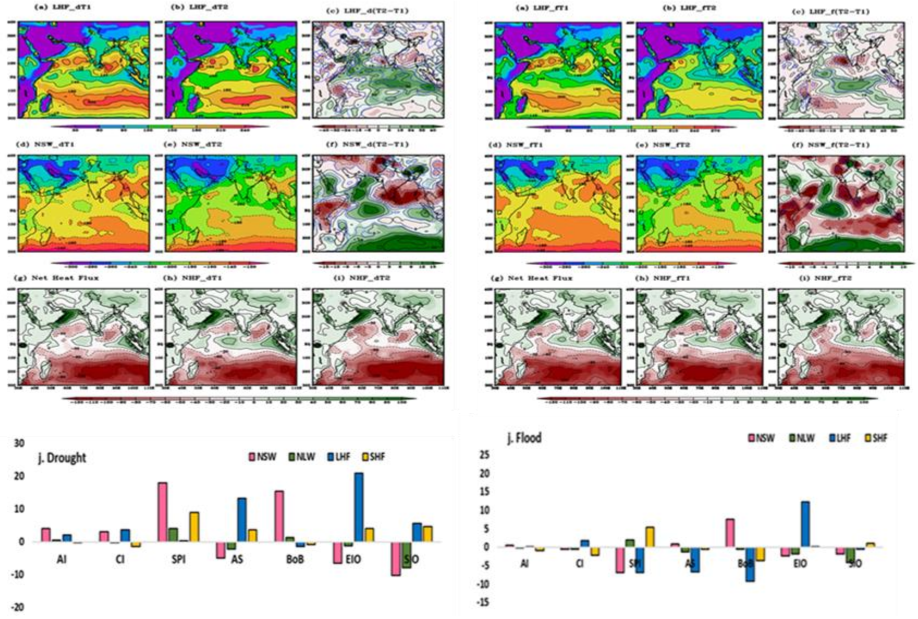


Fig. 23 & 24(a-i) Composite distribution of surface heat fluxes for all India drought and flood events using NCEP reanalysis data during June-September (JJAS) from 1961 to 2020, for drought (flood) events of latent heat flux (LHF; W/m2), net incoming Shortwave radiation (NSWRS; W/m2) and net heat flux (NHF; W/m2), (g) average NHF of (h) past and (i) recent three decades all monsoonal drought events (j) temporal three decades departure of land surface fluxes over selected regions during drought (flood) events (Maurya et al., 2023).

Pant et al., 2023 measured twelve thresholds-based **climate indices** to investigate the characteristics of **rainfall extremes** during a three-time window: 1986–2005 (historical), 2041–2060 (near future), and 2080–2099 (far future). The **RegCM4** projections suggested a substantial decline in mean **Indian summer monsoon rainfall (ISMR)** and wet days (rainfall ≥ 1 mm; 7%–14%) over IGP under high-emission **RCP8.5** scenarios (Fig. 24 & 25). The contribution of 90th and 99th percentile days and total rainfall on wet days appeared to be enhanced in the future by 14%–35%, implying the increase and intensification in rainfall extremes over IGP by the end of the 21st century. Further, the decline in ISMR and negligible changes in annual rainfall over IGP suggest the possible shift of the monsoon regime during the year's later months in a warming climate (Pant et al., 2023).

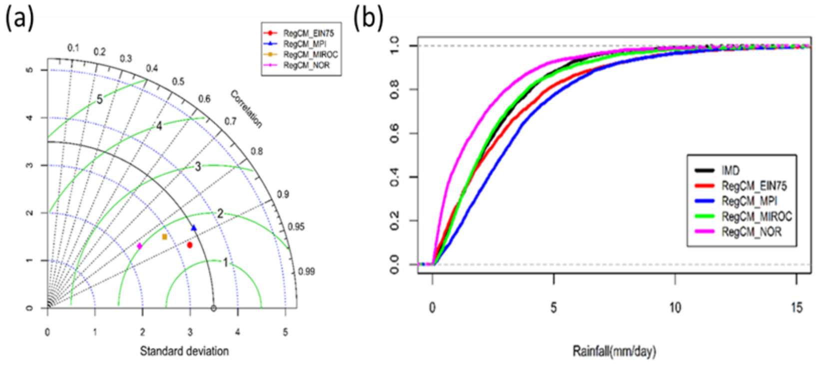


Fig. 24(a) Taylor diagram for RegCM4 simulated daily mean rainfall with four different forcings. (b) The ECDF of observed and RegCM4 simulated daily ISM rainfall (mm/day) during the historical period (1986–2005) (Pant et al., 2023).

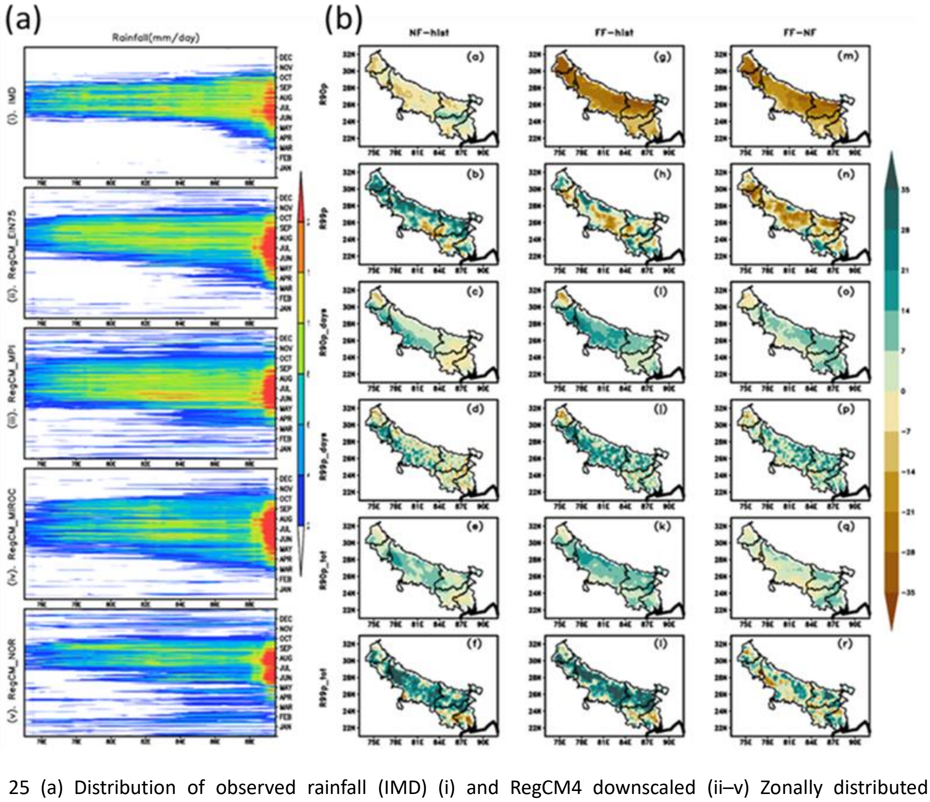


Fig. 25 (a) Distribution of observed rainfall (IMD) (i) and RegCM4 downscaled (ii–v) Zonally distributed meridional mean (over 22°N–32°N) rainfall pattern (mm/day) with four different Global Climate Model forcing over Indo-Gangetic Plain during the historical period 1986 – 2005. (b) The spatial distribution of RegCM4 Projected relative changes (in %) under RCP8.5 scenario in various climate indices during near (NF-hist) and far future (FF-hist) as compared to the historical period and during far future as compared to the near future (FF-NF) (Pant et al., 2023).

Chaubey et al., 2023 examined the **extreme weather** events over the **Teesta River Basin** (TRB). An increasing trend was noticed in the observed rainfall frequency in the 80s and 90s of the 20th century and the current decade of the 21st century over the River Basin. The 5-days projected maximum precipitation showed some flood events in the mid-21st century (2024-2031) (Fig. 26).

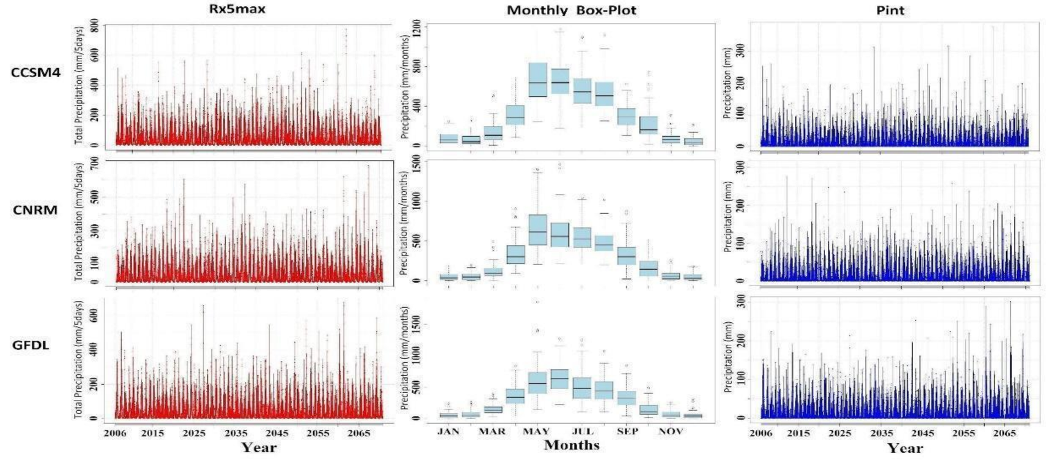


Fig. 26 Temporal variation in projected model outputs (2006-2070) for CCSM4, CNRM-CM5, and GFDL-CM3 scenarios at different extreme precipitation indices as greatest 5-day total rainfall per year (Rx5max) and simple daily intensity (rain per rain day ≥1 mm) (Pint) with boxplot of monthly accumulated rainfall for extreme indices (Chaubey et al., 2023).

Moreover, a significant rise in the **extremes of precipitation** events was observed over the **Teesta River Basin** (TRB), **Sikkim**, and **India** during the first half of the 21st century. In addition, accumulated precipitation will increase by five days in the future, while the precipitation maxima will increase from 200 to 300 mm/day at the 2-year, 50-year, and 100-year return periods. Finally, it is found that during the middle of the 21st century, the 23.37% number of events will increase over the TRB at the 90th percentile (Fig. 27).

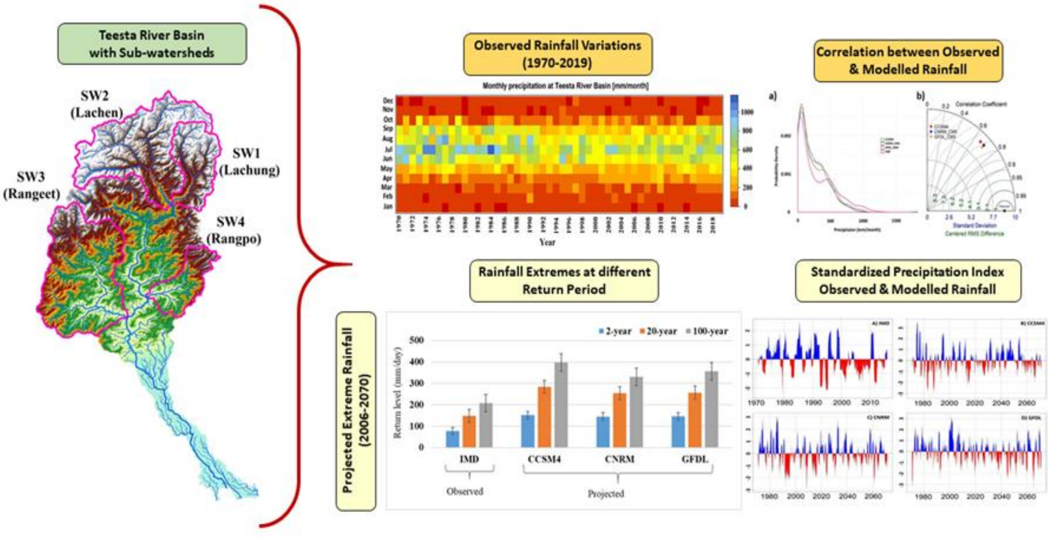


Fig. 27 Projected Change in extremes of precipitation events over the Teesta River Basin (TRB) (Chaubey et al., 2023).

An increase in **extreme events** (15% - 58.74%) was observed over the western ghats in the west-flowing river basins of IRBs in the last 119 years (Chaubey et al. 2022). The study revealed a **shift in extreme rainfall events** over the western river basins of the central India homogeneous climate region (Fig. 28).

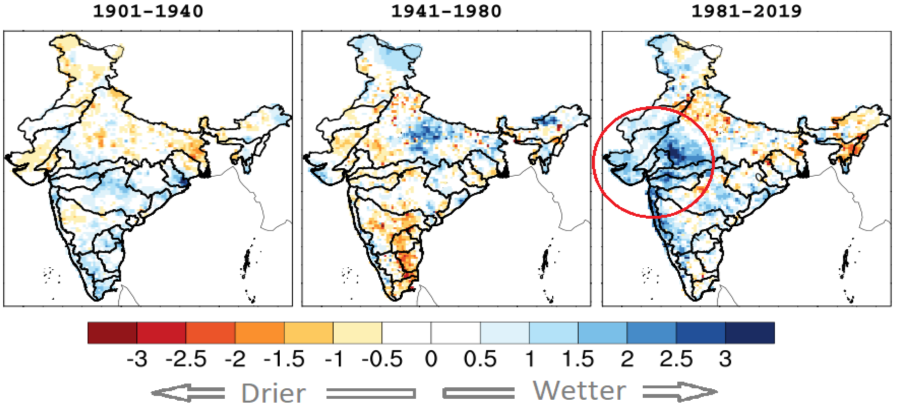


Fig. 28 Calculated standardized precipitation indices (SPI) showing the changes in extreme rainfall over the Indian River Basin during 20th and 21st century (Chaubey et al., 2022a).

Chaubey et al., 2021 analyzed the **Extreme weather events** over the **Gandak River Basin** (GRB). The extreme rainfall in the middle part of the basin received more than 700 mm/month and 2000 mm/year rainfall in monsoon seasons (JJAS) over the entire study area, which creates a flood situation every year over the downward part of the basin in India (Chaubey et al., 2021) (Fig. 29).

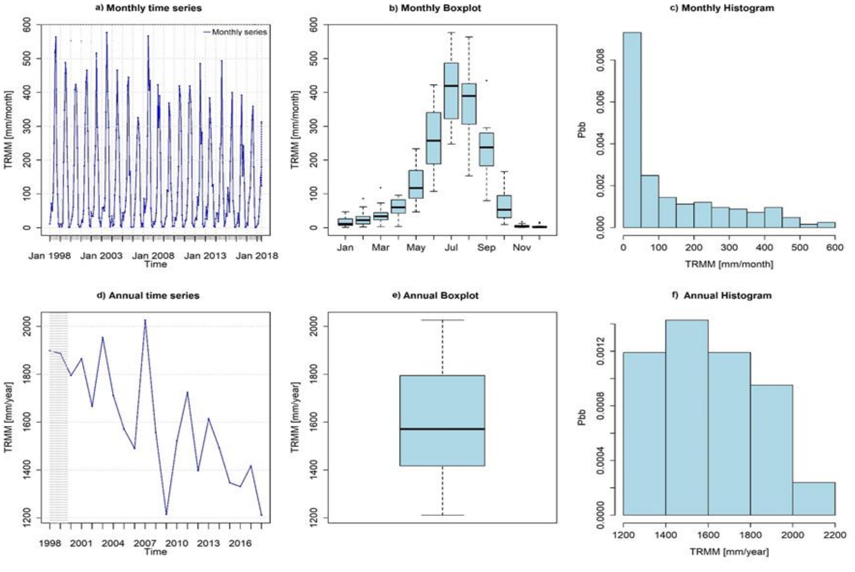


Fig. 29 Seasonal rainfall pattern of the Gandak River Basin (Chaubey et al., 2021).

Nagalapalli et al., 2019 performed an assessment of **flood events** over the **Vaigai river basin** using meteorological and model datasets, i.e., **IMD, CRU, CCSM4** (Nagalapalli et al., 2019). According to **CCSM4 data**, it was found that the years 2008, 2021, 2038 may receive a high amount of rainfall which may result in a flood. Apart from that, there were years that may also experience low rainfall conditions (2028, 2033, and 2036).

Pandey et al., 2020 analyzed a comprehensive evaluation of multi-satellite precipitation products against ground-measured **Indian Meteorological Department (IMD)** precipitation data to estimate and forecast the meteorological drought in the **Bundelkhand region** of Central India. The high-resolution **CHIRPS data** showed the closest agreement with the IMD precipitation and well captured the drought characteristics (Pandey et al., 2020). The **Standardized Precipitation Index (SPI)** identified seven major drought events from 1981 to 2016. The forecasting result showed a reasonably good agreement with the observed datasets with the one-month lead time (Fig. 30).

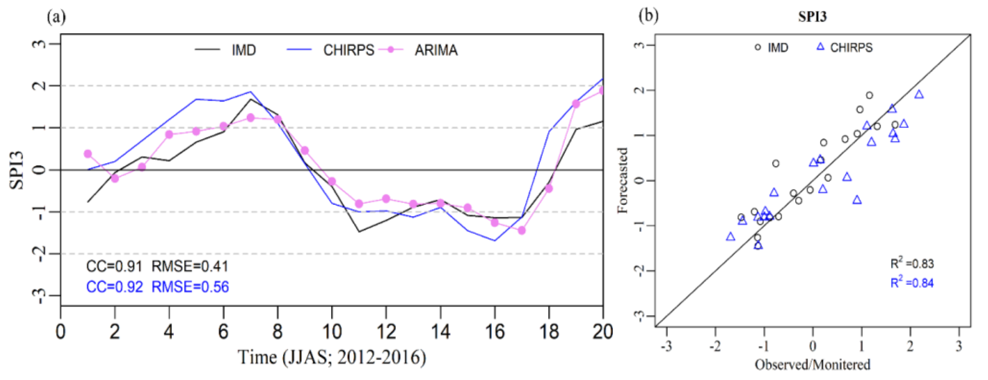


Fig. 30 (a) SPI time series and (b) scatter plot for observed (IMD), CHIRPS along with the forecasted data using the ARIMA (1,0,3) model (Pandey et al., 2020).

Pandey et al., 2021 measured the average **drought duration (DD), severity (DS), and intensity (DI)** for all the seven districts in the **Bundelkhand region** during the years 1981–2018. The average DD identified by SPI12 was 20 months, whereas the maximum DD was identified for Jhansi and Chitrakoot as 25 and 23 months, respectively (Pandey et al., 2021) . The average DI events for all the districts were greater than 0.8, and the regional average DI value was estimated as 0.96**.** Severe drought was observed in all the districts with DS > 17 and the regional average DS for the entire Bundelkhand region was estimated as 19.41 (Fig. 31).

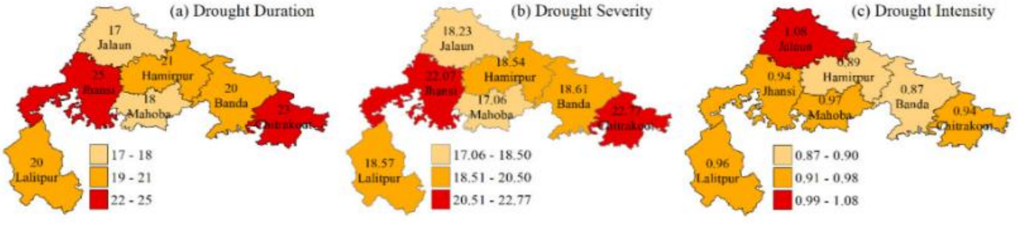


Fig. 31 Average drought duration (a), severity (b), and intensity (c) calculated from SPI12 for 7 districts during the years 1981–2018 in Bundelkhand (Pandey et al., 2021).

Bhatt et al., 2022 carried out a study to ascertain the occurrence of **droughts** (if any) from 1986 to 2015 within **the Gomati River basin**, in terms of inter-dependencies of drought-causing variables through the study of multivariate drought indices (Fig. 32). **Soil Water Assessment Tool (SWAT)** was used in combination with the **Copula approach** to construct **multivariate standardized drought indices (MSDIs)** for drought onset detection through simulation in the face of data scarcity (Bhatt et al., 2022). Although MSDI-based assessment of the basin as a whole did not detect any droughts, in the upper basin, MSDIs indicated the possibilities of impending agricultural droughts marked by their consistent variability around near-normal conditions. This methodology can be used to detect drought situations in data-scarce non-perennial river basins within the **Ganga River floodplains,** including the north central temperature homogeneous region **(NCTHR)** of India.

Bhatla et al., 2023 analyzed the impact of rainfall in the **El Nino/La Nina (phases of ENSO)** and IOD years on the crops (rice, maize, pulse and sugarcane) productions over the mentioned zones viz. (Central plateau and hills region; Western plateau and hills region; Gujarat hills and plains region; Western dry region) from 1966–2011 (Fig. 33). The results showed that **rice (Oryza sativa)** productions which require hot and humid conditions had been primarily affected during drought years associated with El Nino. This resulted in poor rainfall over all the zones. The production of **pulses** which does not require excess humid conditions showed marginal improvement during the neutral years or non-El Nino/non-La Nina years. **Maize (Zea mays)** production seems to be better in La Nina years and worse in the El Nino years as La Nina years are responsible for good rainfall in all zones. El Nino years provide a minor impact on **sugarcane (Saccharum ofcinarum)** productions in different zones. La Nina years are well suited for sugarcane production in all our study zones as sugarcane requires a good amount of moisture (Bhatla et al., 2023).

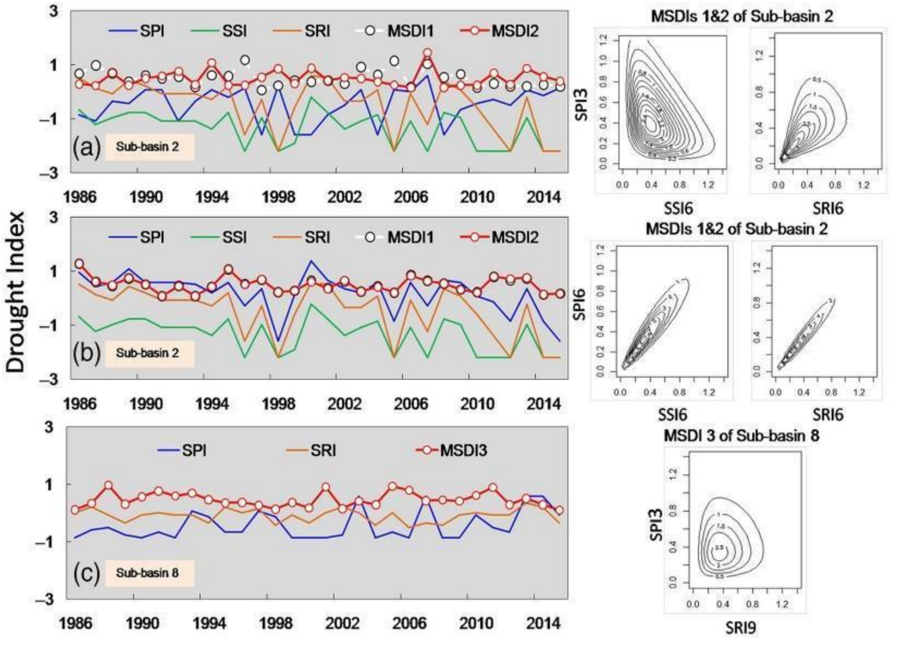


Fig. 32 Estimated MSDIs and their corresponding contour plots of the joint distribution generated using case-specific Archimedean Copula members (Bhatt et al., 2022).

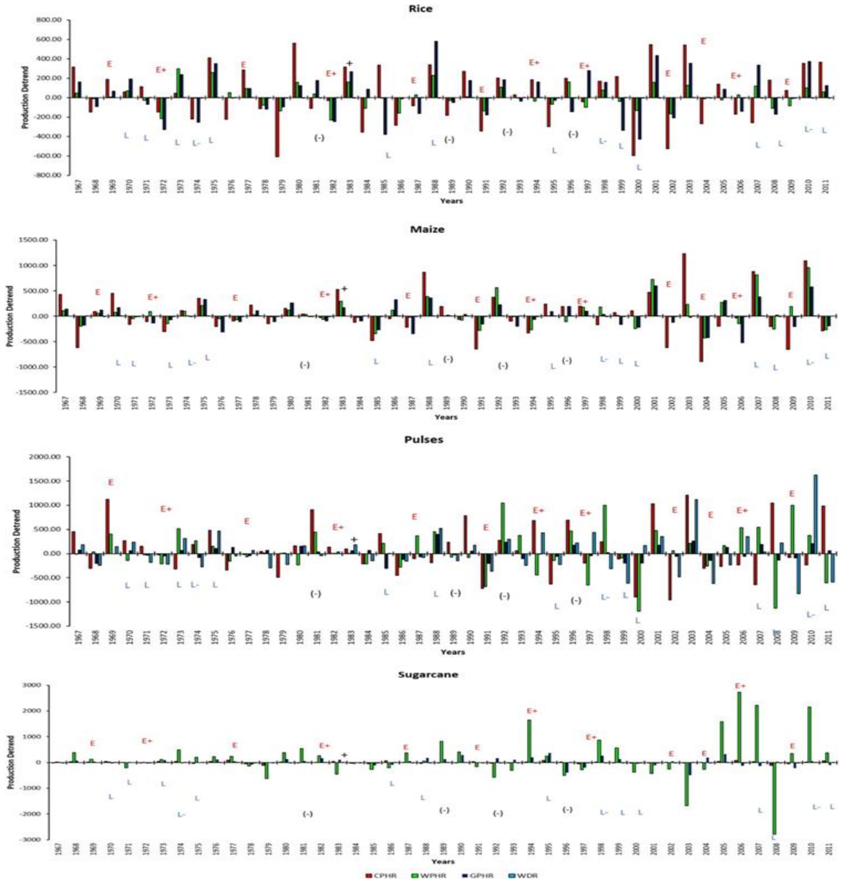


Fig. 33 Time series bar plot representing the detrending of a rice, b maize, c pulses and d sugarcane during El Nino, La Nina, positive IOD and negative IOD years. Note: El Nino: E, La Nina: L, El Nino + positive IOD: E+, La Nina + negative IOD: L-, positive IOD: (+) and negative IOD: (−) (Bhatla et al., 2023).

Gupta et al., 2023 explored long-term (2009-2020) gridded total columnar ozone (TCO) datasets retrieved from **Modern-ERA Retrospective dataset**. The dataset was validated against observations (IMDTCO) and compared with **Atmospheric Infrared Sounder (AIRSTCO)** satellite datasets (Fig. 34). The analysis showed a significant correlation between **MERRA-2TCO** and **IMDTCO** for Delhi (0.31%) and Varanasi (0.44%), with an increasing TCO trend of 0.31% and 0.44% per decade for both cities, respectively. The study observed that the MERRA-2 ozone dataset could be effectively used for air quality studies.

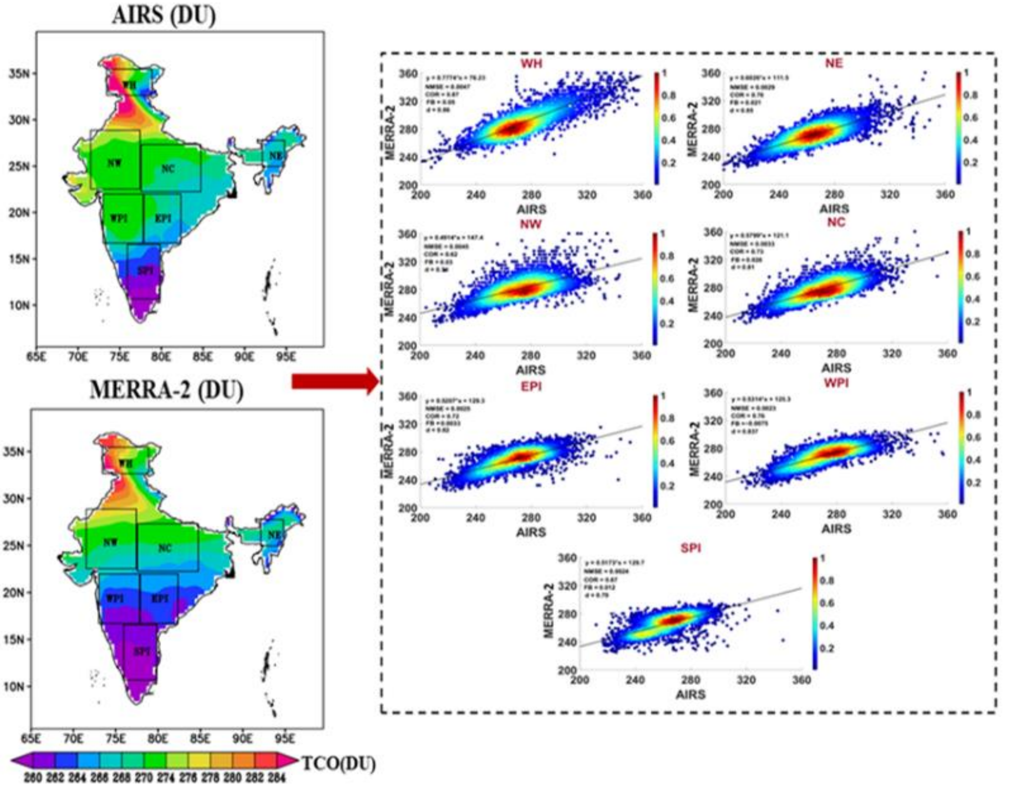


Fig. 34 Variation of annual mean TCO derived from MERRA-2 and AIRS datasets during the time period of 2009–2020 (Gupta et al., 2023).

Chaubey & Mall, 2023 revealed that in the near future, the upper **Ganga and Indus river basin** found to be 10 to 30 mm/day change in precipitation (Fig. 35). The **projected daily precipitation** is highly concentrated over the western and central Indian river basins. Moreover, the lower Ganga river basin is found to have a decrease in monthly mean precipitation of approximately 7 to 11 mm/day in the near future (Chaubey & Mall, 2023).

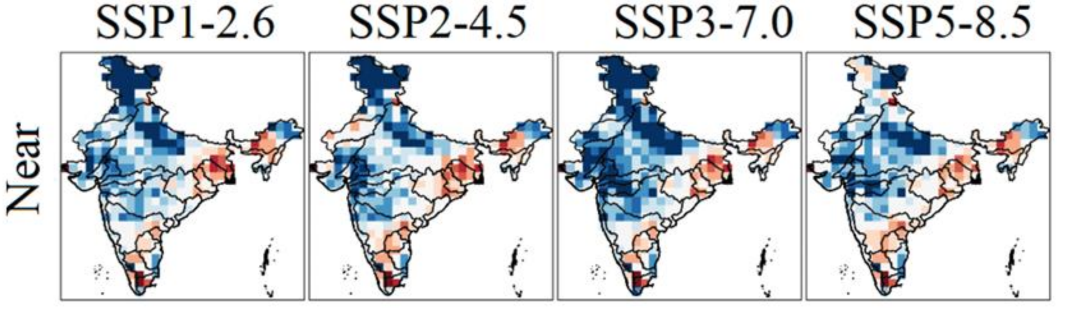


Fig. 35 Annual mean precipitation change (%) for Near- (2021-2040), Mid- (2041-2060), and Far-future 2081-2100) relative to 1995–2014. **(**Chaubey & Mall, 2023)

B. Aerosols

Kumar et al., 2018 evaluated **long-term aerosol climatology** over the Indo-Gangetic Plain (IGP), South Asia using **Terra MODIS** (Collection 6) enhanced **Deep Blue (DB) AOD retrieval algorithm** (Fig. 36). A comparatively high aerosol loading (AOD: 0.50±0.25) was evident over IGP with a statistically insignificant increasing trend of 0.002 year^{-1} (Kumar et al., 2018). Analysis highlighted the existing spatial and temporal gradients in aerosol loading with stations over central IGP like Varanasi (decadal mean AOD±SD; 0.67±0.28) and Patna (0.65±0.30) exhibiting the highest AOD, followed by stations over lower IGP (Kolkata: 0.58±0.21; Dhaka: 0.60±0.24), with a statistically significant increasing trend (0.0174-0.0206 year^{-1}). A distinct "**aerosol pool**" region over the eastern part of the Ganges plain is identified, where meteorology, topography, and aerosol sources favor the persistence of airborne particulates. Strong seasonality in aerosol loading and types is also witnessed, with high AOD and dominance of fine particulates over central to lower IGP, especially during post-monsoon and winter. Concentration-weighted trajectory analyses identified the crucial contributions of western dry regions and partial contributions from central Highlands and north-eastern India, in regulating AOD over stations across IGP.

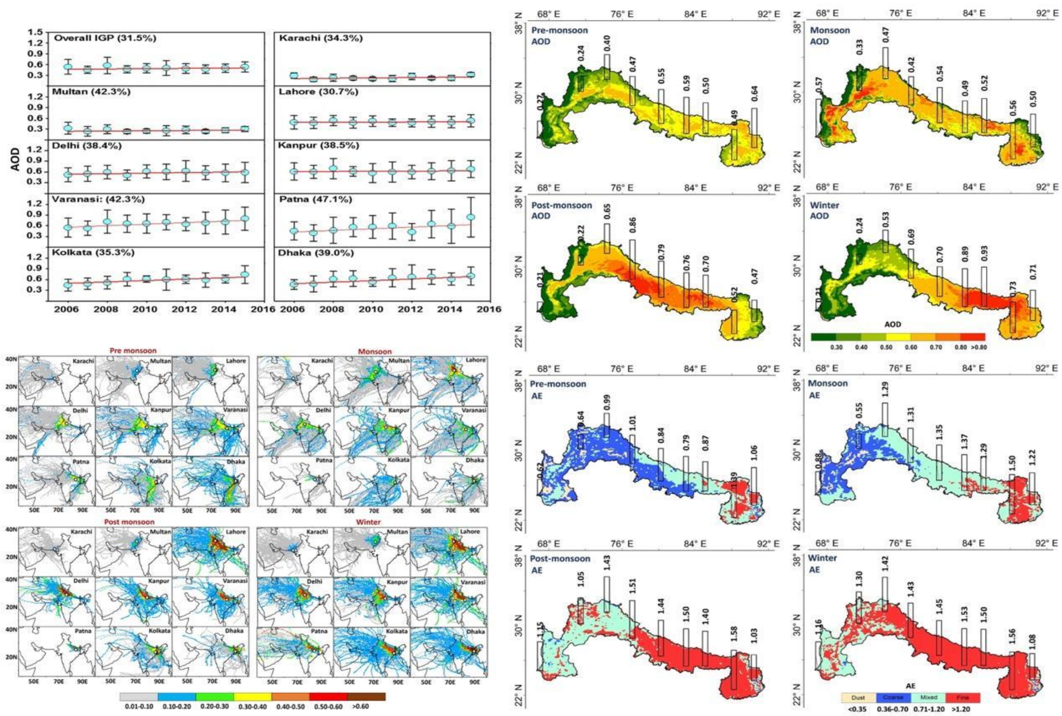


Fig. 36 Aerosol climatology over Indo-Gangetic plain, concentration weighted trajectories, and Inter-annual variation over prominent cities (Kumar et al., 2018).

Murari et al., 2020 revealed that in two contrasting locations: a rural (Mirzapur) and an urban (Varanasi) site in central Indo-Gangetic Plain (IGP), **PM10 (particulate matter with aerodynamic diameter ≤ 10 µm)** concentrations during 2014-2017 exceeded the **national ambient air quality standard (NAAQS)** both in Varanasi and Mirzapur on around 72% and 62% of the monitoring days, respectively (Murari et al., 2020). A significant proportion of 15%–18% of the particulate-bound metals in **PM10** mass was noted, with the highest contribution from Ca (7%–10%) and Fe (2%–3%). Transport of airborne particulates from upper IGP by prevailing **westerlies** was identified as the important contributor to air pollution over the study region, especially during high particulate loading days. Health risks associated with particulate-bound toxic metal exposure were also assessed. Accordingly, the **non-carcinogenic health risk** was found within the permissible limit, however, the elevated risk for PM10-bound Cr and Cd plausibly indicates that health risk upon exposure to these metals can be higher in the near future if adequate control measures are not taken (Fig. 37).

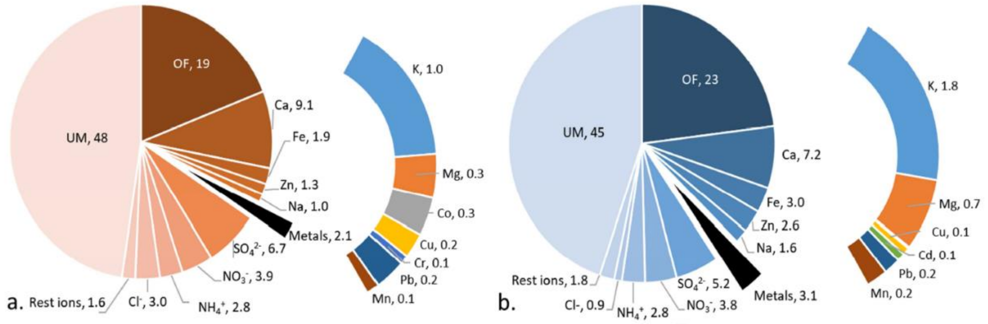


Fig. 37 Relative composition of particulate matter in (a) Varanasi and (b) Mirzapur (Murari et al., 2020).

In another study, Singh et al., 2021 analyzed **submicron particles** collected between 2015 and 2018 in an urban environment at Varanasi in central Indo-Gangetic Plain (in South Asia). **Submicron aerosol** mass concentrations were typically high during winter (DJF, 115 ± 50 µg m^{-3}) and post-monsoon seasons (ON, 79 ± 52 µg m^{-3}) (Singh et al., 2021a). Submicron particles constituted a major fraction (69%) of fine fraction aerosols (PM2.1) which were metal-enriched (17 ± 6%) and had the signature of crustal and road dust resuspensions (Fig. 38). Sulfate ions contributed 10% (±4%) of the particulate mass followed by nitrate (6 ± 3%) and ammonium (4 ± 2%). Overall, water-soluble ions accounted for one-third of the particulate mass and were mainly secondary ones (Fig. 37). Metal enrichment was evident specifically for Zn, Co, and Cr. Furthermore, a strong enrichment of **levoglucosan** (600 ± 388 ng m^{-3}) was noted especially during peak biomass-burning emission episodes. Source apportionment using the **positive matrix factorization (PMF)** receptor model indicates that secondary aerosols and biomass-burning emissions were the major sources of submicron aerosols (43%), followed by resuspensions of mineral dust (18%) and emissions from refuse/waste combustion (18%).

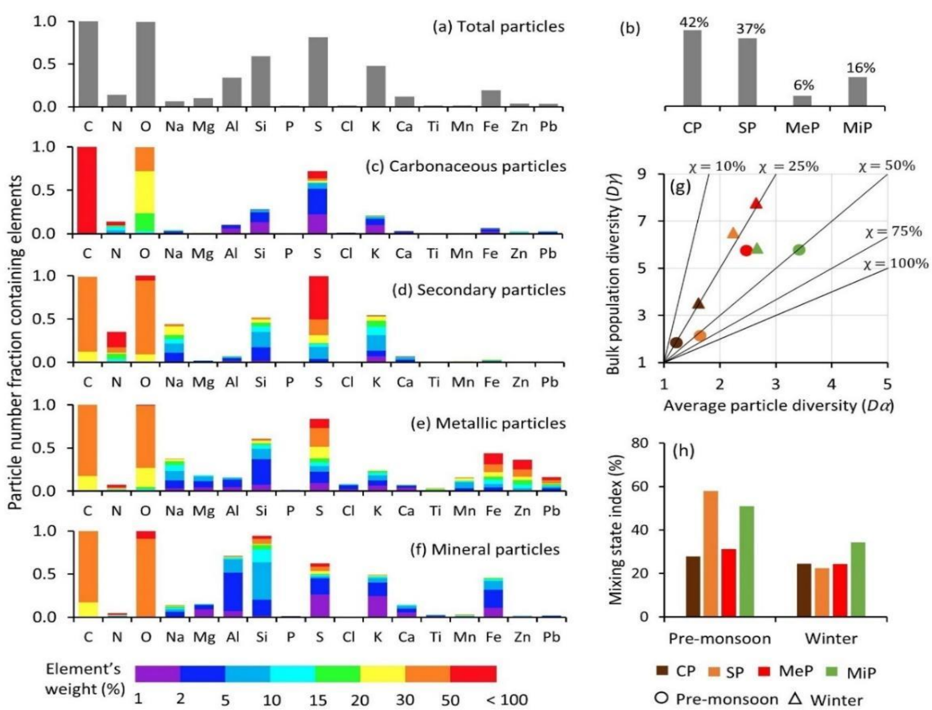


Fig. 38 (a) Elemental frequencies in total analyzed particles, (b) contribution of different particle types to total particle number, (c–f) elemental frequencies in different particle classes, (g) average particle and bulk population diversities, and (h) and mixing state indices for different particle classes during pre-monsoon and winter seasons (Singh et al., 2021).

Singh et al., 2021 explored the **molecular distributions** of organics indicating their biogenic and **anthropogenic emissions**. Secondary aerosols and biomass burning emissions are the dominant sources of PM2.1. Both crustal resuspensions and secondary aerosols were responsible emitters of **PM>2.1** (Fig. 39) (Singh et al., 2021). Fine particulates were secondary in nature against metal-enriched coarse particulates. Ammonium-based neutralization of particulate acidity was predominant in PM2.1 compared to Ca^{2+} and Mg^{2+} based neutralization in PM>2.1 (Fig. 40).

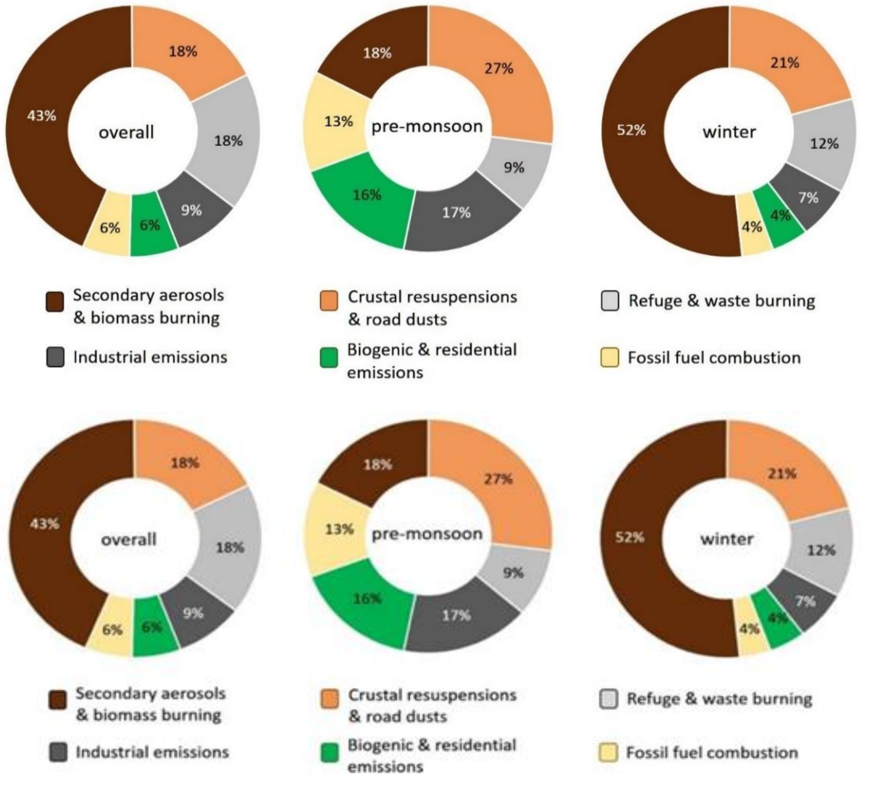


Fig. 39 Relative contributions of various emission sources to submicron particulates (Singh et al., 2021).

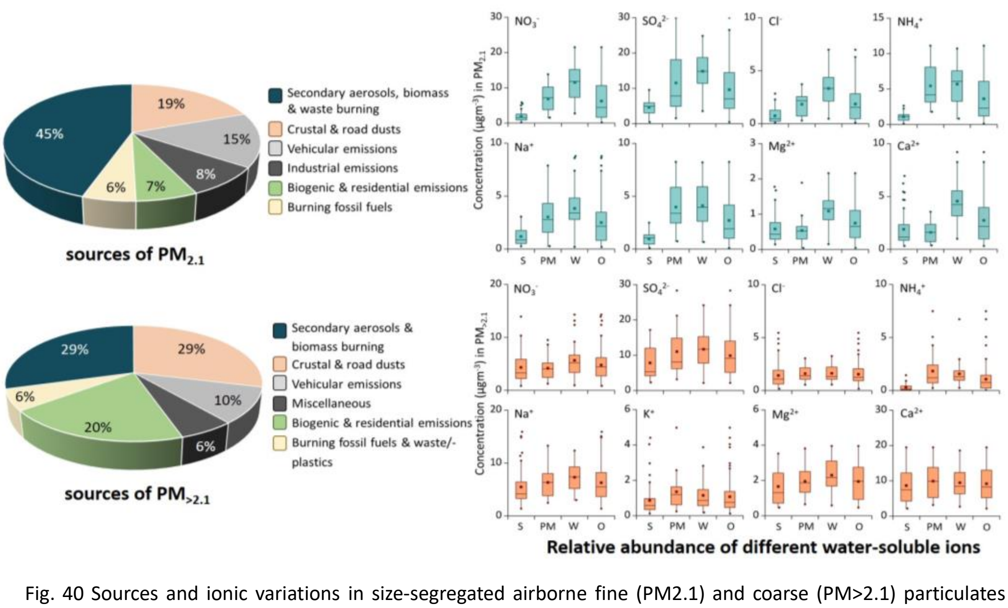


Fig. 40 Sources and ionic variations in size-segregated airborne fine (PM2.1) and coarse (PM>2.1) particulates were measured in an urban environment over the central Indo-Gangetic Plain (Singh et al., 2021).

Banerjee et al., 2022 conducted a multicity study across South Asia using the **CALIPSO AOD** dataset, which clearly suggested that mineral dust was the major aerosol type during summer months (MAM), particularly over the cities in IGP contributing 49–69% of total AOD with dominance over Karachi (80%) and least in Dhaka (21%) (Fig. 41). Approximately 46–71% of aerosols over Kathmandu, Dhaka, Varanasi, Nagpur and in Mumbai were urban aerosols while together with dust, these shared >80% of AOD across all the cities except in Chennai and Colombo wherein these contribute ~40% only (Banerjee et al., 2022). A contrasting pattern in **aerosol vertical distribution** over cities across the Indo-Gangetic Plain (IGP) was noted compared to non-IGP cities, with considerable dependency on the geographic location of the city itself. In all the cases, total extinction decreased with increasing altitude, however, with varying degrees of slope. A clear intrusion of transported aerosols at higher altitudes (>3 km) was also evident. The extinction coefficient of type-separated aerosols indicates a robust contribution of **smoke aerosols**, urban aerosols/polluted dust, and mineral dust below 3 km height. At higher altitudes (>3 km), dust and urban aerosols dominate over the majority of the stations. Overall, 51% of total **columnar aerosols** remained within 0 to 1 km height over South Asian cities, slightly higher over the IGP (57%) than non-IGP cities (39%). When partitioned against the **planetary boundary layer (PBL)**, 41% (59%) of aerosols remained within the PBL (free troposphere) that too exhibiting strong diurnal variations irrespective of seasons.

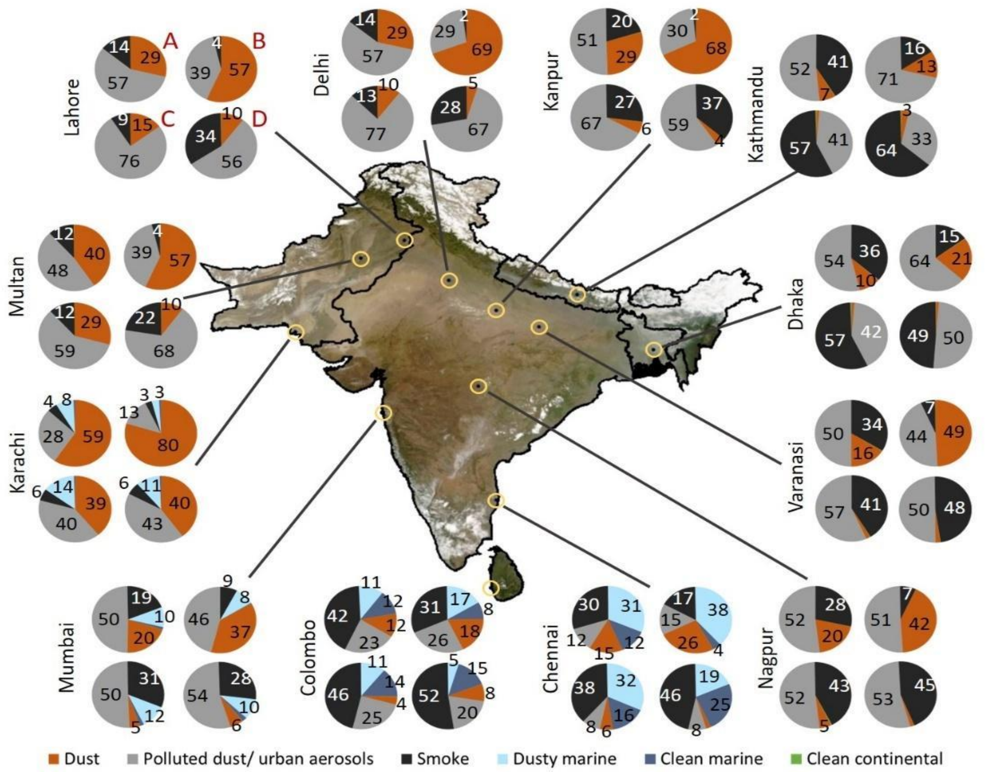


Fig. 41 Predominantly contributing aerosol types (in % contribution to total AOD) over South Asian cities averaged over 2010 to 2021. The predominating aerosol types were classified as per the CALIPSO aerosol classification system. The four pie charts indicate the multi-year mean contribution of individual aerosol type to total aerosol loading (in %) averaged for annual (A), and for three seasons MAM (B), ON (C), and DJF (D). For image clarity, the aerosol type which contributes >3% of total aerosol loading is indicated here (Banerjee et al., 2022).

In further studies, Banerjee et al., 2021a explored **aerosol climatology** during the typical haze-dominating period over South (Oct.-Feb.) and Southeast Asia (Sept.-Jan.) using various **Earth Observing System (EOS)** products from 2010-2020. High aerosol loading with the dominance of fine and UV-absorbing aerosol was observed across the Indo-Gangetic Plain (IGP) (AOD: 0.58; UVAI: 0.74) in sharp contrast to weak UV-absorbing fine aerosols over Southeast Asia (AOD: 0.26; UVAI: 0.07) (Banerjee et al., 2021a)(Fig. 42).

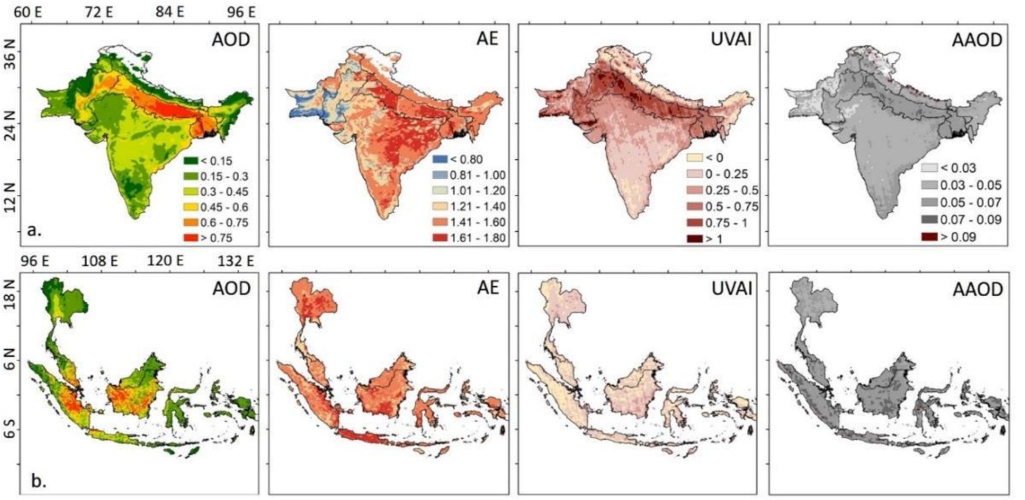


Fig. 42 Aerosol climatology over South and Southeast Asia.

Banerjee et al., 2021b assessed the **aerosols distribution** in urban hotspots of IGP and revealed a spatially consistent minor increasing trend in AOD (0.2-1.8x10-2 $year^{-1}$) while an increase in **Ultra-Violet Aerosol Index (UVAI)** was more prominent over the upper region of IGP. **Smoke aerosols** appeared to be more UV-absorbing across South Asia compared to Southeast Asia (SEA) (Banerjee et al., 2021b). Vertical stratification of aerosol types was noted across IGP as in the lower atmosphere (<4 km) mineral dust and urban aerosol remain abundant (Fig. 43). In the upper atmosphere (>4 km), dust aerosols clearly dominate over the IGP. However, smoke and urban aerosols were found to be more abundant in SEA.

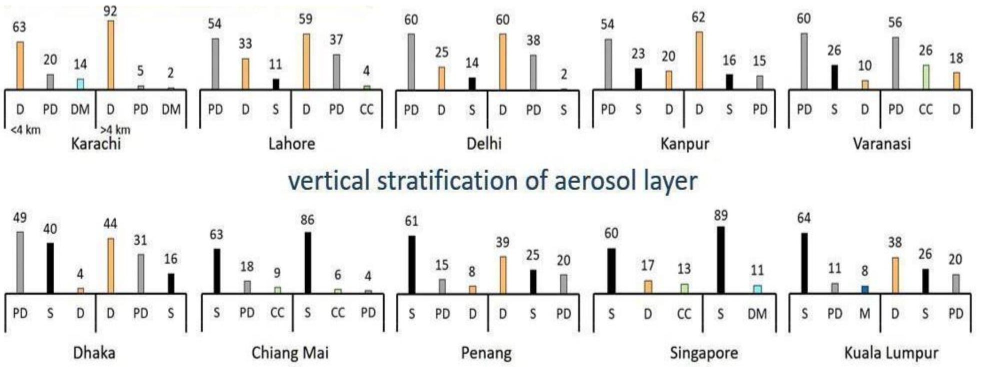


Fig. 43 Vertical stratification of the aerosol layer by its types. D: dust; PD: polluted dust; DM: dusty marine; S: smoke; CC: clean continental; M: marine (Banerjee et al., 2021b).

Vinjamuri et al., 2020a carried out a **Vertical distribution analysis** of smoke aerosols across South Asia, showing their higher abundance over upper IGP, particularly during the October to February months. Over upper IGP, near-surface **total aerosol extinction** was found > 0.1 km^{-1} throughout the year having a 2–50% contribution from smoke aerosol. The highest contribution was noted particularly during winter months (~50%) (Vinjamuri et al., 2020). Smoke extinction displayed strong **diurnal variation** with abundance at a lower height (<4 km) during daytime compared to higher height during the night (>4 km), indicating primary contribution from local emission sources (Fig. 44).

In another study, Vinjamuri et al., 2020b evaluated **average smoke injection heights** for **rice residue burning** (October-November) and **wheat** (April-May) **residue burning emission** periods, which were 0.71 and 2.34 km, respectively. A significant positive association between injection height and planetary boundary layer height was noted (Fig. 45) during both emission periods. Smoke aerosols from wheat residue burning were found mostly to inject above the boundary layer directly at the free troposphere in contrast to the rice residue burning emissions which mostly remain confined under the boundary layer.

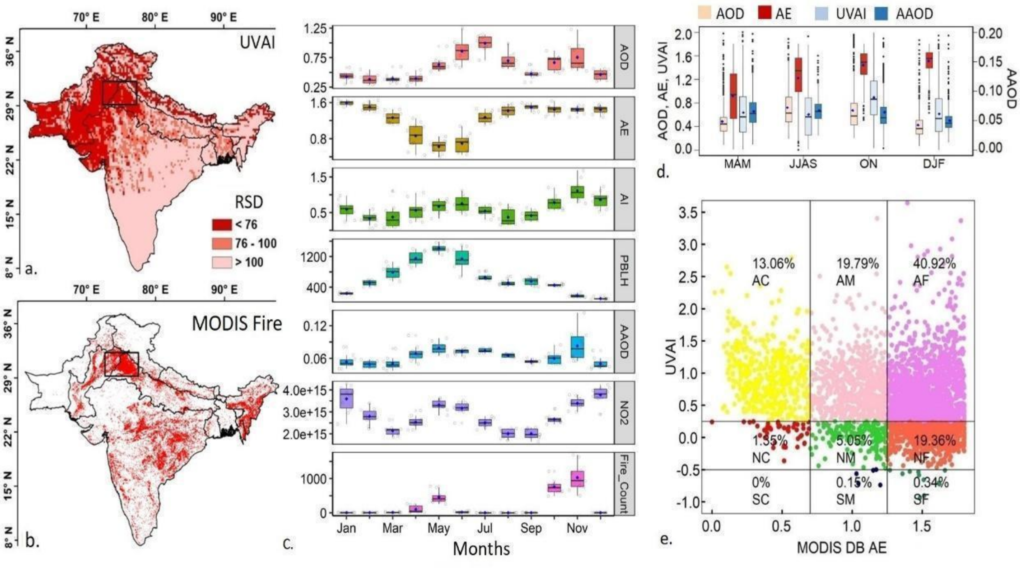


Fig. 44 Variations of OMI UVAI and MODIS fire counts with smoke injection height against the PBLH (planetary boundary layer height) (Vinjamuri et al., 2020a).

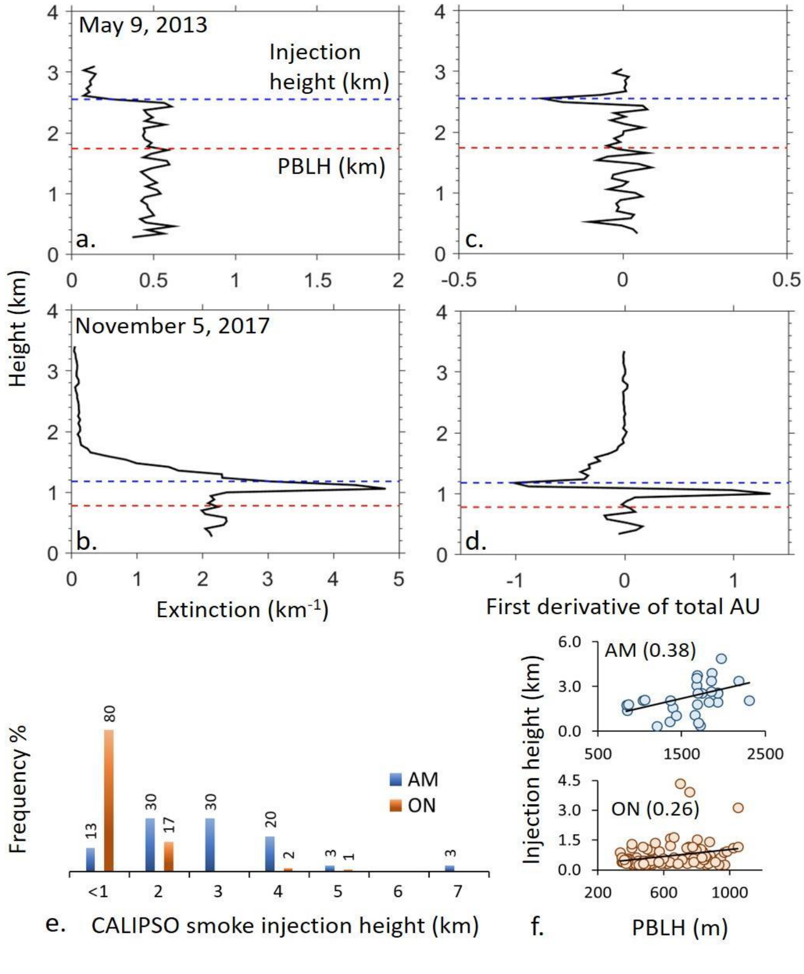


Fig. 45 Diurnal variations of the mean smoke extinction relative to boundary layer height (Vinjamuri et al., 2020b).

Vinjamuri et al., 2020c analyzed the **vertical distribution of smoke aerosols** over the Indo-Gangetic Plain between 2008 and 2017 using **space-borne Lidar**. Across South Asia, smoke aerosols were most abundant over upper IGP, and the relative abundance of smoke-dominating days increased during the October to February months (Vinjamuri et al., 2020c) (Fig. 46).

In another study, Singh et al., 2022, observed high aerosol loading over the IGP and east coast of India. The vertical stratification analysis of aerosol layer over most of the South Asian cities showed accumulation of aerosols relatively at higher altitude (1–3 km) which may have a potential impact on many of the **earth system processes** including cloud formation, and in modifying thermal structure of the atmosphere (Fig. 47) (Singh et al., 2022).

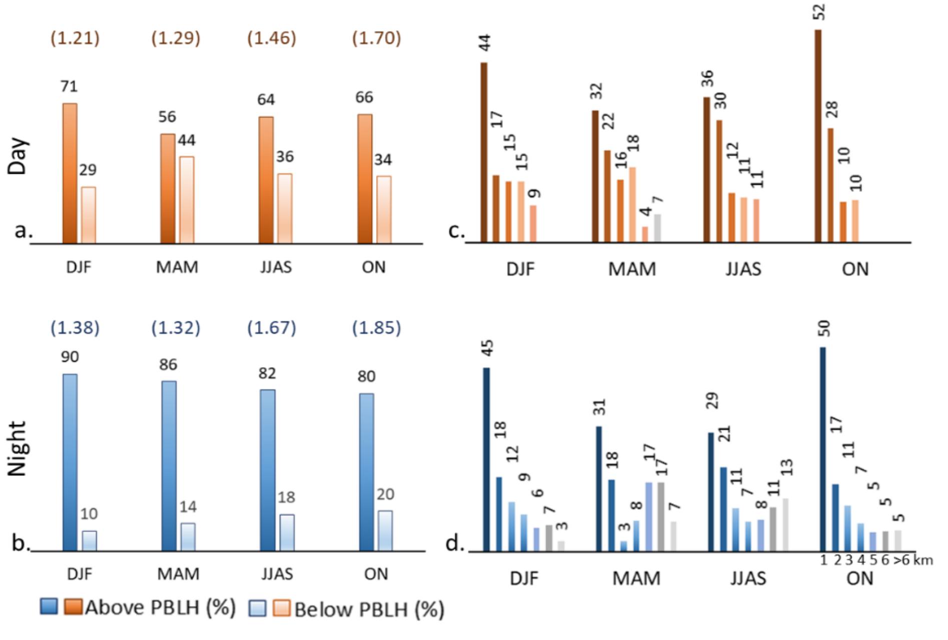


Fig. 46 Vertical distribution of smoke AOD over upper IGP, (a-b) diurnal variation against PBLH, and (c-d) relative percentage of smoke AOD in each km above the surface (Vinjamuri et al., 2020c).

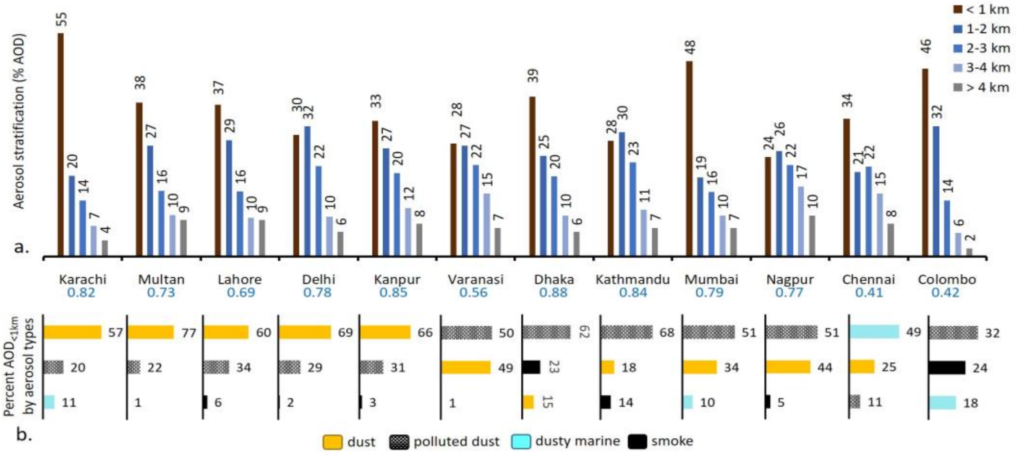


Fig: 47 Vertical stratification of aerosol layer over different South Asian cities (a) percent of CALIOP AOD retrieved for total atmospheric column as stratified against height (b) relative contribution of individual aerosol sub-types to near-surface AOD measured below 1 km height. In panel ‘a’, values in blue shade indicate mean CALIOP AOD for total atmospheric column whereas in panel ‘b’, CALIOP AOD present below 1 km height is classified in terms of individual aerosol sub-types (Singh et al., 2022).

Mhawish et al., 2020 estimated **high-resolution PM2.5** over Indo-Gangetic Plain using **machine learning** and **linear mixed effect model** by fusion of satellite data, meteorology, and land use variables (Fig. 48). Accordingly, high **PM2.5 levels** were found over the middle and lower IGP, with the annual mean exceeding 110 µg/m^3 (Mhawish et al., 2020). Seasonally, winter was the most polluted season while monsoon was the cleanest.

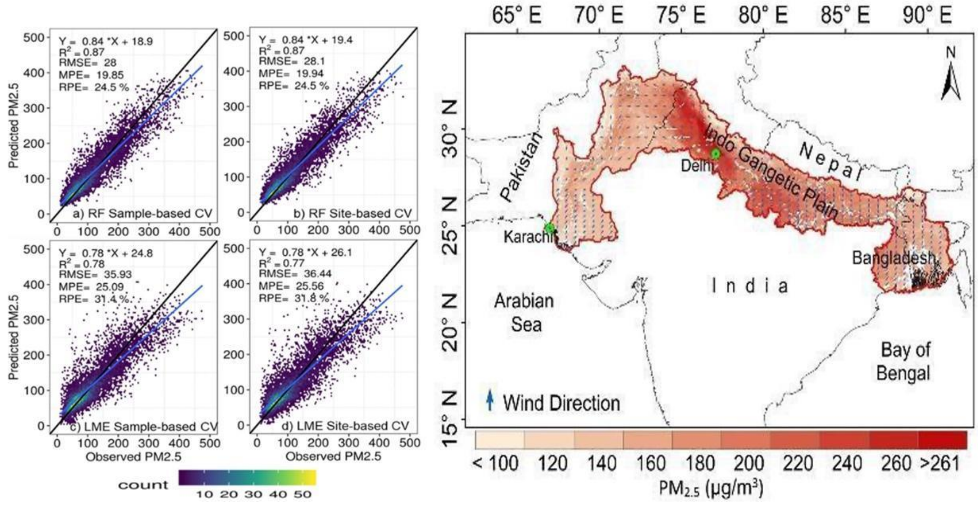


Fig. 48 PM2.5 estimates over Indo-Gangetic plain (Mhawish et al., 2020).

Soni et al., 2022 estimated the ground-level PM10 concentrations by effectively combining the Aerosols Optical Depth (AOD) from **Moderate Resolution Imaging Spectroradiometer (MODIS)** satellite retrievals and **Weather Research and Forecasting Model** coupled with **Chemistry (WRF-Chem)**. The model simulates typical dust storm events during 17-22 April 2010 and 05–10 May 2010 which has severely affected the air quality over northern and north-western India (Fig. 49 & 50). Basically, the satellite retrievals show high AOD (>1.0) over the Indo-Gangetic Plain and nearby Thar Desert (Soni et al., 2022). The model further captured the spatial pattern of AOD very well. However, it underestimated high aerosol loading in comparison to **MODISAOD**. The modeled AOD (MODELAOD) shows an underestimation by 37% as compared to the MODISAOD over the study region. Therefore, the **WRF-Chem model Particulate Matter (PM10),** as well as MODELAOD, were scaled up using the satellite MODISAOD to provide a better estimation of the particulate pollution (Fig. 51).

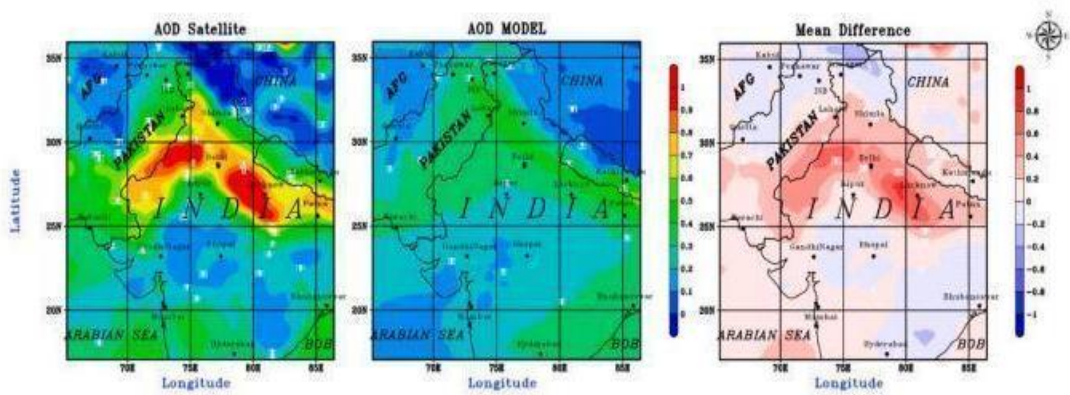


Fig. 49 Spatial comparison of MODISAOD with MODELAOD at 550 nm and Mean difference (MODISAOD with MODELAOD) during storm event from 17-22 April 2010 (Soni et al., 2022).

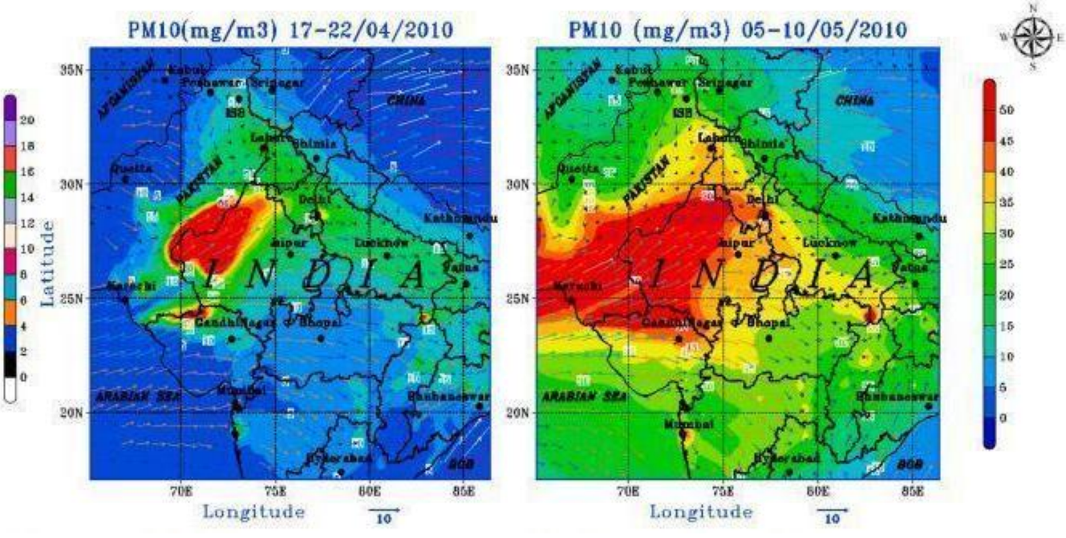


Fig. 50 Total pollution load (PM10) during the peak of events (a) 17-22 April 2010 (b) 5-10 May 2010 (Dust storm). The colour bar on the right shows PM10 in micrograms/cubic meter (Soni et al., 2022).

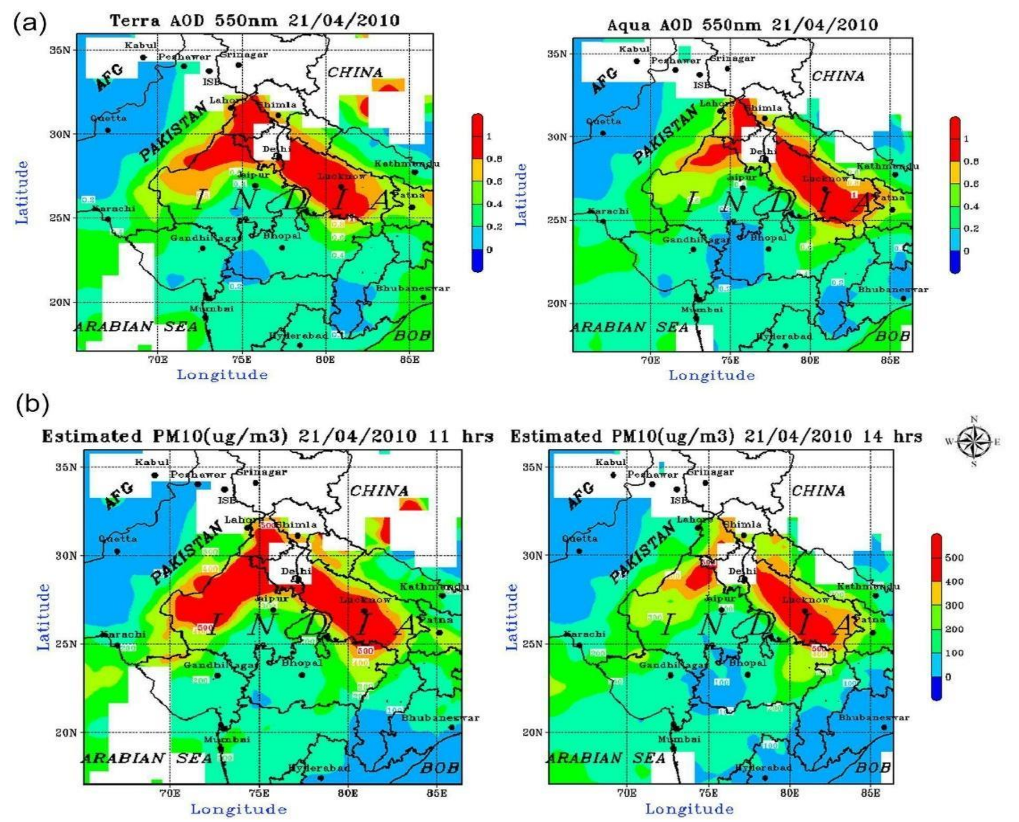


Fig. 51 (a) MODIS Terra and Aqua AOD on 21st April 2010 at 10:30 a.m. and 01:30 pm. (b) Estimated PM10 on 21st April 2010 at 11:00 am and 02:00 p.m. after Terra and Aqua satellite overpass time (Soni et al., 2022).

Pratap et al., 2021 investigated the **Short-term variability** of **atmospheric pollutants (PM10, PM2.5, SO_2, NO_2, O_3, and CO)** over Varanasi during the **Diwali festival** for a period of six years from 2011 to 2016 (Pratap et al., 2021). In this study, the aerosol Optical Depth (AOD) was found considerably much higher, almost 3-fold than the control days with a total scattering aerosol optical thickness as well as aerosol extinction coefficient at 550 nm beyond the value of 1.0 on the Diwali day event**.**

MODIS true-colour images also revealed dense smoke plumes and haze over the entire Indo-Gangetic Plain (IGP) on Diwali days of 2011–2016 which resuspended in the ambient atmosphere over a few days after the event. Proper planning and regular monitoring are needed to mitigate localized air pollution during such episodic emission events (Fig. 52).

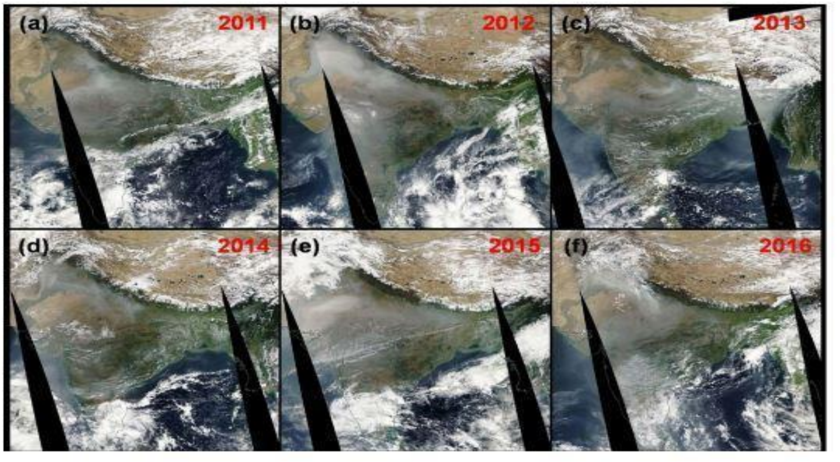


Fig. 52 Spatial distribution of MODIS True Color Images from the Aqua satellite during corresponding Diwali days for (a) 2011, (b) 2012, (c) 2013, (d) 2014, (e) 2015 and (f) 2016 (Pratap et al., 2021).

Kumari et al., 2023 studied the **retrieval accuracy** and **stability** of two operational aerosol retrieval algorithms, **Deep Blue (DB)** and **Dark Target (DT)**, applied on **Visible Infrared Imaging Radiometer Suite (VIIRS)** on-board **Suomi National Polar-orbiting Partnership (S-NPP)** satellite over South Asia. Area-weighted annual average Aerosol Optical Depth (AOD) (±SD) as retrieved by **Dark Target (DT)** was 0.47 (±0.19), 27% higher than the **Deep Blue** (DB) AOD (0.37 ± 0.16). Also, Both **DB and DT** recorded (Kumari et al., 2023) minimum variation in mean AOD between post-monsoon (DB: 0.37 ± 0.18; DT: 0.47 ± 0.22) and winter (DB: 0.37 ± 0.18; DT: 0.45 ± 0.24). Spatial nature of DB-DT agreement also matches well as both algorithms recognize the IGP**,** especially the lower IGP having highest AOD during majority of the year (Fig. 53).

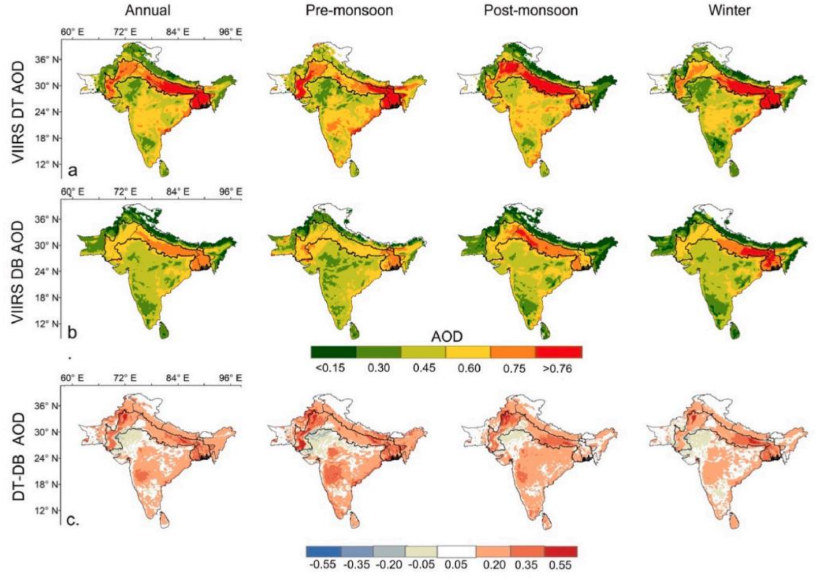


Fig. 53. Spatial distribution of seasonal and annual mean DT (a) and DB AOD (b) over South Asia, retrieved from year 2012–2021. The spatial difference (τDT − τDB) in daily mean AOD is also included (c). (Kumari et al. 2023)

C. Health

As per recent estimates, air pollution (AP) is responsible for ~7 million deaths globally resulting in an economic burden of more than \$2.9 trillion per year (WHO, 2014*). Furthermore, ambient air pollution (AAP) has been linked to about 3.7 million deaths annually whereas household air pollution (HAP) has been linked to 4.3 million deaths (WHO, 2014*). From the public health perspective, the WHO has revised the air quality (AQ) guidelines recently to achieve clean air for all and for the larger co-benefits (WHO, 2021*). According to the latest report on world air quality (IQAir, 2021*), 37 out of 40 top-most polluted cities in the world are situated in South Asia. These cities have annually averaged PM2.5 concentrations (in the year 2020) exceeding over 10 times the WHO AQ guideline value (of 5 µg /m^{-3}) with the highest concentrations observed during the months of October through February (IQAir, 2021*).

Singh et al., 2021a evaluated the short-term effect of exposure to air pollutants e.g., **aerosols (black carbon, BC; PM2.5 and PM10)** and **trace gases (NO_2, SO_2, and O_3)** on **all-cause mortality** from a typical urban pollution hotspot in the central Indo-Gangetic Plain (IGP). This was the first-ever report on all-cause mortality estimates from exposure to BC aerosols and multiple trace gases from South Asia. Daily all-cause mortality and ambient air quality were analyzed from 2009 to 2016 using a **semiparametric quasi-Poisson regression model** adjusting for mean temperature (Tmean), relative humidity (RH), and long-term time trend (Time) as potential confounders (Singh et al., 2021). **Single pollutant model** clearly established the significant impact of BC aerosols (for every 10-units increase in pollutant's concentration there is an increase in relative risk by 4.95% (95% CI: 2.16–7.74) in all-cause deaths), the mortality risk for exposure to NO_2 (2.38%, 95% CI: 0.88–3.87%) and PM2.5 exposure (1.06%, 95% CI: 0.45–1.66%) was also assessed (Fig. 54). However, co-pollutant model showed an increased mortality risks for BC aerosols (7.3%). **Mortality** estimates were further stratified considering different effect modifiers viz. sex, age, place of death, and season. Almost in all the cases, statistically insignificant differences in effect modification were noted for all the pollutants except PM10. A distributed **lag nonlinear model** estimated the lag effect and all the pollutants showed a significant lag of up to 3 days while BC showed a lag effect of up to 5 days (Fig. 54) (Singh et al., 2021).

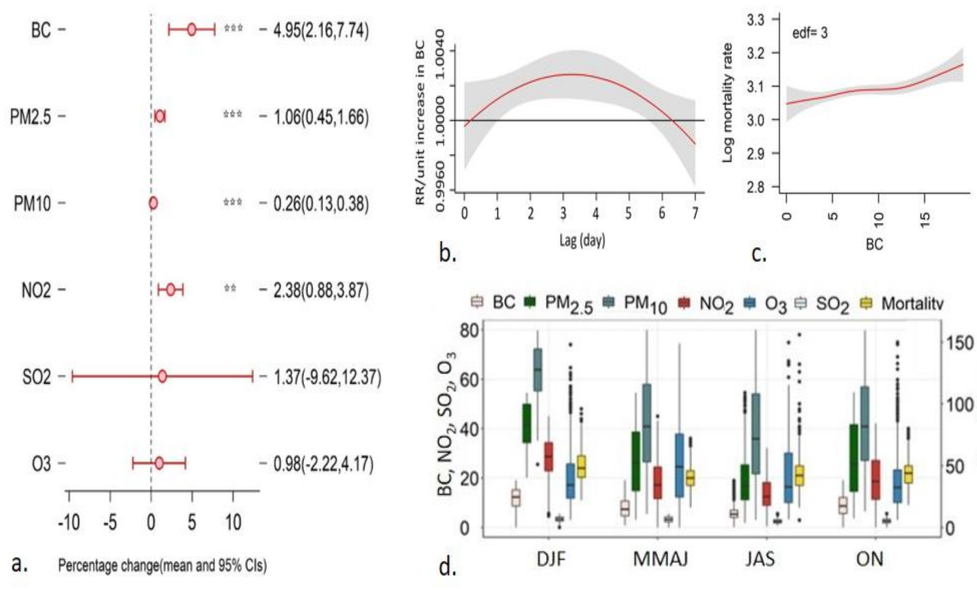


Fig. 54 Air pollution and premature all-cause mortality in Varanasi (Singh et al., 2021a).

*Source:
IQAir, 2021*: IQAir, 2021. World Air Quality Report, Region & City PM2.5 Ranking.
WHO, 2021. What are the WHO Air quality guidelines? Improving health by reducing air pollution.
WHO, 2014. 7-million-premature-deaths-annually-linked-to-air-pollution.

In another Singh et al., 2021b further explored a **time-series study** on the association between **all-cause mortality** and **extreme temperature** from 2009-2016 over Varanasi, which showed an increase in excess mortality, was strongly associated with the rise in daily mean temperature, both during the summer (5.61%) and wintertime (1.50%). The effect was found to be much more severe for females and infants (Fig. 55). The increase in mortality risk was high during summer compared to winter. Similarly, the risk ratio was high due to heat waves compared to cold spells. The **diurnal temperature range (DTR)** has exhibited a downward trend over the years and showed a negative association with all-cause mortality. Significant association of mortality and different metrics of temperature extremes along with a decreasing trend in DTR clearly indicate the potential impact of climate change on human health in the city of Varanasi.

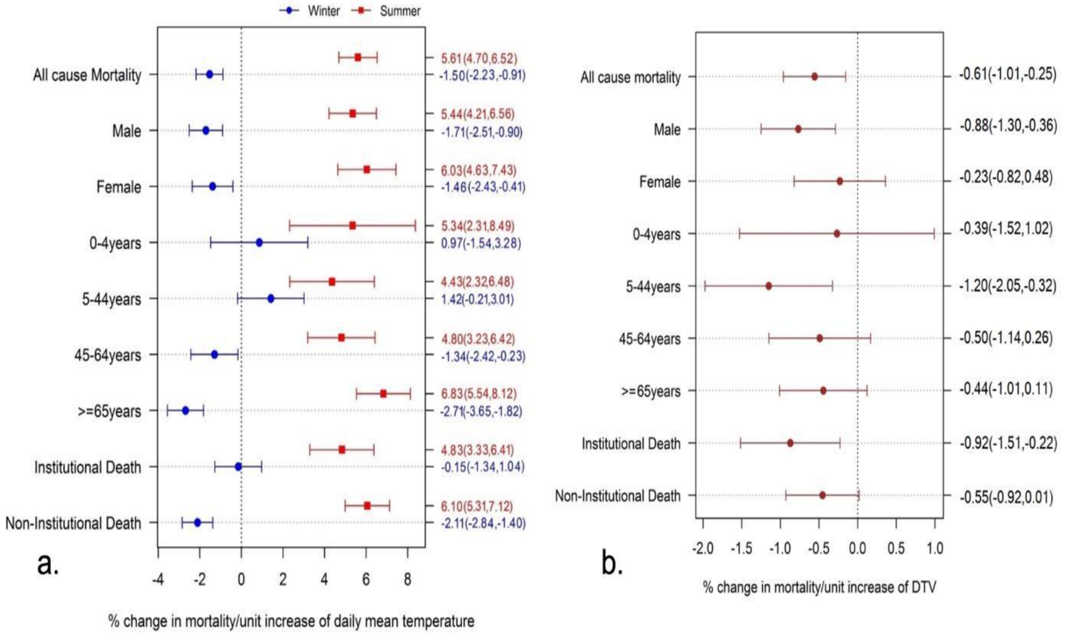


Fig. 55 Percent change in all-cause mortality associated with (a) increase in mean temperature and (b) with increase in diurnal variability (Singh et al., 2021b).

Moreover, the effects of **climate** on **infectious diseases** were also studied as climate can influence health impacts, particularly in children. In a prospective cohort, the association between maximum temperature (Tmax), relative humidity (RH), absolute humidity (AH), rainfall (RF), wind-speed (WS), solar radiation (SLR), and prevalent **infectious diseases** like **Diarrhea, Common cold and flu, Pneumonia, Skin-disease, Malaria**, **and Dengue** was examined. Several statistics like binomial regression were used, adjusting for confounders and effect modifiers (**socioeconomic-status; SES and child anthropometry**), from January 2017 to January 2020. Attributable-fraction (AFx) was calculated due to each climate variable for each infectious disease. The result showed that each unit ($1^{O}C$) rise in Tmax was associated with an increase in diarrhea and skin-disease cases by 3.97% (95% CI: 2.92, 5.02) and 3.94% (95% CI: 1.67, 6.22), respectively. A unit decrease in **Tmax** was associated with an increase in cold and flu cases by 3.87% (95% CI: 2.97, 4.76) (Fig. 56). Likewise, a rise in humidity (RH) was associated with an increase in cases of cold and flu by 0.73% (95% CI: 0.38, 1.08) and malaria (AH) by 7.19% (95% CI: 1.51, 12.87) while each unit (1 g/m^3) decrease in **humidity (AH)** was found to be associated with increase in pneumonia cases by 3.02% (95% CI: 0.75, 5.3) (Fig. 57). Furthermore, WS was found to be positively associated with diarrhea (14.16%; 95% CI: 6.52, 21.80) and negatively with dengue (17.40%; 12.32, 22.48) cases for each unit change (kmph). Rainfall showed marginal association while SLR showed no association at all. The combined AFx due to climatic factors ranged from 9 to 18%. SES and anthropometric parameters modified the climate-morbidity association in children with a high proportion of children found suffering from stunting, wasting, and underweight conditions.

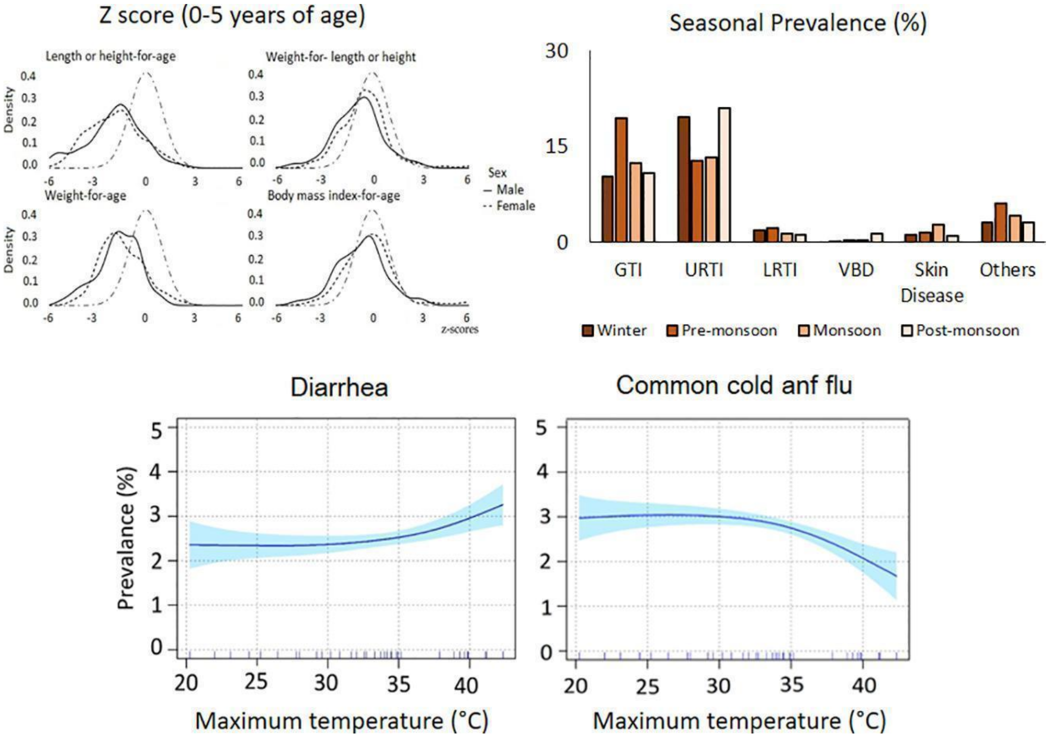


Fig. 56 Associations between climate, and infectious diseases among children in Varanasi City, India (Singh et al., 2021b).

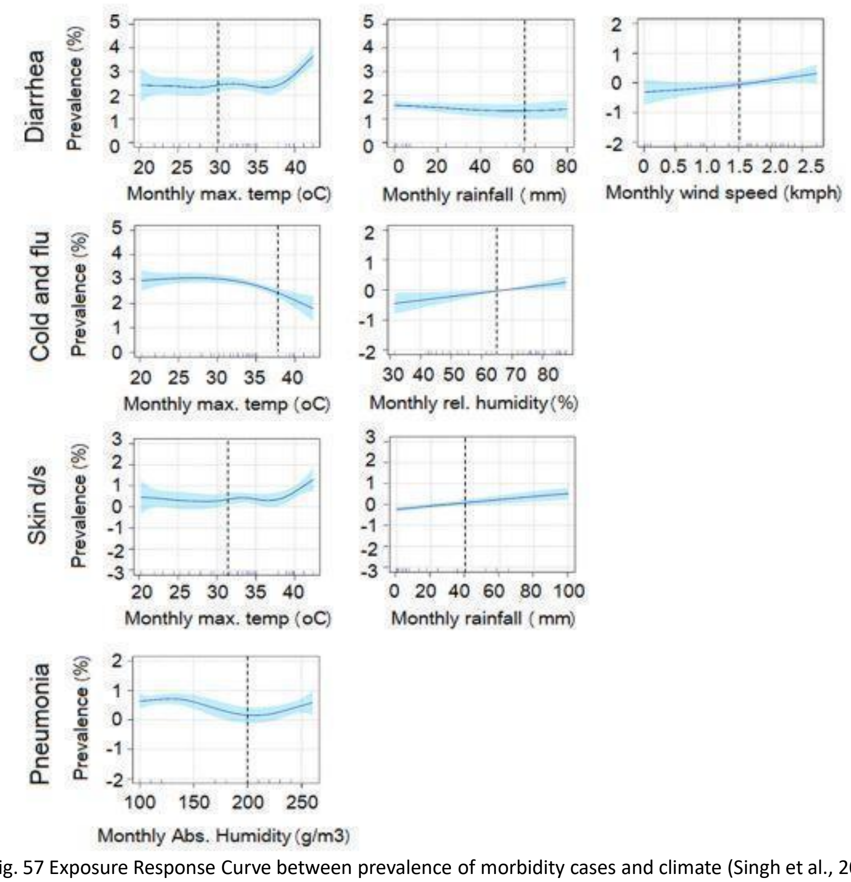


Fig. 57 Exposure Response Curve between prevalence of morbidity cases and climate (Singh et al., 2021b).

Singh et al., 2020a showed that India and other **Southeast Asian countries** are severely affected by **Japanese encephalitis (JE),** one of the deadliest **vector-borne diseases**. Several **epidemiological observations** suggest that climate variables play a significant role in providing a favourable environmental condition for mosquito development and virus transmission. In a study, **generalized additive models** were employed to determine the association of JE admissions and **mortality** with climate variables in Gorakhpur district (of U.P. state), India, from 2001–2016 (Singh et al., 2020a). The model predicted that for every 1 unit increase in mean (**Tmean**; ˚C), and minimum **(Tmin**; ˚C) temperature, **rainfall (RF**; mm), and **relative humidity (RH**; %) the JE admissions **on average increase** by 22.23% (Fig. 58), 17.83%, 0.66%, and 5.22% respectively and JE mortality by 13.27 %, 11.77 %, 0.94 %, and 3.27 % respectively. Conversely, every unit decrease in **solar radiation** (Srad; MJ/m^2/day) and **wind speed** (WS; Kmph) caused an increase in JE admission by 17% and 11.42% and in JE mortality by 9.37% and 4.88% respectively suggesting a protective effect at higher levels. The seasonal analysis showed that temperature was significantly associated with JE in pre-monsoon and post-monsoon while **RF, RH, Srad, and WS** were associated with JE in the monsoon. The effect modification due to age and gender showed an equal risk for both genders and increased risk for adults above 15 years of age, however, males under 15 outnumbered females and adults. The study concludes that climate variables could influence the JE vector development and multiplication and parasite maturation and transmission in the Gorakhpur region whose indirect impact was noted for JE admission and mortality. In response to the changing climate, **public health interventions**, **public awareness**, and **early warning systems** would play an important role in reducing the vector-borne burden of diseases and deaths in the region.

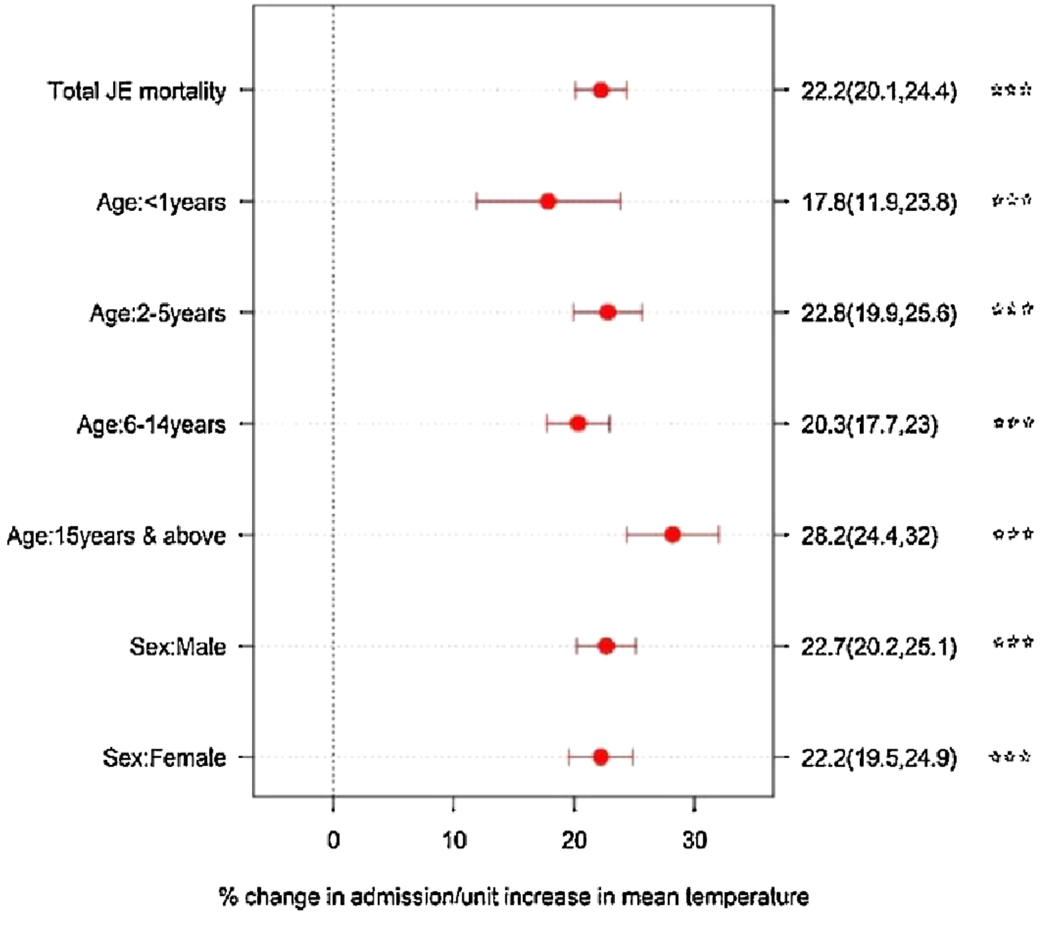


Fig. 58 Percent change in JE admissions by total, age and sex associated with change in mean temperature (Singh et al., 2020).

In another study, Mishra et al., 2021 explored the effect of **lockdown amid COVID-19** on ambient air quality for 16 Indian cities (Chandigarh, Delhi, Jaipur, Lucknow, Patna, Kolkata, Gandhinagar, Bhopal, Nashik, Mumbai, Nagpur, Hyderabad, Bengaluru, Chennai, Visakhapatnam, and Thiruvananthapuram) during January 1–June 30 for 4 years (2017–2020) (Fig. 59). All assessed air pollutants showed a substantial decrease in AQI values during the lockdown period compared to the reference period (2017–2019) for almost all the assessed cities across India (Mishra et al., 2021). On average, about 30–50% reduction in AQI has been observed for **PM2.5, PM10, and CO**, and a **maximum reduction** of 40–60% had been observed for **NO_2**, while the data was averaged for northern, western, and southern India. **SO_2** and **O_3** showed an increase in a few cities as well as a decrease in the other cities. Maximum reduction (of 49%) in PM2.5 was observed over northern India during the lockdown period. Furthermore, the changes in pollution levels showed a significant reduction in the first three phases of the lockdown and a steady increase during subsequent phases of the lockdown and unlock period.

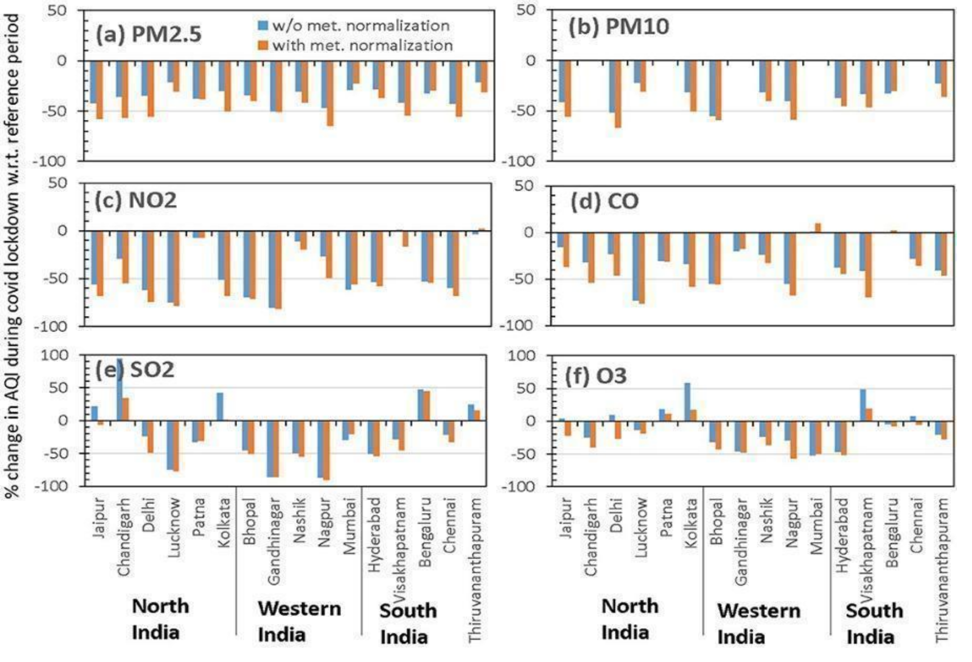


Fig. 59 City-specific percent change of key pollutants (with and without meteorology normalization) during complete lockdown with respect to the reference time-period (Mishra et al., 2021).

Singh et al., 2021 studied the pattern of **air pollution** for ten of the most affected countries in the world (USA, India, Brazil, Russia, France, Spain, Argentina, UK, Colombia, and Mexico) in the context of the 2020 development of the **COVID-19 pandemic** using **Sentinel-5P** based datasets, including the **Aerosol Absorbing Index** (AAI), **Carbon Monoxide Column Density**, **Tropospheric NO_2** Concentration, **Ozone Total Atmospheric Column** and **Sulphur Dioxide Column Density** (Singh et al., 2021). It was found that the concentrations of some of the principal atmospheric pollutants were temporarily reduced during the extensive lockdowns in the spring. Large AAI is generally found in the northern parts and west of the central part of Russia, USA, India, UK, Colombia, Mexico, and Spain due to **desert dust** and **anthropogenic pollution**. The AAI over the western and eastern coasts of the USA can also be attributed to anthropogenic sources, as those regions are the main industrialized areas in the country (Fig. 60). For all countries, the level of CO generally decreased though having a significant spatial variation, NO_2 levels also decreased generally in some countries during Phase-2 (25 May 2020 to 31 May 2020). Conversely, e.g., in India, the USA, and Russia, regional concentrations of NO_2 and O_3 increased significantly, in some cases by more than 50% during the **lockdown Phase-2** as compared to **Phase-1** (25 January 2020 to 31 January 2020). Air pollution levels appeared to be a good predictor of incidences of COVID-19 infections at the local and national levels.

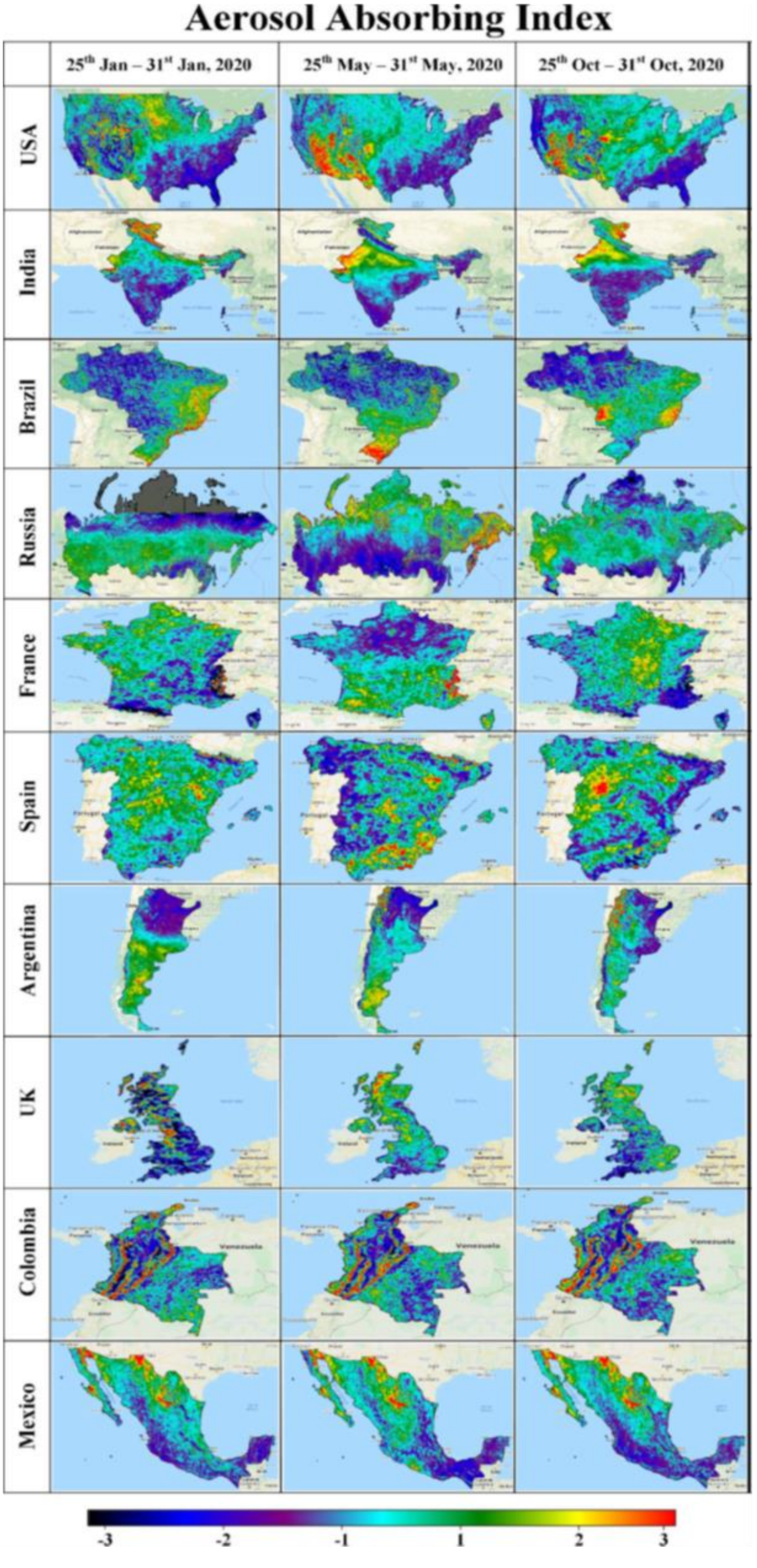


Fig. 60 Aerosol absorbing index of the top ten most affected countries. (Singh et al., 2021).

Rajput et al., 2023 conducted a **review study** that documents a global overview of the **nexus** between **climate change** and **public health** with a major aim to provide a perspective toward strengthening the health infrastructure system in Indian Cities. In this study, a summary of some of the important aspects of climate change and human health was presented. Mobilization of funds for researching Climate change-Air pollution-Public health domain has been suggested to keep on a top-rank priority owing to the increase in frequency and intensity of extreme weather events associated with rise in temperature (Fig. 61). Healthcare professionals and researchers working on air pollution and climate change must keep collaborating and share their data for a joint study on different health outcomes.

Moreover, **gridded mapping** of the vulnerable population across the country based on **gender**, **age groups**, **socio-economic status (SES)**, etc. is needed to better understand the extent of direct as well as indirect negative impacts of climate change on public health in India. **Climate-resilient** and **climate-smart healthcare system** approaches are needed to guide actions required to transform and reorient healthcare systems to effectively align health development and delivery with global climate goals. Stringent policies and actions in India on a gridded basis are also needed for coping with the impact of climatic change on public health in near-term, mid-term, and long-term future scenarios.

The effects of climate change on India's energy demand, employment, and labor market have also been highlighted. Finally, the **National policies** implemented or actions underway to mitigate climate change and improve public health were discussed and some recommendations to carry forward have also been provided. Recommendations to stakeholders for implementing policies in the country were also been provided (as given below):

A. Community-based mapping of the vulnerable population on both regional and national levels.

B. City-level climate action plans account for specific microclimates and health impacts.

C. Climate change mitigation and adaptation policies must be assessed and combined with air pollution abatement policies.

D. Promote research and facilitate capacity building on climate change and health to understand the changing disease burden and health impact assessment.

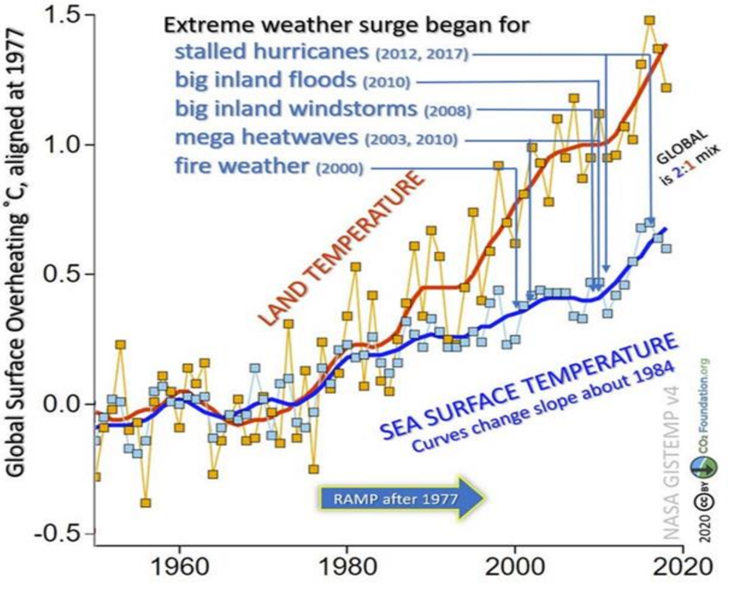


Fig. 61 Time-series record of the global surface overheating and mega heat waves and other extreme weather surges (Source: The Conversation, 2020) (Rajput et al., 2023).

D. Agriculture

Climate change has the potential to significantly impact agriculture across different parts of the globe. It's important to note that the specific effects can vary depending on the local conditions and the extent of climate change. Rising temperatures can have detrimental effects on crop growth and productivity. Extreme heat can lead to increased water stress, reduced photosynthesis, and accelerated crop maturity, resulting in decreased yields. Climate change can disrupt traditional rainfall patterns, leading to changes in the timing, intensity, and distribution of rainfall. These changes can result in droughts or floods, both of which can adversely affect crop production. Droughts can lead to water scarcity and crop failure, while heavy rainfall and flooding can damage crops and soil, leading to erosion and nutrient leaching. Furthermore, climate change can influence the distribution and behavior of pests and diseases. Higher temperatures and altered rainfall patterns can create more favorable conditions for the proliferation of pests and the spread of diseases, impacting crop health and productivity. Farmers may need to adapt their pest management strategies and invest in disease-resistant crop varieties.

To mitigate the negative impacts of climate change on agriculture, adaptation strategies are needed. These can include implementing climate-smart agricultural practices, improving water management systems, promoting crop diversification, investing in irrigation infrastructure, adopting improved crop varieties, and providing farmers with access to information and resources to make informed decisions. It's important for policymakers, agricultural researchers, and farmers to work together to develop and implement sustainable strategies that build resilience to climate change and ensure the long-term productivity and viability of agriculture. The various activities carried out by the Centre under the agriculture stream are broadly discussed below.

i. Field experiments and development of Genetic coefficient

Field experiments were conducted for the collection of the extensive crop data sets of wheat varieties (HUW669, HUW468, and HD2967) grown under different treatments for the season 2018-2023. The data regarding crop phenological parameters, crop management parameters, and quantitative and qualitative parameters were collected. The existing crop datasets were also used for the calibration and validation of the crop models for the development of **genetic coefficients** of the wheat, rice, potato, tomato, pigeon pea, mustard, sorghum, and sugarcane cultivars using **CROPGRO-Pigeon pea**, **CERES-Wheat, CERES-Rice, SUBSTOR-Potato, CROPGRO-Tomato, CERES-SORGHUM and CANEGRO-Sugarcane models**, respectively. Moreover, these genetic coefficients are used for understanding the performance of the cultivars grown under different environmental conditions and for identifying the potential zones for better crop production (GxE Interactions) (Fig. 62).

Fig. 62 Field experiments for developing genetic coefficients

Table 1 Genetic coefficients used for impact assessment and developing adaptation strategies.

Wheat

VAR-NAME	ECO#	P1V	P1D	P5	G1	G2	G3	PHINT
HUW-234	DSWH04	20	65	750	25	42	1.5	99
HUW-468	DSWH04	25	70	780	22	40	1.0	95
HUW-510	DSWH04	22	66	740	24	35	1.0	95
HUW-668	DSWH04	25	70	750	25	44	1.5	95
MALVIYA 234	DSWH04	20	60	820	26	49	1.7	90
PBW 343	DSWH04	20	70	300	20	35	1.0	95

Rice

VAR-NAME	ECO#	P1	P2R	P5	P2O	G1	G2	G3	G4
SARJOO 52	IB0001	820	140	230	11.2	43	300	1.0	0.8
PUSA 1	IB0001	700	105	600	12.0	40	240	1.0	1.0
MALVIYA 36	IB0001	820	142	225	12.0	43	300	1.0	1.0
IR 36	IB0001	450	160	500	11.0	41	210	1.0	0.9
PANT 4	IB0001	830	160	300	11.4	45	300	1.0	0.8
SUGANDHA	IB0001	700	105	600	12.0	40	240	1.0	1.0
SWARNA	IB0001	700	120	530	11.8	48	220	1.0	1.0

Sugarcane

VAR-NAME	PARCEMAX	APFMX	STKPFMAX	TBFT	Tthalfo	TBase	LFMAX	MXLFARNO	MXLFAREA	TTBASELFE	TTBASELFEX (PI2)	PSWITCH	MAX_POP	POPTM	TTBASEEM	CHUPIBASE
CoS767	8.85	0.88	0.65	25	250	16	12	360	15	89	176	16	26	11.5	340	1740
CoJ64	8.5	0.86	0.6	25	250	16	11	355	14	95	180	15	25	10.3	340	1850
Colk8102	8.95	0.88	0.65	25	250	16	12	360	15	92	175	16	26.5	11.5	350	1710
CoSe95422	9.5	0.88	0.65	25	250	16	12	370	16	110	200	15	24	10	360	1580
CoSe1421	9.9	0.88	0.65	25	250	16	12	360	17	110	200	14	24	10.5	360	1600
CoP 94211	8.6	0.85	0.58	0.64	27.5	220	16	11	90	170	203	750	670	26	220	0.08
CoS 8436	8.4	0.83	0.55	0.64	28	220	16	10	95	180	203	950	610	22	220	0.09

Pigeon pea

VAR-NAME	CSDL	PPSEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LFMAX	SLAVR	SIZLF	XFRT	WTPSD	SFDUR	SDPDV	PODUR
UPAS-120	12.73	0.39	38.5	16.4	17.6	27	10.1	0.70	312	151.4	0.70	0.11	16.5	2.99	10.3
PUSA-992	12.53	0.39	39.5	16.4	17.6	27	10.7	0.74	316	152.4	0.70	0.11	16.5	2.99	10.3
AL-201	12.45	0.40	40.0	15.8	19.5	26	11.0	0.71	318	150.4	0.79	0.12	14.5	2.99	10.2
PUSA-991	12.94	0.56	39.5	19.5	18.8	30	11.2	0.74	317	150.0	0.72	0.11	16.5	2.99	10.2

Potato

VAR-NAME	ECO#	G2	G3	PD	T2	TC
K BADSAH	IB0001	1000	20.0	0.2	0.6	20.0
K BAHAR	IB0001	2000	22.2	0.9	0.8	23.2
K PUSHKAR	IB0001	2150	24.8	0.7	0.8	22.8
K SURYA	IB0001	2000	22.4	0.8	0.7	21.2

Sorghum

VAR-NAME	P1	P2	P20	P2R	PANTH	P3	P4	P5	PHINT	G1	G2
CSH-16	335.0	80.0	12.50	90.0	580.5	135.5	95.0	650.0	49.0	5.0	6.0

Tomato

VAR-NAME	EC0#	CSDL	PPSEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LFMAX	SLAVR	SIZLF	XFRT	WTPSD	SFDUR	SDPDV	PODUR	THRUSH	SDPRO	SDLIP
NDT-4	TM001	11.3	0.0	10.0	6.0	12.0	40	40	1.16	350	300	1.0	0.004	25	400	40	9	0.3	0.00

ii. Effect of climate change on Sugarcane

Climate change scenarios are increasingly used to quantify the impacts of climate change on major staple crops globally. The multi-model approach reveals the uncertainty level associated with projections, which helps in providing a direction and magnitude of change in crop production in the future. Jaiswal et al., 2023 applied the **CANEGRO-Sugarcane** crop model to downscale and **bias-corrected simulations** outputs for the mid-future (2040-2069) and far-future (2070-2099) under the two emission scenarios **RCP4.5 and RCP8.5** to simulate the effect of climate change on sugarcane's **stalk fresh mass (SFM)** and **Sucrose Mass (SM)** over major sugarcane growing states of India. Out of three **phenological phases** analyzed, two were found to be shortened (planting to emergence up to 14.5 days and emergence to stalk elongation up to 6.3 days) and one i.e., peak population to harvest got extended up to 9.5 days under RCP 8.5, far-future (Jaiswal et al., 2023) (Fig. 63). An increase in sugarcane's **stalk fresh mass** is projected substantially in the mid-future under RCP 8.5 for the tropical state **of Gujarat (11.2 to 18.1%) and the least for Odisha** (6.8 to 10.7%).

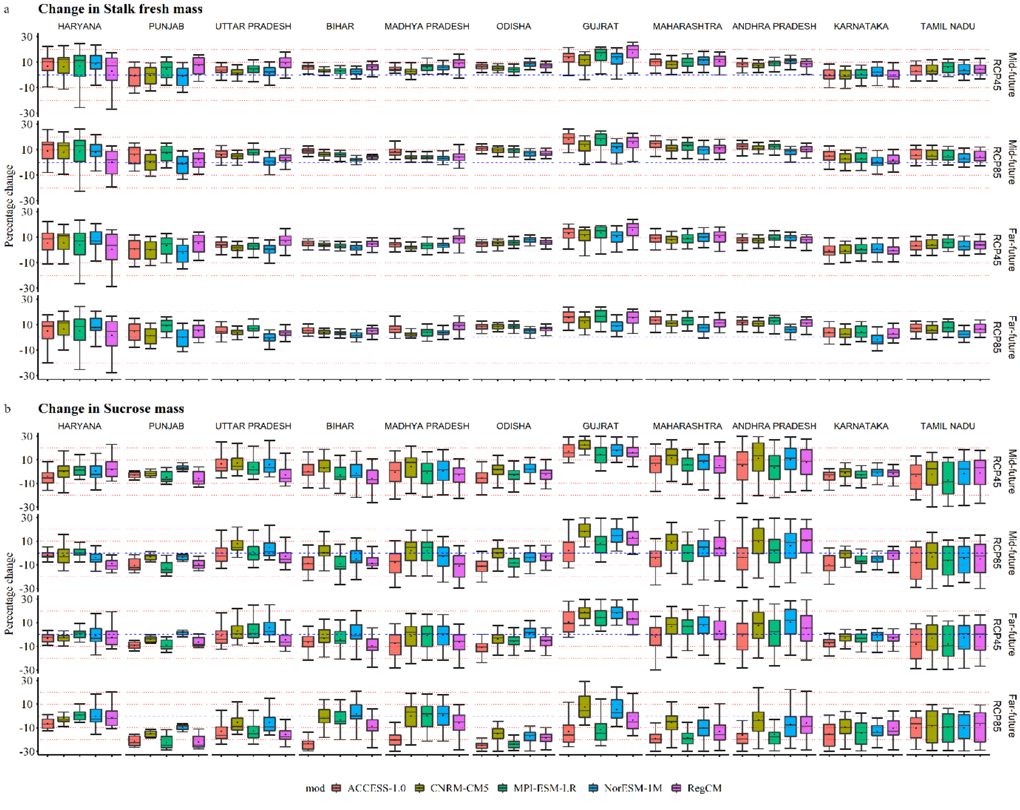


Fig. 63 Simulated change in (a) sugarcane's stalk fresh mass (SFM) and (b) SM (compared with baseline 1980–2009) in mid-future (2040–2069) and far-future (2070–2099) under RCP 4.5 and RCP 8.5 using different climate models for 11 states of India. The point within the box presents the mean value and the median is given by horizontal line (Jaiswal et al., 2023).

On the contrary, **sucrose mass** was found to decrease overall except for the states of Uttar Pradesh, Maharashtra, Gujarat, and Andhra Pradesh. The changes in the sugarcane's **stalk fresh mass** and **sucrose** mass were found to be regulated by the large and unanimous increase in maximum **(Tmax)** and minimum temperature **(Tmin)**, and a decline in solar radiation **(Srad)**, leading to an increase in **sugarcane's stalk fresh mass** and a reduction in sugar content, i.e., SM in the future which may cause economic loss markedly from one of the most important cash crops of India. With uncertainties in the magnitude of change, the findings are useful for plant breeders and policymakers to develop appropriate strategies to minimize the loss and increase sugar production (Fig. 63).

Furthermore, future changes in sugarcane crop yield were assessed over major sugarcane-producing states of India for mid future (2040-2069) and far future (2070-2099) period in **RCP 4.5 & RCP 8.5 scenarios** (Jaiswal et al., 2023). It was found that the increase in minimum and maximum temperatures will cause an increase in **stalk fresh mass** while a decrease in **sucrose mass**. Increase in stalk fresh mass is projected to increase substantially in the mid-future under RCP 8.5 for the tropical state (6.8% to 18.1%) (Fig. 64).

The increase in temperature also leads to the shortening of **phenological phases** i.e., planting to emergence (up to 14.5 days) and emergence to stalk elongation (up to 6.3 days) while the peak population to harvest period was extended up to 9.5 days, all under **RCP8.5,** far-future. Sucrose mass was found to decrease overall except for the states of Uttar Pradesh, Maharashtra, Gujarat, and Andhra Pradesh (Fig. 64).

Additionally, Sonkar et al., 2020 conducted a regional scale study over different **agro-climatic zones** of Uttar Pradesh to observe the climate change impact on sugarcane crops using the **CANEGRO-sugarcane model**. It showed that the stalk fresh mass and sucrose mass of the sugarcane were highly vulnerable and sensitive to the rising temperature in both rainfed and irrigated conditions (Fig. 65). The projections for the 2050s revealed that the **sucrose mass** will be highly affected compared to stalk fresh mass (Sonkar et al., 2020) which suggests an improvement and development of new tolerant varieties maintaining the sugar content.

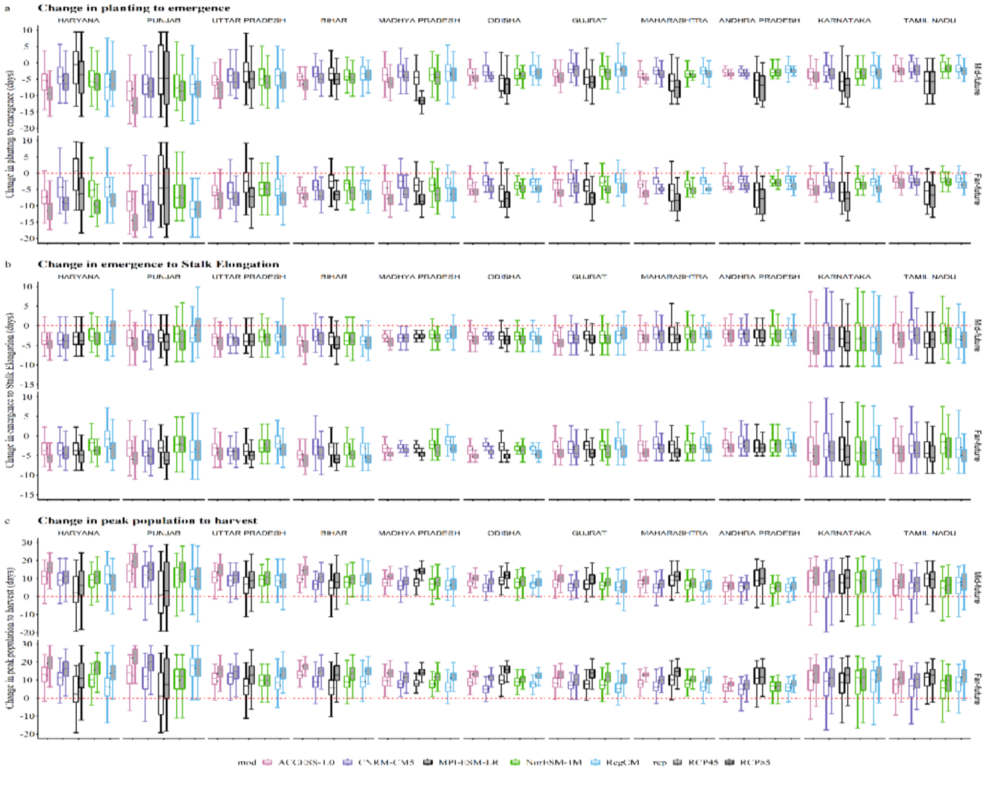


Fig. 64 Simulated change in phenological stages a) change in planting to emergence b) change in emergence to stalk elongation c) change in peak population to harvest (compared with baseline 1980–2009) in mid-future (2040–2069) and far-future (2070–2099) under RCP 4.5 and RCP 8.5 using different climate models for 11 states of India (Jaiswal et al., 2023). The point within the box presents the mean value and the median is given by line.

iii. Effect of Climate Change on Wheat

Patel et al., 2022 evaluated the climate change impact on wheat yield in nine **agro-climatic zones (ACZs)** of Uttar Pradesh using the **CERES-Wheat crop model**, driven by projected climate data from different climate models under **RCP 4.5 and 8.5** in two time periods: 2050s (2040- 2069) and 2080s

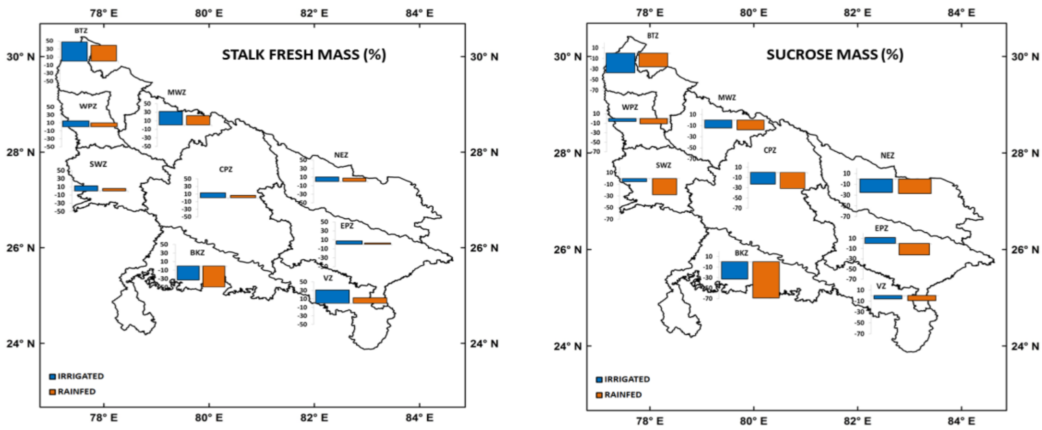


Fig. 65 Change in irrigated and rainfed stalk fresh mass (%) and sucrose mass (%) under RegCM4.0-RCP4.5 climate scenario (2041-2060) in comparison to the baseline over the nine agro-climatic zones of Uttar Pradesh. (Sonkar et al., 2020).

(2070-2099) (Fig. 66). The study shows that the vegetative growth period would be shortened in all the ACZs and scenario with higher reductions under **RCP 8.5** up to one week in 2050 and two weeks in 2080s. Without consideration of the CO_2 effect, the wheat yields will reduce by up to 20.5% and 30% under RCP 4.5 and RCP 8.5 respectively in the 2050s. In the 2080s the losses will be more pronounced reaching up to 41.5% under RCP 8.5. With the consideration of CO_2, the yield reductions will be up to 14% and 18% under RCP 4.5 and RCP 8.5 respectively in 2080s.

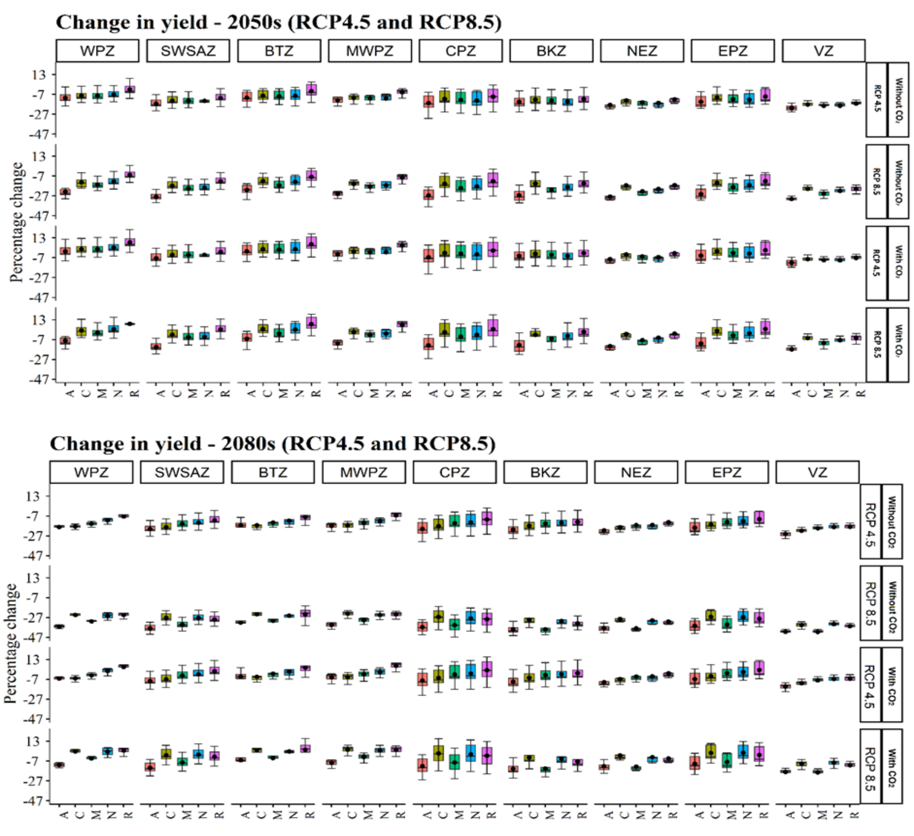


Fig. 66 Simulated wheat yield change in mid-century (2050s) and end-of-century (2080s) under RCP 4.5 and RCP 8.5 compared with baseline (1980-2009) using different climate models for 9 agro-climatic zones of Uttar Pradesh. The point within the box presents the mean value and median is given by black line. Here- A- ACCESS1-0, C- CNRM-CM5, M-MPI-ESM-MR, N-NorESM, R-RegCM (MPI-ESM-MR) (Patel et al., 2022).

Sonkar et al., 2019 examined the **vulnerability** of wheat crops to rising temperatures and aerosols over **five wheat-growing zones** in India. It was noted that every 1°C rise in **Tmean** resulted in a 7% decrease in wheat yield for the entire India, which varied disproportionately across the zones by a range of -9% (peninsular zone, PZ) to 4% (northern hills zone, NHZ) (Sonkar et al., 2019). Rise in 1^{o}C Tmean exclusively during grain filling duration was noted positive for all the wheat growing regions (0-2%) except over the central plain zone (-3%). When estimates of weather variables on wheat yield were combined with the estimated impact of aerosols on weather, the most significant impact was noted over the NHZ (-23%), which otherwise varied from -7 to -4% (Fig.67).

Singh et al., 2019 analyzed the impact of climate on the **wheat crop (Triticum aestivum)** and **Spot Blotch (SB) (Bipolaris sorokiniana)** disease. The study revealed that the incidence and severity increased rapidly during the 8th and 13th standard meteorological week of the wheat crop (Singh et al., 2019). Weather parameters influence the **outbreak of diseases** on the crop (Fig. 68 & 69). Temperature >30°C and humidity >50% are very crucial, especially during the **heading stage**. This study will help the farmers with the timely **adaptation** of the **management practices** and breeders for the screening of SB-resistant germplasms.

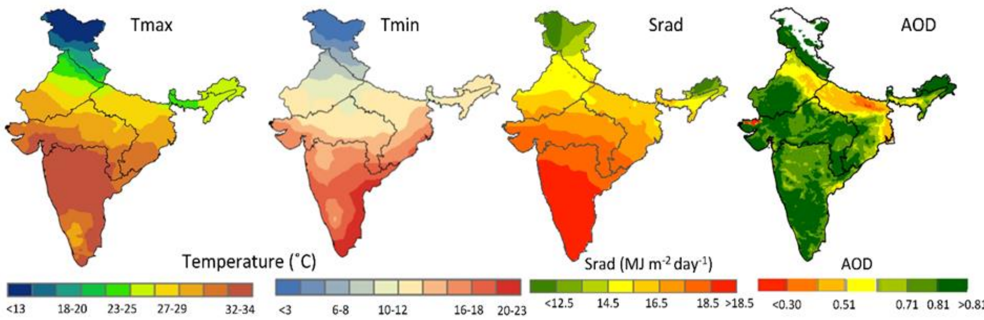


Fig. 67 Climate and AOD profile over different wheat growing zones of India (Sonkar et al., 2019).

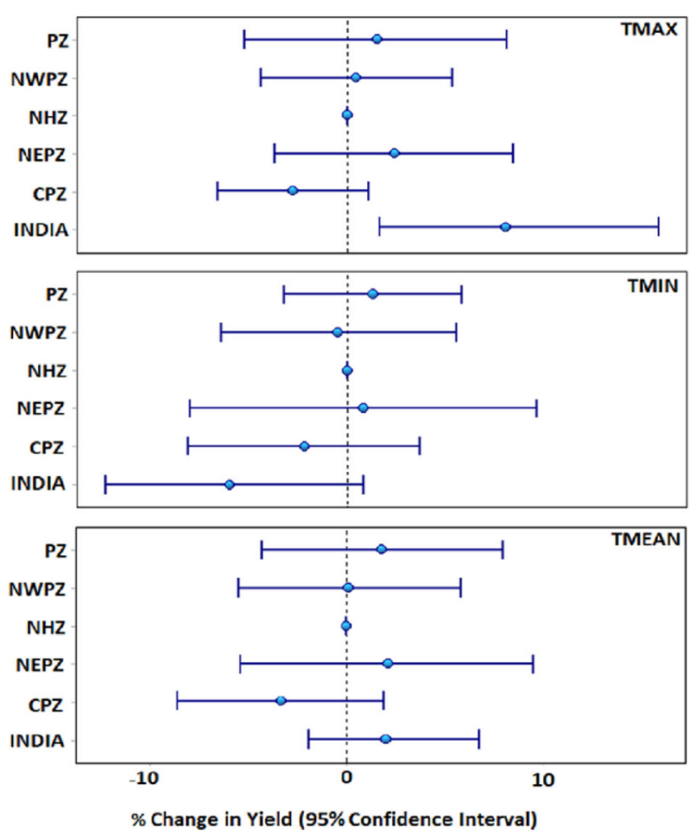


Fig. 68 Percent change in wheat yield against temperature during grain filling duration (Singh et al., 2019).

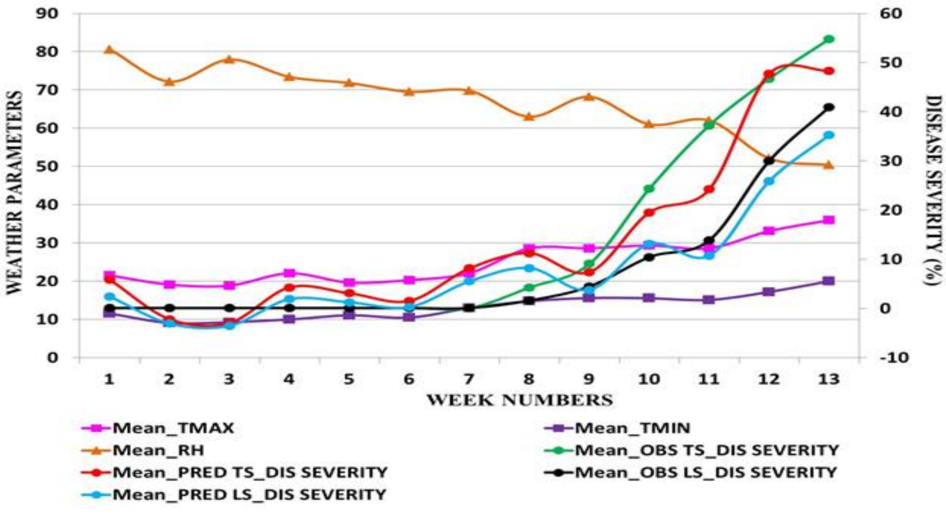


Fig. 69 Average maximum and minimum temperature (°C), relative humidity (%), spot blotch disease severity (%) in observed (OBS) and predicted (PRED) at timely (TS) and late sown condition (LS) wheat for 2014 to 2017 (Singh et al., 2019).

iv. Effect of climate change on Rice

The impact assessment revealed that the **panicle initiation days** and **anthesis days** of **rice** will be reduced across all the zones by 4 to 5days and the total **maturity period** will be shortened by 5–6 days showing a negative impact on rice yield. Trans-and lower Gangetic Plain have shown a positive change on the yield in **SSP5-8.5** far-future scenario under the influence of elevated CO_2 level. In order to meet the future rice demand, increasing production and productivity of rice is essential to fulfill the demand. A higher yield reduction across IGP was projected under **SSP2-4.5** mid and far-future scenario. It can be concluded that upper and middle Gangetic Plain represents the most vulnerable region for rice production in the mid-future and far-future under both scenarios **SSP2-4.5 and SSP5-8.5** within the study site (Fig.70).

Gupta et al., 2021 studied a **Nutrient modeling** of the subsurface under the **Boro Rice cropping system** for the assessment and optimization of fertilizers and showed agreeable results for the simulation of **Potassium** (K) and **Phosphorus** (P). The **finite element analysis** showed better performance in simulating the nutrients for the subsurface layers than the deeper layers (Fig.71) having larger underestimation (Gupta et al., 2021).

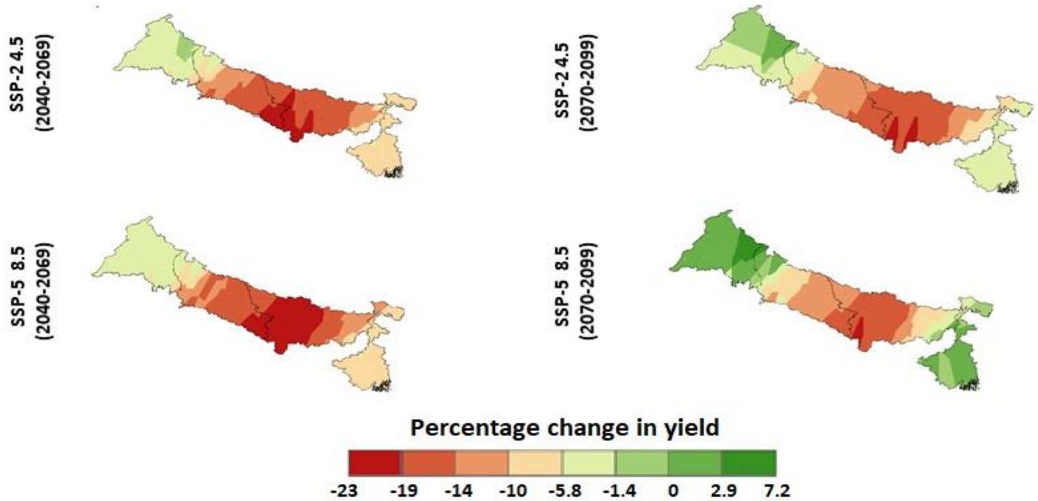


Fig.70 Change in rice yield for future scenarios over IGP

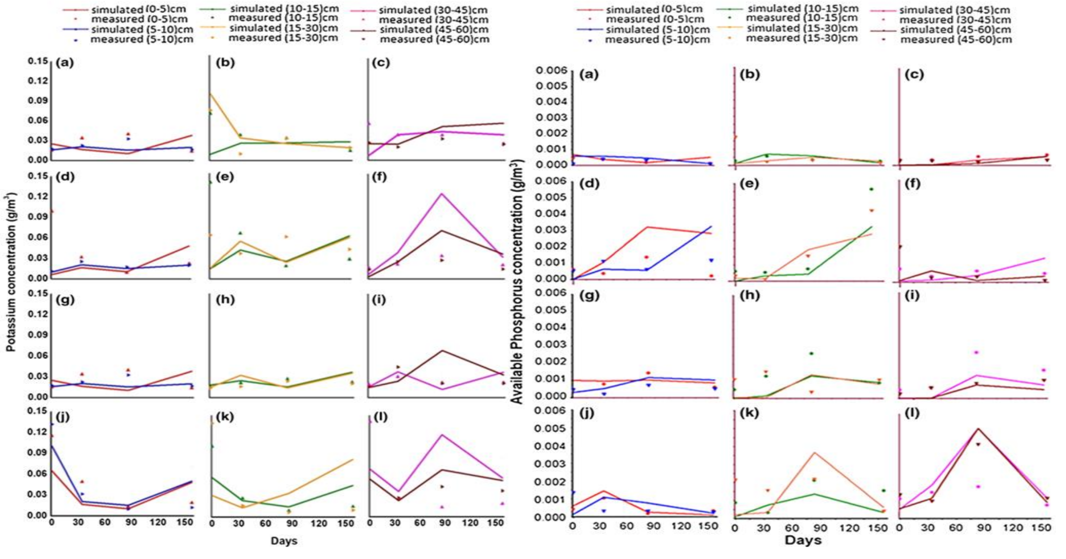


Fig. 71 Simulated and observed Potassium and Phosphorous concentrations at different depths (Gupta et al., 2021).

v. Effect of climate change on Pigeon pea

Yadav et al., 2021 assessed the climate change impact on eleven **pigeon pea maturity** groups in north Indian climate conditions for **RCP 2.6, 4.5, 6.0, and 8.5** with their respective projected years: 2010, 2035, 2065, and 2095. The findings revealed that the impact of climate change **delayed reproductive stages** (anthesis, maturity) and decreased grain yield of reference **genotypes** of different pigeon pea maturity groups were evident in all scenarios (Yadav et al., 2021). **Short-duration genotypes (MN5, ICPL88039, Prabhat, UPAS120)** showed a progressively higher decrease in yield as compared to medium (**Maruti, Asha, ICP7035**) and long (**Bahar, MAL13**) duration genotypes.

vi. Effect of climate change on Potato over India

The validated **SUBSTOR-Potato crop model** along with downscaled future climate data using different **RCMs** were used to simulate the effect of climate change on **potato production** for the years 2040-2069 (mid-future) and 2070-2099 (far-future) over the five major potato-growing states of India (Fig.72). The results showed that without considering elevated CO_2, tuber yield reduction was in the range of -3.6 to -17.5 % and -0.1 to -15.2 % under optimistic scenario, and -2.4 29 to -20.5 % and -0.3 to -20.5 % under pessimistic scenario during mid-future and far-future, respectively. While considering elevated CO_2, the **tuber yield** was found to be increased by +28.7% and +36.5 % under an optimistic scenario, and +34.4% and +35.9 % under a pessimistic scenario during mid-future and far-future period.

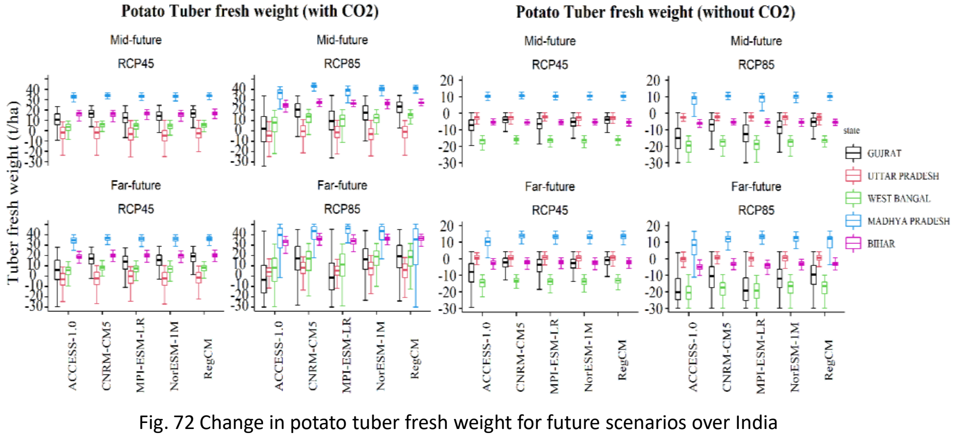


Fig. 72 Change in potato tuber fresh weight for future scenarios over India

In addition, the **SUBSTOR potato model** which is embedded in the **DSSAT v4.7** was used for the crop simulation modelling of an important potato cultivars, namely **Kufri Badshah** (Fig. 73). The impact of climate change on the production and development for without CO_2 condition, the **tuber fresh weight (UYAHS)** showed a maximum reduction by 30.7% in the **SSP5-8.5** far-future scenario. However, when the CO_2 was considered, an increase in the yield was noticed in the **SSP2-4.5** far-future scenario. In the other scenarios the reduction was negated to some extent in the mid future and far-future time period.

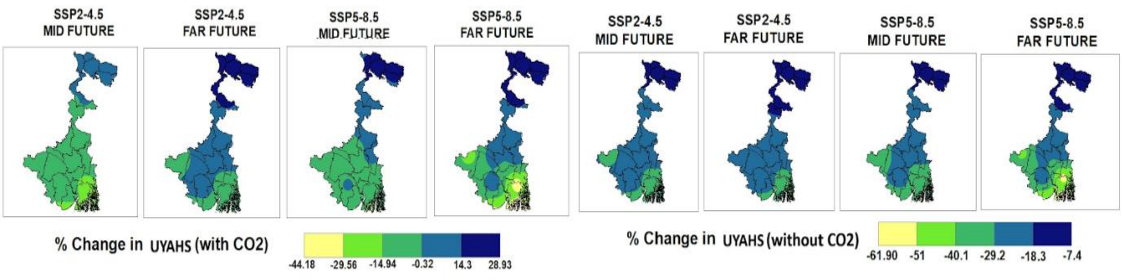


Fig. 73 Projected percentage change in potato yield for West Bengal in future scenarios

vii. Effect of climate change on Sorghum

The future yields of **Sorghum** had simulated **CERES-SORGHUM crop model** embedded in **DSSAT v4.8**, driven by **downscaled and bias-corrected simulations** forced by 10 different **general circulation models (GCMs)** participating in **CMIP-6**, for the mid-future (2040–2069) and far-future (2070–2099) under the two shared **socio-economic pathway scenarios(SSP), SSP2-4.5 and SSP5-8.5** to simulate the effect of climate change on the future yields of Sorghum, and change in days required for **panicle initiation, anthesis** and **maturity** of crop across the state of Karnataka. It was found that **future yields** of sorghum are going to **decrease** (Fig.74) across all the scenarios in the future with minimum reductions in mid future under SSP2-4.5 (-23.28%) and maximum in the far future under SSP5-8.5 (-37.37%).

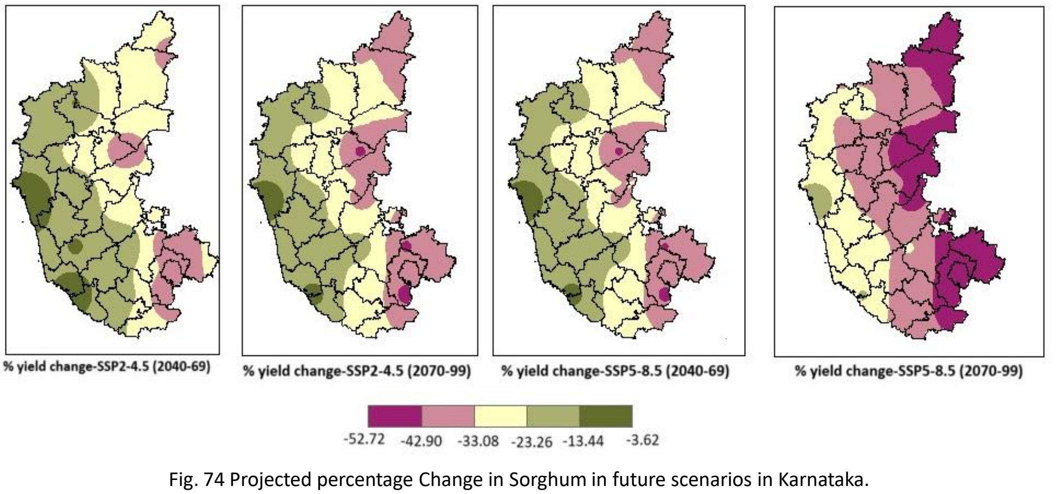


Fig. 74 Projected percentage Change in Sorghum in future scenarios in Karnataka.

Viii. Analysis of Soil moisture

Suman et al., 2021 evaluated the existing **soil moisture** products, and the development of a **soil moisture retrieval algorithm** over the **croplands** with high accuracy (Fig. 75). The outcome indicates that the results can be used for the Indian region for **irrigation scheduling** and **demand model technique development** (Suman et al., 2021). In this connection, a **high-resolution model** was also developed for **fine-scale soil moisture mapping** usable for farmers. This product can be further used for **flood** and **drought prediction modeling**.

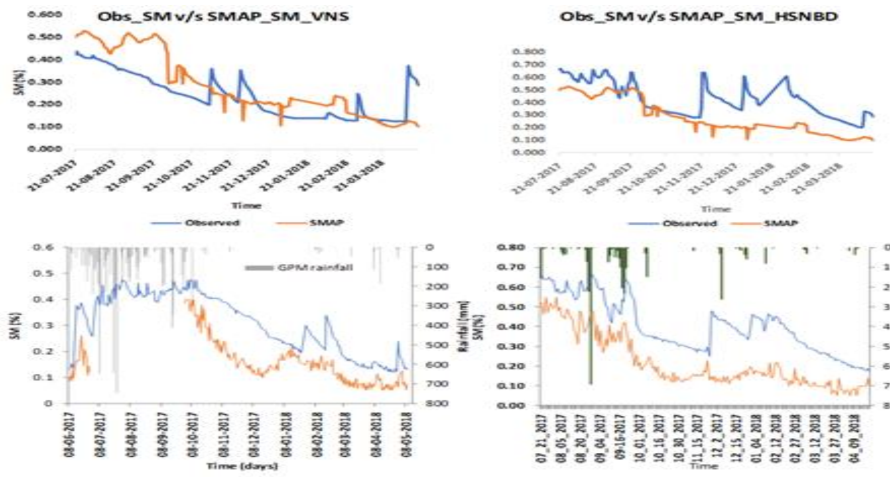


Fig. 75 Trend analysis of soil moisture (Suman et al., 2021).

ix. Development of a hyperspectral-based crop stage estimator interface

Singh et al., 2022 developed a **hyperspectral-based crop stage estimator** interface. To analyze the performance, an example workflow was created for wheat at different crop growth stages (Singh et al., 2022). The presented interface can perform simple steps which make it robust and user friendly. It also has the quick process ability of larger datasets. This interface will provide a common platform for the generation of the spectral library, calculation of vegetation indices, and development of the best **LAI model** and its mapping. This common platform will also be helpful for non-programming users due to its simple layout and working. This novel model extends the basic tools which combined with other R packages, will facilitate the development of robust and reproducible scientific modeling workflows (Fig. 76).

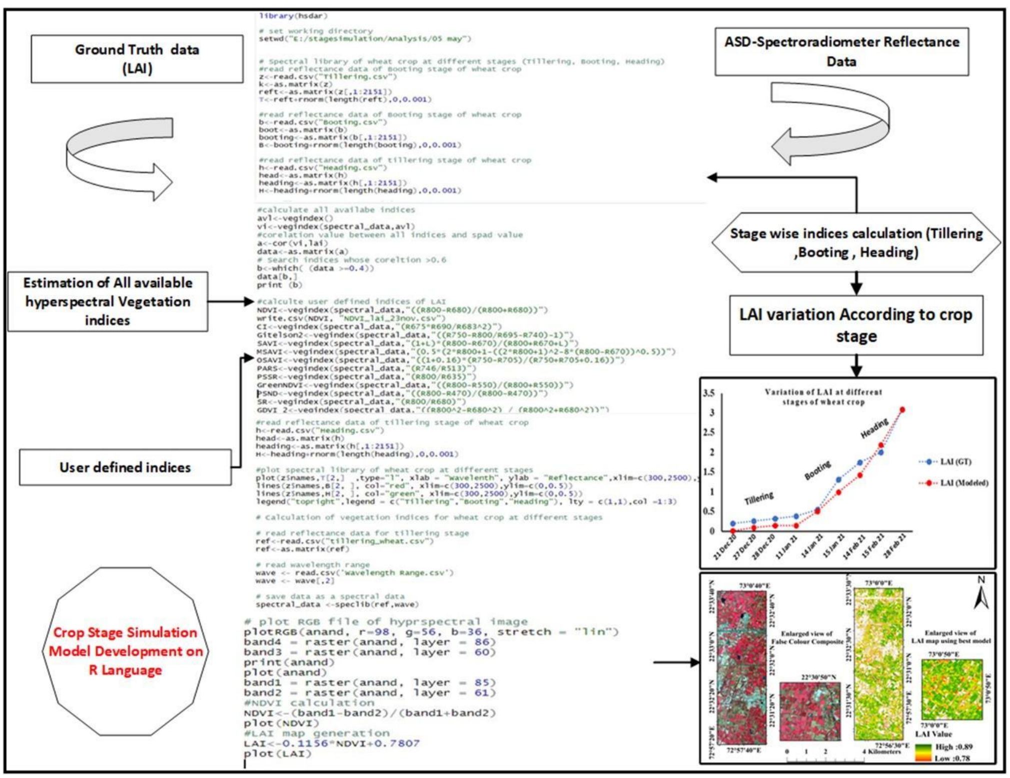


Fig. 76 Example workflow of Crop Stage Simulator (Singh et al., 2022).

The **generic model structure** provides an easy way to test and modify the importance of crop parameter namely **Leaf Area Index** to deduce crop growth stages of winter wheat **(Triticum aestivum L.)** particularly during –heading, tillering, and booting (Fig. 77).

Further, to know the **LAI variations** at different agriculture sites, the best model was implemented using the **AVIRIS-NG (Airborne Visible Near-Infrared Imaging Spectrometer - Next Generation)** hyperspectral datasets. The analysis indicates that during **tillering stage** the performance was found best during calibration (r = 0.66, RMSE = 0.40, and bias = -0.80) and validation (r = 0.98, RMSE = 0.20, and bias = 0.12) in comparison to the field measurements.

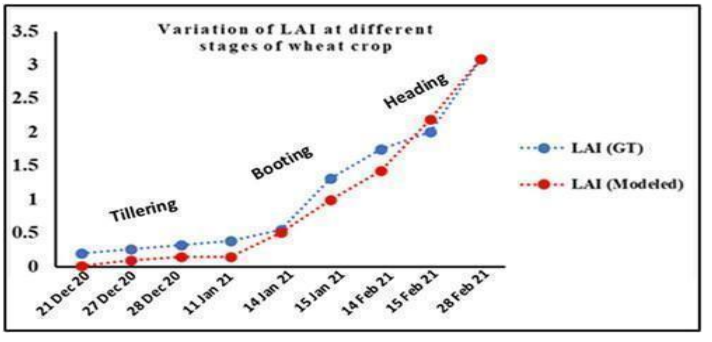


Fig. 77 Variations of LAI at different stages of wheat crop (Singh et al., 2022a).

x. Evaluation of the Radiative Transfer Model

Singh et al. 2023 evaluated the capability of the **Radiative Transfer Model** using **LUT (lookup-table) inversion** for **Leaf Chlorophyll Content (LCC)** mapping over a subtropical pine forest plantation in Western Himalaya using **high-spatial-resolution UAV-acquired imagery**. A variety of LUT-based inversion algorithms using 12 distinct cost functions were systematically tested against reflectance data obtained from a UAV (Singh et al. 2023). The inversion evaluation was conducted in ARTMO's LUT-based inversion toolbox. Among all the CFs evaluated, the "**Bhattacharyya divergence**" provided the most accurate **LCC inversion** (Fig. 78). In combination with the leaf-level and **canopy level PROSAIL model**, LCC was estimated from the retrieved canopy reflectance, with an adequate accuracy (R2 = 0.94, RMSE = 6.20 µg/cm^2 and NRMSE = 12.27%) during the validation for the Almora sites. The **optimized inversion strategy** with the Bhattacharya divergence CF was subsequently applied to the UAV-acquired imagery at 8.2 cm spatial resolution. It produced a detailed LCC map over the pine forest with retrieved LCC values ranging between 30 to 75.

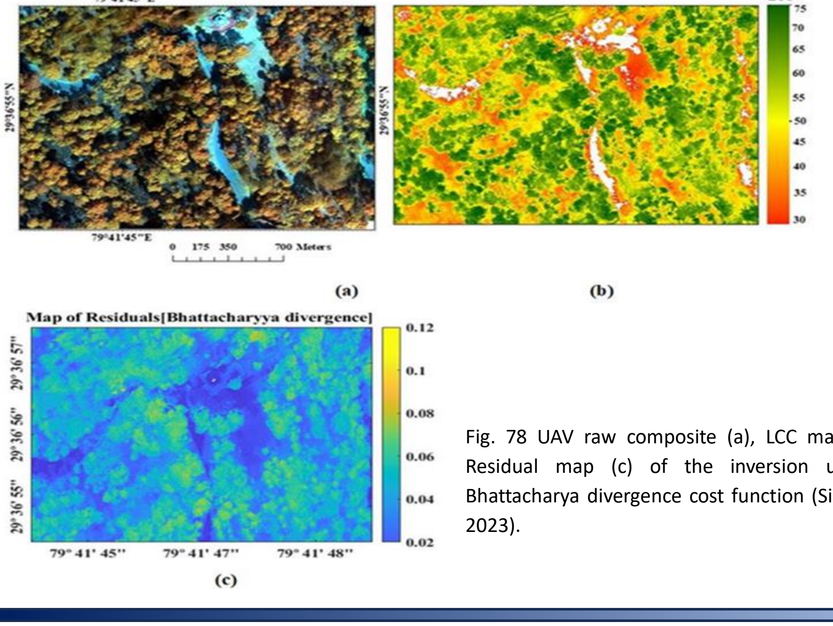


Fig. 78 UAV raw composite (a), LCC mapping (b) Residual map (c) of the inversion using the Bhattacharya divergence cost function (Singh et al. 2023).

xi. Farm innovations and adaptation practices

Dubey et al., 2023 carried out a study to validate promising **farm innovation** and **adaptation practices** used by **small-medium landholding farmers** for **rice cultivation** in eastern Uttar Pradesh (UP), north India, as well as to examine the sustainability of innovative practices for large-scale adaptation. For this, a 3-year study comprising extensive field surveys and experiments was undertaken to compare **single transplantation (ST)** and **double transplantation (DT)** in **rice** along with **organic addition (farm-yard manure, FYM)** on crop growth, yield, climate resilience, soil quality, and overall sustainability i.e., social (women involvements and labor productivity), environmental (water productivity and nutrient use efficiency), and economic (benefit-cost ratio) dimensions of sustainability (Dubey et al., 2023). Field experiments were conducted in triplicate using two local rice varieties (**MotiNP360 and Sampurna Kaveri**) in two agroclimatic zones, namely the middle Gangetic plain and the Vindhyan zone, in the Mirzapur district of eastern Uttar Pradesh. The Residual effects of **FYM application** significantly improved ($p < 0.05$) the grain yield in subsequent years of cropping. Optimizing **DT cultivation practices**, preferably with FYM input for various agro-climatic regions, is essential for large-scale sustainable rice production under changing climatic conditions (Fig. 79).

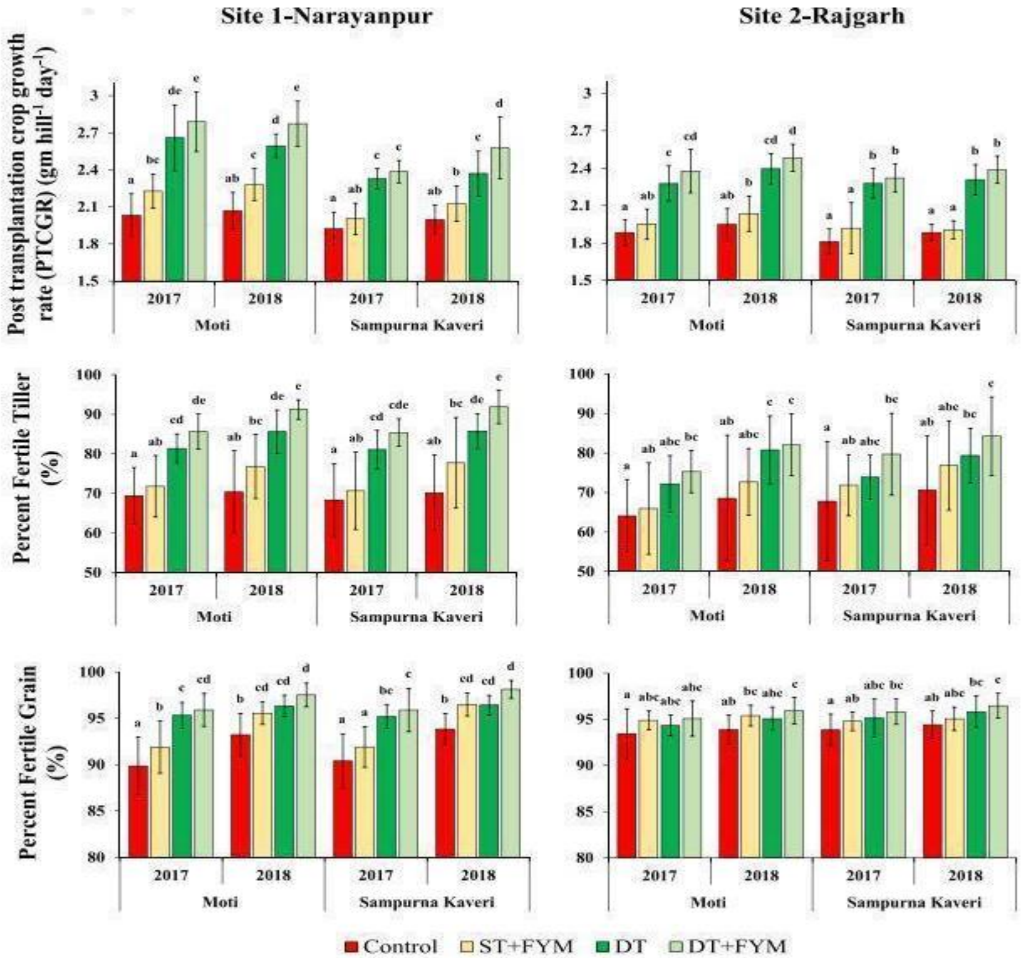


Fig. 79 The effect of various cultivation practices on post transplantation crop growth; percent fertile tiller; and percent fertile grains in two different locally grown rice varieties (Moti-NP360 and Sampurna Kaveri) grown at Narayanpur (middle Gangetic plain) and Rajgarh (Vindhyan zone) experimental sites in Mirzapur district of eastern Uttar Pradesh. Data shown are Mean ± SD. Mean values followed by different letters within a particular column are significantly different at $p < 0.05$ by DMRT. Figure legends: Control = Single transplantation with 100% RDF; ST + FYM = Single transplantation with 75% RDF +25% FYM; DT = Double transplantation with 100% RDF; DT + FYM = Double transplantation with 75% RDF +25% FYM; FYM = Farm yard manure (Dubey et al., 2023).

xii. Adaptation Strategy for enhancing crop production

Shifting of sowing date, **Irrigation scheduling**, **Conservative agriculture**, New **heat tolerant** wheat varieties, and **Alternative crops** have been suggested to reduce the impact of climate change on crop production. In this regard, the **SUBSTOR-Potato model** was run for sixteen different sowing dates as an **adaptation strategy** to reduce the impact of climate change on potato yield under the **SSP2-4.5 and SSP5-8.5 scenarios** for West Bengal. A week after the normal sowing date (2nd November) was found to produce the best yield against climate change (26th October) for mid and far future during **SSP2-4.5 and SSP5-8.5** (Fig. 80 & 81). Furthermore, the **CERES-SORGHUM model** was run for ten different sowing dates as an adaptation strategy to reduce the impact of climate change on yield under the SSP2-4.5 and SSP5-8.5 scenarios for Karnataka. 7th June was found to be the best date of sowing for reduced impact on crop production i., e., one week before the original sowing date (14th June) for mid and far future during SSP2-4.5 & SSP5-8.5 (Fig. 82).

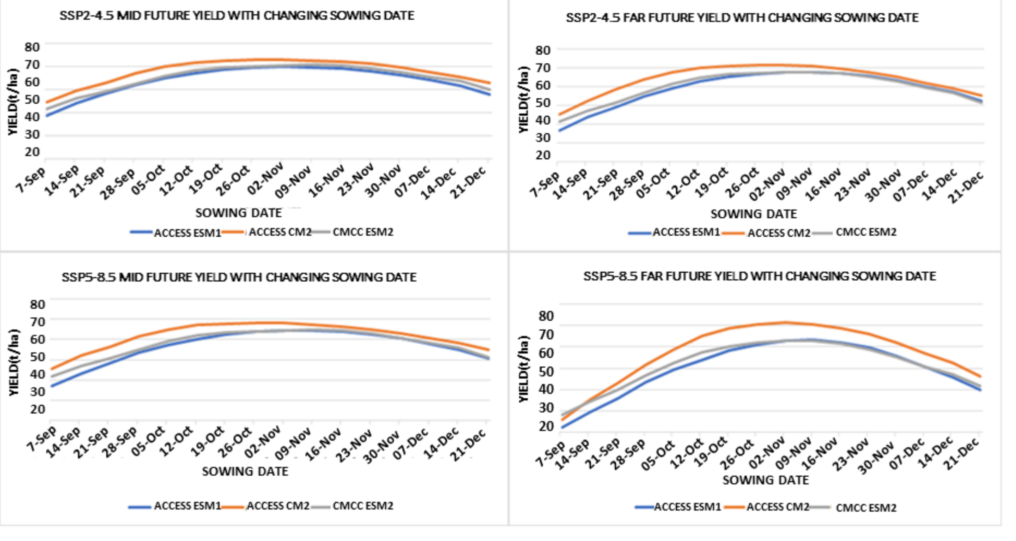


Fig 80. Shifting of sowing dates for an adaptation strategy for Potato.

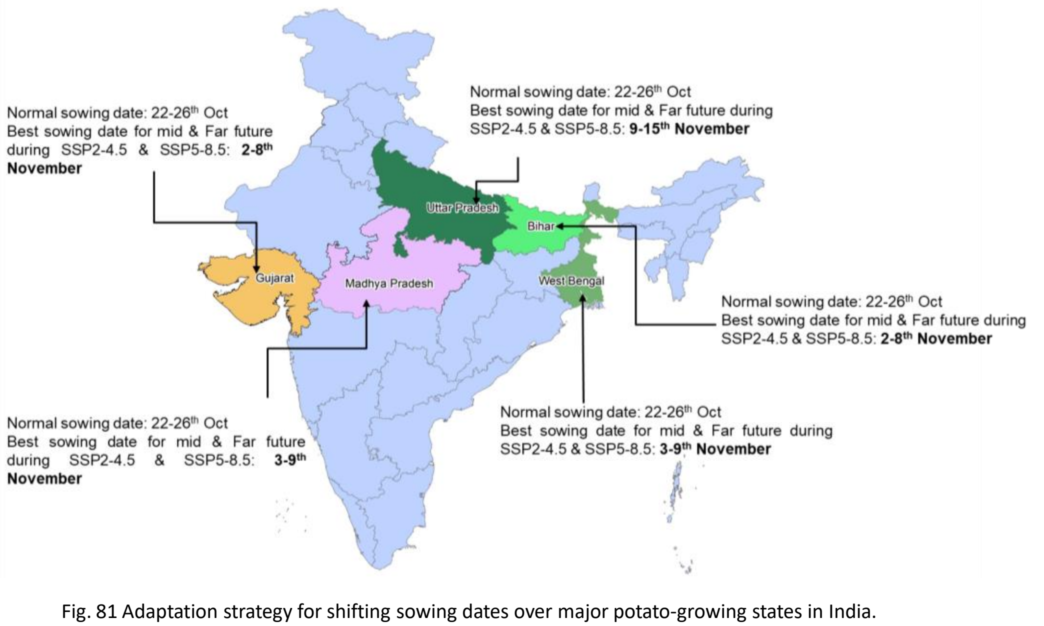


Fig. 81 Adaptation strategy for shifting sowing dates over major potato-growing states in India.

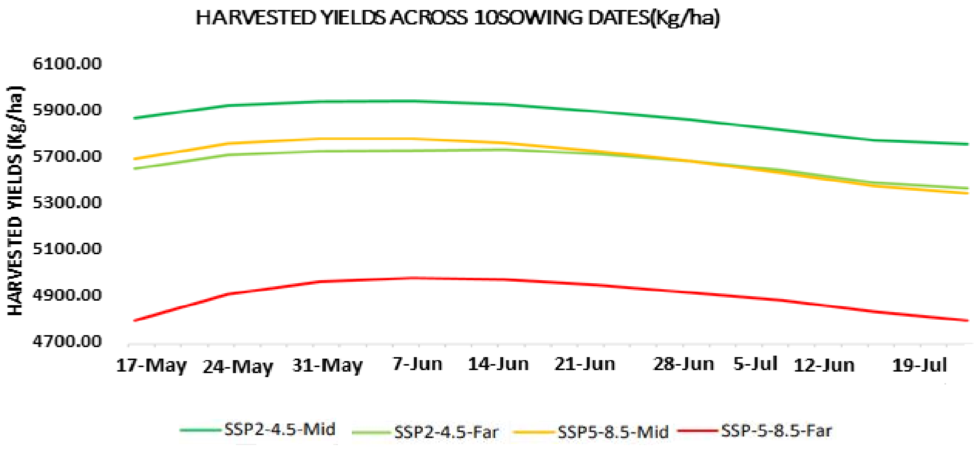


Fig. 82 Shifting of sowing dates for an adaptation strategy for Sorghum.

xiii. Farmers' perception and awareness of climate change

Patel et al., 2023 conducted a **survey of 300 farmers** in three districts of eastern Uttar Pradesh**,** viz. Mirzapur, Chandauli, and Varanasi to understand the farmers' perception and awareness of **climate change** and its impact in Eastern Uttar Pradesh. The interaction during the survey with farmers helped them be aware of the detrimental effects of climate variability and change. More than 82% of farmers perceived a temperature rise, an alteration in the rainfall pattern. Over 60% of the farmers agreed that temperature and precipitation alterations reduce production and revenue. Farmers opted for strategies like shifting the sowing date (87%), changing variety (86%), and increasing irrigation (83%) (Table 2) depending upon their monetary benefit and not upon knowledge, i.e., Passive Adaptation (Patel et al., 2023). The survey will further help in developing an **advisory** regarding the suitable varieties of different crops and will help to draw an insight to assess the **social-psychological factors**, the extent of **community awareness**, and how farmers perceive the impacts of climate change and adaptation (Fig. 83 & 84).

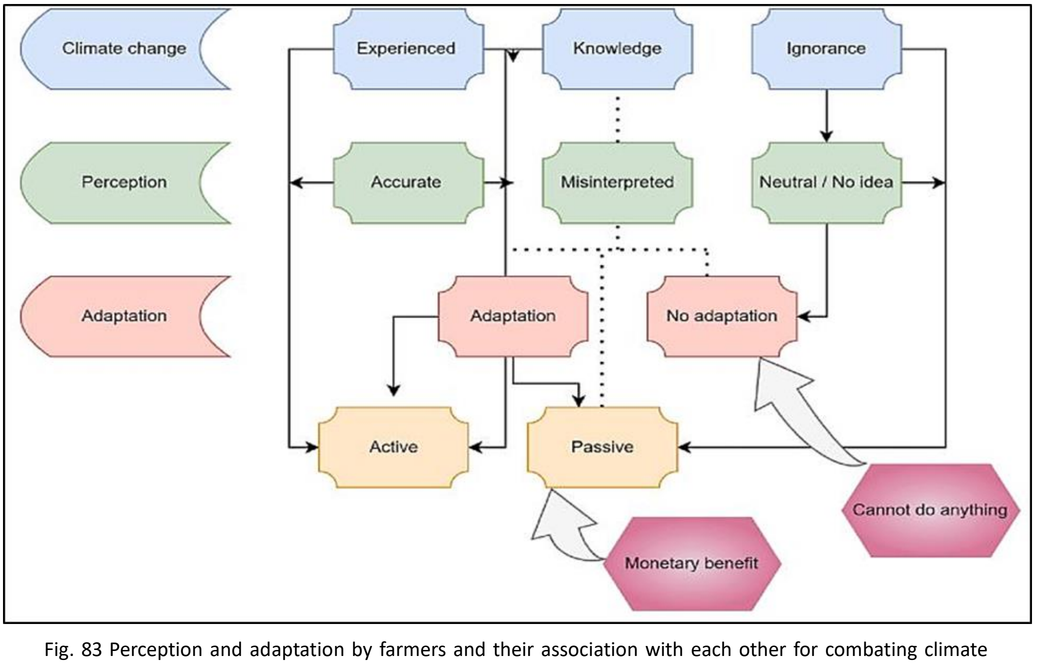


Fig. 83 Perception and adaptation by farmers and their association with each other for combating climate change (Patel et al., 2023).

Table 2: Adopted passive adaptation Strategies by the Indian Farmers to Climate Change

Adaptation strategy	Adopted	Reasons for adoption		
		Knowledge	Monetary benefit	Both
Shifting of sowing dates	87	28	46	26
Increase irrigation	83	46	43	11
Mixed farming	47	35	53	12
Contract farming	12	3	77	20
Shift to non-agriculture	51	8	87	5
Conservation agriculture	24	37	59	4
Opted dairy/poultry	31	34	60	7
Change in crop area	38	36	55	10
Variety change	86	37	46	17
Soil testing	49	30	59	11
Crop insurance	37	23	71	5
Water harvesting	10	74	19	6
Agro-forestry	37	36	59	5
New technology	29	25	57	17
Crop change	56	43	45	12

Fig. 84 Interaction with farmers at Pidkhir village, Mirzapur, and the Centre.

D. Water

Hydrological responses to water resources management are the function of Precipitation, evapotranspiration, soil moisture, etc. The center focuses on the variation of such different hydrologic responses to climate change to evaluate its impact on water resources. The studies estimated Soil erosion and Evapotranspiration, SWAT and WRF modeling, Groundwater effect, and drainage morphometric characteristics through topographic, geologic, and hydrological information over the different River Basins of India.

i. Impact of Climate Change on Surface Water Reserves

Bhatt et al., 2020 analyzed the long-term **soil moisture**, **evapotranspiration**, **vegetation dynamics** using **NDVI,** and crop yield in the context of extreme weather events (wet and dry) over the **Gomti River basin**. The extreme years established a significant correlation between **rainfall variability** and **vegetation cover dynamics** over the basin (Fig. 85 & 86). Vegetation including the **crop cover** was found healthy in correspondence to excellent rainfall during wet years whereas, it was poor during the dry years (Bhatt et al., 2020).

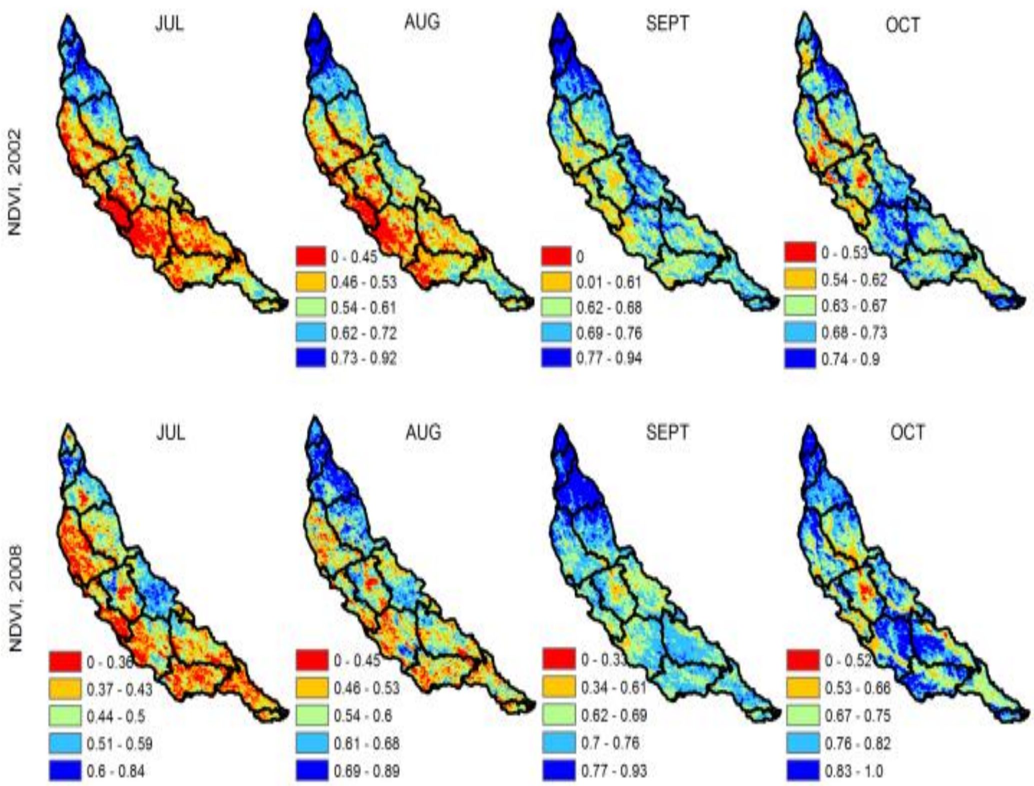


Fig. 85 Spatial pattern of seasonal NDVI over Gomti river basin (Bhatt et al., 2020).

Maurya et al., 2023 explored the impact of climate change **(rainfall, temperature)** on **stream flow** over the **Mahi River Basin** using **CMIP5** output and the **SWAT model**. The finding indicated that the ensemble means of **CMIP5** performed well and successfully applied to future climate change scenarios with less uncertainty (Maurya et al., 2023). Further, the **SWAT model** results showed increased streamflow sustained during the period 2011-2040 (Fig. 87 & 88).

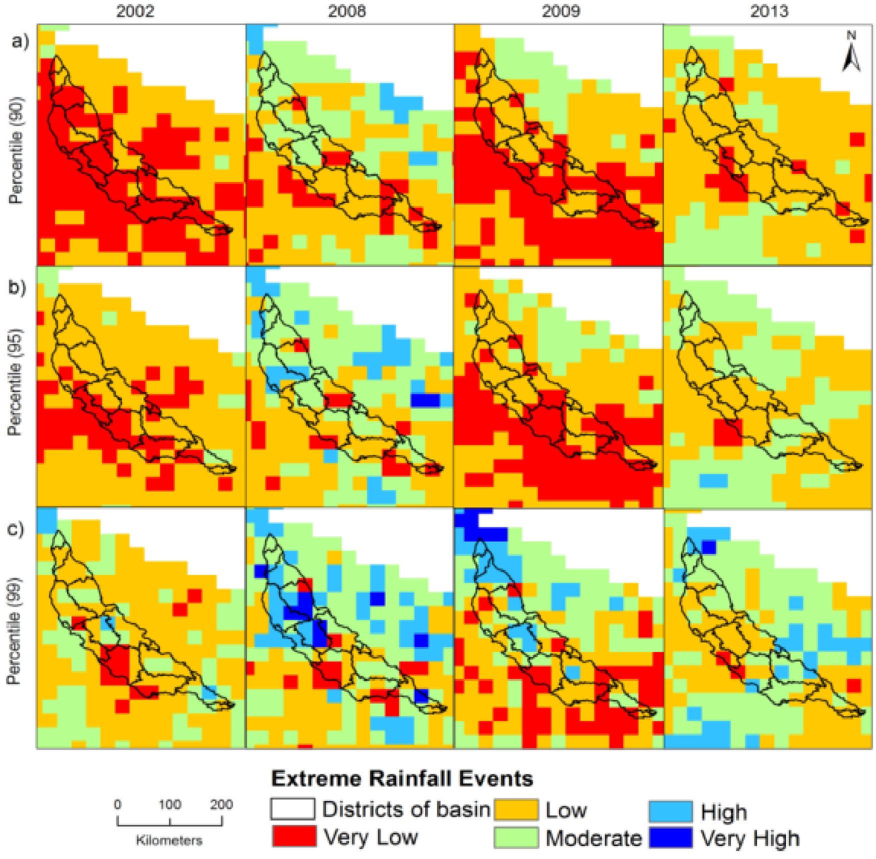


Fig. 86 Distribution of rainfall extreme events of various categories during the dry years (2002 and 2009) and wet years (2008 and 2103) (Bhatt et al., 2020).

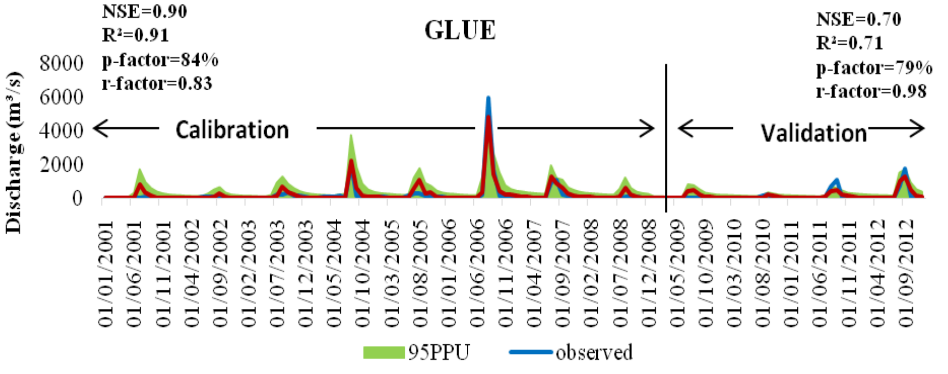


Fig. 87 Observed and Simulated Discharge during Calibration and Validation, Mahi River Basin (Maurya et al., 2023).

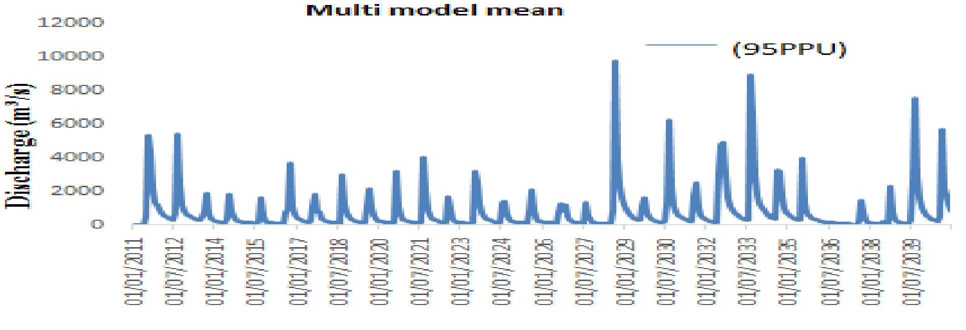


Fig. 88 Forecasted discharge of Multi-model mean during the period 2011-2040 (Maurya et al., 2023).

Again, Maurya et al., 2023 carried out a streamflow projection based on the **NEX-GDDP-CMIP5** datasets during the period of 2011-2040, revealed that annual average streamflow will be increased by 76.74% (1031.24 m^3/sec) based on the **INMCM-4** outputs, 25% (778.71 m^3/sec) based on the **MRI-CGCM3** outputs, and 24.53% (773.11 m^3/sec) based on the ensemble mean in the near future (Fig. 89). Further, the percentage change in high and low streamflow with respect to the baseline time period and the difference between the high and low streamflow would be increasing in the near future (Maurya et al., 2023). Thus, it can be illustrated that low streamflow is observed during the summer season, which causes water shortage, drought, and high flow during the rainy season, leading to food and other **water-related disasters**. Similar trends are observed on monthly and seasonal flows under the **INMCM-4, MRI-CGCM3**, and **ensemble mean**.

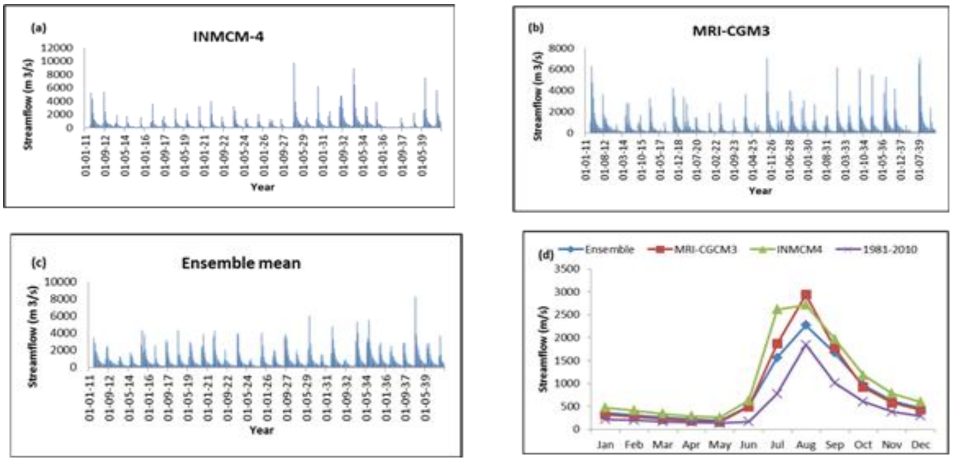


Fig. 89 Streamflow projection based on the NEX-GDDP-CMIP5 datasets, during the period of 2011-2040 (a)–(c) and (d) mean monthly streamflow using the NEX-GDDP-CMIP5 v/s IMD datasets (Maurya et al., 2023).

Srivastava et al., 2020 estimated the performance assessment of **Evapotranspiration (ETo)** from different data sources over the agricultural landscape in Northern India. The results indicated that after **WRF downscaling**, some marginal improvement was found in the **ETo** as compared to without downscaling datasets (Fig. 90). Overall, **NASA/POWER** and **WRF** downscaled data can be used for **ETo estimation**, especially in the ungauged areas (Srivastava et al., 2020). However, NASA/POWER is recommended as the ETo calculations are less complicated than those required with WRF.

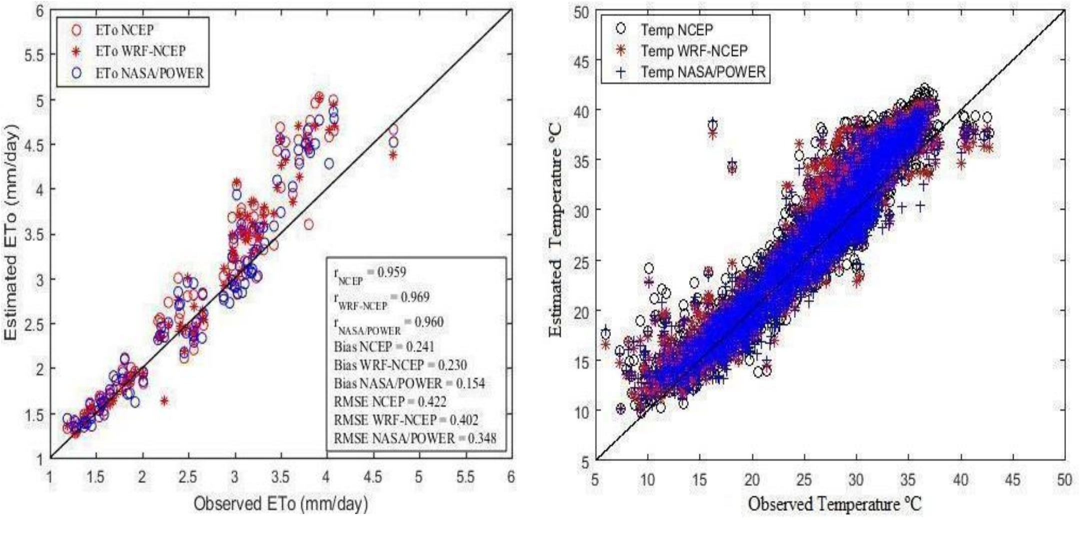


Fig. 90 Scatter plot representing the variations among WRF-NCEP, NCEP, and NASA/POWER temperature and daily ETo with observed datasets (Srivastava et al., 2020).

Srivastava et al., 2021, in another study, assessed the **Precipitation and Extreme Events** over the **Kosi River basin** using statistical approaches. The study indicated that the extreme indices viz. R10 and R20 days showed a decreasing trend from the northeastern to the southwest part of the basin (Srivastava et al., 2021), whereas, in the case of the highest one-day precipitation (RX1 day), no clear trend was found (Fig. 91).

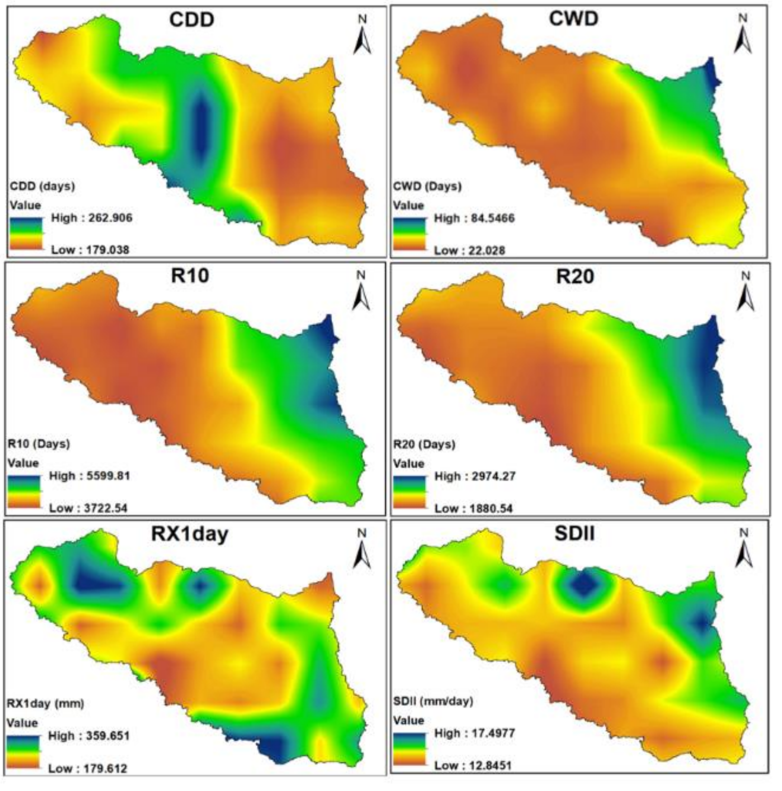


Fig. 91 Spatial variability of extreme precipitation indices over the RRB during 1901–2016. The RX1 day represents the most intense one-day precipitation over the region. CDD and CWD represent consecutive dry days and consecutive wet days. SDII is the annual total precipitation divided by the number of wet day.

Maurya et al., 2021 compared the **IMD data** (i.e., the observations) with the **NEX-GDDP-CMIP5's** six models output data for the period 1981-2010 showing that all individual model and ensemble mean clusters lie in between a correlation coefficient of 0.5 to 0.85 (Fig. 92). The models (i.e., **CanESM2, MPI-ESM-LR, GFDL-ESM2M and GFDL-CM3**) showed large inter-model differences, while ensemble mean had less error and hence can be used for future projections of rainfall.

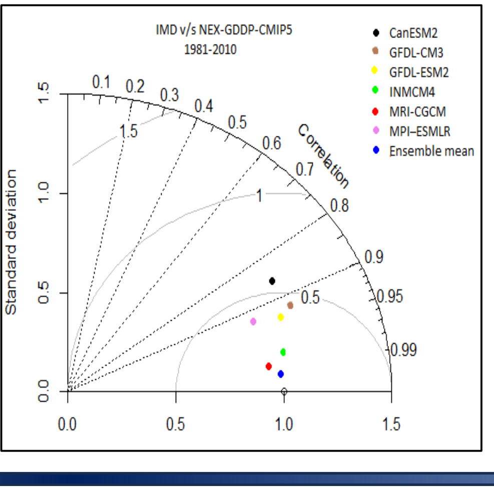


Fig. 92 Taylor diagram of the six NEX-GDDP-CMIP5 models versus observation (IMD), for rainfall datasets during the monsoon months (1981-2010) (Maurya et al., 2021).

Further Maurya et al. 2021 carried out **future projections** (2011-2040) of soil erosion losses after calibrating the **soil erosion model** on past datasets. The results revealed that soil erosion occurred at the rate of 58.65 t/h/year, during the present time from 1981-2010 and significantly increase in the future up to 71.46 t/h/year, in the **Mahi River Basin** (MRB), a region of key environmental significance in India (Maurya et al. 2021) (Fig. 93).

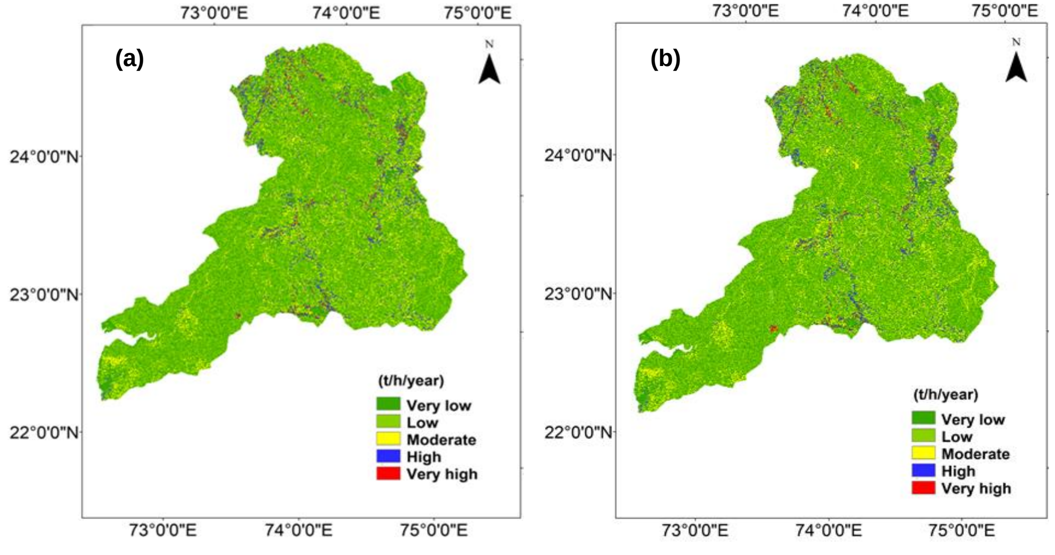


Fig. 93 Soil erosion status (a) IMD (1981-2010), and (b) CMIP5 Ensemble mean (2011- 2040) (Maurya et al., 2021).

Pratap et al., 2020 found that during the **cloudburst**, the **relative humidity** of the total cloud cover was at the maximum level while **temperature** and **wind speed** were found to be very low. It is evident that because of this situation, a high amount of clouds may get condensed at a very rapid rate and result in a **cloudburst** over the **Kedarnath** region low (Pratap et al., 2020) (Fig. 94).

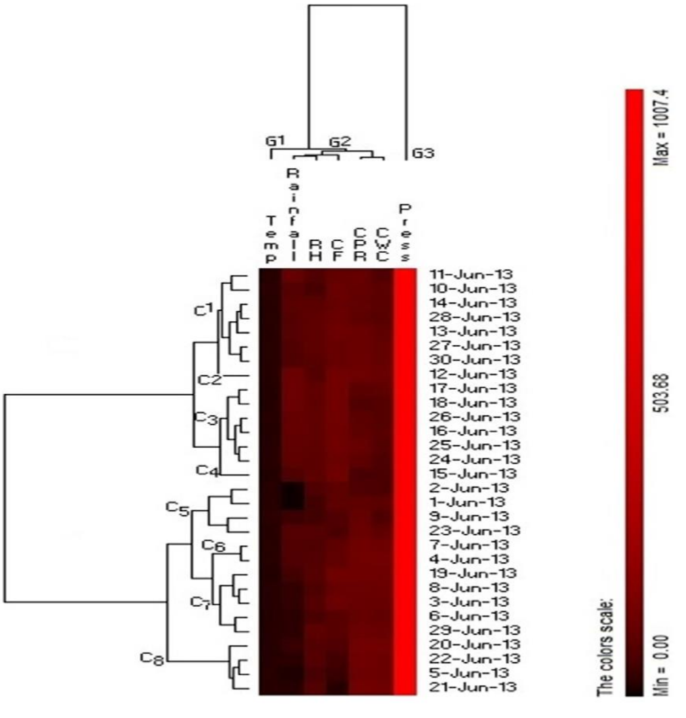


Fig. 94 Clustering of meteorological variables on the day of cloudburst (Pratap et al., 2020).

ii. Impact of Climate Change on Groundwater Reserves

Dey et al., 2021a evaluated the efficiency of the **deep machine learning method** to predict **long-term groundwater table** variation with respect to climatic variables. The model used **BLSTM** with the **highway LSTM (BHLSTM) network** and improved by incorporating **straight LSTM** at the top of the architecture. The relative performances were compared by increasing the network stack size. A stack of four BHLSTM and a straight LSTM in a **dynamic prediction** had proven to be the most appropriate architecture to predict long-term groundwater levels (Dey et al., 2021). The study experimented over the **Varuna River basin** for twenty years by incorporating the historical annual average of total precipitation, temperature, relative humidity, actual evapotranspiration, and groundwater level data. Results revealed that the river basin will face groundwater scarcity in the near and distant future. (Fig. 95).

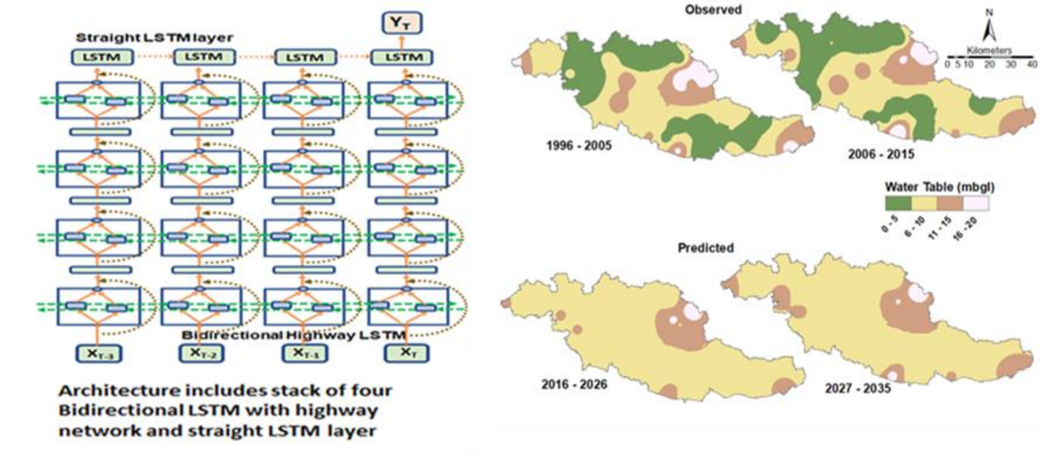


Fig. 95 Groundwater potential zones through (a) AHP method (b) MIF method with well discharge points and receiver operating characteristic (ROC) curve for the groundwater potential maps (Dey et al., 2021a).

In another study, Dey et al., 2021b used the **Analytical Hierarchy Process (AHP)** and **Multi-Influence Factor (MIF)** techniques to delineate the groundwater potential zones in the **Varuna River basin**. The final output derived from the models was categorized into three classes - **'Low,' 'Moderate,'** and **'High'** groundwater potential area. Both models represent the maximum extent of the study area under moderate (45% and 43% in AHP and MIF, respectively) groundwater potentiality. 31% of the block is overexploited, and 15% is under the **critical zone** over the river basin. This estimation exhibits an increase in the **draft** (10%) due to expansion in population, agricultural extent, and industrialization, which ultimately causes water table depletion (Fig. 96).

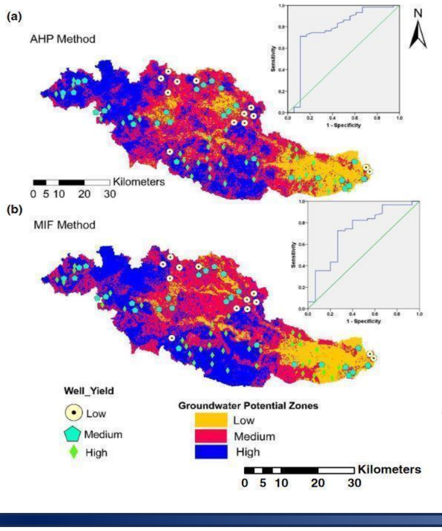


Fig. 96 Overview of the proposed model involves a stack of four, a straight LSTM, and spatial distribution of Observed and Predicted water levels in the Varuna River basin (Dey et al., 2021b).

Dey et al., 2023 evaluated the geochemical evolution of groundwaters in the **Varuna River basin** and associated **human health risks** through **inverse geochemical modeling** and **quality assessments**. The abundance of significant ions was Na >Ca >Mg >K, and HCO_3 >Cl >SO_4 >NO_3 >F. The mixing analysis showed that the groundwater quality of this alluvial plain is controlled by mixing phenomena (Fig. 97). Most samples expressed excellent **EWQI (Entropy Water Quality Index)** (Dey et al., 2023). Salinity (TDS), pH, and Mg were the key factors affecting groundwater quality in the study area, indicating geogenic control and the need to limit anthropogenic contributions.

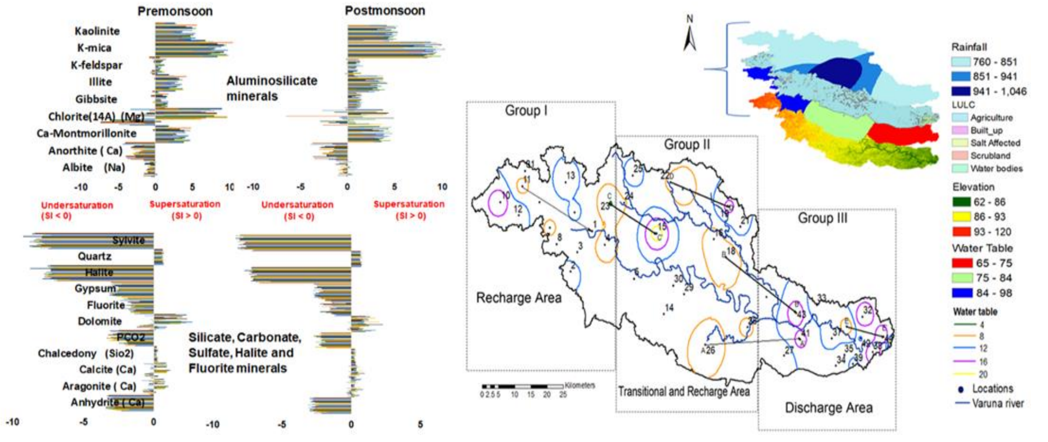


Fig. 97 Plot of saturation indices of different minerals and three groups along the flow path i. recharge area waters (Group I: Na- HCO3- Cl), ii. Transitional area waters (Group II: Na- Ca- HCO3), and iii. Discharge area waters (Group III: Na-Mg-HCO3) depend on the parameters shown in thematic maps and Inverse modeling (Dey et al., 2023).

F. Paleoclimate and Paleoceanography

In, DST - Mahamana Centre of Excellence in Climate Change Research (DST-MCECCR), Banaras Hindu University, India, most of the paleoclimatic studies are based on the analysis of tree-ring from western Himalaya, and foraminiferal (calcareous microfossils) assemblages and geochemical proxies from Deep-Sea sediments retrieved from the Indian Ocean and Atlantic Ocean. The important research highlights of these research articles are as follows

Singh et al., 2023 presented the **planktic foraminiferal assemblage** and **Artificial Neural Network** (ANN) based **Sea Surface Temperature (SST)** records from IODP Site U1385 provided a centennial-millennial scale record of surface ocean conditions of SW Iberia for the last three terminations (TI, TII & TIII) and the subsequent **interglacials** (Holocene, MIS 5e & 7e). The findings shed important light on the range and magnitude of natural **climate variability** and **climatic fluctuations** in the northeastern Atlantic Ocean. This knowledge can be used to improve **climate models**, forecast future patterns of climate change, and evaluate the possible effects of current human climate change (Fig. 98).
Our understanding of climate variability is poor due to limited observational records from all over the globe. However**, paleoclimatic** studies are the only source that provides various ways to understand the past in a proper climatic context. By using different natural proxies, we can visualize the **pastclimate extremities** and can take precautionary measures for the future. The high-resolution proxy-generated records have the potential to reveal precise information about the past environment and these records can be of immense use to analyze the changes in different climatic parameters under the background of **major climatic episodes** of the past and ongoing **global warming**. The long-term climate reconstruction can be a useful tool to examine the natural cyclicity in climate and to evaluate the impact of anthropogenic advancements.

Verma et al., 2021 presented a high-resolution benthic foraminiferal assemblage record from the western Bay of Bengal (BoB)(off Krishna–Godavari Basin) showing millennial-scale variations during the last 45,000 years BP. Records of **oxygen-sensitive benthic taxa** (low-oxygen vs. high-oxygen benthic) indicate that changes in **deep-water circulation** combined with the primary productivity-driven organic matter flux modulated the sea bottom oxygen condition. The study enhances our understanding of past **ecosystem dynamics** and contributes to improved predictions of future climate and ecological changes in the Bay of Bengal region.

Again, Verma et al., 2022 presented a high-resolution **planktic foraminiferal assemblage** record to reconstruct sea surface hydrographic structure and productivity in response to the changes in seasonal **monsoon precipitation** and **wind intensity** over the last 45,000 BP (Fig. 99).

Singh et al., 2022 evaluated Himalayan cedar (Deodar) **tree-ring-width** samples from remote sites of Kishtwar, Jammu, and Kashmir and developed the first annual **Standardized Precipitation Index** (SPI from the previous year June to current year May, SPI12-May) record from the region to understand the **drought variability** (Singh et al., 2022). The SPI series revealed a close agreement with available hydrological records of the western Himalayas.

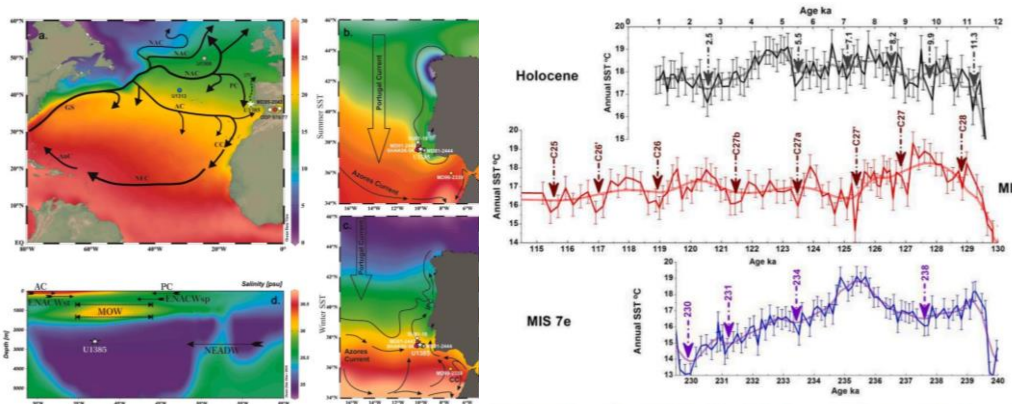


Fig. 98 (a) Map showing the location of IODP sites U1385 in the SW Iberian and other core sites. (b)Comparison of ANN-based annual SST records of the three interglacials (Holocene, MIS 5e & 7e) at from IODP Site U1385. The bold curve shows the FFT smoothing downward pointing arrows denote the brief cold stadials interrupting the interglacials.

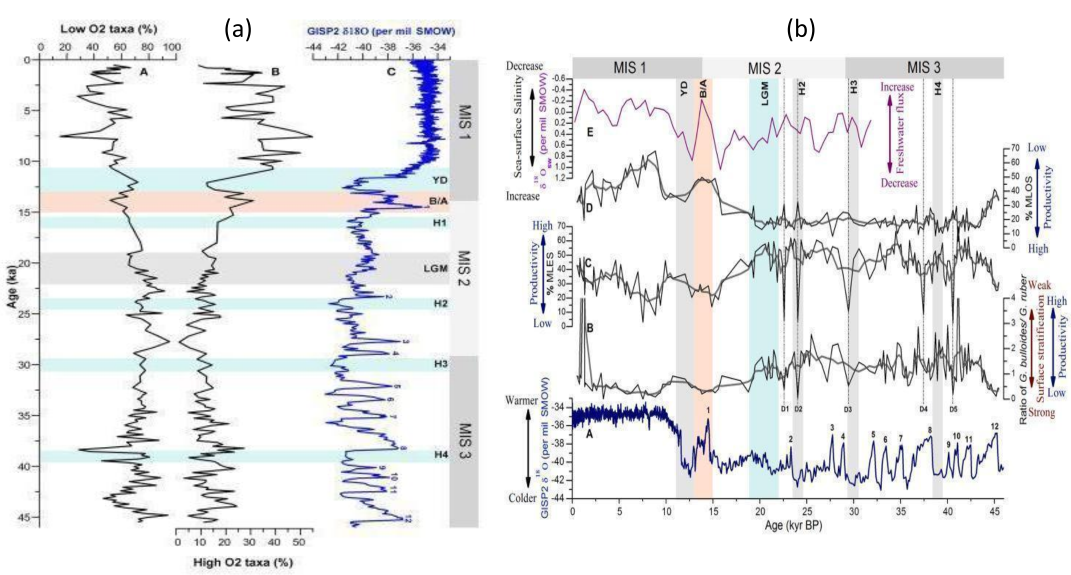


Fig. 99 (a) Comparison of (A) % low-oxygen and (B) % high-oxygen taxa of benthic foraminiferal assemblages with (C) GISP2 $\delta^{18}O$ ice core record. MIS 1–3 denotes the Marine Isotope Stages; H1–H4, Heinrich Events; YD, Younger Dryas; B/A, Bølling/Allerød; LGM, Last Glacial maxima (Verma et al., 2021). (b) Records of faunal proxies for surface water stratification and productivity (this study) are compared with sea-surface salinity record of core SK218/1 and GISP2 ice core δ18O record (A) GISP2 ice core δ18O; (B) ratio of G. bulloides and G. ruber; (C) % MLES (Mixed-layer eutrophic species); (D) % MLOS (Mixed-layer oligotrophic species) and (E) δ18Osw (‰ SMOW) of core SK218/1. The numbers 1–12 in the GISP2 δ18O record denote the D/O interstadials (Verma et al., 2022).

6. New Observations

The vision and work plan of the DST-MCECCR have clarified the working nature of the center in various important work areas, along with this, the center has also included other inter-disciplinary areas in its scope.

The DST-MCECCR is progressively promoting research and innovation works in the above areas, using the necessary knowledge, skills, and available resources, as well as contributing significantly to social awareness and human resource development, keeping in view the current and future climate change. Providing a strategic approach to address the emergent issues of climate change in the future and the present. The new observation has been divided into these parts according to the core working areas of DST-MCECCR.

A. Climate variability and change

The reality of climate change and variability is reflected in the various repercussions in our surroundings. As DST-MCECCR continues to enhance its understanding of this aspect. Some new observations from the studies are as follows:

i. DTR and Surface Temperature

A large uncertainty exists about the change in DTR within the seasons such as the mid-century (2041-60) period as well as the hotspot shifted toward northeastern, central, and southern India (Singh et al., 2023). There is a decrease in DTR in the future climate but the rate of decline was not necessarily higher in high-emission scenarios. On the contrary, Tmax and Tmin displayed a significant increase both in the past and future, particularly in the high-emission scenario.

ii. Drought and Flood

The basic and derived meteorological parameters such as rainfall, surface pressure, temperature, wind, cloud cover, and surface energy fluxes have a significant impact on the occurrence of monsoonal drought and flood events in India. One of our working groups found that drought and flood conditions are changing over the Indian continent using different climate modeling techniques such as; A new method using Soil Water Assessment Tool (SWAT) in combination with the Copula approach was developed to construct multivariate standardized drought indices (MSDIs) for drought onset detection through simulation in the face of data scarcity. This model can be used to detect drought situations in data-scarce non-perennial river basins within the Ganga River floodplains including the NCTHR of India (Bhatt et al., 2022).

During drought and flood events, convective heating plays a significant role in changing surface fluxes. Meanwhile, the radiative imbalance plays a secondary role in determining the variability and nature of droughts and floods. It is worth noting that the elevated value of net incoming shortwave radiation is expected to cause more severe droughts than floods in the near future. Therefore, it is important to take into account both the role of convective heating and radiative imbalance in understanding and predicting droughts and floods (Maurya et al., 2023). Climate extreme indices, standardized precipitation index (SPI), and empirical orthogonal function (EOF) were used to understand the regional modulation of ISMR events based on duration, frequency, and severity. Significant decreasing trends in ISMR-modulated characteristics (intensity, spell, and frequency) were observed over Northeast India (NEI) and Northcentral India (NCI). The study also identified major hotspots for land degradation and effective management and adaptation towards water resources and hazards related to flood/drought events. Also moderate to severe flood occurrences are dominated towards the Himalayan region, western peninsular region, and western ghat (Verma et al., 2022).

The Center works on the analysis of the changes in the extreme rainfall events conducted over the Indian River Basin (IRB), during the 20th and 21st century by using observed rainfall at high resolution, about 25 km, spatial distribution over the river basins. Results pointed to a western shifting pattern and increasing trend of rainfall extremes over the IRB during the 21st century (Chaubey et al., 2022). The team further projected daily precipitation in the near future showing 10 to 30 mm/day change in precipitation over the upper Ganga and Indus river basins. Moreover, the Lower Ganga river basin is found to have a decrease in monthly mean precipitation of approximately 7 to 11 mm/day in the near future (Chaubey & Mall, 2023).

iii. Heatwave

CNRM-CM5, ACCESS 1.0, and CCSM4 were not able to significantly reproduce heat waves over India showing opposite trends to that observed. Hence, they cannot be used to study heat wave characterization and changes without improvement in them. Also, GFDL-CM3, NorESM1-M, and MPI-ESM-LR can be further improved and explored to study heat waves over India, particularly in the Western, Central, and South- Central regions (Singh et al., 2021). LMDZ4 and GFDL-ESM2M (RegCM 4.1.1 ensemble) were found to be the best-performing models (ensemble) in reproducing the heat wave frequency and spatial variability in closer proximity with observations over India among all models after bias correction (Singh et al., 2021). Furthermore, the mid-term (2041-2060) and long-term period (2081-2099) heat wave projections over India showed a four-to-seven-fold increase in heatwave frequency with an average of 20 events/yr to 35 events/yr and five-to-ten-fold increase with 25 events/yr to 70 events/yr under RCP 4.5 and RCP 8.5 scenario respectively (Singh & Mall, 2023). Again, the maximum heatwave intensity was projected to rise by 54°C to 59°C in the long-term future, and heatwave duration would rise to 18 to 22 days and 22 days to 51 days for the same period. Northwestern, central, and south-central India recorded the highest heat wave events, emerging as future heat wave hotspots over India with the largest increase in The south-central region.

iv. Climate modeling

Climate modeling is immensely important to know the observed and future climate change conditions. Based on the climate models different valuable and informative studies have been conducted in DST-MCECCR. On the performance assessment of the regional climate model (RegCM4) in simulating interannual variation in the summer monsoon rainfall during the El Nino Southern Oscillation (ENSO) phases it was found that El Nino and La Nino have been assessed. It was found that the model performance was good in defining the characteristics, spatial distribution, and trend of a dry spell during ENSO phases with the observation while overestimating the wet spell (Verma and Bhatla, 2021). The performance of the regional climate model RegCM4 is satisfactory in portraying the spatial and temporal intra-seasonal variability (ISV) of monsoon over MCR and all India regions. It is found that the model performance is better in simulating the onset and break phases (dry days) than the active phases. The analysis indicates that the BIAS of RegCM4 is 0.85 during the active phase while the BIAS is 1.1 during the break phases. These values indicated a slight underestimation of the active phase and a minor overestimation of break phase frequency in the RegCM4 simulation. The limited skill of the RegCM4 model in representing the active phase is due to the model simulated low temperature and weak pressure gradient over the MCR which prevents the convection and gives rise to small and weak active phases over the region (Ghosh et al., 2022). Also, sea surface temperature studies have been done by DST-MCECCR using different climate modeling.

v. Sea Surface Temperature

Another study carried out by DST-MCECCR on Sea surface temperature using Climate modeling has shown a strong relationship between sea surface temperature (SST) changes in the Niño-3.4 region and rainfall variation over the monsoon core region (MCR) of India, indicating greater dependency on SST variation in MCR than all India rainfall. In this study, the RegCM4 model performs satisfactorily in simulating spatial and temporal intraseasonal variability (ISV) of the monsoon in MCR and all India regions, with higher performance in simulating onset and break phases than active phases. The simulation of the monsoon phase by the model is heavily regulated by the changes of SST over the Niño-3.4 region, indicating a significant impact of ENSO variability on the interannual and Intra-seasonal variability of monsoon over the MCR region (Ghosh et al., 2022).

B. Aerosol

The investigation of the effect of multiple air pollutants e.g., aerosols (black carbon, BC; PM2.5 and PM10) and trace gases (NO_2, SO_2, and O_3) is very crucial for different parts of India to know the intensity of pollutants and suggested remedial measure for that pollutant. One of our expert groups from our DST-MCECCR has worked on multiple air pollutants e.g., aerosol, and has obtained immensely major findings. The following section elaborates on the findings which are very much supreme for our country.

i. IGP and India

India is a developing country, located in the Northern Hemisphere. Due to the industrial revolution and agriculture waste burning, car use, fossil fuel use, an increase in air pollution over the past

decades in the cities in India has been observed. Some of the studies found significantly high aerosol loading over the IGP and the east coast of India. Vertical stratification of the aerosol layer was noted over most of the South Asian cities with aerosols primarily remaining close to the surface. However, accumulation of aerosols was also noted relatively at higher altitudes (1–3 km) which may have a potential impact on many of the earth's system processes including cloud formation, and in modifying the thermal structure of the atmosphere (Singh et al.,2022). Short-term investigations of atmospheric pollutants (PM10, PM2.5, SO_2, NO_2, O_3, and CO) were performed during the Diwali festival over Varanasi for a period of six years from 2011 to 2016.

Aerosol Optical Depth (AOD) was found to be considerably much higher, almost 3-fold higher than the control days with a total scattering aerosol optical thickness as well as aerosol extinction co-efficient at 550 nm crossing the value of 1.0 in almost all the Diwali day cases. The concentrations of PM10 and PM2.5 crossed beyond the safer limits which are 500 µg/m3 (in 2015) and 450 µg/m3 (in 2016) respectively, i.e., basically 5–6 times higher than the standard NAAQS limit. In comparison with the trace gas concentrations (e.g., SO_2, NO_2, O_3, and CO) on the control day, it was observed higher on the respective Diwali day (Kumar et al., 2022). Aerosol climatology during the typical haze-dominating period was explored using several Earth Observing System (EOS) products from 2010-2020. High aerosol loading with the dominance of fine and UV-absorbing aerosols are noted across the Indo-Gangetic Plain (IGP) (AOD:0.58; UVAI:0.74) against weak UV-absorbing fine aerosols over Southeast Asia (AOD:0.26; UVAI:0.07) (Banerjee et al., 2021). The vertical distribution of smoke aerosols was explored over the upper Gangetic plains. Smoke injection height varied considerably during the rice (October-November: 0.71±0.65 km) and wheat (April-may: 2.34±1.34 km) residue burning period with a significant positive correlation with the prevailing boundary layer. Besides, despite traveling efficiently to the free troposphere, a major proportion of smoke AOD (50-80%) continues to remain close to the surface (<3 km) (Banerjee et al., 2021).

ii. South Asia and Aerosol

In the case of the whole of South Asia, it was found that dust was the main aerosol type during MAM, particularly over the cities in IGP contributing 49–69% of total AOD with maximum dominance over Karachi (80%) and least in Dhaka (21%). Approximately 46–71% of aerosols over Kathmandu, Dhaka, Varanasi, Nagpur, and Mumbai were urban aerosols while together with dust, they shared >80% of AOD across all the cities except in Chennai and Colombo (~40%) (Banerjee et al., 2022). Three-dimensional (temporal-spatial-vertical) climatology of South Asian summertime (MAMJ, 2010–2019) aerosols and aerosol sub-types were explored using multiple high-resolution satellite-based observations and a reanalysis dataset. Overall, mineral, dust, smoke, and urban aerosols were the three major aerosol sub-types that prevailed across South Asia during summer. Prevailing aerosols were vertically stratified as 50–70% of total AOD was retrieved <2 km from the surface except in a few cities where 70–80% of AOD was retrieved <3 km height (Singh et al, 2022).

iii. Aerosol and Covid-19

One of the most interesting findings of our Centre is that during COVID-19, aerosol intensity and air pollutants have decreased. The study on the effect of lockdown amid COVID-19 on ambient air quality in 16 Indian cities shows a substantial decrease in AQI values during the lockdown compared with the reference period (2017–2019) for almost all the reported cities across India. On average, about 30–50% reduction in AQI has been observed for PM2.5, PM10, and CO, and a maximum reduction of 40–60% of NO_2 has been observed herein, while the data was average for northern, western, and southern India. SO_2 and O_3 showed an increase in a few cities as well as a decrease in other cities (Mishra et al., 2021). Maximum reduction (49%) in PM2.5 was observed over north India during the lockdown period. A substantial effect of lockdown on the reduction in atmospheric loading of key anthropogenic pollutants due to less-to-no impact from industrial activities and vehicular emissions, and relatively clean transport of air masses from the upwind region was observed (Mishra et al., 2021).

iv. Total Columnar Ozone

A study on the evaluation of long-term (2009-2020) gridded datasets of total columnar ozone (TCO) retrieved from Modern-ERA Retrospective Analysis for Research and Applications, version 2 (MERRA-2TCO) has been done for the Indian region. The dataset was validated against observations (IMDTCO) and compared with Atmospheric Infrared Sounder (AIRSTCO) satellite datasets. The results of the analysis, which focused on seven distinct regions of India, showed a significant correlation between MERRA-2TCO and IMDTCO for Delhi and Varanasi, and an increasing TCO trend value of 0.31% and 0.44% per decade in both cities, respectively. The comparison of MERRA-2TCO with AIRSTCO also showed a significant correlation in different regions of India. The study observed an increasing shift of columnar ozone from low to high latitudinal regions in support of Brewer's circulation pattern. The study concludes that the MERRA-2 ozone dataset can be effectively used for ozone air quality studies over India and highlights the need for independent, high-quality, and consistent ozone measurements with small uncertainties.

C. Health

Better health and education are crucial components in transforming people from being humans into human resources. India has a demographic dividend right now. This dividend situation can only be helpful with healthy and skilled human resources. At present, due to increasing population pressure, anthropogenic activities, etc., almost insurmountable challenges like environmental pollution and climate change have arisen. Today air pollution is the third leading cause of mortality in India. Different research groups of the DST MCECCR are examining the detrimental impacts on human health due to the increasing trend of heat waves and air pollution (aerosols) in view of climate change. Some of the important observations of the center are presented below.

A study from the center highlighted an increase in daily mean temperature was strongly associated with excess mortality in Varanasi, both during summer (5.61%) and winter (1.50%). Daily mortality was found to be increased by 12% due to heat waves. The study is the first of its kind to present an increase in mortality with a decrease in diurnal temperature variation. The increase in mortality was high during summer compared to winter. Similarly, the risk ratio was high due to heat waves compared to cold spells (Singh et al., 2019). Another group from the center demarcated the effect of multiple air pollutants e.g., aerosols (black carbon, BC; PM2.5 and PM10) and trace gases (NO_2, SO_2, and O_3) on all-cause premature mortality was systematically investigated over the central Indo-Gangetic Plain (IGP).

The highest and statistically significant impact of BC aerosols on mortality, followed by NO2 and PM2.5 exposures was noted (Singh et al., 2021). The inclusion of black carbon provides more robust evidence of the negative impact of air pollution on human health (Singh et al., 2021). Gastrointestinal tract infections (GIT) and upper respiratory tract infections (URTI) are the most prevalent causes of morbidity in children (0-16 years) accounting for approx. 78% of the cases (Singh et al., 2021).

infection (Singh et al., 2021) Among several socioeconomic and anthropometric factors, age, gender, WaSH (unsafe water, sanitation, and hand washing), family income, and socio-economic class are the significant contributing factors (Singh et al., 2021).

D. Agriculture

The Centre is working towards tackling various emerging issues such as farmers' problems, food security, and phenological change, etc. due to climate change, and providing innovative solutions for them. Various achievements related to this have been presented below.

i. Development of Crop Stage Estimator

A team from DST-MCECCR has developed a new novel crop estimator model with the name "Crop Stage estimator". The estimator model was developed using the HRS data on an open-source R platform. This model is based on a hyperspectral crop stage estimator interface that will provide a common platform for the generation of the spectral library, calculation of vegetation indices, and development of the best LAI model and its mapping. This common platform will also be helpful for non-programming users due to its simple layout and working (Singh et al., 2022).

As Chlorophyll is a very important element for the photosynthesis process, this group has done another study to evaluate the capability of the Radiative Transfer Model using LUT inversion for Leaf Chlorophyll Content mapping over a subtropical pine forest plantation in Western Himalaya using high-spatial-resolution UAV-acquired imagery. A variety of LUT-based inversion algorithms using 12 distinct cost functions were systematically tested against reflectance data obtained from a UAV. The inversion evaluation was conducted in ARTMO's LUT-based inversion toolbox. Among all the CFs evaluated, the "Bhattacharyya divergence" provided the most accurate LCC inversion. In combination with the leaf-level and canopy-level PROSAIL model, LCC was estimated from the retrieved canopy reflectance, with adequate accuracy (R2 = 0.94, RMSE = 6.20 $\mu g/cm^2$ and NRMSE = 12.27%) during the validation for the Almora sites. The optimized inversion strategy with the Bhattacharya divergence CF was subsequently applied to the UAV-acquired imagery at 8.2 cm spatial resolution. It produced a detailed LCC map over the pine forest with retrieved LCC values ranging between 30 to 75 (Singh, et al. 2023).

ii. Impact Assessment of Organic Manure on Soil Quality

Soil quality is a major determinant of crop production, productivity, and nutrition value. A group from the center has evaluated the impact of animal manures (sheep and poultry manure) and plant residue-based organic amendments (rice husk biochar and sugarcane pressmud) on soil quality, nutrient uptake and balance, yield, and sustainability of rice-wheat cropping in alluvial (rainfed) and red lateritic soil (dryland) of middle Gangetic plains (Narayanpur) and Vindhyan region (Rajgarh) of Mirzapur district in eastern UP. The soil organic carbon (SOC) was found to show a significant ($p < 0.05$) increase in biochar amended plots, animal manures followed by pressmud showed a year-wise increase in both SOC and microbial biomass carbon.

In rainfed areas, where amendments were made the plant growth and yield attributes for both rice and wheat were at par rather than control plots. While in dryland, the 100% RDF showed better performance during the first year, after that amended plot showed better performance. Our study suggests that validation of suitable amendment packages based on organic inputs is imperative for improving the yield, soil quality and nutrient balance of the rice-wheat cropping system and thereby attaining the UN-SDGs at the village/local level (Dubey et al., 2022).

iii. Impact of Climate Change on Crops

Climate change has direct impacts on agricultural production and productivity, therefore another group from the center is working on the impact of projected climate change on various aspects of different crops. Future changes in sugarcane crop yield over India for mid future (2040-2069) and far future (2070-2099) period under RCP 4.5 & RCP 8.5 scenarios indicate that with the increase in the

Maximum temperature above 35°C, increases the prevalence of GIT cases almost linearly. Absolute Humidity plays the most important role in transmitting lower respiratory tract infection (LRTI; 0.15-0.17 Kg/m3). Maximum temperature below 35°C and absolute humidity >0.17 Kg/m^3 promotes skin maximum and minimum temperature, a substantial increase in the stalk fresh mass in the mid-future under RCP 8.5 for the tropical state (6.8% to 18.1%) is projected. However, a decrease is projected in the case of sucrose mass. The increase in temperature also leads to the shortening of phenological phases i.e., planting to emergence (up to 14.5 days) and emergence to stalk elongation (up to 6.3 days) while the peak population to harvest period was extended up to 9.5 days, all under RCP8.5, far-future. SM was found to decrease overall except for the states of Uttar Pradesh, Maharashtra, Gujrat, and Andhra Pradesh (Jaiswal et al., 2023).

Another study of the center also assessed the impact of climate change on sugarcane yield using the CANEGRO Sugarcane model. This study revealed that the stalk fresh mass and sucrose mass are highly vulnerable to rising temperatures in both rainfed and irrigated conditions. It is projected that the SM will be highly affected compared to stalk fresh mass which suggests an improvement and development of new tolerant varieties for maintaining the sugar content under the climate change conditions (Sonkar et al., 2020).

The assessment of the impact of projected climate change on wheat yield in nine agro-climatic zones (ACZs) of Uttar Pradesh for two time periods: 2050s (2040- 2069) and 2080s (2070-2099) under RCP 4.5 and 8.5 was done by the group. The results revealed that the vegetative growth period would be shortened in all the ACZs. However, under the RCP 8.5 scenario, a reduction of up to one week in 2050 and two weeks in 2080s is projected. Without consideration of the CO_2 effect, the wheat yields will reduce by up to 20.5% and 30% under RCP 4.5 and RCP 8.5 respectively in the 2050s. In the 2080s the losses will be more pronounced reaching up to 41.5% under RCP 8.5. With the consideration of $CO_{2,}$ the yield reductions will be up to 14% and 18% under RCP 4.5 and RCP 8.5 respectively in the 2080s (Patel et al., 2022).

Conclusive evidence of the negative impact of rising temperatures on wheat yield across India was reported. A 1 ˚C rise in mean temperature resulted in a 7% decrease in wheat yield over India which varied disproportionally across the wheat-growing zones by a range of -9% (peninsular zone, PZ) to 4% (northern hills zone, NHZ) (Sonkar et al., 2019).

Shifting of sowing date, Irrigation scheduling, Conservative agriculture, new tolerant wheat varieties, and alternative crops have been suggested to enhance crop production. A week after the normal sowing date (2nd November) was found to be the best yield for potatoes against climate change (26th October) and June was found to be the best date of sowing for reduced impact on crop production i.e., one week before the original sowing date of sorghum (14th June) for mid and far future during SSP2-4.5 & SSP5-8.5.

E. Water

Water is one of the most essential needs with 0.3% of the total being available for use. There has been severe water scarcity in different parts of the world with 1 billion people in the world facing immediate water shortage. The center is playing a strategic role in this direction keeping in view the changing rainfall patterns with the changing climate by giving important suggestions towards ensuring sustainable use of available water resources. Various new observations related to the above field are presented below.

A study from the Centre reveals that annual average streamflow will be increased by 76.74% (1031.24 m^3/sec) based on the INMCM-4 outputs, 25% (778.71 m^3/sec) based on the MRI-CGCM3 outputs, and 24.53% (773.11 m^3/sec) based on the ensemble mean in the near future. Further, the percentage change in high and low streamflow with respect to the baseline time period and the difference between the high and low streamflow would be increasing in the near future. Thus, it can be illustrated that low streamflow is observed during the summer season, which causes water shortage, drought, and high flow during the rainy season, leading to food and other water-related disasters. Similar trends are observed in monthly and seasonal flows under the INMCM-4, MRI-

CGCM3, and ensemble mean (Maurya et al., 2023). This group has also estimated the rainfall-runoff erosivity. According to the findings of their study, the rainfall-runoff erosivity gradually decreased over the Mahi River Basin (MRB) from 475.18 MJ mm/h/y (1981–1990) to 425.72 MJ mm/h/y (1991–2000). A value of 428.53 MJ mm/h/y was obtained in 2001–2010, while significantly higher value of 661.47 MJ mm/h/y has been reported for the 2011–2040 in the ensemble model mean output of Coupled Model Inter-comparison Project 5 (CMIP5) (Maurya et al., 2021).

A significant correlation between rainfall variability and vegetation cover dynamics was observed over the Gomti River basin (Bhatt et al., 2020) by analyzing long-term soil moisture, evapotranspiration, vegetation dynamics using NDVI, and crop yield in the context of extreme weather events (wet and dry). In another study of the center, precipitation and extreme events were assessed over the Kosi River basin (Srivastava et al., 2021). The northeastern to the southwest part of the basin showed a decreasing trend in extreme indices (R10 and R20 days) and no trend in the highest one-day precipitation (RX1 day).

Furthermore, the group studied the performance assessment of Evapotranspiration (ETo) over the agricultural landscape in Northern India using different data sources (Srivastava et al., 2020). It has been observed that the ETo data downloaded from WRF downscaling showed marginal improvement than without downscaled data. For the ungauged areas, NASA/POWER and WRF downscaled data can be used for ETo calculations, in which NASA/POWER is recommended as less complicated in the ETo calculations than those required with WRF.

A group of researchers in the center showed that the Kedarnath cloudburst was triggered by high relative humidity, total cloud cover, and very low temperature and wind speed (Pratap et al., 2020).

The center's study also focuses on the variations in the groundwater reserves of the Varuna River basin. A long-term water table prediction over the river basin was performed using the Bidirectional Long Short Term Memory (BLSTM) network improved by incorporating straight LSTM at the top of the architecture (Dey et al., 2021). The method efficiently predicted the water table for twenty years and is applicable to data sparse small scale other river basins. The Results revealed that the river basin will face groundwater scarcity in the near and distant future. The group further studied the groundwater potentiality over the River basin using Analytical Hierarchy Process (AHP) and Multi-Influence Factor (MIF) techniques. The Varuna River basin has been identified as 15% potentially low in groundwater reserves which may further lead to more groundwater decline due to rapid urbanization in the catchment area (Dey et al., 2021). Also, the non-carcinogenic health risk assessment of the river basin showed that children are more susceptible to fluoride and nitrate contamination in this region (Dey et al., 2023). Such studies are crucial for policymakers to implement measures to improve water quality, reduce health risks, and increase water conservation.

F. Paleoclimate and Paleoceanography

A center's study on the planktic foraminiferal assemblage and Artificial Neural Network (ANN) based Sea Surface Temperature (SST) records from IODP Site U1385 provided a centennial-millennial scale record of surface ocean conditions of SW Iberia for the last three terminations (TI, TII & TIII) and the subsequent interglacials (Holocene, MIS 5e & 7e) (Singh et al. 2023). The focused important light on the range and magnitude of natural climate variability and climatic fluctuations in the northeastern Atlantic Ocean. This knowledge can be used to improve climate models, forecast future patterns of climate change, and evaluate the possible effects of current human climate change. The long-term climate reconstruction can be a useful tool to examine the natural cyclicity in climate and to evaluate the impact of anthropogenic advancements.

7. Innovation, Techniques and Products developed

Innovation, Techniques, and Product Development are integral aspects of driving progress and success in various fields, ranging from societal development, problem-solving, and betterment of life to sustainability and beyond. DST- MCECCR plays a crucial role in fostering innovation, and the development of problem-solving techniques and products by exploring new ideas, developing cutting-edge techniques, and generating societal awareness about products that have the potential to transform society and improve our lives by meeting the evolving needs and expectations through upcoming climatic conditions.

At DST-MCECCR, a diverse team of researchers, scientists, and experts collaboratively work to tackle complex and ground-level challenges and develop groundbreaking solutions. They employ a multidisciplinary approach, drawing insights from various fields and leveraging unique technologies to drive innovation and the betterment of society. This enables them to uncover unique perspectives and discoveries that have a profound impact on their respective core area of knowledge. Here some research-based innovations, techniques, and products are presented below, developed in the DST-MCECCR.

1. A hyperspectral-based crop stage estimator interface has been developed on freely available R software. To analyze the performance, an example workflow was created for wheat at different crop growth stages. The presented interface can perform simple steps which make it robust and user friendly. It also has quick processability of larger datasets. This interface will provide a common platform for the generation of the spectral library, calculation of vegetation indices, and development of the best LAI model and its mapping. This common platform will be also helpful for non-programming users due to its simple layout and working. This novel model extends the basic tools which combined with other R packages will facilitate the development of robust, reproducible, scientific modeling workflows. It was used to deduce crop growth stages of winter wheat (Triticum aestivum L.) (Singh et al., 2022).

2. A new method using the Soil Water Assessment Tool (SWAT) in combination with the Copula approach was developed to construct multivariate standardized drought indices (MSDIs) for drought onset detection through simulation in the face of data scarcity. MSDIs indicate the possibilities of impending agricultural droughts marked by their consistent variability around near-normal conditions. This methodology can be used to detect drought situations in data-scarce non-perennial river basins within the Ganga River floodplains including the NCTHR of India (Bhatt et al., 2022a).

3. The capability of the Radiative Transfer Model using LUT inversion for Leaf Chlorophyll Content mapping is evaluated over a subtropical pine forest plantation in Western Himalaya using high-spatial-resolution UAV-acquired imagery. A variety of LUT-based inversion algorithms using 12 distinct cost functions were systematically tested against reflectance data obtained from a UAV. The inversion evaluation was conducted in ARTMO's LUT-based inversion toolbox. Among all the CFs evaluated, the "Bhattacharyya divergence" provided the most accurate LCC inversion. In combination with the leaf-level and canopy-level PROSAIL model, LCC was estimated from the retrieved canopy reflectance, with adequate accuracy (R^2 = 0.94, RMSE = 6.20 μg/cm^2 and NRMSE = 12.27%) during the validation for the Almora sites. The optimized inversion strategy with the Bhattacharya divergence CF was subsequently applied to the UAV-acquired imagery at 8.2 cm spatial resolution. It produced a detailed LCC map over the pine forest with retrieved LCC values ranging between 30 to 75 (Singh et al., 2023).

4. The RegCM4 performs satisfactorily in simulating rainfall characteristics and threshold-based climate indices over Indo-Gangetic Plains during the Indian Summer Monsoon season. The projected decrease in ISM rainfall and numbers of wet days (7-21%) while a rise by 14-35% in above 90th and 99th percentile of rainy days and their contribution in total seasonal rainfall during near (NF; 2041-2060) and far (FF; 2080-2099) future time slices over sub-regions of IGP. Projected increase in extreme rainfall indices over upper IGP and Himalayan foothills during NF and FF under RCP8.5 scenario (Pant et al., 2023).

5. The RegCM4.6 regional climate model successfully captured and simulated the extreme rainfall event over Mumbai on 26th July 2005. The distribution of various thermodynamical and dynamical quantities supported the occurrence of extremely heavy rainfall events. The mixed cumulus parameterization scheme (CPS) mode, particularly the EL_GO scheme, proved to be effective in downscaling the heavy rainfall event with higher accuracy compared to other CPS modes (Pant et al., 2022).

6. Climate extreme indices, standardized precipitation index (SPI), and empirical orthogonal function (EOF) were used to understand the regional modulation of ISMR events based on duration, frequency, and severity. Significant decreasing trends in ISMR-modulated characteristics (intensity, spell, and frequency) were observed over Northeast India (NEI) and Northcentral India (NCI). The study also identified major hotspots for land degradation and effective management and adaptation towards water resources and hazards related to flood/drought events. Also moderate to severe flood occurrences are dominated towards the Himalayan region, western peninsular region, and western ghat (Verma et al., 2022).

7. A western shift and significantly increasing trend in extreme rainfall events has been observed over the past 119 years in India which indicates greater vulnerability in the western region due to floods (Chaubey et al., 2022). An increase in daily precipitation and a decrease in monthly mean precipitation in the near future is also observed over the Upper and Lower Ganga River basin, respectively (Chaubey & Mall, 2023).

8. Statistical techniques such as the standardized anomaly index of surface temperature, rainfall, and zonal and meridional wind were used to uncover significant spatial changes in the value of standard deviation and coefficient of variation, confirming early-late phase and multidecadal modulation of seasonal variability. This study found an alarming range of escalating surface temperature multidecadal variability and trend dominating over North India, Central India, and Southern India regions. The recent decadal anomaly is also a matter of concern as precipitation and wind circulation anomalies at 850 and 200 hPa have shown decreasing trends over all the regions during the summer monsoon season in a changing climate (Bhatla et al., 2022).

9. A decrease in DTR in the future climate is observed but the rate of decline was not necessarily higher in high-emission scenarios. On the contrary, Tmax and Tmin displayed a significant increase both in the past and future, particularly in the high-emission scenario (RCP8.5), with Tmin showing a relatively higher increase than Tmax. A large uncertainty exists about the change in DTR within the seasons such as the mid-century (2041-60) period of both RCPs shows a hotspot of declining DTR centered in northwestern and central India, while the hotspots shift towards northeastern, central, and southern India in the far century (2071-2099) future in winter and pre-monsoon (Singh et al., 2023).

10. The mid-term (2041-2060) and long-term period (2081-2099) heat wave projections over India showed a four-to-seven-fold increase in heatwave frequency, intensity, and duration under RCP 4.5 and RCP 8.5 scenario respectively (Singh & Mall, 2023). Northwestern, central, and south-central India recorded the highest heat wave events, emerging as future heat wave hotspots over India with the largest increase in The south-central region.

11. We have noted significantly high aerosol loading over the IGP and the east coast of India. Vertical stratification of the aerosol layer was noted over most of the South Asian cities with aerosols primarily remaining close to the surface. However, accumulation of aerosols was also noted

relatively at higher altitudes (1–3 km) which may have a potential impact on many of the earth system processes including cloud formation, and in modifying the thermal structure of the atmosphere (Singh et al., 2021).

12. It was clearly noted that dust was the main aerosol type during MAM, particularly over the cities in IGP contributing 49–69% of total AOD with maximum dominance over Karachi (80%) and least in Dhaka (21%). Approximately 46–71% of aerosols over Kathmandu, Dhaka, Varanasi, Nagpur, and Mumbai were urban aerosols while together with dust, they shared >80% of AOD cross all the cities except in Chennai and Colombo (~40%) (Banerjee et al., 2022).

13. An increase in annual average streamflow was noticed by 76.74% (1031.24 m3/sec) based on the INMCM-4 outputs, 25% (778.71 m3/sec) based on the MRI-CGCM3 outputs, and 24.53% (773.11 m3/sec) based on the ensemble mean in the near future. Further, the percentage change in high and low streamflow with respect to the baseline time period and the difference between the high and low streamflow would be increasing in the near future. Thus, it can be illustrated that low streamflow is observed during the summer season, which causes water shortage, drought, and high flow during the rainy season, leading to food and other water-related disasters. Similar trends are observed on monthly and seasonal flows under the INMCM-4, MRI-CGCM3, and ensemble mean (Maurya et al., 2023).

14. On the evaluation of the impact of animal manures (sheep and poultry manure) and plant residue-based organic amendments (rice husk biochar and sugarcane pressmud) on soil quality, nutrient uptake and balance, yield, and sustainability of rice-wheat cropping in alluvial (rainfed) and red lateritic soil (dryland) of middle Gangetic plains (Narayanpur) and Vindhyan region (Rajgarh) of Mirzapur district in eastern UP. The soil organic carbon (SOC) showed a significant ($p < 0.05$) increase in biochar amended plots, and animal manures followed by pressmud showed year year-wise increase in both SOC and microbial biomass carbon. In rainfed areas, plant growth and yield attributes for both rice and wheat were at par in amendments than control while in dryland, the 100% RDF showed better performance during the first year, after that amended plot showed better performance. Our study suggests that validation of suitable amendment packages based on organic inputs is imperative for improving the yield, soil quality, and nutrient balance of the rice-wheat cropping system and thereby attaining the UN-SDGs at the village/local level (Dubey et al., 2022).

15. The impact of El Nino/La Nina and IOD years on crop production varies for different crops and agro-climatic zones. Drought years associated with El Nino have a detrimental effect on rice production. In contrast, La Nina years benefit maize and sugarcane production in all zones due to good rainfall. Positive IOD years are generally associated with poor crop production in all zones, mainly because most of the positive IOD years coincide with El Nino years, which have a more dominant impact on rainfall. El Nino-rainfall relation being dominant than positive IOD-rainfall relation is responsible for negative rainfall anomalies over the selected zones (Bhatla et al., 2023).

16. Convective heating plays a significant role in changing surface fluxes during drought and flood events. Meanwhile, the radiative imbalance plays a secondary role in determining the variability and nature of droughts and floods. It is worth noting that the elevated value of net incoming shortwave radiation is expected to cause more severe droughts than floods in the near future. Therefore, it is important to take into account the role of both convective heating and radiative imbalance in understanding and predicting droughts and floods (Maurya et al., 2023).

17. A long-term gridded dataset of total columnar ozone for the Indian region is evaluated and compared with observations and satellite datasets. The dataset shows a significant correlation with observations and a trend of increasing ozone values in Delhi and Varanasi. This study concludes that the MERRA-2 ozone dataset can be effectively used for air quality studies over India, but high-quality and consistent ozone measurements with small uncertainties are still needed (Gupta et al., 2023).

18. The Southern Ocean is an important part of the Earth's climate system, and its upper ocean variability significantly impacts carbon and water mass formation. The Southern Ocean's mixed layer depth (MLD) was analyzed in a specific domain using a high-resolution model and compared with ECCO2 reanalysis. The study finds that near-surface wind forcing contributes more to changing the MLD than atmospheric temperature, but the effect of air temperature is also significant (Kumar and Bhatla, 2022).

19. A model was developed to assess child morbidity due to selected infectious diseases and climate, adjusting the model for a set of socioeconomic and anthropometric parameters for a humid subtropical climate (Singh et al., 2021).

20. The multipollutant model developed incorporating Black carbon, NO_2, and residual PM2.5 is the first multipollutant model developed in India that can be used in other parts of the country with the same pollution profile to assess the association between human health and air pollution (Singh et al., 2021).

21. The concept of using residual PM2.5 is novel and has yet to be used in any study. It provides an opportunity to exclude the contribution of SO_2, NO_2, and BC from PM2.5 and use the residual PM2.5, the variation of which is contributed by some unknown sources so that it does not create a multi-collinearity problem with NO_2, SO_2, and BC in multipollutant problem. The same can be adopted in other multipollutant studies.

22. Satellite-derived aerosol optical depth (AOD), columnar water vapor (CWV), meteorological parameters, and land use data were used as variables within a linear mixed effect model (LME) and a random forest (RF) model, to predict daily ground-level concentrations of PM2.5 at 1km×1km grid across IGP (Vinjamuri et al., 2020).

23. The multivariate generalized additive regression model for the calculation of risk associated with heat and cold waves and air pollution after adjusting for RH, long-term time and seasonal trend, and day of the week can be used as a generalized equation that can be used in any part of the country (Singh et al., 2019).

24. The genetic coefficients developed by the center for different crop varieties are being used by IMD’s Agro met Cell for wheat and rice yield forecasting at the national and regional levels.

25. Shifting of sowing date, Irrigation scheduling, Conservative agriculture, New heat tolerant wheat varieties, and Alternative crops have been suggested to enhance crop production.

26. A model was developed to quantify the impact of air pollution and climate parameters on the wheat crop. It will be helpful to critically understand the role of climate and air pollution on wheat crops and will help to identify future agricultural risks and help in framing the policies accordingly (Sonkar et al., 2019).

27. The high-resolution soil moisture product was developed by merging different satellite sensors. It was presented in the Ministry of Agriculture. The product is now recommended for use in crop monitoring and insurance policies.

28. A prototype of Irrigation scheduling is now developed for Android phones usable for Varanasi. After seeing its application potential, it will now be extended to other districts of India (Srivastava et al., 2021).

8. Outreach Activities

Outreach Activities

1. Location and crop specific weather-based advisories are issued for the benefit of the farming community of the eastern UP region every Tuesday and Friday under Gramin Krishi Mausam Seva.

2. Seva (GKMS) Scheme works in collaboration with IMD, ISRO, and Ministry of Agriculture & Farmers Welfare, Govt. of India through different print/visual/Radio/IT-based media including short message service (SMS) and Interactive Voice Response Service (IVRS). It is a step to weather-based crop and livestock management strategies and operations to enhance crop production and reduce crop damage due to extreme weather events.

3. Several awareness programs/roving seminars are organized for farmers about the new and useful initiatives for crop management, weather-borne pest and disease outbreak management, crop advisories, and discussion on crop-related issues with experts in the field. Around 800 farmers have participated and interacted with experts from the fields of climate, crop & vegetable research and remote sensing, etc. The farmers also regularly visit DST MCECCR to interact with the experts and update themselves with new knowledge and innovations.

4. Apart from workshops, a new initiative in the form of the DST-MCECCR Lecture series (DMLS) has been initiated for knowledge and capacity building of the students by inviting lectures from distinguished scientists of the world.

5. Through these initiatives around 652 students have been trained with 92 master dissertations, 21 awarded PhD, and 32 ongoing PhD students. The students are currently placed at various world-renowned institutions such as IUF-Leibniz Research Institute for Environmental Medicine, Germany, Weizmann Institute of Science, Israel, Chinese University of Hong Kong, Hong Kong, and Stockholm University, Sweden, etc.

Capacity building/Scientist/Faculty Trained

1. Neha Dwivedi, Research Scholar, Department of Environmental Science, Central University of Jharkhand, Ranchi, (SWAT: Soil & Water Assessment Training) 1st to 30th April, 2023.

2. R. N. Singh, Scientist (Agricultural Meteorology), SASM, ICAR-National Institute of Abiotic Stress Management (NIASM), Baramati, Pune, Maharashtra, Professional Attachment Training from 13th May to 14th August, 2019.

3. Gaurav Kumar, Ph.D. Scholar, GB Pant University, Crop modeling training, 15th May-15th June 2019.crop-specificcrop-specific

List of Workshops Organized

1. An International Workshop on “Emerging Solutions for Sustainable Environmental Remediation has been organized by IESD, BHU, and DST-MCECCR, from 18-20 April, 2023.

2. A National Conclave on “Sustainability Challenges of Emerging Economics” has been organized by IESD, BHU, and DST-MCECCR, from 24-26th Feb. 2023.,

3. Sustainable Agricultural Practices for Food Security & Environmental Protection organized by NASI-Varanasi Chapter and DST-MCECCR, BHU at Krishak P.G. College Rajgarh, Mirzapur, U.P. on 13th Feb 2023.

4. National Consultation Workshop on Charter and Framework of University Level Knowledge Network on climate Change and Its Operationalization in Uttar Pradesh organized by DST-MCECCR, IESD, BHU, Department of Environment, Forest and Climate Change, Government of Uttar Pradesh and GIZ (Indo-German Technical Cooperation Project-CAFRI) on 15th Dec. 2022.
5. Lecture on 'Setting up of Dakshin Gangotri at Antarctica: A Miracle & Climate Change' by Padma Shri Prof. Harsh Gupta, Former Secretary, Department of Ocean Science & Technology, GOI, on 4th Aug 2022 in the DST-MCECCR Lecture Series (DMLS).
6. DST-MCECCR Lecture Series on "Climate in Himalaya: Challenges for Sustainable Development" Prof. A.P. Dimri, Director, Indian Institute of Geomagnetism, Mumbai, and Professor, School of Environmental Sciences, Jawaharlal Nehru University, held on 23rd July 2022.
7. DST-MCECCR Lecture Series on "Urban Integrated Modeling and Services: Science Transformations" by Dr. Akshara Kaginalkar, Senior Director (Sc. G), Centre for Development of Advanced Computing (C-DAC) Pune, held on 13th Dec. 2022.
8. Lecture on 'Planet Earth Needs Risk Resilient Infrastructures Under Climate Chang Scenarios' by Dr. O.P. Mishra, Director, National Centre for Seismology (NCS), MoES, GOI on 5th June 2022 in the DST-MCECCR Lecture Series (DMLS) (62 participants).
9. Lecture on 'Climate Research in India: Current Status and Way Forward' by Dr. Akhilesh Gupta, Scientist H, Department of Science & Technology, GOI on 14th May 2022 in the DST-MCECCR Lecture Series (DMLS) (63 participants).
10. DST-MCECCR Lecture Series on "Groundwater Variability Across India, Under Contrasting Human and Natural Conditions" by Dr. V.M. Tiwari, Director, CSIR-NGRI, held on 17th May 2022.
11. Lecture on 'Career Help Desk by Expert Reviewer' by Prof. Gordana Medunic, Professor, Department of Geography, University of Zagreb, Croatia on 21st April 2022 in the DST-MCECCR Lecture Series (DMLS) (35 participants).
12. 'A Six Lecture Course on Data Assimilation' by Prof. V.K. Gaur, Honorary Scientist, CSIR-CMMACS, Bangalore, Dr. Ashish Rourtray, Scientist E- NCMRWF, and Dr. Shubhadeep Haldar, Asst. Professor, Dept. of Geophysics, on 22- 24 Mar 2022, in the DST-MCECCR Lecture Series (DMLS) (45 participants).
13. Training cum Hands-on Practice on Basics of Climate & Climate Modeling' by Dr. Abhijeet Sarkar Scientist-F, NCMRWF on 1st - 2nd Oct 2021, in the DST-MCECCR Lecture Series (DMLS) (35 participants).
14. Online Data Assimilation Techniques lecture by Prof. V.K. Gaur, Honorary Scientist, CSIR-CMMACS, Bangalore on 2nd Sept 2021 in the DST-MCECCR Lecture Series (DMLS) (40 participants).
15. Online Workshop on QGIS, Image Processing and Species Distribution Modelling, 30th Aug – 4th 2021 (32 participants).
16. Online Talk on 'Climate Research 2.0: A Framework for Climate Studies for the Decade' by Prof. Dev Niyogi Sir, Elliott Centennial Endowed Professor, Department of Geological Sciences, The University of Texas at Austin, USA on 10th Aug 2021 in the DST-MCECCR Lecture Series (DMLS) (80 participants).
17. Online Workshop on Species Distribution Modelling Using R studio software, – 16th March 2021 (40 participants).
18. 2nd National Workshop on Techniques in Hyperspectral Data Analysis and Processing" organized by IESD, Banaras Hindu University in collaboration with the Department of Physics, IIT-BHU. This workshop was duly convened by Prof. R K Mall, DST-MCECCR, IESD, BHU on 27th January - 31st January 2020 (Participants: 45).
19. Advanced Training Programme on Crop Simulation Modelling and its applications from 21 – 31 Jan 2019 organized by the centre. The hands-on training was provided by Prof Gerrit Hoogenboom, University of Florida, U.S.A. and Dr. K. K. Singh, Head, Agro Advisory Cell, India Meteorological Department, India organized in collaboration with IMD (participants: 45).

Lab to Society

Health Survey and Awareness

20. Piloting Climate Outlook Forums at State level– Eastern Uttar Pradesh, India organized in collaboration with I MD, WMO, RIMES-Bangkok and GFCS from 18-19th May 2017 (62 participants, national/regional/district level officers).

21. ICTP-Workshop on Climate Impacts on Health in Asia (SMR---2838), 5-16 Dec. 2016, New Delhi, India (Other organizers: S.K. Dash, IITD, New Delhi, Adrian Tompkins, ICTP-Italy, Fabien Solmon, ICTP-Italy) – Sponsored by ICTP-Italy and DST-India (60 participants).

Capacity Building and Awareness Program

1. Capacity building programme (hands-on training) for M.Sc. 2nd year students of Environmental Science (Earth and Atmospheric Sciences) on Simulation modelling during August 2019 at HPC lab, DST-MCECCR, BHU (10 participants).

2. Capacity building program (hands-on training) for Ph.D. students of Geophysics (Meteorology) and Environmental Science on Computer Programming and Regional Climate Modelling (RegCM) during July 2019 at HPC lab, DST-MCECCR, BHU (21 participants).

3. Capacity building program (hands-on training) for M.Sc. 1st year students of Environmental Science (Earth and Atmospheric Sciences) on Disaster Management during February 2019 at HPC lab, DST- MCECCR, BHU (32 participants).

4. Capacity building program (lectures and hands-on training) for DST-MCECCR research personnel and research scholar on simulation modeling (crop modelling) during Feb-March 2018 at DST-MCECCR, BHU (12 participants).

5. Farmers Awareness Program on 'Weather, Climate and Farmers' organized by Gramin Krishi Mausam Seva (GKMS), DST-MCECCR, IESD-BHU, Dept. of Geophys., BHU in collaboration with IMD and ICAR on 26th February 2022 at Khanpur village, Mirzapur (225 farmers).

6. Farmers Interaction Meet held at DST- Mahamana Centre of Excellence in Climate Change Research, IESD, Banaras Hindu University, Varanasi on 20th March 2021 (100 participants).

7. Roving Seminar Cum Farmer Awareness Meet on "Effect of Weather on Crops" held at Village: Purushottampur, District Mirzapur (U.P.) on 21st November 2020 (150 participants).

8. Awareness program "फसलों पर मौसम का प्रभाव" for farmers jointly organized by Gramin Krishi Mausam Seva (GKMS), Geophysics Department, BHU and Kiran Seva Samiti, Lucknow, U.P. on 21 July, 2019 at Mirzapur, U.P. (74 participants).

9. Roving Seminar Cum Farmer Awareness Meet On "Effect of Weather on Crops" Held at Village: Mangraha (Mata Shanti inter College) Block Seekhad, District Mirzapur (U.P.) on 21st July 2019 (250 participants).

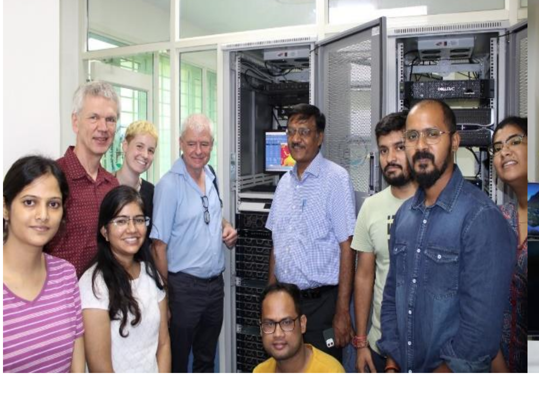
10. Roving Seminar cum Farmer Awareness meet held at Village: Dhaurhara, District Sonbhadra (U.P.) on 28th July 2019 (50 participants).

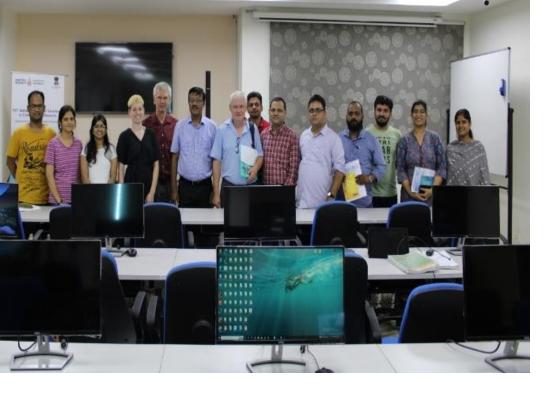
11. Roving Seminar cum Farmer Awareness meet held at: Naugarh, District Chandauli (U.P.) on 20th October 2019 (60 participants).

12. Roving Seminar Held at Village: Bighapur, District Mirzapur (U.P.) On 13th January 2018 (60 participants).

13. Roving Seminar Held at Village: Sonwal, District Ghazipur (U.P.) On 9th December 2017 (65 participants).


SETTING UP OF DAKSHIN GANGOTRI AT
ANTARCTICA : A MIRACLE & CLIMATE
CHANGE
Harsh K. Gupta
Hyderabad-500007, India
04 August 2022
Prof. Harsh Gupta





Workshops/Training Programmes and DST- MCECCR Lecture Series

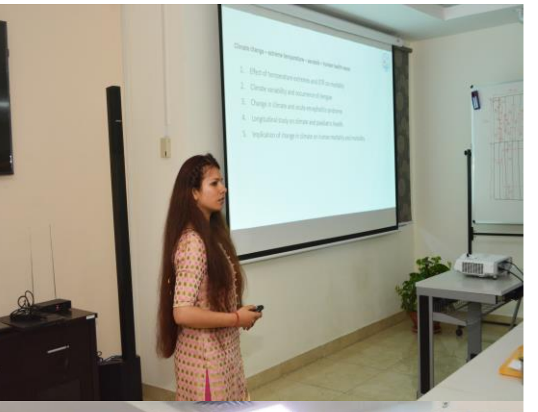
Foreign Deputation/Visit

Sl. No.	Name	Events	Venue	Date/Year
2023				
1.	Dr. Manas Pant	International Conference on Regional Climate-Coordinated Regional Climate Downscaling Experiment 2023 (ICRC-CORDEX 2023)	International Centre for Theoretical Physics (ICTP)	Trieste
2.	Dr. Prashant Srivastava	Advance in earth observation hyperspectral data analysis	University of Sunshine, Australia	11 – 14 July
3.	Prachi Singh	Advance in earth observation hyperspectral data analysis	University of Sunshine, Australia	11 – 14 July
4.	Prachi Singh	Asia Oceania Geosciences Society (AOGS, 20th Annual meeting)	Singapore	30 July – 4 Aug
5.	Pawan Kumar Chubey	Asia Oceania Geosciences Society (AOGS, 20th Annual meeting)	Singapore	30 July – 4 Aug
6.	Saumya Singh	UNITAR Hiroshima Women's Leadership in Tsunami-based Disaster Risk Reduction Training Programme for World Tsunami Awareness Day 2022 organized by United Nations Institute of Training and Research supported by Ministry of Foreign Affairs in Japan	Apia, Samoa	7-11 March
7.	Dr. Pradeep Kumar Dubey	Visited as a Fellow for the Nexus Assessment UN-IPBES	South Africa	18-26 Mar
8.	Prof. R. K. Mall	Visited at University of Nottingham	United Kingdom	01-4 Jan
2022				
1.	Prof. R. K. Mall	Visited at University of Bristol and University of Leeds	United Kingdom	18-30 Dec
2.	Dr. Prashant Srivastava	Session chair IEEE Whispers 2022	Rome, Italy	13-16 Sept
3.	Dr. Pradeep Kumar Dubey	Visited as a Fellow for the Nexus Assessment UN-IPBES	Bonn, Germany	3-9 July
2020				
1.	Alaa Mhawish	Visiting Researcher at NASA Ames Research Center Palo Alto	California, United States	Jan 2020
2019				
1.	Dr. Geetika Sonkar	American Geophysical Union (AGU) Fall Meeting	San Francisco, U.S.A.	9-13 Dec.
2.	Nandita Singh	American Geophysical Union (AGU) Fall Meeting	San Francisco, U.S.A.	9-13 Dec.
		For research work at the Physico-Chemistry Laboratory of the Atmosphere, University of the Littoral Opal Coast	Dunkerque, France	15-27 Sep.

Sl. No.	Name	Events	Venue	Date/Year
3.	Dr. T. Banerjee	Visiting Professor at Physico-Chemistry Laboratory of the Atmosphere, University of the Littoral Opal Coast	Dunkerque, France	15-27 Sep.
4.	Prof. Ravi S. Singh	Leadership for Academicians Programme (LEAP) training & workshop, The Ohio State University	Columbus, U.S.A.	8-15 Sep.
5.	Prof. Vinod K. Mishra	Leadership for Academicians Programme (LEAP) training & workshop, The Ohio State University	Columbus, U.S.A.	8-15 Sep.
6.	Shubhi Patel	Youth Ambassador in Indian Youth Delegation to China 2019, Govt. of India.	Beijing, Dunhuang, Lanzhou, China	2-9 July
7.	Alaa Mhawish	4th Atmospheric Composition and the Asian Monsoon Workshop (ACAM 2019), University Kebangsaan Malaysia	Bangi, Selangor, Malaysia	26-28 June
		3rd ACAM training school, University Kebangsaan Malaysia	Bangi, Selangor, Malaysia	24-25 June
8..	Dr. P. K. Srivastava	The EGU General Assembly 2019	Vienna, Austria	7-12 April
9.	Geetika Sonkar	3rd Agriculture and Climate Change Conference	Budapest, Hungary	24-26 Mar
2018				
1.	Prof. R. K. Mall	The World Urban Database and Access Port Tools (WUDAPT) workshop	CUHK, Hong Kong	8-10 Dec
		10th International Conference on Urban Climate/ 14th Symposium on the Urban Environment	New York, U.S.A.	6-10 Aug
2.	Dr. P. K. Srivastava	Asian Conferences of Remote Sensing" ACRS-2018	Kuala Lumpur, Malaysia	15-19 Oct
3.	Prachi Singh	Asian Conferences of Remote Sensing" ACRS-2018	Kuala Lumpur, Malaysia	15-19 Oct
4.	Nandita Singh	Tenth International Aerosol Conference, St. Louis	Missouri, U.S.A.	2-7 Sep
5.	Soumik Ghosh	Second Training Workshop on Regional Climate Modelling for Southeast Asia	Hanoi, Vietnam	22-26 Oct
		International Conferences on Sub-seasonal to Decadal Prediction (S2D)	NCAR, Boulder, U.S.A.	17-21 Sep
		Ninth ICTP Workshop on the Theory and Use of Regional Climate Models”	Trieste, Italy	28 May-08 Jun
		Applications of Atmospheric Modeling; Air pollution Impact research in South Asia	Kathmandu, Nepal	17-19 Apr
		ICACGP-IGAC Science conference 2018	Takamatsu, Japan	17-19 Apr
6.	Prof. Abhay K. Singh	42nd COSPAR Scientific Assembly	Pasadena, U.S.A	14-22 Jul

Sl. No.	Name	Events	Venue	Date/Year
7.	Nandita Singh	Tenth International Conference on Climate Change: Impacts Responses, University of California	Berkeley, U.S.A.	20-21 Apr
8.	Prof. V. K. Mishra	Borlaug Global Rust Initiative (BGRI), Technical Workshop	Marrakech, Morocco	14-17 Apr
9.	Dr. P. C. Abhilash	Attended IUCN-CEM Steering Committee Meeting	Pokhara, Nepal	26 Feb-2 Mar
10.	Manish Kumar	International Conference on Atmospheric Composition and Climate Change in Asia	Bangi, Malaysia	27-28 Mar
2017				
1.	Prof. Abhay K. Singh	Attend American Geophysical Union (AGU) Fall Meeting-2017	New Orleans, Louisiana, U.S.A.	10-22 Dec
2.	Prof. R. K. Mall	Invited Talk as a Senior Associate	ICTP, Italy	10-17 Sep
		Attended UN-Intergovernmental Platform on Biodiversity and Ecosystem Services meeting at United Nations University	Shibuya, Japan	24-29 Jul
3.	Dr. P. K. Srivastava	International Scientific Committee Member, 10th World Congress on Water Resources Environment, EWRA	Athens, Greece	5-9 Jul
4.	Geetika Sonkar	14thInternational Annual Meeting of the Asia Oceania Geosciences Society (AOGS)	Singapore	5-9 Jul
5.	Manish Kumar	Asian Aerosol Conference	South Korea	3-6 Jul
		Advanced Institute on Disaster Risk Reduction with Systems Approach for Slow-Onset Climate Disasters	Taipei, Taiwan	10-14 Jul
6.	Nidhi Singh	Workshop on Mathematical Models of Climate Variability, Environmental Change and Infectious Diseases	Trieste, Italy	8-16 May
		2nd Conference on "Impact of Environmental Changes on Infectious Diseases"	Trieste, Italy	17-19 May
7.	Dr. P. C. Abhilash	Attended and delivered an invited talk during 5th Biological Control Symposium at FCAV/UNES	Ribeirao Preto, Sao Paulo, Brazil	4-8 Jun
		Visiting Professor	Sao Paulo State University, Brazil	8-15 Jun
		Visiting Professor	University of Sharjah, UAE	20-30 Jun

Student Colloquium



9. Research Paper Published

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2. Patel, S., Mall, R.K., Chaturvedi, A., Singh, R., Chand, R. (2023). Passive adaptation to climate change among Indian farmers. Ecological Indicators, Volume 154, 110637, ISSN 1470-160X, https://doi.org/10.1016/j.ecolind.2023.110637 **[IF: 6.90]**

3. Singh, S. & Mall, R. K. (2023). Frequency Dominates Intensity of Future Heat Waves over India, iScience, 108263 https://doi.org/10.1016/j.isci.2023.108263**.** **[IF: 6.1]**

4. Dubey, P.K., Chaurasia, R., Pandey, K.K., Bundela, A.K., Singh, A., Singh, G.S., Mall, R.K. and Abhilash, P.C., (2023). Double transplantation as a climate resilient and sustainable resource management strategy for rice production in eastern Uttar Pradesh, north India. Journal of Environmental Management, 329, p.117082. https://doi.org/10.1016/j.jenvman.2022.117082 **[IF: 8.91]**

5. Jaiswal, R., Mall, R.K., Patel, S., Singh, N., Mendiratta, N., and Gupta, A. (2023). Indian sugarcane under warming climate: A simulation study, European Journal of Agronomy, Volume 144,,126760,ISSN 1161-0301. https://doi.org/10.1016/j.eja.2023.126760 **[IF: 5.7]**

6. Bhatla, R., Bhattacharyya, S., Verma, S. Mall, R. K. & Singh, R. S. (2023). El Nino/La Nina and IOD impact on Kharif season crops over western agro-climatic zones of India. Theor. Appl. Climatol. https://doi.org/10.1007/s00704-023-04361-z **[IF: 3.5]**

7. Pant, M., Bhatla, R., Ghosh, S., Das, S., & Mall, R. K. (2023). Will warming climate affect the characteristics of summer monsoon rainfall and associated extremes over the Gangetic Plains in India? Earth and Space Science, 10, e2022EA002741. https://doi.org/10.1029/2022EA002741 **[IF: 3.4]**

8. Dey, S., Raju, N. J., Gossel, W., Mall, R. K (2023). Hydrogeochemical characterization and Geochemical Modeling for the evaluation of groundwater quality and health risk assessment in the Varuna River basin, India, Environmental Geochemistry and Health. https://doi.org/10.1007/s10653-023-01521-y **[IF: 4.90]**

9. Mall, R.K. Singh,N., Patel,S., Singh, S., Arora, A., Bhatla, R., Singh R. S., & Srivastava,P. K. (2023). Climate Changes over the Indian Subcontinent: Scenarios and Impacts. In: Khare, N. (eds) Science, Policies and Conflicts of Climate Change. Springer Climate. Springer, Cham. https://doi.org/10.1007/978-3-031-16254-1_2

10. Singh, N., Chaturvedi, M., Mall, R.K. (2023). Unraveling Diurnal Asymmetry of Surface Temperature under warming scenarios in diverse Agroclimate Zones of India. Theoretical and Applied Climatology. **[IF: 3.4]**

11. Chaubey, P.K., Mall, R. K., Srivastava, P.K. (2023). Changes in Extremes Rainfall Events in Present and Future Climate Scenarios over the Teesta River Basin, India. Sustainability 2023, 1, 0. **[IF: 3.88]**

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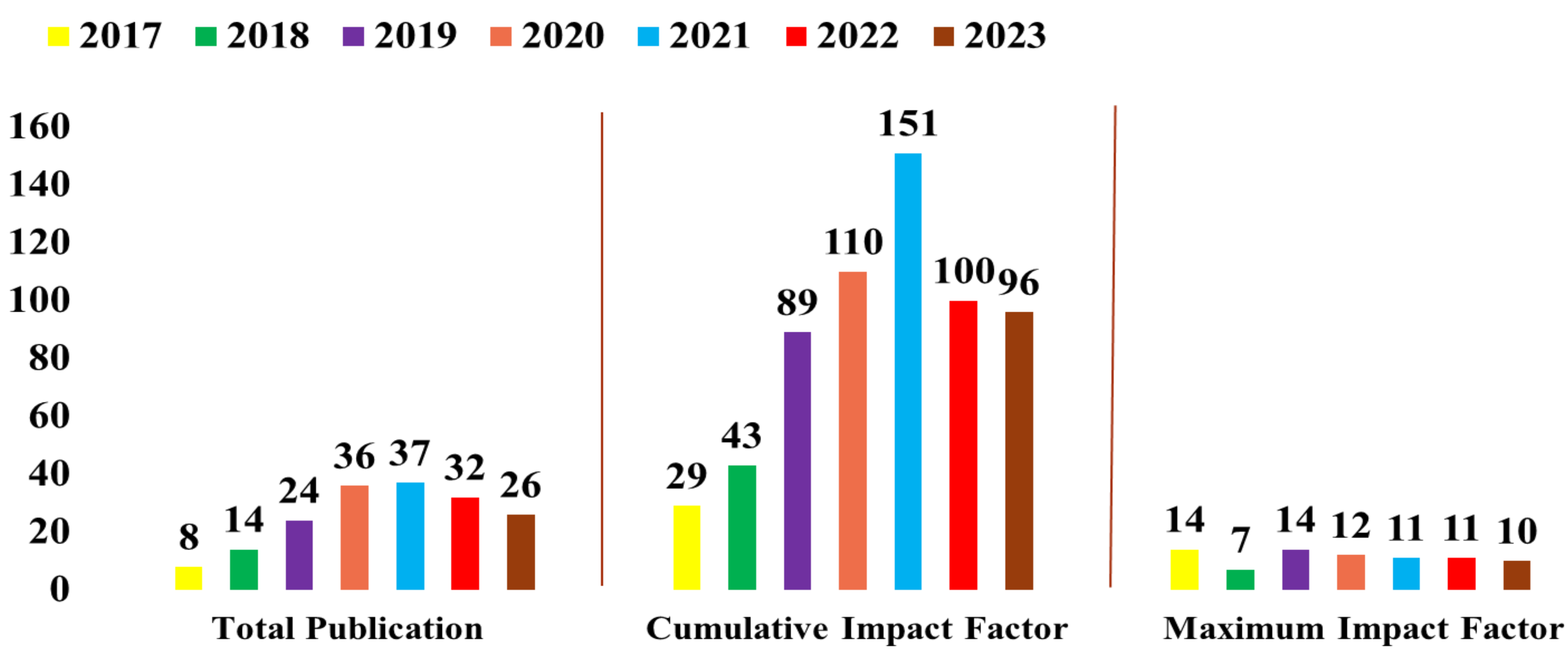
14. Singh, H., Singh, A.D., Tripathi, R., Singh, P., Verma, K., Voelker, A.H. and Hodell, D. A. (2023). Centennial-millennial scale ocean-climate variability in the northeastern Atlantic across the last three terminations. Global and Planetary Change, p.104100. https://doi.org/10.1016/j.gloplacha.2023.104100 **[IF: 4.9]**

15. Singh, P., Srivastava, P.K., Jochem Verrelst, J., Mall, R.K., Rivera, J.P., Dugesar, V., Prasad, R. (2023). High-resolution retrieval of leaf chlorophyll content over Himalayan pine forest using Visible/IR sensors mounted on UAV and radiative transfer model, Ecological Informatics, Volume 75,102099,ISSN 1574-9541, https://doi.org/10.1016/j.ecoinf.2023.102099 **[IF: 4.4]**

Publication statistics of DST-MCECCR



16. Singh, S., Mall, R.K. (2023). Building the Road to a Resilient Asia-Pacific: A New Dawn Begins for Womens Leadership in Disaster Risk Reduction in Samoa. Anthr. Sci. https://doi.org/10.1007/s44177-023-00058-0
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18. Bhatla, R., Singh, P.K., Kumar, A., Verma, S., Pant, M., Mall, R. K., & Singh, R. S. (2023). The Unified Response of the Atlantic Multidecadal Oscillation and Quasi-Biennial Oscillation on Indian Summer Monsoon Rainfall. Pure Appl. Geophys. 180, 2419 2441. https://doi.org/10.1007/s00024-023-03253-7 **[IF: 2.1]**
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25. Dani, B., Srivastava, V., Singh, A.P., & Bhatla, R., (2023). Tsunamis in the Past and Recent Years over Indian Coasts: A Review. In: Sandeep, Kumar P., Mittal H., Kumar R.Eds.,. Geohazards: Analysis, Modelling and Forecasting, pp.137-154.
26. Maurya, S., Srivastava, P.K., Zhuo, L., Yaduvanshi, A., Mall, R.K. (2023). Future Climate Change Impact on the Streamflow of Mahi River Basin Under Different General Circulation Model Scenarios. Water Resour Manage. https://doi.org/10.1007/s11269-022-03372-1 **[IF: 4.42]**

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3. Pant, M., Ghosh, S., Verma, S., Sinha, P., Mall, R. K., & Bhatla, R. (2022). Simulation of an extreme rainfall event over Mumbai using a regional climate model: a case study. Meteorology and Atmospheric Physics, 134(1), 1-17. https://doi.org/10.1007/s00703-021-00845-7 **[IF: 2.29]**
4. Jaiswal, R., Mall, R. K., Singh, N., Lakshmi Kumar, T. V., & Niyogi, D. (2022). Evaluation of bias correction methods for regional climate models: Downscaled rainfall analysis over diverse agroclimatic zones of India. Earth and Space Science, 9, e2021EA001981. https://doi.org/10.1029/2021EA001981 **[IF: 3.68]**
5. Ghosh, S., Sinha, P., Bhatla, R., Mall, R. K., & Sarkar, A. (2022). Assessment of Lead-Lag and Spatial Changes in simulating different epochs of the Indian summer monsoon using RegCM4. Atmospheric Research, 265, 105892. https://doi.org/10.1016/j.atmosres.2021.105892 **[IF: 5.96]**
6. Verma, K., Singh, A.D., Singh, P., Singh, H., Satpathy, R.K., Uddandam, P.R. and Naidu, P.D., 2022. Monsoon-related changes in surface hydrography and productivity in the Bay of Bengal over the last 45 kyr BP. Palaeogeography, Palaeoclimatology, Palaeoecology, p.110844. doi.org/10.1016/j.palaeo.2022.110844 **[IF: 3.56]**
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8. Singh, P., Srivastava, P.K., Mall, R.K., Bhattacharya, B.K., & Prasad, R. (2022). A hyperspectral R based Leaf Area Index estimator: Model development and implementation using AVIRIS-NG, Geocarto International. https://doi.org/10.1080/10106049.2022.2071476 **[IF: 3.45]**

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2018

1. Kumar, M., Parmar, K. S., Kumar, D. B., Mhawish, A., Broday, D. M., Mall, R. K., Banerjee, T. (2018) Long-term aerosol climatology over Indo-Gangetic Plain: Trend, prediction and potential source fields. *Atmospheric Environment*, 180, 37-50. doi: https://doi.org/10.1016/j.atmosenv.2018.02.027 **[IF: 5.76]**

2. Singh, N., Banerjee, T., Raju, M. P., Deboudt, K., Sorek-Hamer, M., Singh, R. S., Mall, R. K. (2018) Aerosol chemistry, transport, and climatic implications during extreme biomass burning emissions over the Indo-Gangetic Plain. *Atmospheric Chemistry and Physics*, 18(19), 14197-14215. doi: https://doi.org/10.5194/acp-18-14197-2018 **[IF: 7.20]**

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2017

1. Mhawish, A., Banerjee, T., Broday, D. M., Misra, A., Tripathi, S. N. (2017) Evaluation of MODIS Collection 6 aerosol retrieval algorithms over Indo-Gangetic plain: Implications of aerosols types and mass loading. Remote Sensing of Environment, 201, 297-313 https://doi.org/10.1016/j.rse.2017.09.016 **[IF: 13.85]**

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4. Kumar, M., Raju, M. P., Singh, R. S., Banerjee, T. (2017) Impact of drought and normal monsoon scenarios on aerosol induced radiative forcing and atmospheric heating in Varanasi over middle Indo-Gangetic Plain. Journal of Aerosol Science, 113, 95-107. doi: https://doi.org/10.1016/j.jaerosci.2017.07.016 **[IF: 5.59]**

5. Mall, R. K., Singh, N., Prasad, R., Tompkins, A., Gupta, A. (2017) Impact of climate variability on human health: A pilot study in tertiary care hospital of Eastern Uttar Pradesh, India. Mausam, 68 (3), 429-438. **[IF: 0.91]**

6. Mall, R. K., Gupta, A., Sonkar, G. (2017) Effect of climate change on agricultural crops in Current Developments in Biotechnology and Bioengineering. Dubey, S. K., Pandey, A., Sangwan, R. (Eds)., Elsevier, pp. 23-46. doi: https://doi.org/10.1016/C2014-0-04871-X

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8. Srivastava, R. K, Singh, P., Mall, R. K., Mishra, O. P. (2017) Urban setups in South Asia Region (SAR) under climate change induced risks: a suggestive urban risk resilient model for SAR, Indian Journal of Applied Research, 7(5), 571-585

10. Students Placement

The researchers from DST-MCECCR are placed at world class institutions with high QS rankings.

Sr. No.	Name	Institute	Designation
1.	Dr. Nidhi Singh	Leibniz research institute for environmental sciences, Germany	Post Doctoral Fellow
2.	Dr. Geetika Sonkar	Ram Manohar Lohia Avadh University, Ayodhya	Assistant Professor
3.	Dr. Manish Pandey	Birla Institute of Technology, Mesra, Ranchi	Assistant Professor
4.	Dr. Alaa Mhawish	Jiangsu, China	Research Scientist
5.	Dr. Soumik Ghosh	ESCER Centre UQAM , Université du Québec à Montréal, Montréal, Canada	Researcher
6.	Dr. Swati Suman	Université de Tunis, Italy	Post Doctoral Fellow
7.	Dr. Vishnu Murari	IMT-NORD-Europe	Post Doctoral Fellow
8.	Dr. Manish Kumar	Centre for Environment and Energy Development, Ranchi	Director
9.	Dr. Varsha Pandey	IIT Bombay, Mumbai	Post Doctoral Fellow
10.	Ms. Pranjali Singh	Tampere University, Finland	Ph.D.
11.	Dr. Nandita Singh	Juls Lab, USA	Analytical Chemist
12.	Dr. Vikram Singh Negi	Birbal Sahni Institute of Palaeosciences, Lucknow	Post Doctoral Fellow
13.	Dr. Ankur Pandey	Rajiv Gandhi Institute of Petroleum Technology (RGIPT), Uttar Pradesh	Assistant Professor
14.	Dr. Shruti Verma	Charles University, Czech Republic	Post Doctoral Fellow
15.	Dr. Manas Pant	La Aquila University, Italy	Post Doctoral Fellow
16.	Dr. Pradeep Kumar Dubey	World Resources Institute, Delhi	Program Manager
17.	Dr. Aman Arora	University Gustave Eiffel, France	Post Doctoral Fellow

11. Institutional Collaborations

12. Institutional Facilities

The High Performance Computing (HPC) is set up to centre the ever increasing demand for supercomputing facilities of researchers at DST-Mahamana Centre of Excellence in Climate Change Research, IESD, Banaras Hindu University. Regional & Global Modeling, Atmospheric and Ocean Modeling, Agriculture, Hydrology and Human Health are some of the active research areas in DST-MCECCR, IESD, BHU, where such large scale of Data computing will be used. High Performance Computing System (Core Speed: 44 Teraflop, Compute node: 16 (1 Compute node = 36 core, Internal Memory: 192 GB, Storage: 330 TB, interconnection: 100 GBPS Infiband), Soil moisture meter, Soil pH meter, Leaf area index meter, Workstation-Server, Desktops etc.

High Performance Computing (HPC), (also known as: Research Computing or Scientific Computing) is for those computing tasks which for some reason or another just won't run on a desktop computer. The task may be to sort through a huge amount of data, solve a difficult numerical problem, or just repeat the same calculation over and over for different situations. There are basically three types of High-Performance computing architectures available, SMP (Symmetrical Multi Processor computing), Cluster computing and Grid computing. Each of these architectures is designed to handle different types of computing problems based on what is needed.



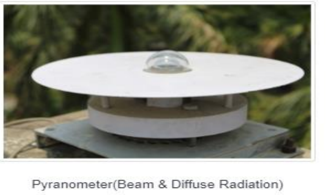

Weather Station, Department of Geophysics

Digital Standard Barometre


Sunshine Recorder

Pyranometer(Diffuse Radiation)

Pyrheliometer



Pyranometer(Beam & Diffuse Radiation)


OPPO F17 Pro
OnePlus+

13. Distinguished Visiting Scientist/Academician

2023

1. Prof. R. N. Singh, Former Director (NEERI, Nagpur), FASc, FNA / Visiting Professor (Earth Science) IIT Gandhinagar (25th, August 2023).
2. Dr. Abhay R. Bansal, Chief Scientist NGRI Hyderabad, (19th July).
3. Dr. Archana Bhattacharyya, Former Director, IIGM-Mumbai (2nd April, 2023)
4. Prof. Axel Kleidon, Max-Planck-Germany (2nd April, 2023).
5. Prof. Shovonlal Roy, University of Reading, Department of Geography and Environmental Science, (17 March 2023).
6. Prof. Kalachand Sain, Director, Wadia Institute of Himalayan Geology, Uttarakhand, (24th Feb, 2023).
7. Dr. Akhilesh Gupta, Secretary, SERB DST; Head Climate Change Program, Department of Science & Technology, Government of India, New Delhi (16th, October 2023)
8. Prof. Talat Ahmed, Former Vice Chancellor, University of Kashmir, Srinagar (16th, October 2023)
9. Dr. Anita Gupta, Head, Climate Change and Clean Energy, DST, New Delhi (16th, October 2023)
10. Dr. Nisha Mendiratta, Advisor & Head wise Kiran Division, DST, New Delhi (16th, October 2023)
11. Dr. Kalachand Sain, Director, Wadia Institute of Himalayan Geology, Dehradun (16th, October 2023)
12. Prof. Geetha Laxmi, Vice Chancellor Tamil Nadu Agricultural University, Tamil Nadu (16th, October 2023)
13. Prof. N. H. Ravindranath, Former Professor, Centre for Sustainable Technologies, IISc Bangalore (16th, October 2023)
14. Dr. Akshara Kaginalkar, Senior Director (Sc. G), Center for Development of Advance Computing (C-DAC), Pune (27th, October 2023)
15. Prof. Elena Surovyatkina, Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany (31st October, 2023)

2022

1. Dr. Shiraj Wajih, NGO, Gorakhpur Environment Action Group, Gorakhpur, Uttar Pradesh, (15th Dec, 2022).
2. Dr. Gopal Iyengar, MoES, (20th Dec 2022).
3. Prof. Dev Niyogi, William Stamps Farish Chair, University of Austin, USA, (13th Dec, 2022).
4. Dr. Jochem Verrelst, Scientist, Image Processing Laboratory (IPL), University of Valencia, (13th Dec, 2022).
5. Dr. Akshara Kaginalkar, Senior Director (Sc. G), Centre for Development of Advanced Computing (C-DAC) Pune (13th Dec, 2022).
6. Dr. A.K. Sahai, (Retired) Scientist -G IITM Pune, (19th Oct 2022).
7. Dr. Akhilesh Gupta, Scientist H, Senior Advisor, Department of Science & Technology (22nd Sept 2022).
8. Dr. Nisha Mendiratta, Head, Climate Change Programme, Department of Science and Technology, Delhi (22nd Sept 2022).
9. Padma Shri Prof. Harsh Gupta, Former Secretary, Department of Ocean Science & Technology, GOI (4th Aug 2022).
10. Dr. R. K. Srivastawa, IAS (6th August, 2022)
11. Mr. Ashish Tiwari, Secretary, Ministry of Environment and Climate Change, U.P. (23rd July, 2022)
12. Prof. A. P. Dimri, Director, Indian Institute of Geomagnetism, Mumbai / Professor, School of Environmental Sciences, Jawaharlal Nehru University (23 July, 2022)
13. Dr. O.P. Mishra, Director, National Centre for Seismology (NCS), MoES, GOI (5th June 2022).
14. Dr. Virendra M. Tiwari, Director, CSIR-National Geophysical Research Institute (17th May 2022).
15. Dr. Akhilesh Gupta, Scientist H, Senior Advisor, Department of Science & Technology (14th May 2022).

2021

1. Dr. Abhijeet Sarkar Scientist-F, National Centre for Medium Range Weather Forecasting, Noida (1-2 Oct 2021).
2. Prof. V.K. Gaur, Honorary Scientist, CSIR-CMMACS, Bangalore (2nd Sept 2021).
3. Dr. Milind Mujumdar, Scientist E, Indian Institute of Tropical Meteorology (IITM), Pune. (4th Mar 2021)
4. Prof. A P Dimiri, Professor, School of Environmental Science, Jawaharlal Nehru University, New Delhi (17 Mar 2021).

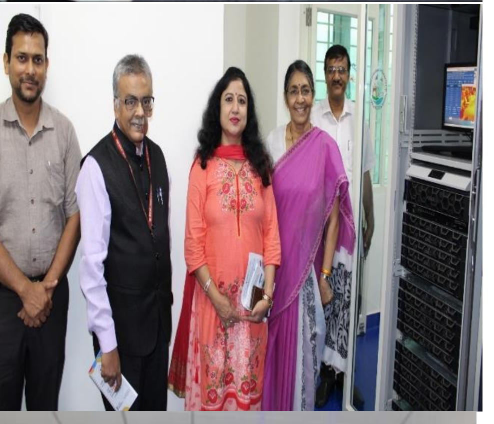
2020

1. Prof. Jagadish Shukla, Centre for Ocean-Land-Atmosphere Studies, George Mason University, VA, USA (07-02-2020)
2. Campbell Watson, Research Staff Member IBM Research Thomas J. Watson Research Centre Yorktown Heights, NY USA. (29-01-2020).

2019

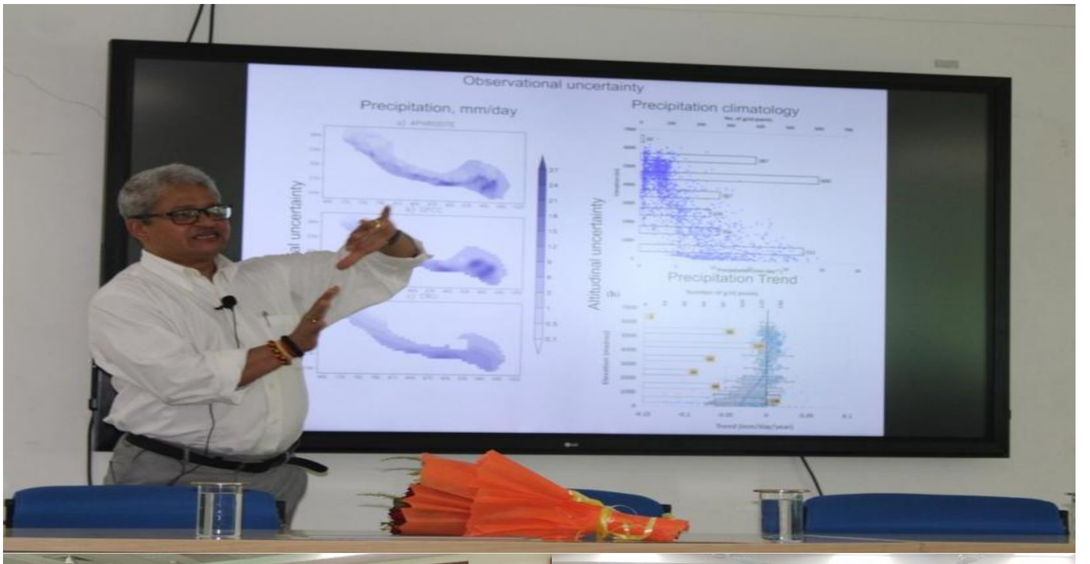
1. Prof. Ramesh P. Singh, School of Earth and Environmental Sciences, Chapman University, U.S.A. (27-06-2019).
2. Prof. Gerrit Hoogenboom, Department of Agricultural and Biological Engineering, University of Florida, Gainesville, U.S.A. (21-01-2019 to 01-02-2019).
3. Prof. David Broday, Technion - Israel Institute of Technology, Israel (22-02-2019 to 25-02-2019).


DST- Mahamana Centre of Excellence
in Climate Change Research



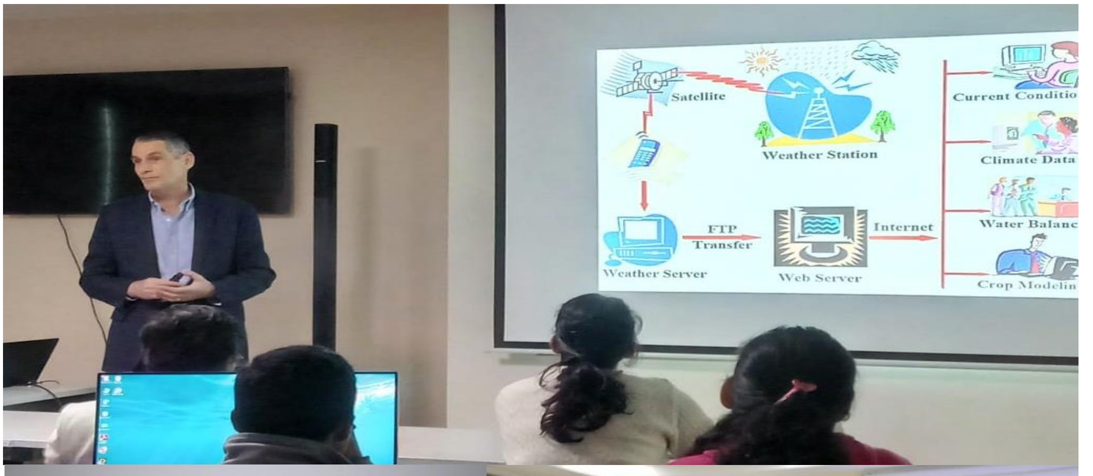

Strong Temporal Variability in Summer Monsoon Rainfall


Why is Climate Change a Problem?


Observational uncertainty
Precipitation, mm/day
Precipitation climatology
Precipitation Trend
Altitudinal uncertainty


Criticality of Indian Continental Waters


May 17th, 2022
11:30 AM


Satellite
Weather Station
Climate Data
FTP Transfer
Internet
Weather Server
Web Server


Prof. V.K Gaur
Chief Guest


Data Analysis and Processing


Mahamana Centre of Excellence in Climate Change Research
MCECCR
DST- Mahamana Centre of Excellence in Climate Change Research


डी.एस.टी. महामना
जलवायु परिवर्तन
उत्कृष्ट शोध केन्द्र
DST MAHAMANA CENTRE OF
EXCELLENCE IN CLIMATE
CHANGE RESEARCH
IESD - BHU
पर्यावरण एवं धारणीय


Urban Integrated Environment Modeling and Services
Akshara Kaginalkar
Senior Director
Centre for Development of Advance Computing (C-DAC)
India

4. Dr. Mangala Rai, Former Secretary, Department of Agricultural Research and Education, GOI, Former Director General, ICAR, Ministry of Agriculture, Former Vice-Chancellor, G.B. Pant University of Agriculture & Technology, Pantnagar (22-04-2019)..

5. Dr. Akhilesh Gupta, Head Climate Change Program, Department of Science & Technology, Government of India, New Delhi (22-04-2019).

6. Prof. Anil K. Gupta, Geology & Geophysics, IIT-KGP, Kharagpur & Former Director, Wadia Institute of Himalayan Geology (WIHG), Dehradun (22-04-2019).

7. Dr. Y. S. Ramakrishna, Former Director, ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad (12-04, 2019).

8. Dr. K. K. Singh, Scientist-G, Head, Agroadvisory, India Meteorological Department (IMD), Ministry of Earth Sciences, Govt. of India, New Delhi (28-01-2019 to 01-02-2019& 22-04-2019).

2018

1. Prof. Dev Niyogi, Department of Agronomy and Department of Earth, Atmospheric and Planetary Sciences, Purdue University, U.S.A. (07-08 July, 2018).

2. Dr. L. S. Rathore, Former Director General of Meteorology, India Meteorological Department (IMD), New Delhi (02-12-2018).

3. Dr. R. N. Singh, Visiting Professor, IIT-Gandhinagar & Former Director, CSIR-National Environmental Engineering Research Institute, Nagpur (02-11-2018).

4. Dr. R. R. Navalgund, Former Director, Space Applications Centre, Ahmedabad & National Remote Sensing Centre, Hyderabad, ISRO (02-11-2018).

5. Prof. U. C. Mohanty, Visiting Professor, School of Earth, Ocean and Climate Sciences, Indian Institute of Technology-Bhubaneswar, Odisha (31-10-2018).

6. Prof. Anil Kumar Gupta, Professor, Geology & Geophysics, IIT-KGP, Kharagpur & Former Director, Wadia Institute of Himalayan Geology (WIHG), Dehradun (31-10-2018).

7. Dr. Akhilesh Gupta, Head Climate Change Program, Department of Science & Technology, Government of India, New Delhi (26-10-2018).

8. Dr. A. K. Sahai, Scientist-G, Head CRS, IMD & Co-ordinator Indo-UK Water Centre, Indian Institute of Tropical Meteorology, Pune (23-10-2018 to 02-11-2018).

9. Dr. Sunil Singh, Director, CSIR-National Institute of Oceanography, Goa (27-10-2018).

10. Dr. Ranjeet Singh, Scientist-F (AASD), India Meteorological Department (IMD), New Delhi (08-02-2018).

2017

1. Prof. Jagadish Shukla, Managing Director, Centre for Ocean-Land-Atmosphere Studies (COLA) & Professor, George Mason University, U.S.A. (23-02-2017).

2. Prof. Dev Niyogi, Department of Agronomy and Department of Earth, Atmospheric and Planetary Sciences, Purdue University, U.S.A. (24-26 September, 2017).

3. Prof. S. K. Dube, Former Director, Indian Institute of Technology-Kharagpur, Kharagpur (23-02-2017).

4. Dr. K. J. Ramesh, Former Director General, India Meteorological Department (IMD), New Delhi (23-02-2017).

5. Prof. S. K. Dash, Emeritus Professor, Centre for Atmospheric Sciences, Indian Institute of Technology-Delhi (23-02-2017).

6. Dr. Akhilesh Gupta, Head Climate Change Program, Department of Science & Technology, Government of India, New Delhi (23-02-2017).

7. Prof. Prasad Kumar Bhaskaran, Professor & Head, Ocean Engineering & Naval Architecture, Indian Institute of Technology-Kharagpur, Kharagpur (23-02-2017)

8. Dr. G. Srinivasan, Chief Scientist-Climate Applications, Regional Integrated Multi-Hazard Early Warning System (RIMES), Asian Institute of Technology Campus, Bangkok (23 February & 18-19 May, 2017).

9. Dr. Ch. Srinivasa Rao, Director, Central Research Institute for Dry-land Agriculture (CRIDA), Hyderabad (18-19 May, 2017).

10. Prof. S. N. Tripathi, Rajeeva and Sangeeta Lahri Chair Professor and Head, Department of Civil Engineering & Department of Earth Sciences, Indian Institute of Technology-Kanpur, Kanpur (23-02-2017).

11. Dr. D. S. Pai, Head, Climate Services Division, India Meteorological Department (IMD), New Delhi (18-19 May, 2017).

12. Dr. A. K. Sahai, Scientist-G, Head CRS, IMD & Co-ordinator Indo-UK Water Centre, Indian Institute of Tropical Meteorology, Pune (18-19 May, 2017).

13. Dr. K. K. Singh, Scientist-G, Head, Agro advisory, India Meteorological Department (IMD), Ministry of Earth Sciences, Govt. of India, New Delhi (18-19 May, 2017).

14. Media Coverage

The research at the Centre has been covered by various national and international media disseminating it globally.

The Indian EXPRESS
Study identifies three prominent heatwave prone regions in India

Northwestern, central and south-central India are new hotspots of intense heatwave over the past 50 years, a study has said. The study also highlights the need for developing effective heat action plans in the three heatwave hotspot regions with a focus on different vulnerabilities among the inhabitants.

The Economic Times | Panache
Children vulnerable to infectious diseases mainly due to climate change, says study

NEW DELHI: Scientists have found that climate parameters accounted for 9 to 18 per cent of the total infectious disease in children under 16 years of age in Varanasi, according to a study.

THE HINDU
Black carbon linked to premature mortality

Black carbon (BC), a form of particulate matter that results from carbon emissions, was most associated with premature mortality, according to a study that tracked mortality rates from different classes of air pollutants in Varanasi, Uttar Pradesh.

mint lounge
Air pollution: Study links black carbon with premature deaths

Black carbon has a significant adverse effect on human health and can lead to premature death, according to a new study, which could help improve the estimation of the future air pollution mortality burden.

The Weather Channel – An IBM Business | The Times of India
Declining Diurnal Temperature Range Poses Risk to Agriculture and Health: Study

Northwestern, central and south-central India are new hotspots of intense heatwave over the past 50 years, a study has said. The study also highlights the need for developing effective heat action plans in the three heatwave hotspot regions with a focus on different vulnerabilities among the inhabitants.

mint
Three new heatwave hotspots in India put large population at immediate health risk: Study

The study focuses on the need of developing an effective heat action plans in the three heatwave hotspot regions with a focus on different vulnerabilities among the inhabitants

THE WEEK
Study links Black Carbon with premature deaths

Black Carbon has a significant adverse effect on human health and can lead to a premature death, according to a new study, which could help improve the estimation of the future air pollution mortality burden. The Indo-Gangetic plain is exposed to Black Carbon (BC) with serious implications on regional climate and human health, but the health effects in terms of mortality due to BC aerosol exposure have never been evaluated in India, the study says.

DNA
Climate change: Study reveals three new heatwave hotspots in India, larger population at risk

The summer duration in India is increasing over the time with severe heat waves across the country. This year Northern India reeled under an intense heatwave with monsoons hitting the region late. Now a new study has revealed that north-western, central, and south-central regions of the country have emerged as new heatwave hotspots.

DELHI POST
Study Links Black Carbon to Premature Mortality

राष्ट्रीय सहारा
क्लाइमेट चेंज से बढ़ा तापमान, जनजीवन बेहाल

DT NEXT
Agriculture, health at risk from declining diurnal temperature range

आज तक
Heat Wave In India: हीट वेव का खतरा बढ़ा, मध्य और दक्षिण भारत के कई राज्य लिस्ट में शामिल

ET Healthworld.com
Children vulnerable to infectious diseases mainly due to climate change, says study

The Weather Channel
North-West, Central, South-Central India are Country's New Heatwave Hotspots, Finds New Study

The study also highlights the need for developing effective heat action plans in the three heatwave hotspot regions with a focus on different vulnerabilities among the inhabitants.

NATIONAL HERALD
'Climate change makes children vulnerable to infectious diseases'

A study that was conducted to look into the association between climate parameters and infectious diseases in children under 16 years have found that climate variables accounted for 9-18 per cent

NDTV
Northwest, Central, South-Central India New Heatwave Hotspots, Says Study

New Delhi: Northwestern, central and south-central India are new hotspots of intense heatwave over the past 50 years, a study has said.

NEWS18 हिंदी
अलर्ट! बीते 5 सालों में भारत के तीन हिस्से बने तेज गर्म हवाओं के हॉटस्पॉट, स्टडी में आया सामने

EAST COAST DAILY

INDIA TODAY
Climate change making children vulnerable to infectious diseases: Study

The study was conducted to probe the association between climate parameters and infectious diseases in children under 16-years-of-age in Varansi city.

THE LOGICAL INDIAN
Children Are Endangered To Infectious Diseases Due To Climate Change: Study

the pioneer
Climate change inflicting infectious diseases on kids: study

Tech Live
Study Links Black Carbon With Premature Deaths

पांच दशकों में भारत में हीट-वेव के तीन नए हॉटस्पॉट बने

Three new heatwave hotspots emerge in India, huge population at risk: Study

UNI United News of India

Climate Change makes children vulnerable to infectious diseases: Study

Kolkata, Dec 13 (UNI) Scientists have found that climate parameters accounted for 9-18% of the total infectious disease cases in a study to probe the association between climate parameters and infectious diseases in children under 16-years-of-age in Varanasi-city in central Indo-Gangetic Plane.

Climate change driven by anthropogenic activities may challenge the gains in public health over the past many years, particularly in a country like India that ranks high in the list of climate-vulnerable countries in the world.

the pioneer
Study by BHU rings alarm over drought in lower Ganga basin

Hindustan Times
Lower Ganga basin may face drought in near future: Study

ET The Economic Times
Heatwave intensity set to spike, new hot spots likely: Govt study


वाराणसी

वाराणसी। शनिवार • 26 मार्च • 2022 | राष्ट्रीय सहारा | www.rashtriyasahara.com

डीएसटी : महामना जलवायु परिवर्तन उत्कृष्ट शोध केंद्र

लैब से लेकर किसानों के खेत तक पहुंचे वैज्ञानिक

गर्मी से कम हुई गन्ने की मिठास

बदलते मौसम पर सामूहिक प्रयास जरूरी

मौसम की सटीक भविष्यवाणी में भारत की क्षमता में हुई वृद्धि

सुपर कंप्यूटर भांपेगा जलवायु में परिवर्तन

भविष्य में चक्रवात कम आएंगे लेकिन तीव्रता बढ़ेगी

आपदा है परिवर्तन की चेतावनी

वाटर रिचार्ज से दूर होगी जल की कमी

जलवायु परिवर्तन अध्ययन में सामूहिक सामंजस्य जरूरी

बीएचयू में राज्य स्तरीय जलवायु दृष्टिकोण मार्गदर्शी फोरम कार्यशाला

जलवायु अध्ययन का स्वदेशी मॉडल जरूरी

अब राजस्थान, गुजरात में भारी वर्षा व बाढ़ का खतरा

मौसम पूर्वानुमान कार्यप्रणाली से किसानों को कराया परिचित

सटीक पूर्वानुमान प्राकृतिक आपदाओं से निपटने में सहायक: डॉ. अतुल

खेती आधारित मौसम की भविष्यवाणी जरूरी

BHU hosts meet on climate change

TIMES NEWS NETWORK

Varanasi: A two-day workshop on 'Simulation modelling and climate change: Issues and challenges' organised by Institute of Environment and Sustainable Development, Banaras Hindu University (BHU) began on Monday.

Speaking on the occasion, RD Singh, director, National Institute of Hydrology, Roorkee said that adaptation to the climate change is really a big issue. Change of climate cannot be stopped.

However, its impact can be minimised. "So adaptation to this change is required and we should do work in this regard," he said.

SK Das from IIT-Delhi ... the necessity of ... ment said that increase in urbanization would lead to decrease in water recharge.

The government should promote water recharge and monitor groundwater to avoid an extreme adverse situation.

Earlier, institute director AS Raghuvanshi welcomed the participants. A panel discussion was also held.

The Statesman

Deadly heatwaves reported from 3 regions in country; severe impact on health, agriculture, economy and infrastructure likely

Statesman News Service | New Delhi | September 8, 2021 6:00 am

Business Standard

Northwest, central and south-central India new hotspots of intense heatwave

Northwestern, central and south-central India are new hotspots of intense heatwave over the past 50 years, a study has said.

The study also highlights the need for developing effective heat action plans in the three heatwave hotspot regions with a focus on different vulnerabilities among the inhabitants.

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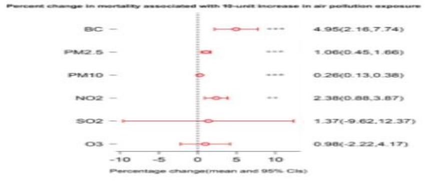
Home >> Black carbon could lead to premature mortality: study

Black carbon could lead to premature mortality: study

Black Carbon has a significant adverse effect on human health and leads to premature mortality, says a new study. The study could help in the estimation of future burden of mortality associated with air pollutants more accurately.

The Indo-Gangetic plain is exposed to black carbon (BC) with serious implications on regional climate and human health. However, most of the pollutions-based epidemiological studies essentially relate exposure to particulate mass concentration (PM 10 and/-or PM 2.5) that invariably generalize all particulates with equal toxicity without distinguishing individuals by its' source and composition, which genuinely have different health consequences. Importantly, the health effects in terms of mortality due to BC aerosol exposure have never been evaluated in India.



R.K. Mall led the team of scientists including Nidhi Singh, Alaa Mhawish, Tirthankar Banerjee, Santu Ghosh, R. S. Singh from the Department of Science & Technology-Mahamana Centre of Excellence in Climate Change Research (MCECCR) at Banaras Hindu University explored the individual as well as the cumulative impact of BC aerosol, fine (PM 2.5), and coarse (PM 10) particulates, and trace gases (SO_2, NO_2, O_3) on premature mortality in Varanasi. They have recently published their research in a

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Home >> Three new heatwave hotspots in India put large population at immediate health risk

Three new heatwave hotspots in India put large population at immediate health risk

North-Western, Central, and further to south-central region of India are the new hotspot of intense heatwave events over the past half-century, said a study which found an increase in deadly Indian heat waves in recent years. The study also highlights the need for developing effective heat action plans in the three heatwave hotspot regions with a focus on different vulnerabilities among the inhabitants.

Heatwaves emerged as a deadly health hazard, claiming thousands of lives across the globe in recent decades, with episodes strengthening in frequency, intensity, and duration in the past half-century in India as well. This has caused severe impacts on health, agriculture, economy, and infrastructure. In such a scenario, it is extremely important to identify the most heatwave vulnerable regions of the country to prioritize immediate policy intervention and stringent mitigation and adaptation strategies.

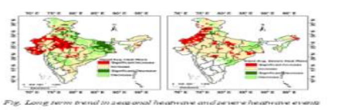

Fig. Long term trend in seasonal heatwave and severe heatwave events

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Home >> Accelerating decline in diurnal temperature range in parts of India over 30 years may put agriculture & health at risk

Accelerating decline in diurnal temperature range in parts of India over 30 years may put agriculture & health at risk

Variation in diurnal temperature range is asymmetric over India's 3 agroclimatic zones with a marked accelerating decrease in the range witnessed over the last 30 years in the north-west, parts of Gangetic plain, north-east, and central India said a new study. This short term decrease in maximum and minimum temperature range is most prominent during monsoon and post-monsoon and stands out despite a long term trend of increasing differences between the two. This accelerating decline in diurnal temperature range owing to faster rise in minimum temperature and decline in solar radiation, as suggested in the study, may put agriculture and health at risk.

Diurnal temperature range (DTR) is an important indicator of climatic change and a critical thermal metric to assess the impact on agriculture and human health. Hence it is extremely important to identify the regions of wide diurnal variation and decreasing DTR and to assess the explicit causes responsible for these phenomena.

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Home >> Hydroclimate extremes will be more intensified in near-future over the Indian River Basins (IRBs)

Hydroclimate extremes will be more intensified in near-future over the Indian River Basins (IRBs)

Frequency of extreme rainfall is likely to increase over the Western Ghats and Northeast river basins, while an increase in heavy rainfall intensity is projected over the Upper Ganga and Indus basins. The study explored the new possible hotspot regions for future urban flooding due to increasing heavy rainfall patterns over different Indian River Basins.

In the past few decades, the increased frequency of hydroclimate extreme events over the Indian River basins (IRBs) due to global warming has led to a significant rise in flood-related disasters, mortality rates, and economic losses, ultimately affecting the gross domestic product. In this context, it becomes exceedingly essential to examine the future hydroclimate extremes and identify hotspot regions over the Indian River Basins (IRBs) that are most susceptible to hydroclimate extremes. This can enable the prioritization of urgent policy interventions, mitigation and adaptation strategies.

A research led by Prof. R. K. Mall, Cordinator of the Department of Science & Technology-Mahamana Centre of Excellence in Climate Change Research (DST-MCECCR) at Banaras Hindu University (BHU), including Ph.D. scholar Pawan Kumar Chaubey, used high-resolution simulated precipitation from Coupled Model Intercomparison Project-6 (CMIP6) experiments to examine the future hydroclimate extremes over the different River Basins of India. The work supported under the Climate Change Program of the Department of Science & Technology (DST), projected intense precipitation specially over the Western Ghats and Northeast river basins, and an increase in heavy rainfall intensity (14.3%) over the upper Ganga and Indus basins as well as intensification of severe droughts.

ANNEXURE

ANNEXURE I

c. Conference/Seminar/Symposium/Workshop attended:

Sl. No.	Events	Attendees	Duration
International:			
2023			
1.	International Conference on Regional Climate-Coordinated Regional Climate Downscaling Experiment 2023 (ICRC-CORDEX 2023), at Indian Institute of Tropical Meteorology (IITM), Pune *AND* International Centre for Theoretical Physics (ICTP), Trieste	Prashant Rajput Pawan Kumar Chaubey Saumya Singh Manas Pant	25 - 29 Sept.
2.	Asia Oceania Geosciences Society (AOGS), 20th Annual Meeting, Singapore	Pawan Kumar Chaubey Prachi Singh	30 July - 04 Aug
3.	Workshop on climate models, Divesha center for climate change, IISc. Bangalore	Pradip Sarkar	24-28 July
4.	Advances in earth Observation Hyperspectral data Analysis, University of Sunshine, Australia	Prachi Singh	11 - 14 July
5.	"Introductory Webinar: Connecting Citizen Science with Remote Sensing" by NASA	Prachi Singh	24-31 Jan
6.	VIth Xiamen Symposium on Marine Environmental Sciences (XMAS-VI) held in Xiamen, China	Pradyumna Singh	9-12 Jan
2022			
1.	AGU Fall Meeting 2022 organized by American Geophysical Union, Chicago, USA	Saumya Singh Pawan Kumar Chaubey Prachi Singh	12-16 Dec
2.	Training on Selecting Climate Change Projection Sets for Mitigation, Adaptation and Risk Management Applications	Abhiraj Chaturvedi	19-20 Sep
3.	International Conference under the project 'Indo-German Competence Center for Riverbank Filtration' organized by IESD BHU Varanasi	Saumya Singh	
4.	12th Workshop on Hyperspectral Imaging and SignalProcessing: Evolution in Remote Sensing (WHISPERS), Rome, Italy	Prachi Singh	13-16 Sep
5.	Webinar on the Role of Air Quality Management in Low Carbon Healthy Buildings organized by CERCA, IIT Delhi	Aditi Kumar	30 June
6.	EGU General Assembly, 2022, Vienna, organized by European Geosciences Union	Prachi Singh Saumya Singh Pawan Kumar Chaubey R.K Mall P.K. Srivastava	23-27 May
7.	Webinar on Atmospheric CO_2 and CH_4 Budgets to Support the Global Stocktake (Session A) organized by NASA- ARSET	Aditi Kumar	25 May
8.	Webinar on Citizen Science and Air Quality organized by CERCA, IIT Delhi	Aditi Kumar	13 May
9.	The WMO/WCRP Working Group on Numerical Experimentation (WGNE) is a hybrid workshop on systematic errors in weather and climate models.	Sunita Verma Manish Soni Swagata Payra	10-11 Mar
10.	"International Webinar Series on Advances in Earth and Environmental Geosciences" organized by Dept. of Geophysics, BHU in association with Distinguished Lecture Series Programme, American Geophysical Union	Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Manas Pant Praveen Kumar Singh	10-11 Mar
2021			
1.	International Symposium on Tropical Meteorology "Changing Climate: Consequences and Challenges (INTROMET-C4)" INTROMET 2021", CUSAT, jointly Organized by Indian Meteorological Society - Cochin Chapter & Cochin University of Science and Technology (CUSAT), Cochin, Kerala State,	Saumya Singh Pawan Kumar Chaubey Prachi Singh Manas Pant R Bhatla RK Mall Prashant K. Srivastava	23-26 Nov
2.	'International Conference on Recent Advances in Earth Sciences' organized by Institute of Earth and Environmental Sciences, RML Avadh University, Ayodhya	Shiv Mangal Singh R. K. Mall R. Bhatla	26 -28 Oct
3.	NIICE International Studies Convention on Reimagining the world: Reflections on the future of world order organized by Nepal Institute for International Cooperation and Engagement, Kathmandu, Nepal.	R. K. Mall	27-29 Aug

Sl. No.	Events	Attendees	Duration
4.	Participated and presented paper titled "Flood Risk Assessment of climate change induced pluvial floods using Machine Learning and Geospatial Technology" in "Bringing Land, Ocean, Atmosphere and Ionosphere Data to the Community for Hazard Alerts" organized by American Geophysical Union (AGU)	Nidhi Singh Prashant Rajput Aman Arora Pawan Kumar Chaubey Pranjali Singh R K Mall	24-28 May
2020			
1.	32^{nd} annual conference of the international society of environmental epidemiology	Nidhi Singh	24-27 Aug
2.	International Conference on 'Ensemble Methods in Modelling and Data Assimilation' (EMMDA) at NCMRWF Noida	Shruti Verma Manas Pant R Bhatla R. K. Mall	24-26 Feb
3.	International e-conference on "Science & Technology Research – policy –Practice interface for climate Risk Management" at NIDM, New Delhi	R. K. Mall	25-27 Aug
2019			
1.	American Geophysical Union (AGU) Fall Meeting held in San Francisco, California, USA during 9^{th} to 13^{th} Dec, 2019.	Geetika Sonkar	9-13 Dec
2.	Workshop on Priorities for Advancing Research on Health Effects of Air Pollution in India held at AIIMS, New Delhi	Nidhi Singh	2-4 Dec
3.	International Workshop on Prediction skill of extreme Precipitation events and tropical cyclones: Present status and future Prospect (IP4) & Annual Climate Change Workshop organized by Indian Institute of Tropical Meteorology, Pune	Manas Pant	25-28 Nov
4.	Training Workshop for Scientific Staff under ICAR-HRM Programme 2019-2020 on "Advances in Simulation Modelling and Climate Change Research towards Knowledge Based Agriculture "organized by Centre for Environment Science and Climate Resilient Agriculture, ICAR-Indian Agricultural Research Institute, New Delhi	Geetika Sonkar Rohit K. Jaiswal Chandrakant Singh	13 Nov-3 Dec
5.	Asian Air Pollution Workshop (AAPW-5) held at Department of Botany, Institute of Science, BHU, Varanasi	Nidhi Singh	5-7 Nov
6.	Invited Doctoral Student for research work at the Physico-Chemistry Laboratory of the Atmosphere, University of the Littoral Opal Coast, Dunkerque, France	Nandita Singh	15-27 Sep
7.	Leadership for Academicians Programme (LEAP) training & workshop, The Ohio State University, Columbus, U.S.A.	Ravi S. Singh Vinod K. Mishra	8-15 Sep
8.	4^{th} Atmospheric Composition and the Asian Monsoon Workshop (ACAM 2019), University Kebangsaan Malaysia, Bangi, Selangor, Malaysia	Alaa Mhawish	26-28 June
9.	3^{rd} ACAM training school, University Kebangsaan Malaysia, Bangi, Selangor, Malaysia	Alaa Mhawish	24-25 June
10.	IITD-ANCST International Workshop on Modelling Atmospheric -Oceanic Processes for Weather and Climate Extremes (MAPEX-2019), IIT-Delhi	Diva Bhatt Shruti Verma	28-29 Mar
11.	3^{rd} Agriculture and Climate Change Conference, Budapest, Hungary	Geetika Sonkar	24-26 Mar
12.	International Conference on Air Pollution and Monitoring (ICAM-2019), Kottayam, Kerala	Nandita Singh Alaa Mhawish Dr. T. Banerjee	8-11 Mar
13.	International short course on "Causal Modelling" jointly organized by CCDC-PHFI-HSPH at Public Health Foundation of India, Gurugram, Haryana	Nidhi Singh Pragya Mehrishi Saumya Singh Alaa Mhawish	6-10 May
14.	International Conference on Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighborhood (CCIVA-2019), Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology-Kharagpur (IIT-KGP), West Bengal	Dr. Soma Dutta Dr. Sangita Dey Dr. Ajay Singh Dr. Arnab Kundu Geetika Sonkar Nidhi Singh Shruti Verma Saumya Singh Chandra Kant Singh Pawan K. Chaubey Rohit K. Jaiswal Jiteshwar Dadich Himangi Singh Ashish K. Khanna R. K. Mall R. Bhatla T. Banerjee	26 Feb-02 Mar

Sl. No.	Events	Attendees	Duration
2018			
1.	The World Urban Database and Access Port Tools (WUDAPT) workshop at the Chinese University of Hong Kong, Hong Kong	R. K. Mall	8-10 Dec
2.	Second Training Workshop on "Regional Climate Modelling for Southeast Asia" by ICTP-Italy, VNU University of Science, Hanoi, Vietnam	Soumik Ghosh	22-26 Oct
3.	Asian Conferences of "Remote Sensing" ACRS-2018, Kuala Lumpur, Malaysia	Prashant K. Srivastava Prachi Singh Varsha Pandey	15-19 Oct
4.	ICACGP-IGAC Science conference 2018, Takamatsu, Japan	Manish Kumar	22-29 Sep
5.	International Conferences on "Subseasonal to Decadal Prediction (S2D)", NCAR, Boulder, U.S.A.	Soumik Ghosh	17-21 Sep
6.	10th International Aerosol Conference, St. Louis, Missouri, U.S.A.	Nandita Singh	2-7 Sep
7.	10th International Conference on "Urban Climate/ 14th Symposium on the Urban Environment", New York, U.S.A.	R. K. Mall	6-10 Aug
8.	9th ICTP Workshop on "the Theory and Use of Regional Climate Models", Trieste, Italy	Soumik Ghosh	28 May-8 Jun
9.	ISPRS TC III Mid-term Symposium "Developments, Technologies and Applications in Remote Sensing", Beijing, China	Varsha Pandey	7-10 May
10.	10th International Conference on "Urban Climate/ 14th Symposium on the Urban Environment", New York, U.S.A.	R. K. Mall	6-10 Aug
11.	10th International Conference on Climate Change: Impacts Responses, University of California, Berkeley, U.S.A.	Nandita Singh	20-21 Apr
12.	Applications of Atmospheric Modelling; Air pollution Impact research in South Asia, Kathmandu, Nepal	Manish Kumar	17-19 Apr
13.	Borlaug Global Rust Initiative (BGRI), Technical Workshop, Marrakech, Morocco	Prof. V. K. Mishra	14-17 Apr
14.	Short course on Air pollution, health and climate: Methods and Modelling at PHFI, Gurgaon, Haryana	Nidhi Singh	15-19 Jan
15.	International Conference on Atmospheric Composition and Climate Change in Asia, Bangi, Malaysia	Manish Kumar	27-28 Mar
2017			
1.	American Geophysical Union (AGU) Fall Meeting-2017, New Orleans, Louisiana, U.S.A.	Abhay K. Singh	11-15 Dec
2.	INTROMET-2017, International Tropical Meteorology Symposium on Advancements in Space-based Earth Observations and Services for Weather and Climate, SAC, Ahmedabad, Gujarat	Geetika Sonkar Diva Bhatt Nidhi Singh Shruti Verma Alaa Mhawish T. Banerjee Prashant K. Srivastava R. K. Mall	7-10 Nov
3.	International 14th Annual Meeting of the Asia Oceania Geosciences Society (AOGS), Singapore	Geetika Sonkar	6-11 Aug
4.	Asian Aerosol Conference, South Korea	Manish Kumar	3-6 Jul
5.	10th World Congress on Water Resources Environment, EWRA, Athence, Greece	Prashant K. Srivastava	7 Jul
6.	5th Biological Control Symposium at FCAV/UNESP, Ribeirão Preto, São Paulo, Brazil	P. C. Abhilash	4-8 Jun
7.	Workshop on "Mathematical Models of Climate Variability, Environmental Change and Infectious Diseases", ICTP, Trieste, Italy	Nidhi Singh	8-16 May
8.	2nd Conference on "Impact of Environmental Changes on Infectious Diseases", ICTP, Trieste, Italy	Nidhi Singh	17-19 May
9.	International Conference on "Water and Wastewater Management and Modelling (ICWWMM-2018), Ranchi, Jharkhand	Varsha Pandey Swati Maurya	16-17 Jan
National: **2023**			
1.	National Conclave on Sustainability Challenges of Emerging Economies	Kumari Aditi Saumya Singh Krishna K. Pandey Abhiraj Chaturvedi Pradip Sarkar Pawan Kumar Chaubey Manisha Chaturvedi Ganesh Prasad Shaloni Dash Shiv Mangal Singh Prachi Singh	24-26 Feb

Sl. No.	Events	Attendees	Duration
2.	Second Frontiers in Geosciences Research Conference (2nd FGRC) held in Physical Research Laboratory (PRL), Ahmedabad (offline)	Pradyumna Singh	1-3 Feb
3.	Training Course on Numerical Modelling	Abhiraj Chaturvedi Pradip Sarkari Pawan Kumar Chaubey Manisha Chaturvedi Prashant Rajput Pradip Kumar Gautam Shaloni Dash	18 Jan
2022			
1.	3D Mapping and Modelling using drone and GIS Software	Prachi Singh	5-11 Dec
2.	National Symposium on Tropical Meteorology (TROPMET) -2022 held at IISER Bhopal	Manas Pant	23 Nov-2 Dec
3.	Rural Transformation for Sustainable Growth (Conference)	Abhiraj Chaturvedi Manisha Chaturvedi	11-13 Nov
4.	Indo-German Competence Center for Riverbank Filtration	Abhiraj Chaturvedi Manisha Chaturvedi	26-27 Sep
5.	High-end workshop on eco-friendly, Management of Natural Resources using Geospatial Technology, College of Horticulture and forestry, RLBCAU, Jhansi	P.K. Srivastava	18 June-1July
6.	Lecture on 'Planet Earth Needs Risk Resilient Infrastructures Under Climate Change Scenarios' by Dr. O.P. Mishra, Director, National Centre for Seismology (NCS), MoES, GOI, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Ankur Pandey Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Praveen Kumar Singh Abhiraj Chaturvedi Prachi Singh	5 June
7.	Lecture on 'Climate Research in India: Current Status and Way Forward' by Dr. Akhilesh Gupta, Scientist H, Department of Science & Technology, GOI, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Ankur Pandey Vikas Dugesar Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Manas Pant Praveen Kumar Singh Abhiraj Chaturvedi Prachi Singh	14 July
8.	Lecture on 'Career Help Desk by Expert Reviewer' by Prof. Gordana Medunic, Professor, Department of Geography, University of Zagreb, Croatia, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Ankur Pandey Vikas Dugesar Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Praveen Kumar Singh Abhiraj Chaturvedi Prachi Singh	21 April
9.	High end workshop on Remote Sensing and Digital Image Processing of Satellite, RLBCAU, Jhansi	P.K. Srivastava	10-23 Jan
10.	'Online Training on Data Assimilation' in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Ankur Pandey Vikas Dugesar Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Manas Pant Praveen Kumar Singh Abhiraj Chaturvedi	22-24 Mar
11.	National webinar on "Issues and Challenges of Children from Marginalized Communities during Covid-19 Pandemic in India" organized by Tata Institute of Social Sciences, Mumbai	Abhiraj Chaturvedi	21-23 Jan
2021			
1.	Workshop on 'Technical & Ethical Considerations in Scientific Writing' organized by The National Academy of Sciences, India - Varanasi Chapter & Banaras Hindu University	Saumya Singh Rohit Kr. Jaiswal	22 Oct
2.	Online course on "Basics of Geographical Information System" organized by Indian Institute of Remote Sensing, Dehradun.	Manas Pant	27 Sep - 22 Oct
3.	Workshop on Space Physics organized by SRM Institute of Science and Technology, Delhi	Shivam Kumar Chaubey	8-9 Oct

Sl. No.	Events	Attendees	Duration
4.	'Training cum Hands on Practice on Basics of Climate & Climate Modelling' by Dr. Abhijeet Sarkar Scientist-F, NCMRWF, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Saumya Singh Rohit Kr. Jaiswal Pawan Kumar Chaubey Prachi Singh Manas Pant Praveen Kumar Singh Shivam Kumar Chaubey Rajeev Ranjan	1 - 2 Oct
5.	Participated in webinar: Ozone for life Organized by VBSP University	Shivam Kumar Chaubey	16 Sep
6.	One-week online workshop on "QGIS, Image Processing and species distribution modelling" organized by IESD, BHU, Varanasi	Prachi Singh	30 Aug - 04 Sep
7.	Online Lecture on 'Data Assimilation Techniques' by Prof. V.K. Gaur, Honorary Scientist, CSIR-CMMACS, Bangalore in the DST-MCECCR Lecture Series (DMLS).	Manish K. Pandey Nidhi Singh Prashant Rajput Saumya Singh Rohit Kr. Jaiswal Pawan Kumar Chaubey Prachi Singh Pranjali Singh Harshita R. Ahirwar Manas Pant Praveen Kumar Singh Shivam Kumar Chaubey Rajeev Ranjan	2 Sep
8.	Online Talk on 'Climate Research 2.0: A Framework for Climate Studies for the Decade' by Prof. Dev Niyogi in the DST-MCECCR Lecture Series (DMLS).	Manish K. Pandey Nidhi Singh Aman Arora Prashant Rajput Saumya Singh Rohit Kr. Jaiswal Pawan Kumar Chaubey Prachi Singh Manas Pant Pradyumna Singh Pranjali Singh Harshita R. Ahirwar Praveen Kumar Singh Shivam Kumar Chaubey Rajeev Ranjan	10 Aug
9.	Online Workshop on "Geospatial Technology for Hydrological Modelling", organized by IIRS, Dehradun	Aman Arora Pawan K. Chaubey	19-28 Jul
10.	Online course on "SAR Application for flood hazard mapping and monitoring" organized by Indian Institute of Remote Sensing, Dehradun	Aman Arora	16 Jul
11	Online Workshop on "Overview of WebGIS Technology", organized by IIRS, Dehradun	Aman Arora Pawan K. Chaubey Rohit K. Jaiswal	21 Jun–2 Jul
12.	Participated and presented a paper entitled "Identifying Optimal Absorbance Spectral Bands from AVIRIS-NG data using Standard Derivative Analysis" and secured best presentation award in 6th Graduate Seminar on Natural Resource Management at IESD Banaras Hindu University, Varanasi, India	Prachi Singh Ayushi Gupta Prashant K. Srivastava Akash Anand Manish K. Pandey Neeraj K. Maurya R. K. Mall	17–18 Mar
13 .	Online Workshop on "Species Distribution Modelling Using R studio software", organized by IESD-BHU & DST-MCECCR, IESD BHU	Manish Pandey Prachi Singh Harshita Ahirwar	5–16 Mar
14 .	Participated and presented paper on "A Review of Price Deficit Financing Scheme in Madhya Pradesh" in the International Webinar on Climate Resilient Agriculture for Food and Nutrition Security	Shubhi Patel	9-10 Jan.
2020			
1.	Web based training on "Remote sensing applications to Agriculture" 9-11 Dec, 2020.Ogranized by under TREES and initiative of SAC, ISRO, Ahmedabad.	Pawan K. Chaubey Rohit K. Jaiswal	9-11 Dec.
2.	Web based training on "Satellite based Flood Assessment and Modelling 3-5, Nov, 2020", Organized by under TREES and initiative of SAC, ISRO, Ahmedabad.	Pawan K. Chaubey Prasoon Tiwari	3-5 Nov
3.	Weekly Webinar/Workshop on Atmospheric Processes and applications of computational mathematics (W3APACM-2020) Jointly organized by Department of Applied Mathematics, Gautam Buddha University, Gr. Noida and Indian Meteorological Society, Noida Chapter	Prof. R. Bhatla	20 June
4.	Training Programme on HPC, Big Data and AI Architectures, Programming Models and Languages, Algorithms and Applications, Big Data, AI and Deep Learning in SERC, IISc, Bengaluru	Sandeep Kr. Singh Ashish Kr. Khanna	20-24 Jan

Sl. No.	Events	Attendees	Duration
5.	Short term training course on Remote Sensing of Extreme Hydrological Events under TREES and initiative of SAC, ISRO, Ahmedabad	Rohit K. Jaiswal Pawan K. Chaubey	06-10 Jan
6.	5th Uttar Pradesh Agricultural Science Congress at the Institute of Agricultural Sciences, BHU	Shubhi Patel	22-24 Feb
7.	National Seminar on "Agrometeorological Interventions For Enhancing Farmers' Income, Kerela Agricultural University, Thrissur	Geetika Sonkar Rohit K. Jaiswal Shubhi Patel Parvin K. Mahto	20-22 Jan.
2019			
1.	79th Annual Conference of Indian Society of Agricultural Economics, organized by Indira Gandhi Krishi VishwaVidyalaya, Raipur	Shubhi Patel	21-23 Nov
2.	National Workshop on "Urban Climate Network" held at Interdisciplinary Centre for Water Research, Indian Institute of Science, Bengaluru	R. K. Mall	2-3 Aug
3.	Workshop on Introduction to Numerical Weather Prediction organized by Indian Institute of Remote Sensing and Indian Space Research Organization, Dehradun, Uttarakhand	Sandeep k. Singh	18-22 Nov
4.	3rd Winter Workshop on Developments in Climate Change and Sustainable Development organized by Centre for Climate Change and Sustainable Studies, Tata Institute of Social Sciences, Mumbai	Saumya Singh Pragya Mehrishi	11-23 Nov
5.	National Consultative Workshop on University Network for DRR held at National Institute of Disaster Management, New Delhi	R. K. Mall	5-6 April
2018			
1.	National workshop on "Urban climate resilience: the context of river basins: Urban-Peri-urban-Ecosystems, Inclusive Governance and Partnerships", Patna, Bihar	R. K. Mall	27-28 Nov
2.	Science and Training Workshop on "Climate Change over high mountains of South Asia" at Indian Institute of Tropical Meteorology (IITM), Pune, Maharashtra	Rohit K. Jaiswal Shyno S. John Shruti Verma	8-12 Oct
3.	Training program on "SAR data processing and analysis for land applications with special emphasis on L S bands", SAC, Bhopal	Prachi Singh	24-28 Sep
4.	Training on "Geospatial Technologies in Climate Studies" at National Remote Sensing Centre, ISRO, Balanagar, Hyderabad	Pragya Mehrishi Pawan K. Chaubey Rohit K. Jaiswal	29-31 May
5.	Training on "Integration of Monthly and Seasonal ERFS forecast products with crop models for developing Climate Risk Management tools in Agriculture" at IIT-Bhubaneswar, Bhubaneswar, Odisha	Geetika Sonkar Kismat Kshatriya	3-8 Mar
6.	GIAN course on 'Weather Radar and Hydrology at Indian Institute of Technology, (IIT) Madras, Chennai	Rajani K. Pradhan	5-17 Mar
7.	GIAN Education Program on Remote Sensing of Soil Moisture and its Application in Geophysical Applications, Department of Civil Engineering, Indian Institute of Technology-Delhi, Delhi	Swati Suman	12-16 Feb
8.	Short course on Air pollution, health and climate: Methods and Modelling at PHFI, Gurgaon, Haryana	Nidhi Singh	15-19 Jan
9.	TROPMET-2018, National Symposium On "Understanding Weather and Climate Variability: Research for Society", BHU, Varanasi, Uttar Pradesh	A. K. Singh Geetika Sonkar Nidhi Singh Pawan K. Chaubey Shruti Verma Jiteshwar Dadich Saumya Singh Manas Pant Alaa Mhawish	27 Oct
10.	Recent Developments in Cosmology, Department of Physics, BHU, Varanasi	A. K. Singh	6-8 April
11.	National Conference on Recent Trends in Space Science and Nano Materials, APS University, Rewa	A. K. Singh	26-27 Mar
2017			
1.	National Seminar AGMET-2017 on "Agro-meteorology for Sustainable Development with special emphasis on Agro-meteorological Practices for Climate Resilient Farming and Food Security", CCS Agricultural University, Hisar, Haryana	Geetika Sonkar Diva Bhatt Nidhi Singh	12-14 Oct
2.	National workshop entitled "Urban Climate: Science, Impacts and Adaptation organized by IIT Bhubaneswar, Orrisa	R. Bhatla R. K. Mall	21-22 Sep
3.	Author workshop conducted by Elsevier in association with NIT-Rourkela, Rourkela, Orissa	Utkarsh Verma	23 Aug
4.	NASA-ARSET training on "Satellite Remote Sensing of Air Quality Data, Tools and Applications" organized by IITM, Pune, Maharashtra	Nandita Singh	23-26 May
5.	Regional workshop on "Piloting Climate Outlook Forums at State Level-Eastern Uttar Pradesh, India" at DST- Mahamana Centre of Excellence in Climate Change Research, BHU, Varanasi, Uttar Pradesh	Dr. Sangita Dey Geetika Sonkar Diva Bhatt Soumik Ghosh Shruti Verma Barunava Mandal	18-19 May
6.	Brainstorming meeting on "Climate Change and Way Forward", BHU, Varanasi	A. K. Singh	23 Feb

ANNEXURE II
e. Awards/Achievements/Recognitions:

Sl. No.	Name	Details	Year
1.	Prof. R. K. Mall	Awarded as a Fellow of the prestigious National Academy of Sciences, India	2023
2.	Saumya Singh	Selected for UNITAR Hiroshima Women's Leadership in Tsunami-based Disaster Risk Reduction Training Programme for World Tsunami Awareness Day 2022 held in Apia, Samoa during 7th to 11th March 2023 organized by United Nations Institute of Training and Research supported by Ministry of Foreign Affairs in Japan.	2023
3.	Prachi Singh	CSIR International Travel Grant	2023
4.	Pawan Kumar Chaubey	CSIR International Travel Grant	2023
5.	Prachi Singh	Student Volunteer Award for AOGS 2023, 20th Annual Meeting Singapore by AOGS, 4th August.	2023
6.	Pawan Kumar Chaubey	Student Volunteer Award for AOGS 2023, 20th Annual Meeting Singapore by AOGS, 4th August.	2023
7.	Prachi Singh	Best Presentation award at 3rd International Workshop on BIODIVERSITY AND CLIMATE CHANGE, organized by CORAL, IIT Kharagpur 19th February	2023
8.	Pradyumna Singh	Presented a Paper and got early career Registration Fee support award, VIth Xiamen Symposium on Marine Environmental Sciences (XMAS-VI) held in Xiamen, China (online), 12th January.	2023
9.	Ayushi Gupta	Women in QGIS Grants for practitioners and academics, April 2023 organized by ESRI.	2023
10.	Ayushi Gupta	Best Presentation in Technical Session "Geomatics and Data Analytics" in the 3rd International Workshop on Biodiversity and Climate Change Sustainable Development Perspectives (IIT-Kharagpur), February 2023.	2023
11.	Pawan Kumar Chaubey	DST-SERB Travel Support award for attending AGU Fall meeting 2022 organized by American Geophysical Union, USA 16th December.	2022
12.	Prachi Singh	Austin Endowment Student Travel Support award for attending AGU Fall meeting 2022 organized by American Geophysical Union, USA 16th December.	2022
13.	Prachi Singh	Awarded Early career Scientist's Travel support to attend EGU General Assembly, Vienna, Austria organized by AGU, 27th May	2022
14.	Ayushi Gupta	Berkner Travel Grant for American Geophysical Union (AGU) – December 2022 for attending AGU Fall Meeting- 2022.	2022
15.	Ayushi Gupta	Science and Engineering Research Board (SERB)- International Travel Support (ITS) Grant for attending European Geosciences Union Conference May 2022.	2022
16.	Ayushi Gupta	Department of Biotechnology (DBT) - Conference, Travel, Exhibition, and Popular Lectures (CTEP)- for attending European Geosciences Union Conference.	2022
17.	Saumya Singh	Best Presentation Award in National Conclave on Sustainability Challenges of Emerging Economies organized by IESD BHU	2023
18.	Manas Pant	Poster Presentation, National Symposium on Tropical Meteorology (TROPMET) - 2022 held at IISER Bhopal, 2nd December	2022
19.	Prof. A. D. Singh	National Geoscience award-2019, Ministry of Mines Governments of India, Received by 12 July	2022
20.	Prof. R.K. Mall	Co-Convener of the EGU-2019, Session: Impact of Climate Change on Agriculture (CL3.2.5), 23-27 May, Vienna, Austria	2022
21.	Dr. P. K. Srivastava	Convener of the EGU-2019, Session: Impact of Climate Change on Agriculture (CL3.2.5), 23-27 May, Vienna, Austria	2022
22.	Dr. P. K. Srivastava	Resource Person -Faculty Induction Programme - VIII through online mode organized by HRDC-JNU: 7 February	2022
23.	Dr. P. K. Srivastava	Resource person in Winter School in Geospatial Science and Technology (Level 1) at SGVU on 18th January	2022
24.	Prof. R. Bhatla	Resource person in refresher course on "The climatic extremes changes over Indo-Gangetic Plains: Observations and Model Simulations" in Refresher Course on "Climate Change" held K. Banerjee Centre of Atmospheric and Ocean Studies, University of Allahabad at in collaboration with UGC-HRDC, University of on 18 January	2022
25.	Prof. R. Bhatla	Invited talk in the International Symposium on Tropical Meteorology "Changing Climate: Consequences and Challenges (INTROMET-C4)", Jointly Organized by Indian Meteorological Society - Cochin Chapter & Cochin University of Science and Technology (CUSAT), Cochin, Kerala State, India, November 23-26	2021
26.	Prof. R. Bhatla Prof. R.K. Mall	Invited talk in the 27th International Conference of International Academy of Physical Sciences (CONIAPS-XXVII) on "Recent Advances in Earth Sciences" Organized by Institute of Earth and Environmental Sciences Dr. Rammanohar Lohia Avadh University, Ayodhya in association with International Academy of Physical Sciences, Prayagraj (UP), October 26-28	2021
27.	R. K. Mall	Invited talk in NIICE International Studies Convention on Reimagining the world: Reflections on the future of world order organized by Nepal Institute for International Cooperation and Engagement, Kathmandu, Nepal 27-29 Aug	2021.
28.	Dr. P. K. Srivastava	Organizing Secretary of One-week online workshop on QGIS, Image Processing and species distribution modelling at IESD, BHU during 30 Aug 4 Sep	2021
29.	Dr. P. K. Srivastava	Resource person in the Session-AICTE Training and Learning (ATAL) Academy sponsored 5-day online Faculty Development Program (FDP) on GIS and Remote Sensing and Applications, June 07-11, 2021	2021
30.	Dr. P. K. Srivastava	Organizing Secretary of One-week online workshop on QGIS, Image Processing and species distribution modelling, at IESD BHU 15 -16 March	2021

Sl. No.	Name	Details	Year
31.	Prof. R.K. Mall	Social Impact Award for Climate Service to Society by District Administration & Subhe-Banaras Society-Varanasi	2021
32.	Nidhi Singh	Registration waiver in 33rd annual conference of the international society of environmental epidemiology, Aug 2021.	2021
33.	Nidhi Singh	Awarded Green Talents an international forum for high potentials in sustainable development.	2020
34.	Nidhi Singh	Travel award in 32nd annual conference of the international society of environmental epidemiology, July 2020.	2020
35.	Shubhi Patel	Best poster award in the 5th Uttar Pradesh Agricultural Science Congress, held at the Institute of Agricultural Sciences, BHU, Feb 22-24 2020	2020
36.	Dr. Geetika Sonkar	Received the Student Travel Fellowship to attend Ocean Sciences Meeting 2020-American Geophysical Union (AGU) 16-21 February in San Diego, CA, U.S.A.	2019
37.	Dr. Geetika Sonkar	Received the Lloyd V. Berkner Travel Fellowship to attend American Geophysical Union (AGU) Fall Meeting, 9-13 December in San Francisco, U.S.A.	2019
38.	Nandita Singh	Received Student Travel Grant to attend American Geophysical Union (AGU) fall meeting, 9-13 December in San Francisco, U.S.A.	2019
39.	Subhi Patel	Best PhD paper award in 79th Annual Conference of Indian Society of Agricultural Economics, organized by Indira Gandhi Krishi Vishwa Vidyalaya, Raipur	2019
40.	Soumik Ghosh	Fulbright-Kalam Climate Fellowship for Doctoral Research, Scripps Institution of Oceanography, University of California–San Diego La Jolla, U.S.A.	2019
41.	Prof. R. K. Mall	Member, State Board for Wildlife, Lucknow, Govt. of Uttar Pradesh	2019
42.	Prof. R. K. Mall	Convener of the EGU-2019, Session: Impact of Climate Change on Agriculture (CL4.27/BG2.37), 7-12 April, Vienna, Austria	2019
43.	Dr. P. K. Srivastava	Co-convener of the EGU-2019, Session: Impact of Climate Change on Agriculture (CL4.27/BG2.37), 7-12 April, Vienna, Austria	2019
44.	Dr. Arnab Kundu	2nd best paper award in International Conference on "Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighborhood (CCIVA-2019)", Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology-Kharagpur (IIT-KGP), West Bengal, India [TS07: Extreme Weather Events]	2019
45.	Shruti Verma	2nd best paper award in International Conference on "Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighborhood (CCIVA-2019)", Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology-Kharagpur (IIT-KGP), West Bengal, India [TS09: Modelling (Atmosphere/Ocean/Land/Bio-Chemical)]	2019
46.	Dr. Geetika Sonkar	3rd best paper award in International Conference on "Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighborhood (CCIVA-2019)", Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology-Kharagpur (IIT-KGP), West Bengal, India [TS13: Health, Societal, and Economic Issues]	2019
47.	Nidhi Singh	3rd best paper award in International Conference on "Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighborhood (CCIVA-2019)", Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology-Kharagpur (IIT-KGP), West Bengal, India [TS10: Impacts on Urban Planning, Mitigation and Adaptation]	2019
48.	Pawan K. Chaubey	3rd best paper award in International Conference on "Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighborhood (CCIVA-2019)", Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology-Kharagpur (IIT-KGP), West Bengal, India [TS02: Causes and Consequences/Human Impacts on Coastal Ecosystems]	2019
49.	Prof. R. K. Mall	i) Life Member, European Geosciences Union, Munich, Germany ii) Elected Fellow, National Academy of Agricultural Sciences (NAAS)	2018
50.	Shruti Verma	i) Co-ordinator of PAMC, National Network Programme on Climate Change and Human Health (NNP-CC&HH), DST, New Delhi ii) Senior Research Fellowship (SRF), University Grants Commission (UGC),	2018
51.	Dr. Geetika Sonkar	iii) Expert Committee member for pursuing R&D on Non-polluting Firecrackers/Fireworks, CSIR, New Delhi	2018
52.	Nidhi Singh	iv) Member, Climate Change Programme, M. S. Swaminathan Research Foundation, Chennai, Tamil Nadu	2018
53.	Dr. P. C. Abhilash	i) Selected as an Expert Member of the International Resource Panel of UNEP ii) Financial assistance to attend "International Conferences on Sub-seasonal to Decadal Prediction (S2D)" at NCAR, Boulder, U.S.A. by Banaras Hindu University, Varanasi, India	2018
		i) ICAR-Lal Bahadur Shastri Outstanding Young Scientist Award	2018
54.	Soumik Ghosh	ii) Expert Member, IUCN Commission on Environmental, Economic and Social Policy (CEESP)	2018
		iii) International Travel Support (ITS) for Young Scientist" by Science Engineering Research Board (SERB), Department of Science and Technology, Govt. of India	2018
55.	Vishal Tripathi	Best Poster on "Summer monsoon rainfall distribution over the Indian homogeneous region using RegCM-4.3" in National symposium on "Understanding Weather and Climate Variability: Research for Society" at Banaras Hindu University, Varanasi, India Received Green Talent Award for Bioremediation of contaminated soils for achieving the UN-Sustainable Development Goals.	2018

Sl. No.	Name	Details	Year
56.	Prof. R. K. Mall	Life Member, American Geophysical Union, Washington, U.S.A.	2017
57.	Dr. P. K. Srivastava	Best poster award in National Conference on Emerging Scenarios of Ganga, River Development Water Resource Management, Banaras Hindu University, India	2017
58.	Nidhi Singh	Received travel grant funded by ICTP, Italy for attending International Workshop on Mathematical Models of Climate Variability, Environmental Change and Infectious Diseases and Impact of Environmental Changes on Infectious Diseases, Trieste, Italy	2017
59.	Soumik Ghosh	i) Graduate Research Assistance, Department of Geological Atmospheric Sciences, Iowa State University, U.S.A.	2017
60.	Vishal Tripathi	ii) Best Presentation (Poster) in 2nd Institute Day of Institute of Science, Banaras Hindu University, Varanasi, India	2017
61.	Ramakant Dubey	Received Green Talent Award for agricultural sustainability and restoration of degraded land in times of global warming.	2017
62.	Swati Suman	Received Water Advanced Research and Innovation (WARI) fellowship, University of Nebraska-Lincoln, U.S.A.	2017

ANNEXURE III
g. Number of MCECCR Personnel Trained

Sl. No.	Events	Attendees	Duration
2023			
1.	Lecture on "Carrying Capacity Concept In Sustainability" by Prof. R. N. Singh, Former Director (NEERI, Nagpur), FASc, FNA, Visiting Professor (Earth Science), IIT Gandhinagar, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Sangita Dey Pawan Kumar Chaubey Shiv Mangal Saumya Singh Manisha Chaturvedi Prachi Singh Pradip Sarkar Shaloni Das Pragya Mukharjee Mrinalini Srivastava Pradip Kumar	25th Aug. 2023
2.	UNITAR Hiroshima Women's Leadership in Tsunami-based Disaster Risk Reduction Training Programme for World Tsunami Awareness Day 2022 held in Apia, Samoa during 7th to 11th March 2023 organized by United Nations Institute of Training and Research supported by Ministry of Foreign Affairs in Japan.	Saumya Singh	7 -11 March 2023
3.	Training Course on Numerical Modelling, Department of Geophysics, Institute of Science, Banaras Hindu University, Varanasi, India.	Abhiraj Chaturvedi Pradip Sarkar Pawan Kumar Chaubey Manisha Chaturvedi Saumya Singh Mrinalini Srivastava Prashant Rajput Pradip Kumar Gautam Shaloni Dash Shiv Mangal Singh	18 Jan 2023
2022			
1.	Lecture on 'Setting up of Dakshin Gangotri at Antarctica: A Miracle & Climate Change' by Padma Shri Prof. Harsh Gupta O.P. Mishra, Former Secretary, Department of Ocean Science & Technology, GOI, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Ankur Pandey Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Praveen Kumar Singh Abhiraj Chaturvedi Prachi Singh Pradip Sarkar	4th Aug 2022
2.	Lecture on 'Planet Earth Needs Risk Resilient Infrastructures Under Climate Chang Scenarios' by Dr. O.P. Mishra, Director, National Centre for Seismology (NCS), MoES, GOI, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Ankur Pandey Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey	5th June 2022

Sl. No.	Events	Attendees	Duration
		Praveen Kumar Singh Abhiraj Chaturvedi Prachi Singh Pradip Sarkar	
3.	Lecture on 'Climate Research in India: Current Status and Way Forward' by Dr. Akhilesh Gupta, Scientist H, Department of Science & Technology, GOI, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Ankur Pandey Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Manas Pant Praveen Kumar Singh Abhiraj Chaturvedi Prachi Singh	14th July 2022
4.	Lecture on 'Career Help Desk by Expert Reviewer' by Prof. Gordana Medunic, Professor, Department of Geography, University of Zagreb, Croatia, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Ankur Pandey Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Praveen Kumar Singh Abhiraj Chaturvedi Prachi Singh	21st April 2022
5.	'A Six Lecture Course on Data Assimilation' by Prof. V.K. Gaur, Honorary Scientist, CSIR-CMMACS, Bangalore, Dr. Ashish Rourtray, Scientist E-NCMRWF, and Dr. Shubhadeep Haldar, Asst. Professor, Dept. of Geophysics, on 22-24 Mar,2022, in the DST-MCECCR Lecture Series (DMLS).	Dr. Prashant Rajput Prachi Singh Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Manas Pant Praveen Kumar Singh Pradip Kumar Gautam	22-24 Mar, 2022
6.	"International Webinar Series on Advances in Earth and Environmental Geosciences" organized by Dept. of Geophysics, BHU in association with Distinguished Lecture Series Programme, American Geophysical Union.	Dr. Prashant Rajput Saumya Singh Manisha Chaturvedi Rohit Kr. Jaiswal Pawan Kumar Chaubey Manas Pant Praveen Kumar Singh	10-11 Mar, 2022
2021			
1.	"International Symposium on Tropical Meteorology "Changing Climate: Consequences and Challenges (INTROMET-C4)" INTROMET 2021", CUSAT.	Saumya Singh Pawan Kumar Chaubey Prachi Singh	23rd -26th Nov, 2021
2.	Workshop on 'Technical & Ethical Considerations in Scientific Writing' organized by The National Academy of Sciences, India -Varanasi Chapter & Banaras Hindu University	Saumya Singh Rohit Kr. Jaiswal	22nd Oct 2021
3.	Online course on "Basics of Geographical Information System" organized by Indian Institute of Remote Sensing, Dehradun.	Manas Pant	27 Sept-22 Oct 2021
4.	Workshop on Space Physics organized by SRM Institute of Science and Technology, Delhi	Shivam Kumar Chaubey	8-9 Oct 2021
5.	'Training cum Hands on Practice on Basics of Climate & Climate Modelling' by Dr. Abhijeet Sarkar Scientist-F, NCMRWF, in the DST-MCECCR Lecture Series (DMLS).	Prashant Rajput Saumya Singh Rohit Kr. Jaiswal Pawan Kumar Chaubey Prachi Singh Manas Pant Praveen Kumar Singh Shivam Kumar Chaubey Rajeev Ranjan	1st - 2nd Oct, 2021
6.	Participated in webinar: Ozone for life Organized by VBSP University, Jaunpur	Shivam Kumar Chaubey	16 Sept 2021
7.	One-week online workshop on "QGIS, Image Processing and species distribution modelling" organised by IESD, BHU, Varanasi	Prachi Singh Manish K. Pandey	30th Aug-04th Sept 2021
8.	Online Lecture on 'Data Assimilation Techniques' by Prof. V.K. Gaur, Honorary Scientist, CSIR-CMMACS, Bangalore in the DST-MCECCR Lecture Series (DMLS).	Manish K. Pandey Nidhi Singh Prashant Rajput Saumya Singh Rohit Kr. Jaiswal Pawan Kumar Chaubey Prachi Singh Pranjali Singh Harshita R. Ahirwar Manas Pant Praveen Kumar Singh Shivam Kumar Chaubey Rajeev Ranjan	2nd Sept 2021

Sl. No.	Events	Attendees	Duration
9.	Online Talk on 'Climate Research 2.0: A Framework for Climate Studies for the Decade' by Prof. Dev Niyogi in the DST-MCECCR Lecture Series (DMLS).	Manish K. Pandey Nidhi Singh Aman Arora Prashant Rajput Saumya Singh Rohit Kr. Jaiswal Pawan Kumar Chaubey Prachi Singh Manas Pant Pradyumna Singh Pranjali Singh Harshita R. Ahirwar Praveen Kumar Singh Shivam Kumar Chaubey Rajeev Ranjan	10th Aug 2021
10.	Online Workshop on "Geospatial Technology for Hydrological Modelling", organized by IIRS, Dehradun	Aman Arora Pawan K. Chaubey	19-28 Jul, 2021
11.	Online course on "SAR Application for flood hazard mapping and monitoring" organized by Indian Institute of Remote Sensing, Dehradun	Aman Arora	16 July 2021
12.	Online Workshop on "Overview of WebGIS Technology", organized by IIRS, Dehradun	Aman Arora Pawan K. Chaubey Rohit K. Jaiswal	21 Jun – 2 Jul, 2021
13.	Online Workshop on "Species Distribution Modelling Using R studio software", organized by IESD-BHU & DST-MCECCR, IESD BHU	Manish Pandey Prachi Singh Harshita Ahirwar	15 – 16 Mar, 2021
2020			
1.	Web based training on "Remote sensing applications to Agriculture" 9-11 Dec, 2020.Ogranized by under TREES and initiative of SAC, ISRO, Ahmedabad.	Pawan K. Chaubey Rohit K. Jaiswal	9-11 Dec.,2020
2.	Web based training on "Satellite based Flood Assessment and Modelling 3-5, Nov, 2020", Organized by under TREES and initiative of SAC, ISRO, Ahmedabad.	Pawan K. Chaubey Prasoon Tiwari	3-5 Nov., 2020
3.	Training Programme on HPC, Big Data and AI Architectures, Programming Models and Languages, Algorithms and Applications, Big Data, AI and Deep Learning in SERC, IISc, Bengaluru	Sandeep Kr. Singh Ashish Kr. Khanna	20-24 Jan, 2020
4.	Short term training course on Remote Sensing of Extreme Hydrological Events under TREES and initiative of SAC, ISRO, Ahmedabad	Rohit K. Jaiswal Pawan K. Chaubey	06-10 Jan, 2020
2019			
1.	Workshop on Priorities for Advancing Research on Health Effects of Air Pollution in India held at AIIMS, New Delhi	Nidhi Singh	2-4 Dec
2.	International Workshop on Prediction skill of extreme Precipitation events and tropical cyclones: Present status and future Prospect (IP4) & Annual Climate Change Workshop organized by Indian Institute of Tropical Meteorology, Pune	Manas Pant	25-28 Nov
3.	Training Workshop for Scientific Staff under ICAR-HRM Programme 2019-2020 on "Advances in Simulation Modelling and Climate Change Research towards Knowledge Based Agriculture "organized by Centre for Environment Science and Climate Resilient Agriculture, ICAR-Indian Agricultural Research Institute, New Delhi	Geetika Sonkar Rohit K. Jaiswal Chandrakant Singh	13 Nov - 3 Dec
4.	Asian Air Pollution Workshop (AAPW-5) held at Department of Botany, Institute of Science, BHU, Varanasi	Nidhi Singh	5-7 Nov
5.	Invited Doctoral Student for research work at the Physico-Chemistry Laboratory of the Atmosphere, University of the Littoral Opal Coast, Dunkerque, France	Nandita Singh	15-27 Sep
6.	Leadership for Academicians Programme (LEAP) training & workshop, The Ohio State University, Columbus, U.S.A.	Prof. Ravi S. Singh Prof. Vinod K. Mishra	8-15 Sep
7.	4th Atmospheric Composition and the Asian Monsoon Workshop (ACAM 2019), University Kebangsaan Malaysia, Bangi, Selangor, Malaysia	Alaa Mhawish	26-28 June
8.	3rd ACAM training school, University Kebangsaan Malaysia, Bangi, Selangor, Malaysia	Alaa Mhawish	24-25 June
9.	IITD-ANCST International Workshop on Modelling Atmospheric - Oceanic Processes for Weather and Climate Extremes (MAPEX-2019), IIT-Delhi	Diva Bhatt Shruti Verma	28-29 Mar
10.	National Workshop on "Urban Climate Network" held at Interdisciplinary Centre for Water Research, Indian Institute of Science, Bengaluru	Prof. R. K. Mall	2-3 Aug
11.	3rd Winter Workshop on Developments in Climate Change and Sustainable Development organized by Centre for Climate Change and Sustainable Studies, Tata Institute of Social Sciences, Mumbai	Pragya Mehrishi Saumya Singh	11-23 Nov, 2019
12.	International short course on "Causal Modelling" jointly organized by CCDC-PHFI-HSPH at Public Health Foundation of India, Gurugram, Haryana	Nidhi Singh Pragya Mehrishi Saumya Singh Alaa Mhawish	06-10 May, 2019
13.	Workshop on Introduction to Numerical Weather Prediction organized by Indian Institute of Remote Sensing and Indian Space Research Organization, Dehradun, Uttarakhand	Sandeep k. Singh	18-22 Nov, 2019
14.	National Consultative Workshop on University Network for DRR held at National Institute of Disaster Management, New Delhi	Prof. R. K. Mall	5-6, April

Sl. No.	Events	Attendees	Duration
2018			
1.	The World Urban Database and Access Port Tools (WUDAPT) workshop at the Chinese University of Hong Kong, Hong Kong	Prof. R. K. Mall	8-10 Dec
2.	Second Training Workshop on "Regional Climate Modelling for Southeast Asia" by ICTP-Italy, VNU University of Science, Hanoi, Vietnam	Soumik Ghosh	22-26 Oct
3.	9th ICTP Workshop on "the Theory and Use of Regional Climate Models", Trieste, Italy	Soumik Ghosh	28 May-08 Jun
4.	Borlaug Global Rust Initiative (BGRI), Technical Workshop, Marrakech, Morocco	Prof. V. K. Mishra	14-17 Apr
5.	National workshop on "Urban climate resilience: the context of river basins: Urban-Peri-urban-Ecosystems, Inclusive Governance and Partnerships", Patna, Bihar	Prof. R. K. Mall	27-28 Nov
6.	Science and Training Workshop on "Climate Change over high mountains of South Asia" at Indian Institute of Tropical Meteorology (IITM), Pune, Maharashtra	Rohit K. Jaiswal Shyno S. John Shruti Verma	8-12 Oct, 2018
7.	Training program on "SAR data processing and analysis for land applications with special emphasis on L S bands", SAC, Bhopal	Prachi Singh	24-28 Sep, 2018
9.	Training on "Integration of Monthly and Seasonal ERFS forecast products with crop models for developing Climate Risk Management tools in Agriculture" at IIT-Bhubaneswar, Bhubaneswar, Odisha	Geetika Sonkar Kismat Kshatriya	3-8 May, 2018
10.	GIAN course on 'Weather Radar and Hydrology at Indian Institute of Technology, (IIT) Madras, Chennai	Rajani K. Pradhan	5-17 Mar, 2018
11.	GIAN Education Program on Remote Sensing of Soil Moisture and its Application in Geophysical Applications, Department of Civil Engineering, Indian Institute of Technology-Delhi, Delhi	Swati Suman	12-16 Feb, 2018
13.	IITD-ANCST International Workshop on Modelling Atmospheric - Oceanic Processes for Weather and Climate Extremes (MAPEX-2019), IIT-Delhi	Diva Bhatt Shruti Verma	28-29 Mar
114.	National Workshop on "Urban Climate Network" held at Interdisciplinary Centre for Water Research, Indian Institute of Science, Bengaluru	Prof. R. K. Mall	2-3 Aug
15.	3rd Winter Workshop on Developments in Climate Change and Sustainable Development organized by Centre for Climate Change and Sustainable Studies, Tata Institute of Social Sciences, Mumbai	Pragya Mehrishi Saumya Singh	11-23 Nov, 2019
16.	International short course on "Causal Modelling" jointly organized by CCDC-PHFI-HSPH at Public Health Foundation of India, Gurugram, Haryana	Nidhi Singh Pragya Mehrishi Saumya Singh Alaa Mhawish	06-10 May, 2019
17.	Short course on Air pollution, health and climate: Methods and Modelling at PHFI, Gurgaon, Haryana	Nidhi Singh	15-19 Jan, 2018
2017			
1.	National workshop entitled "Urban Climate: Science, Impacts and Adaptation organized by IIT Bhubaneswar, Orrisa	Prof. R. K. Mall Prof. R. Bhatla	21-22 Sept
2.	Author workshop conducted by Elsevier in association with NIT-Rourkela, Rourkela, Orissa	Utkarsh Verma	23 Aug
3.	NASA-ARSET training on "Satellite Remote Sensing of Air Quality Data, Tools and Applications" organized by IITM, Pune, Maharashtra	Nandita Singh	23-26 May
4.	Regional workshop on "Piloting Climate Outlook Forums at State Level-Eastern Uttar Pradesh, India" at DST- Mahamana Centre of Excellence in Climate Change Research, BHU, Varanasi, Uttar Pradesh	Dr. Sangita Dey Geetika Sonkar Diva Bhatt Soumik Ghosh Shruti Verma Barunava Mandal	18-19 May
5.	Workshop on "Mathematical Models of Climate Variability, Environmental Change and Infectious Diseases", ICTP, Trieste, Italy	Nidhi Singh	8-16 May

ANNEXURE IV

g. Post Graduate students completed their dissertation/thesis/project:

Sl. No.	Name of Candidate	Name of the Supervisor	Course	Subject	Institute/ University	Year
1	Mrinalini Srivastava	Prof. R.K. Mall	M.Phil	ESD	IESD, BHU	2023
2	Priyadarshan Snandilya	Prof. R.K. Mall	M.Sc.	ESD (Earth & Atmos. Sci.)	IESD, BHU	2023
3	Sadhana Kumari	Prof. R.K. Mall	M.Sc.	ESD (Earth & Atmos. Sci.)	IESD, BHU	2023
4	Pragya Mukherjee	Prof. R.K. Mall	M.Phil	ESD	IESD, BHU	2023
5.	Pasupati Nath Singh	Dr. Prashant Srivastava	M.Phil	ESD	IESD, BHU	2023
6.	Sudha Suman	Dr. Prashant Srivastava	M.Phil	ESD	IESD, BHU	2023
7.	Jitendra Kaushadhan	Dr. Prashant Srivastava	M.Sc.	Env. Sci.	Central University of Haryana	2023
8.	Varsha Mishra	Dr. P. C. Abhilash	M.Phil	ESD	IESD, BHU	2023

Sl. No.	Name of Candidate	Name of the Supervisor	Course	Subject	Institute/ University	Year
9.	Anadhiya Khoshik	Dr. P. C. Abhilash	MSc.	ESD (Ecological Science)	IESD, BHU	2023
10.	Dasari giridhar	Dr. P. C. Abhilash	MSc.	ESD (Env. Sc.)	IESD, BHU	2023
11.	Anmol Kumar	Dr. P. C. Abhilash	MSc.	ESD (Ecological Science)	IESD, BHU	2023
12.	Reshabh tirkey	Dr. P. C. Abhilash	MSc.	ESD (Env. Sc.)	IESD, BHU	2023
13.	Shyamli Gupta	Dr. P. C. Abhilash	MSc.	ESD (Ecological Science)	IESD, BHU	2023
14.	Sadhana Chaurasia	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	Institute of Science, BHU	2023
15.	Akansha Pandey	Dr. Sunita Verma	M.Phil	ESD	IESD, BHU	2023
16.	Neelam Chaudhary	Dr. Sunita Verma	M.Phil	ESD	IESD, BHU	2023
17.	Sidhanth Gupta	Dr. Sunita Verma	M.Sc.	ESD (Earth & Atmos. Sci.)	IESD, BHU	2023
18.	Harsh Verma	Dr. Sunita Verma	M.Sc.	ESD (Earth & Atmos. Sci.)	IESD, BHU	2023
19.	Surya Bhanu Singh	Dr. Sunita Verma	M.Sc.	ESD (Earth & Atmos. Sci.)	IESD, BHU	2023
20.	Deepak Kumar Kannauhjia	Dr. Sunita Verma	M.Sc. (Tech.)	Env. Sci. Tech.	IESD, BHU	2023
21.	Ms. Harshita Singh	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	Institute of Science, BHU	2023
22.	Mr. Deepak Kumar Raj	Prof. R. Bhatla	M.Sc.	Env. Sc., Botany	Institute of Science, BHU	2023
23.	Ramanand Anand	Prof. R. Bhatla	M.Sc.	Env. Sc., Botany	Institute of Science, BHU	2023
24.	Pooja Kumari Kannoujaya	Prof. R. Bhatla	M.Sc.	Env. Sc., Botany	Institute of Science, BHU	2023
25.	Ms. Priyanka	Prof. R. Bhatla	M.Sc.	Env. Sc., Botany	Institute of Science, BHU	2023
26.	Himanshu Shekhar	Prof. R.K. Mall	M.Sc.	Environmental Science	ISc., BHU	2022
27.	Sampoornanand Kesari	Prof. R.K. Mall	M.Sc.	Environmental Science	ISc., BHU	2022
28.	Amit Maurya	Prof. R.K. Mall	M.Sc.	Env. Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
29.	Ankit Singh Dinesh	Prof. R. Bhatla	M.Sc.	Env. Sci. (Env. Tech.)	IESD, BHU	2022
30.	Rahul Jaiswal	Dr. Sunita Verma	M.Sc.	Env. Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
31.	Shubha Shivani	Dr. Sunita Verma	M.Sc.	Env. Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
32.	Shruti	Dr. T. Banerjee	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
33.	Ritik	Dr. T. Banerjee	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
34.	Prerna	Dr. T. Banerjee	M.Sc.	Env. Sc.	I.Sc., BHU	2022
35.	Pawan Kumar	Prof. R. Bhatla	M.Sc.	Env. Sci. (Env. Tech.)	IESD, BHU	2022
36.	Nitish Paswan	Prof. R. Bhatla	M.Sc.	Env. Sci. (Env. Tech.)	IESD, BHU	2022
37.	Riya Singh	Prof. R. Bhatla	M.Sc.	Env. Sci. (Env. Tech.)	IESD, BHU	2022
38.	Arun dev Singh	Dr. Prashant Srivastava	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
39.	Manush Maurya	Dr. Prashant Srivastava	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
40.	Priyansh Yadav	Dr. Prashant Srivastava	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
41.	Aditi Jaiswal	Dr. Prashant Srivastava	M.Sc.	Env. Sci. (Env. Tech.)	IESD, BHU	2022
42.	Shreya Tripathi	Dr. Prashant Srivastava	M.Sc.	Env. Sci. (Env. Tech.)	IESD, BHU	2022
43.	Anamitra Banerjee	Prof. R. Bhatla	M.Sc.	Geophysics	I.Sc., BHU	2022
44.	Mamta Sharma	Dr. P. C. Abhilash	M.Sc.	Env.Sc. (Ecological Sci.)	IESD, BHU	2022
45.	Mahesh Chalimalla	Dr. P. C. Abhilash	M.Sc.	Env. Sci. (Env. Tech.)	IESD, BHU	2022
46.	Ayushi Pandey	Dr. P. C. Abhilash	M.Sc.	Env. Sci. (Env. Tech.)	IESD, BHU	2022
47.	Athira Sundaran	Dr. P. C. Abhilash	M.Sc.	Env. Sc.	IESD, BHU	2022
48.	Vishnu Nagyan	Prof. R.K. Mall	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2022
49.	Satyajit Nayak	Prof. R.K. Mall	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2021
50.	Praveen Rawat	Prof. R.K. Mall	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2021
51.	Rishabh	Dr. P. K. Srivastava	M.Tech.	Geoinformatics	UPRSAC, Lucknow	2021
52.	Sujatra Bhattacharya	Dr. P. K. Srivastava	M.Sc. (Tech.)	Geophysics	BHU	2021
53.	Ishan Dev	Dr. P. K. Srivastava	M.Tech.	Ag. Eng.	NIT, TRICHI	2021
54.	Bhavana Singh	Dr. P. K. Srivastava	M.Tech.	Soil and water conversation Engg.	IAS, BHU	2021
55.	Gopal	Dr. P. K. Srivastava	M.Tech.	Soil and water conversation Engg.	IAS, BHU	2021
56.	Krishna	Dr. P. K. Srivastava	M.Tech.	Soil and water conversation Engg.	IAS, BHU	2021
57.	Anam Naheed	Dr. T. Banerjee	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2021
58.	Tsering Lamo	Dr. T. Banerjee	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2021
59.	Shivangi Singh	Dr. P. K. Srivastava	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2021
60.	Gokul Gopal Iyer	Dr. P. K. Srivastava	M.Sc.	Env.Sc. (Earth & Atmos. Sci.)	IESD, BHU	2021
61.	Shubhra Pandey	Dr. Sunita Verma	M.Sc.	ESD	IESD, BHU	2021
62.	Shivam Agrahari	Dr. Sunita Verma	M.Sc.	ESD	IESD, BHU	2021
63.	Asha Yadav	Dr. Sunita Verma	M.Sc.	Env. Sc. (Env. Tech.)	IESD, BHU	2021
64.	Dirgha Parashar	Dr. Sunita Verma	M.Sc.	ESD	IESD, BHU	2021
65.	Kiran Vishwakarma	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2020
66.	Praveen Kumar Singh	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2020
67.	Ankit Ranjan	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2020

Sl. No.	Name of Candidate	Name of the Supervisor	Course	Subject	Institute/University	Year
68.	Neeraj Maurya	Dr. P. K. Srivastava	M.Sc.	Earth & Atmos. Sci.	IESD, BHU	2020
69.	Ek Perna Debey	Dr. P. K. Srivastava	M.Sc.	Earth & Atmos. Sci.	IESD, BHU	2020
70.	Harshita Ashthana	Dr. P. K. Srivastava	M.Sc.	Earth & Atmos. Sci.	IESD, BHU	2020
71.	Abhishek Agrawal	Dr. P. K. Srivastava	M.Tech.	Soil and water conversation Engg.	IAS, BHU	2020
72.	Anamika Gautam	Dr. Sunita Verma	M.Sc.	Env. Sci.	ISc, BHU	2020
73.	Himanshu Yadav	Dr. Sunita Verma	M.Sc.	Env. Sc.	IESD, BHU	2020
74.	Vandana Anand	Dr. Sunita Verma	M.Sc.	Env. Sc.	P.G. College, Ghazipur	2020
75.	Harshita Rani Ahirwar	Dr. P. K. Srivastava	M. Tech.	Soil and water conversation Engg.	IAS, BHU	2020
76.	Ruchi Kumari	Dr. P. K. Srivastava	M. Tech.	Soil and water conversation Engg.	IAS, BHU	2020
77.	Abhinav Singh	Dr. P. K. Srivastava	M. Tech.	Soil and water conversation Engg.	IAS, BHU	2020
78.	Rohit Ranjan	Dr. T. Banerjee	M.Sc. (Tech.)	Env Sci. Tech.	IESD, BHU	2019
79.	Deepika Pandey	Dr. T. Banerjee	M.Phil.	ESD	IESD, BHU	2019
80.	Krishna Pandey	Dr. P.C. Abhilash	M.Phil.	ESD	IESD, BHU	2019
81.	Akash Anand	Dr. P. K. Srivastava	M.Tech.	Geo-Informatics	Central University of Jharkhand	2019
82.	Sowmya Nagaraj	Dr. Sunita Verma	B.Sc.	Biotechnology	PSG College T. N	2019
83.	Dheeraj Kumar	Prof. R.K. Mall	B.Tech	Civil Engg.	Pantnagar	2019
84.	Isha Smriti Thakur	Prof. R.K. Mall	B.Sc.	Geography	University of Delhi	2019
85.	Deepak Gupta	Dr. Sunita Verma	M.Sc.	Env. Sci.	ISc, BHU	2019
86.	Namrata Vishwakarma	Dr. Sunita Verma	M.Sc.	Env. Sc. (Env. Tech.)	IESD, BHU	2019
87.	Pratyush Saini	Prof. R.K. Mall	M.Sc. (Tech.)	Env Sci. Tech.	IESD, BHU	2018
88.	Dharmendra	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2018
89.	Sahil Sharma	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2018
90.	Chetan Singh	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2018
91.	Kaushik Gotam	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2018
92.	Rajhans Sonkar	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2018
93.	Nishant Pandey	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2018
94.	Nitin Kumar	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2018
95.	Vasudha Pandey	Prof. R. Bhatla	M.Sc. (Tech.)	Geophysics	ISc, BHU	2018
96.	Avneesh Kumar Tripathi	Dr. A.K. Singh	M.Sc.	Physics	ISc, BHU	2018
97.	Manish Kumar Yadav	Prof. A.K. Singh	M.Sc.	Physics	ISc, BHU	2018
98.	Pawan Kumar	Prof. A.K. Singh	M.Sc.	Physics	ISc, BHU	2018
99.	Harsha	Prof. V.K. Mishra	M.Sc.	Agriculture	IAS, BHU	2018
100.	Priyanka Upadhayay	Prof. V.K. Mishra	M.Sc.	Agriculture	IAS, BHU	2018
101.	Stuti Krishna	Prof. V.K. Mishra	M.Sc.	Agriculture	IAS, BHU	2018
102.	Neha Singh	Prof. V.K. Mishra	M.Sc.	Agriculture	IAS, BHU	2018
103	Sadhana Yadav	Prof. V.K. Mishra	M.Sc.	Agriculture	IAS, BHU	2018
104.	Shoobhangi Tyagi	Prof. R.K. Mall	M.Phil.	ESD	IESD, BHU	2018
105.	Yogesh Kumar Vishwakarma	Prof. R.K. Mall	M.Phil.	ESD	IESD, BHU	2018
106	Rajan Chaurasia	Dr. P.C. Abhilash	M.Phil.	ESD	IESD, BHU	2018
107.	Prerita Agrawal	Dr. T. Banerjee	M.Phil.	ESD	IESD, BHU	2018
108.	Ajeet Singh	Dr. P.C. Abhilash	M.Phil.	ESD	IESD, BHU	2018
109.	Saumya Singh	Prof. R.K. Mall	M.Phil.	ESD	IESD, BHU	2018
110.	Priya Priyadarshi	Dr. P.C. Abhilash	M.Phil.	ESD	IESD, BHU	2018
111.	Ayushi	Dr. P.K. Srivastava	M.Phil.	ESD	IESD, BHU	2018
112.	Nagalapalli Satish	Prof. R.K. Mall	M.Tech.	Env. Engg.	SRM, Chennai	2018
113.	Satish Kumar Yadav	Dr. P.K. Srivastava	M.Tech.	RS & GIS	SHUATS, Allahabad	2018
114.	Ankur Singh	Dr. P.K. Srivastava	M.Sc.	RS & GIS	SHUATS, Allahabad	2018
115.	Laksitha Nama Mahesh	Prof. A.K. Singh	M.Sc.	Physics	ISc, BHU	2017
116.	Shampa Mondal	Prof. A.K. Singh	M.Sc.	Physics	ISc, BHU	2017
117.	Vivek Pandey	Prof. A.K. Singh	M.Sc.	Physics	ISc, BHU	2017

ANNEXURE V

h. List of Ph.D. Scholars (Awarded)

Sl. No.	Name of Candidate	Title	Supervisor	Co- Supervisor	Subject	Institute/ University	Awarded
1.	R. K. Srivastava	Catastrophe of climate change and urbanization in south Asia	Prof. R. K. Mall	Dr. O.P. Mishra	Physics	IESD, BHU	2017
2.	Neha Singh	Simulating the impact of climate change on wheat	Prof. Hema Singh	Dr. R. K. Mall	Botany	Department of Botany, BHU	2017
3.	Geetika Sonkar	Modelling the influence of crop production in Indo-Gangetic basin	Prof. R. K. Mall	Dr. A. K. Singh	Environmental Science	IESD, BHU	2019

Sl. No.	Name of Candidate	Title	Supervisor	Co- Supervisor	Subject	Institute/ University	Awarded
4.	Manish Kumar	Aerosol surface and columnar properties over middle Indo-Gangetic Plain: Identifying meteorological implications and particulate source apportionment	Dr. T. Banerjee	Dr. R. S. Singh	Environmental Science	IESD, BHU	2019
5.	Barunava Mandal	Numerical Simulation of Indian Summer monsoon phase using Regional Climate Model	Prof. R. Bhatla	-------	Geophysics	Department of Geophys., ISc, BHU	2019
6.	Manvendra Singh	Modelling to assess the impact of climate change on wheat production in NEPZ of India	Prof. G. C. Tripathi	Dr. R. K. Mall	Agricultural Statistics	Institute of Agricultural Sciences, BHU	2019
7.	Diva Bhatt	Impact of climate change on water resources in the Gomati River Basin	Prof. R. K. Mall	Dr. K. N. P. Raju	Environmental Science	IESD, BHU	2020
8.	Alaa Mhawish	Improved estimation of the surface $PM_{2.5}$ by fusing multiple earth-observation A-train satellite products	Dr. T. Banerjee	-------	Environmental Science	IESD, BHU	2020
9.	Nandita Singh	characterization of size segregated particulate-bound Aerosols organic and identification of sources in Varanasi over Middle Indo-Gangetic plain	Dr. T. Banerjee	-------	Environmental Science	IESD, BHU	2020
10.	Vishnu Murari	Airborne particulate emission inventorization and source apportionment through receptor modelling	Dr. T. Banerjee	Dr. A. Ohri	Environmental Science and Technology	IESD, BHU	2020
11.	Swati Maurya	Watershed characterization and discharge estimation using rainfall-runoff model for soil and water conservation	Dr. P. K. Srivastava	-------	Environmental Science	IESD, BHU	2020
12.	Nidhi Singh	Impact of climate change and variability on pediatric health	Prof. R. K. Mall	-------	Environmental Science	IESD, BHU	2020
13.	Soumik Ghosh	Climate Modelling and simulation of Indian summer monsoon dynamics	Prof. R. Bhatla	Dr. R. K. Mall	Physics	Department of Geophys., ISc, BHU	2020
14.	Swati Suman	Soil moisture estimation and downscaling using optical and Microwave datasets	Dr. P. K. Srivastava	----	Environmental Science	Environmental Science	2021
15.	Shruti Verma	Climate modelling in simulated modulated properties of Indian summer monsoon	Prof. R. Bhatla	Prof. R. K. Mall	Environmental Science	I.Sc., BHU	2022
16.	Pradeep K. Dubey	Sustainable agriculture practices for wheat and rice in eastern Uttar Pradesh India	Prof. G. S. Singh	--	Environmental Science	IESD, BHU	2022
17.	Momin Imran Ali	Study of Indian Ocean Features Related to Monsoon Using Numerical Modeling System	Prof. R. Bhatla		Geophysics	I. Sc.	2022
17.	Shubhi Patel	Impact of climate change in crop production and adaptation strategies in India	Prof. R. Singh	Prof. R. K. Mall	Agricultural Economics	IAS, BHU	2022
18.	Manas Pant	A modelling approach to weather/climate extremes: observation, simulation and projections.	Prof. R. Bhatla	-------	Physics	Department of Geophysics, ISc, BHU	2023
19.	Priyanshu Gupta	Extreme weather events and aerosol interaction: Regional Scenario over north India	Prof. Sunita Verma	Prof. R. Bhatla	Environmental Science	IESD, BHU	2023
20.	Archana Maurya	Dynamics of the Indian summer Monsoon in Changing climate	Prof. R. Bhatla	-------	Geophysics	Department of Geophys., ISc, BHU	2023

ANNEXURE VI
i. List of Ph.D. Scholars (Ongoing)

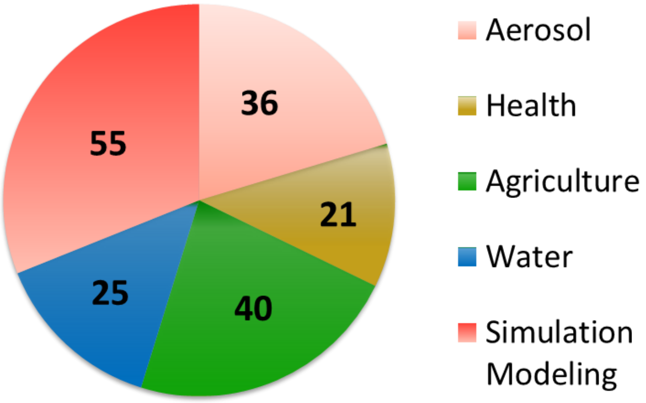
Sl. No.	Name of Candidate	Title	Supervisor	Co- Supervisor	Subject	Institute/ University	Pursuing Since
1.	Pradyumna Singh	Late glacial-Holocene palaeoceanographic studies of the eastern equatorial Indian ocean based on foraminiferal records	Prof. A. D. Singh		Petroleum Geosciences	Department of Geology, Institute of Science, BHU	2017
2.	Priyanka Singh	Sub District level Decision support system using medium range weather forecast and geospatial technology for agriculture risk management	Prof. R. K. Mall		Agrometeorology	Institute of Environment and Sustainable Development, BHU	2017
3.	Pramod Kumar Yadav	Study of ozone variability over India: Role of precursors & Emissions	Dr. Sunita Verma		Environmental Science	Institute of Environment and Sustainable Development, BHU	2018
4.	Pawan Kumar Chaubey	Changing pattern of hydro-climate extremes over India: Uncertainty due to different climate Models	Prof. R. K. Mall		Geophysics	Institute of Environment and Sustainable Development, BHU	2019
5.	Dharmendra Pandey	Retrieval of land Variable from Microwave Satellite observation	Dr. P. K. Srivastava	Dr. Anup Das	Radio Frequency & Microwave	Institute of Environment and Sustainable Development, BHU	2019
6.	Rohit Kumar Jaiswal	Impact of climate change on sugarcane over India: A multi model approach	Prof. R. K. Mall		Environmental Science	Institute of Environment and Sustainable Development, BHU	2019
7.	Saumya Singh	Impact of Climate Change on Heat Waves over India	Prof. R. K. Mall		Environmental Science & Technology	Institute of Environment and Sustainable Development, BHU	2019
8.	Ayushi Gupta	Retrieval and validation of biochemical parameter using hyperspectral remote sensing	Dr. P. K. Srivastava		Environmental Science & Technology	Institute of Environment and Sustainable Development, BHU	2019

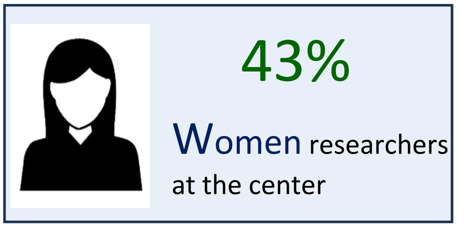
Sl. No.	Name of Candidate	Title	Supervisor	Co- Supervisor	Subject	Institute/ University	Pursuing Since
8.	Manas Pant	A modelling approach to weather/climate extremes: observation, simulation and projections.	Prof. R. Bhatla	-------	Physics	Department of Geophys., ISc, BHU	2018
9.	Priyanshu Gupta	Extreme weather events and aerosol interaction: Regional Scenario over north India	Prof. Sunita Verma	Prof. R. Bhatla	Environmental Science	IESD, BHU	2018
10.	Pramod Kumar Yadav	Study of ozone variability over India: Role of precursors & Emissions	Prof. Sunita Verma	-------	Environmental Science	IESD, BHU	2018
11.	Archana Maurya	Dynamics of the Indian summer Monsoon in Changing climate	Prof. R. Bhatla	-------	Geophysics	Department of Geophys., ISc, BHU	2018
12.	Dharmendra Pandey	Retrieval of land Variable from Microwave Satellite observation	Dr. P. K. Srivastava	Dr. Anup Das	Radio Frequency & Microwave	IESD, BHU	2019
13.	Ayushi Gupta	Retrieval and validation of biochemical parameter using hyperspectral remote sensing	Dr. P. K. Srivastava	-------	Environmental Science & Technology	IESD, BHU	2019
14.	Janhavi Singh	Study of tropospheric Trace gasses using space -born measurement: seasonal and spatial variability	Dr. Sunita Verma	-------	Environmental Science	IESD, BHU	2019
16.	Prachi Singh	Biophysical & Biochemical parameter retrieval of selected crops using hyperspectral datasets.	Dr. P. K. Srivastava	-------	Geoinformatics	IESD, BHU	2020
17.	Krishna Kumar Pandey	Microplastic in agro-ecosystems of Eastern Uttar Pradesh	Dr. P.C. Abhilash	-------	Environmental Science (Environmental Technology)	IESD, BHU	2020
18.	Abhiraj Chaturvedi	Climate change and its impact on human society: A geographical study of Bundelkhand region	Prof. R. K. Mall	-------	Geography	IESD, BHU	2020
19.	Abhishek Singh	Exploring haze aerosol climatology over south and south east Asia	Dr. T. Banerjee	-------	Environmental Science & Technology	IESD, BHU	2020
20.	Praveen Kumar Singh	Influence of Indian ocean sea surface indices on Indian summer monsoon rainfall variability and extreme events	Prof. R. K. Mall	Prof. R. Bhatla	Geophysics	Department of Geophys., ISc, BHU	2020
21.	Shweta Shukla	Evaluation of WRF/urban model over some station of E.U.P	Prof. R. Bhatla	-	Geophysics	Department of Geophys., ISc, BHU	2020
22.	Pradip Sarkar	Migration as an adaptation strategy in the context of climate change	Prof. R. K. Mall	-	Geography	IESD, BHU	2021
23.	Harshita Baranwal	To create an aerosol classification algorithm to identify aerosol subtypes and suburban sources	Dr. T. Banerjee	-------	Environmental Science	IESD, BHU	2021
24.	Ravikant	Integrating Remote Sensing GIS and Seismic microzonation for sustainable development of Bhubaneshwar Development plan area	Prof. R. K. Mall	-	Geoinformatics	IESD, BHU	2022
25.	Tanu Gangwar	Study of environmental impact assessment for major cities of Uttar Pradesh	Prof. Sunita Verma	-	Environmental Science	IESD, BHU	2022
26.	Shaloni Dash	Climate risk and vulnerability assessment: India analysis	Prof. R. K. Mall	-------	Environmental Science and Resource Management	IESD, BHU	2022
27.	Ganesh Prasad	Association between Climate Change and mustard crop from major growing states in India: A multi-model ensemble projection analysis.	Prof. R. K. Mall	Prof. R. S. Singh	Agricultural Economics	IESD, BHU	2022
28.	Manisha Chaturvedi	Machine learning based approach for Climate change Impact assessment	Prof. R. K. Mall	--------	Signal Processing	IESD, BHU	2022
29.	Shiv Mangal Singh	Uncertainties in predicting potato yield by current crop models under a wide range of climatic conditions	Prof. R. K. Mall		Horticulture	IESD, BHU	2021
30.	Aditi Kumari	Satellite based characterization of active fire and estimation of biomass burning emissions.	Dr. T. Banerjee		Environmental Science	IESD, BHU	2022
31.	Ashish Tiwari	--	Prof. R. K. Mall			IESD, BHU	2022
32.	Nivedita	Exploring Multi-dimensional indicators contributing to climate resilience of small marginal women farmers in flood affected areas of eastern UP	Prof. R. K. Mall			IESD, BHU	2023

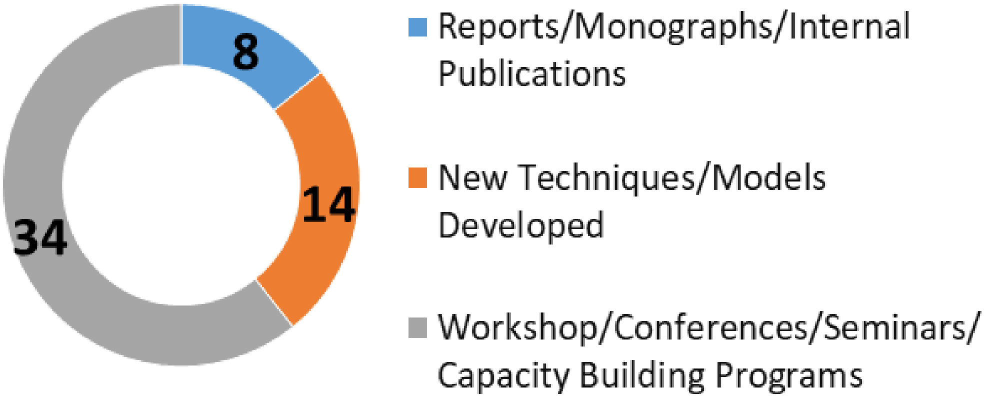
Sl. No.	Name of Candidate	Title	Supervisor	Co-Supervisor	Subject	Institute/ University	Pursuing Since
9.	Janhavi Singh	Study of tropospheric Trace gasses using space -born measurement: seasonal and spatial variability	Dr. Sunita Verma		Environmental Science	Institute of Environment and Sustainable Development, BHU	2019
10.	Saurabh Singh	Study of atmospheric characteristics during winter over India using numerical model.	Prof. R. Bhatla		Environmental Science	Department of Geophysics, Institute of Science, BHU	2019
11.	Prachi Singh	Biophysical & Biochemical parameter retrieval of selected crops using hyperspectral datasets.	Dr. P. K. Srivastava		Geoinformatics	Institute of Environment and Sustainable Development, BHU	2020
12.	Abhishek Singh	Exploring haze aerosol climatology over south and south east Asia	Dr. T. Banerjee		Environmental Science & Technology	Institute of Environment and Sustainable Development, BHU	2020
13.	Shweta Shukla	Evaluation of WRF/urban model over some station of E.U.P	Prof. R. Bhatla		Geophysics	Department of Geophys., ISc, BHU	2020
14.	Krishna Kumar Pandey	Microplastic in agro-ecosystems of Eastern Uttar Pradesh	Dr. P.C. Abhilash		Environmental Science (Environmental Technology)	Institute of Environment and Sustainable Development, BHU	2020
15.	Denesh Kumar Yadav	Role of Indian Ocean on Interannual and Intraseasonal variability of Indian Summer Monsoon using Numerical model	Prof. R. Bhatla		Geophysics	Department of Geophysics, ISc , BHU	2020
16.	Akash Vishvakarmaa	Understanding and simulating flood/drought over different regions of India using Numerical Model	Prof. R. Bhatla		Geophysics	Department of Geophysics, ISc , BHU	2020
17.	Harshita Baranwal	To create an aerosol classification algorithm to identify aerosol subtypes and suburban sources	Dr. T. Banerjee		Environmental Science	Institute of Environment and Sustainable Development, BHU	2021
18.	Pradip Sarkar	Migration as an adaptation strategy in the context of climate change	Prof. R. K. Mall		Geography	Institute of Environment and Sustainable Development, BHU	2022
19.	Ravikant	Integrating Remote Sensing GIS and Seismic microzonation for sustainable development of Bhubaneshwar Development plan area	Prof. R. K. Mall		Geoinformatics	Institute of Environment and Sustainable Development, BHU	2022
20.	Shiv Mangal Singh	Uncertainties in predicting potato yield by current crop models under a wide range of climatic conditions	Prof. R. K. Mall		Horticulture	Institute of Environment and Sustainable Development, BHU	2022
21.	Manisha Chaturvedi	Machine learning based approach for Climate change Impact assessment	Prof. R. K. Mall		Signal Processing	Institute of Environment and Sustainable Development, BHU	2022
22.	Shaloni Dash	Climate risk and vulnerability assessment: India analysis	Prof. R. K. Mall		Environmental Science	Institute of Environment and Sustainable Development, BHU	2022
23.	Aditi Kumari	Satellite based characterization of active fire and estimation of biomass burning emissions.	Dr. T. Banerjee		Environmental Science	Institute of Environment and Sustainable Development, BHU	2022
24.	Ashish Tiwari	---	Prof. R. K. Mall			Institute of Environment and Sustainable Development, BHU	2022
25.	Tanu Gangwar	Study of environmental impact assessment for major cities of Uttar Pradesh	Dr. Sunita Verma		Environmental Science	Institute of Environment and Sustainable Development, BHU	2022
26.	Ganesh	----	Prof. R. K. Mall			Institute of Environment and Sustainable Development, BHU	2022
27.	Richa Singh	Understanding the consequences of Climate Change on extinction of Himalayan Glacier and Ecological Changes	Prof. R. Bhatla		Geophysics	Department of Geophysics, ISc , BHU	2022
28.	Ankit Ranjan	Role of Ocean -atmosphere coupling on Indian monsoon dynamics	Prof. R. Bhatla		Geophysics	Department of Geophysics, ISc , BHU	2022
29.	Nivedita	----	Prof. R. K. Mall			Institute of Environment and Sustainable Development, BHU	2023
30.	Progya Mukherjee	Modelling the impact of climate change on Soil organic carbon in IGP: Developing a climate resilient adaptation strategy	Prof. R. K. Mall		Environmental Science and Sustainable Development	Institute of Environment and Sustainable Development, BHU	2023
31.	Mrinalini Srivastava	---	Prof. R. K. Mall		Environmental Science and Sustainable Development	Institute of Environment and Sustainable Development, BHU	2023
32.	Rahul Jaiswal	Prediction of changes in urban land mapping using advanced techniques	Dr. Sunita Verma		Environmental Science and Sustainable Development	Institute of Environment and Sustainable Development, BHU	2023

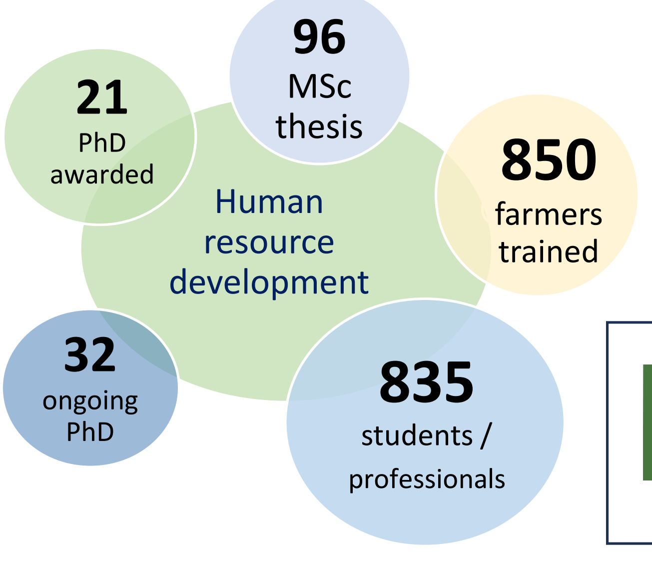
ANNEXURE VII

Total no. of publications in focus research areas









13 CLIMATE ACTION

SDG 13

An initiative to take urgent action to combat climate change and its impacts

TESTIMONIALS

My best wishes for the success of this newly formed center. Climate change is real in human induced and will adversely affect future generations. The center should help society adapt to the consequences of climate change.

Prof. Jagadish Shukla
George Mason University, VA, USA

Happy to see the Developments of Climate Change Centre in Banaras Hindu University, Varanasi. Best Wishes!

Dr. Mangala Rai
Former Secretary, Govt. of India,
Department of Agricultural Research & Education (DARE)
Director-General, Indian Council of Agricultural Research (ICAR)
Vice Chancellor, Govind Ballabh Pant University of Agriculture and Technology Pantnagar, Uttarakhand

This is the climate change center of excellence of first of its kind in an University in India. There is so much potential and expectation. I wish the center all the best!

Dr. Akhikesh Gupta
Secretary, SERB DST
Head, Climate Change Program
DST, Government of India
New Delhi

It has been a wonderful feeling interacting with the students of DST MCECCR. Delighted to learn about the climate center which is working on the upfront challenges. Our best wishes.

Dr. V M Tiwari
Former Director
CSIR-National Geophysical Research Institute

Fantastic young group of researcher with lot of excitement. Very good research work and facilities of modelling activities. Wish you all a great success.

Dr. Sunil Kumar Singh
Director
CSIR-National Institute of Oceanography
NIO, Goa

Delighted to visit and interact with the students and faculty. Some fundamental problems and research questions related with the impact of climate change on humans are being addressed by a group of dedicated students and faculties. My best wishes.

Dr. Harsh Gupta
Panikkar Professor
Secretary, Department of Ocean Development,
Former Director, CSIR-National Geophysical Research Institute

TESTIMONIALS

Highly impressed to see the labs & Institute. I wish you best future.

Prof. Rakesh Bhatnagar
Vice-Chancellor
Banaras Hindu University, Varanasi

It was an excellent experience visiting the Mahamana Center of Excellence in Climate Change Research at BHU. The center was created on international ambience with seriously working group researchers guided by a well experienced Prof R. K. Mall. Their publications are of high quality and I understand that the center is getting a supercomputer support room to excellence in research on climate change and its impact on various fields on human importance. I wish the center all the best!

Dr. Y. S. Ramakrishna
Former Director (ICAR)
Central Research Institute for Dryland Agriculture
Hyderabad, Andhra Pradesh, India

Excellent interactions, inspiring young scientists engaged in climate change research. All the best !

Dr. Ranganath Ramarao Navalgund
Former Director & Distinguished Scientist
Space Application Centre, ISRO

DST MCECCR is an outstanding research center with a heterogeneous group of researchers of different backgrounds to deal with diverse research topics and address key climate change issues that require multi-disciplinary sciences. The center has produced outstanding research in record time.

Dr. O P Mishra
Director
National Centre for Seismology (NCS) and Advisor/Head of Seismology and Geosciences (SAGE)
Ministry of Earth Sciences, Government of India

Research done in this center is high class and it is very relevant to society. I am happy to learn about the importance of work here. The recent students are here very up-to-date in their area of research. All the best !

Dr. Archana Bhattacharyya
Former Director
INSA Honorary Scientist
Indian Institute of Geomagnetism (IIG)
Mumbai

TESTIMONIALS

A most stimulating visit to this Centre of Climate Change. Wish you all a great success.

Prof.Vinod Kumar Gaur
Former Director
National Geophysical Research Institute
Honorary Emeritus Scientist
CSIR Fourth Paradigm Institute, Bangalore

My best wishes for the success of this newly formed Climate Change Centre.

Prof. Uma Charan Mohanty
School of Earth Ocean & Climate Sciences
IIT Bhubaneswar

It was a great pleasure to visit the Centre of Excellence and interacting the young and bright researchers. My best wishes !

Dr. R. N Singh
Former Director
NEERI, Nagpur

All the best for highly challenging multi-disciplinary science based solutions to build climate resilience against adverse impacts of climate change in India

Dr. K. J. Ramesh
Director General of Meteorology India Meteorological Department
Government of India
New Delhi

Well planned, balanced workshop which met objectives outstanding. My best wishes!

Dr. Ch. Srinivasa Rao
Director
ICAR- National Academy of Agricultural Research Management
Hyderabad

Wonderful work ! Great Team of scientists. I am very much impressed ! Keep it up !

Dr. Akshara Kaginalkar
Senior Director
Centre for Development of Advanced Computing (C-DAC)
Pune

TESTIMONIALS

Its indeed honor to be in BHU for attending very important brainstorming meeting on climate change. I am sure the proposed center of excellence will do excellent work. My best wishes!

Prof. S. K Dube
Former Director IIT- Kharagpur

Happy to interact with young and dynamic team of researchers. I am sure the Mahamana center for excellence will achieve new heights.

Dr. Laxman Singh Rathore
Former Director General of Meteorology
India Meteorological Department
Ministry of Earth Sciences
Government of India
IBCS, WMO, UN

It is a pleasure to be here in BHU campus on this occasion for the training on crop weather modelling. I wish all the best for the success of Centre of Excellence.

Dr. Gerrit Hoogenboom
Institute for Sustainable Food Systems
University of Florida's, USA

Enjoyed interacting with the young and highly motivated student and faculty members. The center has bright future.

Dr. P C Pandey
Adjunct Professor
Earth Sciences, IIT Gandhinagar

Excellent research ambience. Diverse minds converging at one platform in the center.

Prof. Anil Kr. Gupta
Former Director
Wadia Institute of Himalayan Geology
Dehradun, India

I am a alumnus of BHU having passed out in 1992 from IT. I have been seeing a steady, upward change in infrastructure and aminites inside campus. I hope that it will continue and I Wish all the best for this great university and its Centre of Excellences.

Dr. Sachchida Nand Tripathi
Professor and Head
Department of Civil Engineering
Department of Earth Sciences, IIT Kanpur

TESTIMONIALS

I loved being here, you are all intelligent and motivated and doing great work. Keep it up !

Campbell Watson
Research Staff Member
IBM Research
Thomas J. Watson Research Center
Yorktown Heights, NY USA

A very stimulating discussion and interaction with students and scientists. A place with great promises. My best wishes.

Prof. Dev Niyogi
Professor and William Stamps Farish Chair,
University of Texas at Austin
USA

It was nice interacting with the fantastic young group of researcher. All the best !

Dr. Kalachand Sain
Director
Wadia Institute of Himalayan Geology, Dehradun
Former Head
Seismic Group at CSIR-NGRI, Hyderabad

Thanks you very much for hospitality and useful discussion. I am looking forward to collaborating with a very good team of scientists in interdisciplinary research.

Prof. Elena Surovyatkina
Potsdam Institute for Climate Impact Research (PIK)
Potsdam, Germany

The Climate TIMELINE

1800-1960

1820

Joseph Fourier

Earth's Atmosphere acts as the way the Glass Greenhouse would

1850

Tyndall Effect

John Tyndall

Tyndall's research demonstrated that the gases (which we now refer to as greenhouse gases) played an important role in maintaining the earth's temperature.

1890

S.Arrhenius

Calculated that emissions from human industry could cause a Global Warming

1930

G.S. Callendar

Found levels of CO2 are climbing and raising global temperature

1950

Roger Revelle

Calculated that emission Demonstrated that CO2 levels had increased due to use of fossil fuels

World Meteorological Organization

1960

Charles Keeling

Measured CO2 in the earth's atmosphere and detects an annual rise. The level is 315ppm.

1961-1970s

1962

IITM established at Pune, India

1963

Calculations suggested that feedback with water vapour could make the climate acutely sensitive to changes in CO2 level.

1965

U.S National Academy of Science Conference

'The Causes of Climate Change' in Boulder, USA

1966

Cesare Emiliani

His analysis of deep sea cores shows the timing of ice ages was set by s mall orbital shifts suggesting that the climate system in sensitive to small changes

1967

International Global Atmospheric Research Program established

Manabe & Wetherald make a convincing calculations that doubling of CO2 would raise world's temperature a couple of degrees.

1969

Nimbus III satellite begins to provide comprehensive global atmospheric temperature measurements

Mikhail Budyko published a theory on the Ice-Albedo feedback: Arctic Amplification

1970

- Green Peace, Vancouver
- First Earth Day
- Creation od US National Oceanic & Atmospheric Administration
- Worry about the Global Cooling

1971-1980s

1971

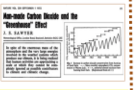
SMIC Conference *reports danger of rapid & serious global climate change caused by humans*

Friends of Earth *, London*

1972

John Swayer

accurately predicted the rate of global warming for the period between 1972 to 2000



UN Conference on the Human Environment

Stockholm, Sweden

1974

CPCB established in India

Serious droughts and other unusual weather *since 1972 increases scientific and public concern about climate change with cooling from aerosols suspected to be as likely as warming*

1975

Discovery of danger to Ozone layer

1976

CFCs & CH4 & O3 can make a serious contribution to the Greenhouse Effect.

1979

First World Climate Conference

:produces declaration & appeal to world to prevent potential man-made changes to climate

The Charney Report: by National Research Council predicts that doubling of CO2 will lead to 3˚C warming-USA.

1981-1990s

1981

- Hansen & Others show that sulphate aerosols can significantly cool climate, raising confidence in models showing future greenhouse warming
- **The Air Act, India enacted**

1982

Strong global warming since mid 1970s is reported with 1981 the warmest year on record

1983

- William Nierenberg's Report by National Academy of Science claims effect of climate change will be negligible-USA

1985

- **MoEF established in India**
- **Discovery of Ozone hole**

1987

Montreal Protocol of the Vienna Convention imposes international restrictions on emissions of ozone destroying gases.

1988

- James Hansen testifies to congress with 12 hearings in Senate and the house on climate change during this period
- **IPCC established**
- Level of CO2 350ppm

1990

First IPCC Assessment Report (FAR) *says the earth has been warming and future warming seems likely*

1991-2000s

1991

Mt. Pinatubo explodes; Hansen predicts cooling pattern

1992

RIO EARTH SUMMIT

Climate change convention, Conference in Rio de Janeiro produces UN Framework Convention on Climate Change, but US blocks calls for serious action.

1993

- Climate for Cities
- NAFTA signed into law which has a dramatic impact on global trade and emission.

1995

CoP1 United Nations Climate Change Conference, The Berlin Mandate, March 28-Apr 7, 1995

IPCC 2nd Assessment Report (SAR) *detects " signature" of human caused GHE warming declares that serious warming is likely in the coming century*

1997

CoP3, Kyoto

Inernational conference produces Kyoto Protocol, setting targets to reduce greenhouse gas emissions if enough nations sign onto a treaty.

1999

Ramanathan detects massive "brown cloud" of aerosols from South Asia

2000

1st Climate Justice Summit

2001-2020

2001

IPCC 3rd Assessment Report (TAR) *states that global warming unprecedented since end of last ice age, is 'very likely', with possible severe surprises. Effective end of debate among all but few scientists*

2002

Studies find surprisingly strong "global dimming" due to pollution has retarded arrival of green house warming but dimming is now decreasing

CoP 8, United Nations Climate Change Conference New Delhi

2004

ICAR-Network Project on Climate Change, India

2005

Level of CO2 reached to 380ppm

CoP 11, Montreal

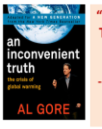
Kyoto treaty goes into effect, signed by all major industrial nations except US and Australia

First EU carbon emission trading levels

USA proclaims: "The doubt is Over, The Globe is Warming"

2006

Ministry of Earth Sciences (MoEF) *established in India*



"The Inconvenient Truth" The Crisis Of Global Warming By AL GORE

- Academy Award Winning documentary film re-energizes the Climate Movement

Clean Development Mechanism open under the Kyoto Protocol

2007

CoP 13, Bali Indonesia

Climate Justice Now!

UN Climate Change Conference 2007 Bali - Indonesia

The Nobel Peace Prize was awarded jointly to IPCC and AL Gore " for their efforts to build up and disseminate greater knowledge about man-made climate change , and to lay the foundations for measures that are needed to counteract such change"

China over takes the US as world's biggest emitter of CO2

IPCC 4th Assessment Report (FAR) *warns that serious effect of warming have become evident & costs of reducing emissions would be far less than the damage they will cause if not reduced*

2008

The Climate Change Act

UK government becomes the first to set binding targets to reduce emissions

Climate scientists (although not the public) recognize that even if all greenhouse gas emissions could be halted immediately, global warming will continue

The Stratigraphy Commission of the Geological Society of London considered a proposal to make the Anthropocene a formal unit of geological epoch divisions (Human Induced Era)

2009

CoP 15, Copenhagen

Conference fails to negotiate binding agreements; end of hopes of avoiding dangerous to future

National Green Tribunal was established in India for Environment related issues

2010

Highest ever increase in global emissions 5.9%

First Non-Governmental International Panel on Climate Change (NIPCC) report published

PM's Council on National Action Plan on Climate Change (NAPCC), India.

Evolve National Policy on Climate Change; Initiate 8 National Missions

2011

International Energy Agency report warns of 6˚C

2012

RIO +20 EARTH SUMMIT

RIO+20 the future we want

Global Temperature Continue to rise

2013

IPCC 4th Assessment Report (AR5)

states with greater certainty than ever that climate change is happening and that human activity is the principal cause

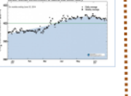
President Obama releases the Climate Action Plan including increased use of renewable energy and climate pollution restriction for power plants

MoA-National Mission for Sustainable Agriculture (NMSA), India

2014

MoEF renamed as MoEFCC, India

April 2014 is the first month in human history with average CO2 level in Earth's atmosphere at **400ppm**



2015

THE PARIS AGREEMENT

CoP 21 *represents ratifications, nearly all nations pledge to set target for their own GHG cuts and to report their progress*

2016

UNITED NATIONS PARIS CLIMATE AGREEMENT SIGNING CEREMONY — 22 APRIL 2016 —

On 22 April, 2016, Earth Day , 175 world leaders signed Paris Agreement at UN Headquarters

2017

CoP 23, Nov 2017, Bula!

Bonn make a history to being the first CoP to be President over by a small island developing state.

28th April,2017; ADDIS ABABA, IPCC hold a scoping meeting to draft the outline of AR6

2019

UN 2019 Climate Summit

Summit will convene on the theme **'A Race We Can Win. A Race We Must Win,'** and seek to challenge states, regions, cities, companies, investors and citizens to step up action in six areas: energy transition, climate finance and carbon pricing, industry transition, nature-based solutions, cities and local action, and resilience.

Contact

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