Integrated Land Ecosystem - Atmosphere Processes Study

ileaps

Newsletter

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Introduction

Welcome to the latest edition of iLEAPS Newsletter, where we delve into the intricate world of Integrated Land Ecosystem Atmosphere Process Studies. The integrated Land Ecosystems Atmospheric Processes Study (iLEAPS) was formed in March 2004 to build an international community of practice to investigate the interactions between terrestrial ecosystems and the atmosphere. Originally part of the International Geosphere-Biosphere Programme, iLEAPS became a Global Research Network of Future Earth in 2014.

As humanity confronts unprecedented environmental challenges, the need for comprehensive, interdisciplinary research has never been more pressing. It is within this context that iLEAPS finds its place within the broader framework of Future Earth. Founded on the principles of collaboration, innovation, and inclusivity, iLEAPS brings together scientists, policymakers, and stakeholders from diverse fields to investigate the intricate interactions between land, atmosphere, and society, fostering collaboration among scientists, facilitating the exchange of knowledge, methodologies, and data across diverse research communities worldwide. By integrating expertise from diverse fields, iLEAPS aims to provide holistic insights into the complex interactions shaping our environment.

iLEAPS' governing body consists of Scientific Steering Committee (SSC) members lead by two co-chairs and managed by the International Project Office (IPO) located at the UK Centre for Ecology and Hydrology (UKCEH). The SSC members of iLEAPS brings a wealth of knowledge and experience into the network where their main expertise falls within the following:

- Understanding Land-Atmosphere Interactions: to elucidate the complex interactions between land surfaces and the atmosphere, including processes such as carbon and water cycling, energy exchange, and the impact of land use and land cover changes.
- Improving Predictive Models: By synthesizing observational data, conducting field experiments, and refining modeling techniques to improve the accuracy and reliability of predictive models for climate, weather, and ecosystem dynamics.
- Assessing Environmental Impacts: Through comprehensive assessments of land use practices, deforestation, urbanization, and other anthropogenic activities, aiming to evaluate their environmental impacts and inform policy decisions for sustainable land management.

The Role of iLEAPS in Future Earth

In the broader context of Future Earth, iLEAPS serves as a cornerstone for advancing interdisciplinary research agendas aimed at promoting global sustainability. By fostering collaboration and knowledge exchange across borders and disciplines, iLEAPS contributes to the development of holistic solutions to pressing environmental challenges.

Furthermore, iLEAPS plays a pivotal role in fostering capacity-building initiatives and nurturing the next generation of scientists and leaders in the field of Earth system science. By providing training opportunities, mentorship programs, and collaborative research projects, iLEAPS empowers young researchers to tackle complex environmental issues and drive positive change in their communities.

Looking Ahead: Towards a Sustainable Future

As we stand at the crossroads of unprecedented environmental change, the importance of initiatives like iLEAPS cannot be overstated. By fostering collaboration, innovation, and knowledge sharing,

iLEAPS together with other Global Research Networks and Future Earth offer a beacon of hope in our quest for a sustainable future.

In the years to come, it is imperative that we continue to support and invest in interdisciplinary research efforts like iLEAPS, as we strive to unlock the mysteries of Earth's systems and chart a course towards a more resilient and equitable planet for future generations.

Together, we have the opportunity to shape a future where the delicate balance between human well-being and environmental integrity is preserved, ensuring a thriving planet for all.

In conclusion, iLEAPS stands as a testament to the power of collaboration and collective action in addressing the defining challenges of our time. As we embark on this journey towards sustainability, let us draw inspiration from the spirit of cooperation embodied by iLEAPS and work together to build a brighter, more sustainable future for all.

In this edition, we explore recent advancements in iLEAPS research, highlight exciting discoveries, and celebrate the achievements of our global network of scientists. From collaborative initiatives to groundbreaking discoveries, each edition will offer a glimpse into the multifaceted world of iLEAPS.

Stay tuned for more updates, insights, and discoveries from the world of iLEAPS.

Sincerely,

The iLEAPS Team

Acknowledgement

We would like to extend our heartfelt appreciation to Bhagyashri Katre, IITM, Pune, India for her exceptional dedication, expertise, and commitment in crafting this comprehensive Newsletter.

Additionally, we would like to express our gratitude to all those who have provided guidance, feedback, and assistance throughout the development of this report. Your collective efforts have been invaluable in shaping the outcome. We are also truly thankful for the contributions from all authors.

Sincerely,

The iLEAPS IPO

Editor's Note

The Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS) is a global research network that aims to investigate the interactions between terrestrial ecosystems and the atmosphere. Founded in 2004, iLEAPS has been a cornerstone in advancing interdisciplinary research agendas aimed at promoting global sustainability. In this editorial, we discuss recent advancements in research and highlight various activate and events in iLEAPS.

One of the key areas of focus for iLEAPS is understanding land-atmosphere interactions. This includes elucidating the complex interactions between land surfaces and the atmosphere, such as carbon and water cycling, energy exchange, and the impact of land use and land cover changes. Improving predictive models is another important aspect of iLEAPS' work, as synthesizing observational data, conducting field experiments, and refining modeling techniques can help improve the accuracy and reliability of predictive models for climate, weather, and ecosystem dynamics. Assessing environmental impacts is also a crucial part of iLEAPS' mission. Through comprehensive assessments of land use practices, deforestation, urbanization, and other anthropogenic activities, iLEAPS aims to evaluate their environmental impacts and inform policy decisions for sustainable land management. This is particularly important in the context of climate change, as altered weather patterns and urban transformation can have significant impacts on ecosystems and human health.

In this edition of the iLEAPS Newsletter, we explore recent advancements in iLEAPS research related to atmospheric phenomena and climate change. Articles cover a range of topics, advanced technique of soil moisture, greenhouse gas observations, and atmospheric polycyclic aromatic hydrocarbons, fog. These studies highlight the importance of understanding and addressing the complex land-atmosphere interactions. The article on field-scale soil moisture monitoring highlights the critical role of soil moisture in hydrological cycles. By examining soil moisture variability, researchers aim to enhance water resource management and resilience in the face of climate change-induced challenges. Observing atmospheric greenhouse gases provides vital insights into human activities' influence on the climate system. The review by Dr. Yogesh Tiwari sheds light on major greenhouse gases' role in shaping our climate, emphasizing the importance of monitoring these indicators for informed decision-making. Exploring sources, inhalation exposure, and associated human health risks of atmospheric polycyclic aromatic hydrocarbons, this article underscores the need to address environmental pollutants that pose significant health hazards. Understanding these pollutants is essential for mitigating their adverse effects on human health and ecosystems. The Winter Fog Experiment in India offers a unique opportunity to study fog formation processes and their implications for air quality and climate dynamics. This initiative provides valuable insights into atmospheric phenomena that impact regional environments and human health.

As we navigate through these scientific insights, it becomes evident that interdisciplinary collaboration and innovative research are essential for addressing complex environmental challenges. The iLEAPS community remains committed to advancing knowledge, fostering collaboration, and empowering the next generation of scientists to drive positive change in our world. Stay tuned for more updates, discoveries, and collaborative endeavors as we continue our journey towards a sustainable future.

iLEAPS says Goodbye to Six SSC Members

Dr. Kirsti Ashworth

Dr David Odee

Dr. Sirkku Juhola

Dr. Kirsti Ashworth is a Royal Society Dorothy Hodgkin Research Fellow at Lancaster Environment Centre at Lancaster University. She has a PhD in Atmospheric Sciences. Her research focuses on the interactions and feedbacks between the biosphere, atmosphere and society. She develops 1-D canopy exchange models to explore and improve our knowledge of how these processes interact, and applies this knowledge to improve 3-D models. She uses these to investigate the impacts of future change, in particular changes in land use and land cover, on air quality, climate, and society.

A note from Dr. Kirsti Ashworth, Outgoing SSC Member: I held the Chair of the Global Organising Committee of the iLEAPS ECSN and also served as a member of the Europe and Mediterranean Regional Committee. I was responsible for providing a platform for peer mentoring and support, and for organising and delivering workshops and other activities for Early Career Scientists (up to 5 years post-PhD award) engaged in research related to iLEAPS themes. The iLEAPS SSC and community highly value her contributions and time as SSC member.

Dr. David Odee is a Chief Research Scientist at the Kenya Forestry Research Institute (KEFRI), Nairobi, Kenya, where he leads the Forest Biotechnology and Ecosystems Group.

He began his research career studying nitrogen-fixing systems in dryland acacia woodlands of Africa. He is currently an Associate Editor for Ecosystems Services Journal. Dr. Odee contributed to the iLEAPS Early Career Scientist Workshop programme. He was leading a national initiative to establish Long-Term Socio-Ecological Research (LTSER) platforms in range of ecosystems, which should also enhance regional coverage for long-term observation points for land-atmosphere interaction studies.

He mobilised various stakeholders in East Africa to effectively engage in iLEAPS science goals and programmes through awareness creation, advocacy, strengthening links with the global land-atmosphere community, and networking for knowledge exchange and technical capacity building. The iLEAPS SSC and community highly value his contributions and time as SSC member.

Sirkku Juhola is professor of urban environmental policy in University of Helsinki, and a guest professor at Linköping University, Sweden and at Western Norway Research Institute, Norway. Dr Juhola holds a BA from the University of Sussex (UK) and a MSc and a PhD from the University of East Anglia (UK). Since obtaining her PhD, Sirkku has worked at the United Nations University - Institute of Advanced Studies (JPN), University of Jyväskylä (FIN) and Umeå University (SWE).

She worked at the United Nations University in Tokyo and at universities in Sweden and Finland. Her area of expertise is environmental policy and governance, in cities and urban areas in particular. She had been interested in the interface of environmental change and social change and how to govern that change.

Sirkku had been involved in the Scientific Steering Committee of iLEAPS and the Development Team of Knowledge Action Network on Emergent Risks and Extreme Events.

The iLEAPS SSC and community highly value her contributions and time as SSC member.

Alison Steiner

Silvano Fares

Sebastian leuzinger

Allison Steiner is a Professor of atmospheric sciences in the Department of Climate and Space Sciences and Engineering and the Department of Earth and Environmental Sciences at the University of Michigan. She received her B.S. in chemical engineering from Johns Hopkins University and her Ph.D. in atmospheric sciences from Georgia Institute of Technology. Her research uses and develops models to explore the interactions of the biosphere and atmosphere, with the goal of understanding the natural versus human influence on climate and atmospheric chemistry.

She had been involved from 2015 in the Scientific Steering Committee member for International Land-Ecosystem-Atmosphere Processes Study. she served as an editor at *Journal of Geophysical Research-Atmospheres* (2014-2018), served on the National Research Council's committee on The Future of Atmospheric Chemistry Research (2016) and is a current member of the National Academy of Sciences Board on Atmospheric Sciences and Climate.The iLEAPS SSC and community highly value her contributions and time as SSC member.

Silvano Fares is a research director at the National Research Council of Italy – Institute of BioEconomy.

A note from Silvano Fares, Outgoing SSC Member: The time I served as ILEAPS SSC member represented for me a great opportunity for several reasons: within ILEAPS community I could interact with excellent scientists and approached land-atmosphere interactions in a global context. I had the opportunity to co-organize training events, very useful for early career researchers but also relevant experiences for trainers as well. In-person and online SSC meeting were always a mean to interact and discuss about the most advanced topics in our field and learn about the state of the art in research activities in all continents. Participation to online seminars as a speaker or just as an attendee especially in times of travel restrictions due to pandemics represented a unique chance to interact with an international community. Last but not least: serving as SSC members was a chance to expand my research network and meet great scientists and great people which I look forward to keep seeing at the upcoming international events. The iLEAPS SSC and community highly value his contributions and time as SSC member.

Sebastian Leuzinger is a broadly interested plant ecologist working at the interface of experimental and modelling work. Coming from an ecophysiological background, he is increasingly interested in meta-analyses and overarching trends in the response of plants to global change drivers. More specifically, he is researching how an increase in atmospheric CO2 can cause plant communities to change through the less known indirect effects operating via soil moisture savings. He involved in a number of international efforts to synthesise global results from elevated CO2 experiments. On a smaller scale, he is interested in how plants transport water and how this relates to carbon exchange and storage. Mangroves provide a great model ecosystems for this purpose, as they are mature forests, yet accessible and located in very homogenous conditions. He was active on an international level as a steering committee member of iLEAPS (integrated Land-Ecosystem Atmosphere Processes Studies), as editor-in-chief for the journal 'Frontiers in Functional Plant Ecology'. The iLEAPS SSC and community highly value his contributions and time as SSC member.

iLEAPS Welcomes Four New SSC Members

Dr. Masayuki Kondo

Masayuki Kondo is an associate professor at the IDEC Institute, Hiroshima University. He has been a leading scientist in the greenhouse gas budget assessment study under the international project, REgional Carbon Cycle Assessment and Processes 2 (RECCAP2), since 2018. His research aims to assess reliable greenhouse gas budgets at regional and global scales using terrestrial ecosystem models, atmospheric inversions, including GOSAT CO2/CH4 inversions, and empirical upscaling of greenhouse gas fluxes from eddy flux observations, and to provide insight into prospects of biogeochemical cycles of Earth.

Currently, his research focuses on filling a gap between carbon budgets from 'top-down' and 'bottom-up' approaches, particularly in tropical regions. Also, he is leading a synthesis of global and regional carbon budget assessments from multiple approaches and processes, aiming to contribute to the Intergovernmental Panel on Climate Change (IPCC). He earned a Ph.D. in Environmental Science from Hokkaido University, Japan.

Dr. Qiaoyun Xie (*Qiaoyun is pronounced like Ciao-young, Hear name*), or Dr. X, is a Lecturer at the School of Engineering, The University of Western Australia. Using satellite and ground data, she tracks ecosystem dynamics, especially plant growth. Her research on ecosystem monitoring focuses on vegetation parameter retrieval; vegetation dynamics; vegetation phenology and shifting seasonality with climate variability; land surface responses and their interactions with climate; and land use activities and major disturbance events.

Currently, her research involves using remote sensing and field measurements to understand the phenology patterns and carbon dynamics of vegetation across Australian landscapes, including vegetation resilience and resistance to droughts.

Dr. Qiaoyun Xie

Dr. Eliani Ezani

Dr. Eliani is currently working as Senior Lecturer at the Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences Universiti Putra Malaysia (UPM). Recently, she was appointed as IGAC Allin-Wayra committee: Small sensors for atmospheric science committee.

Her research interest include: air pollution, indoor air quality, exposure assessment, urban climate, risk based assessment of environmental influences on health and provide solution to control such impact; application of low-cost air pollution sensors, citizen-science, conjoin between planetary health and societal impact.

Dr. Hu is an Associated Professor and Associate Director of the School of Natural Resources and Environment at the University of Arizona (UA), Associate Professor in the Laboratory of Tree Ring Research at UA, and Assistant Dean of Graduate Studies in the College of Agriculture, Life, and Environmental Sciences.

Dr. Hu's research broadly addresses how plants respond to changing climate by focusing on plant carbon-water relations. She has worked around the world in a range of ecosystems, from grasslands in Tibet, to forest in the western U.S., to the cloud forests of the Galapagos Islands.

Dr. Hu received her B.A. from University of California Berkeley, her Ph.D. from University of Colorado Boulder, and two postdocs at the National Center for Atmospheric Research and University of Sydney.

Dr. Hu Jia

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Dr. Milind Mujumdar, is a senior scientist at the Centre for Climate Change Research (CCCR), Indian Institute of Tropical Meteorology (IITM), Pune an autonomous Institute under Ministry of Earth Sciences (MoES), Govt. of India. He is currently engaged in Climate observational programs such as GHG monitoring, Metflux, Paleoclimate, isotope analysis, atmospheric chemistry and field scale soil moisture monitoring using Cosmos Ray Soil-Moisture Monitoring System (COSMOS) and network of various surface hydro-meteorological monitoring systems to study the soil water dynamics. He had conducted diagnostic and modelling studies to understand the Asian monsoon variability and its response to warming climate. He completed his Ph.D. on studies related to 'Climate Modelling' during 2002, from University of Pune. He is also associated with Universities for guiding M.Sc./ M.Tech. and PhD students. During his research career, he has had extended visits to the University of Tokyo, Hokkaido University, Nagoya University, *Japan*; University of Hawaii, *USA*, University of Reading and European Centre for Medium Range Weather Forecast (ECMWF), Reading, University of Stirling, *UK*; CSIRO (Melbourne) *Australia*; University of Cape Town, *South Africa, University of Nebraska Lincoln, University of Chicago, USA*. He received IITM's Silver Jubilee Award for the best research paper of the year 2017, MoES merit award in July 2022 and MoES Rajbhasha award in October 2022.

Digging Deep: Field-Scale Soil Moisture Monitoring in Optimizing Agro-Hydrological Systems

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The increasing impact of climate change on agriculture, particularly in India, poses a significant threat to farmers and other involved communities. A neglect of soil health and reliance on fertilizers make the sector more vulnerable to extreme weather events. A recent climate change assessment report by the Ministry of Earth Sciences, India (Dhara et al., 2020) highlighted rising temperatures, declining summer monsoon rainfall, and a heightened risk of drought and floods across India. In this regard, it is important to examine the soil moisture (SM) variability which regulates or expedites the impact of hydrometeorological extremes via its control on evapotranspiration and thus surface fluxes. Recognizing the importance of SM and its memory is therefore crucial for identifying resilient regions and making informed agricultural decisions in the context of a changing climate. Insufficient observational networks for crucial climate variables, such as SM, hinder our understanding of complex multiscale interactions in the climate system. This limits our ability to comprehend the changing patterns of floods and droughts in India. SM, integral for moderating weather and climate, faces challenges in measurement at the intermediate scale from few hundred meters to few kilometres, impacting land-surface models and agricultural applications. In this context, IITM Pune set up a non-invasive Cosmic ray soil moisture monitoring, system based (COSMOS, Figure 1) on a network of the newly developed neutron scattering method which potentially helps to bridge the gap between

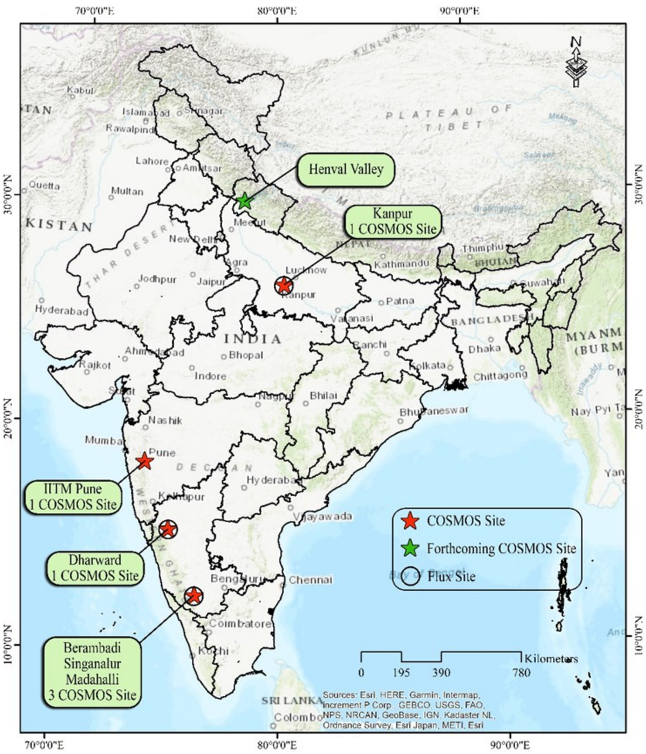


Figure 1: *Map showing current and forthcoming COSMOS-India sites*

the conventional point scale, remote sensing techniques, bridge the gap between the conventional point scale, remote sensing techniques and model simulations of surface soil moisture (Mujumdar et al. 2017). The non-invasive COSMOS system provides a field scale measure of soil moisture, effectively addressing spatial heterogeneity by averaging over the entire area. **This method is inevitable for accurate computations** since the SM variations are sensitive to spatial heterogeneity. Also, the COSMOS system estimates the area-averaged soil moisture, which avoids the challenge of extensive horizontal variability in surface soil moisture fields due to complex interactions between pedologic, topographic, vegetative, and meteorologycal factors while obtaining area-representative soil moisture using the network of point measurements.

Principle of measuring the soil moisture using the COSMOS technique

The cosmic rays were first discovered in 1912 by Victor Hess. Compton and Eastman (1935) later revealed that the ionization observed by Hess was caused by secondary radiation, primarily consisting of electrically charged particles penetrating the atmosphere. Subsequent measurements (Hendrick and Edge, 1966) indicated a correlation between the intensity of "fast" neutrons above the ground and the water content of the soil. Initially considered noise by cosmic-ray physicists, this phenomenon is now recognized by hydrologists as a signal providing information about surface water content (Zreda et al., 2012). The COSMOS technique harnesses the natural occurrence of cosmic rays to measure soil moisture content. Originating from space, cosmic rays interact with atmospheric molecules, generating secondary particles, including neutrons. These neutrons penetrate the Earth's surface and are sensitive to the presence of hydrogen atoms, abundant in soil water. By detecting and analyzing the flux of these neutrons returning to the surface, COSMOS offers continuous, non-invasive measurements of soil moisture across vast areas. This method boasts various advantages, including its capability to monitor soil moisture at different depths and its independence from ground-based sensors or weather conditions. The secondary cosmic ray neutrons cascade through the atmosphere in stages of high energy, fast (epithermal) neutrons, and finally thermalizes, with the epithermal neutrons crucial in determining water content due to their modulation by hydrogen atoms above and within the Earth's surface (Zreda et al., 2012).

Calibration of volumetric water content

A correction for atmospheric moisture content should be included in the conversion of measured neutron intensity to soil moisture. The effect of location and soil chemistry are also accounted for by making a local calibration to define the relationship between the fast neutron intensity, ϕ (normalized for variations in pressure, atmospheric water vapor, and solar activity), and soil moisture, SM. Other sources of hydrogen existing in and near soils, including lattice water, atmospheric water vapor, snow cover, water in and on vegetation, etc., should be considered when converting neutron intensitly to soil moisture. At COSMOS-IITM site, SM or volumetric water content (VWC - θ) is calculated using the following calibration function (Desilets et al., 2010)

$$\theta = \frac{a_0}{N/N_0 - a_1} - a_2 \#(1)$$

where N: Fast neutron count, N_0: neutron count in the air above dry soil and a0, a1 and a2 are the fitting parameters.

Field-scale soil moisture time series (COSMOS-IITM)

The daily variations of COSMOS field -scale soil moisture (SM) and its effective measurement depth at COSMOS-IITM site from January 31, 2017, to November 10, 2023, are shown in Figure 2. Validation against in-situ profiles (yellow dots, Zreda et al. 2012) shows satisfactory agreement. The study utilizes a best-fit N_0 value of 1194 to derive volumetric water content (VWC) from the Cosmic-ray method. Validation with in-situ observations at the IITM site indicates a root mean square error (RMSE) in the range of 1-2% (Mujumdar et al., 2021).

The annual cycle of SM and effective depth mirrors the monsoon cycle, with notable variations exceeding 20% VWC and almost 20 cm in effective depth around monsoon onset and withdrawal phases. During wet periods, SM is around 30% and above, with an effective depth <15 cm, while dry periods exhibit SM below 15%, with rising effective depth above 25 cm. Intriguingly, within the monsoon season, field-scale SM and its effective depth show significant variations.

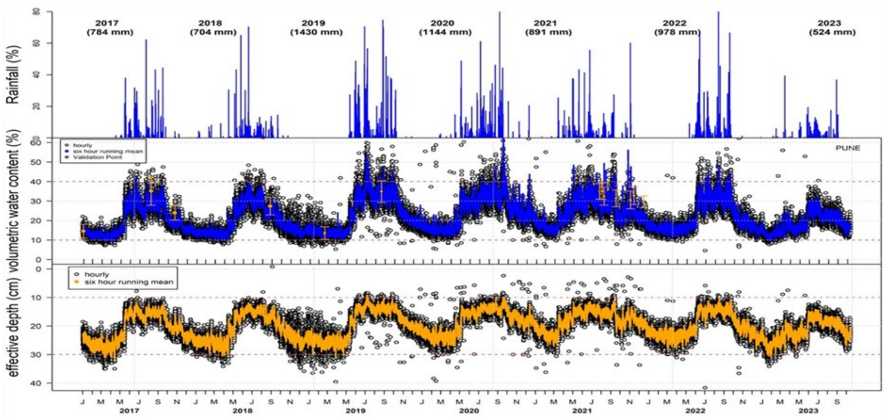


Figure 2: *Time series for the period 2017–2023 (a) COSMOS-IITM field-scale soil moisture and (b) effective depth estimated using equation proposed by Franz et al. (Franz et al., 2012).*

The hourly, six-hourly and validation points of SM are represented by a grey circle and blue line, orange circle respectively. Similarity the hourly and six-hourly effective depth of SM is represented by grey circle and orange line respectively. Orange dots superimposed on soil moisture time series indicate the area-averaged soil moisture values obtained from manual volumetric soil sampling, using the gravimetric method.

COSMOS-IITM field-scale SM data is compared with various available coarser-resolution products comprising coarser-resolution satellite (SMOS, SMAP, AMSR2), reanalysis (ERA5, MERRA-2), and modelled (GLDAS) data products during 2017–2020 (Figure 3).

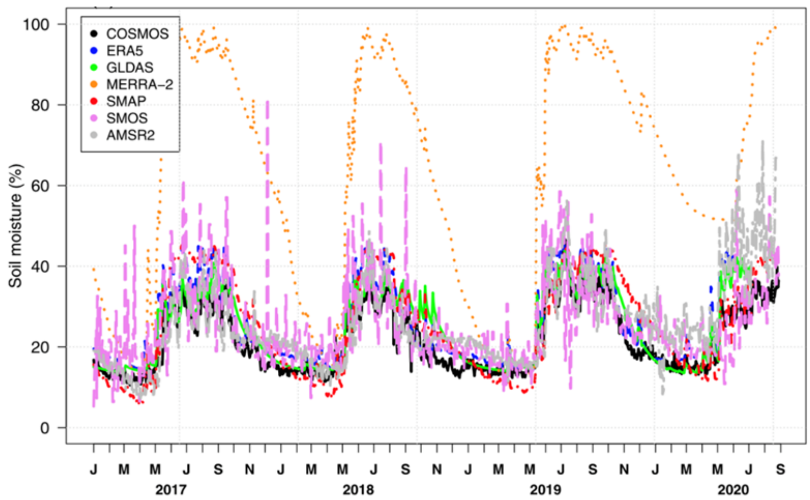
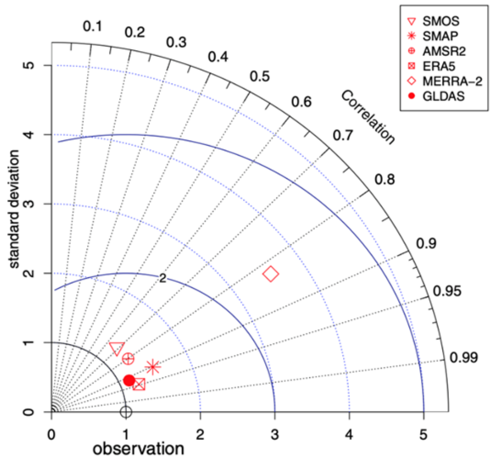


Figure 3: *Time series comparison of daily soil moisture (% of VWC) from SMOS (pink), SMAP (red), AMSR2 (grey), ERA5 (blue), MERRA-2 (orange), and GLDAS (green) with COSMOS-IITM (Mujumdar et al., 2021).*

Among all the SM data products GLDAS and ERA5 have relatively close resemblance to the COSMOS-IITM observations. Also, MERRA-2 SM products show maximum bias, whereas GLDAS exhibits the least bias over the Pune region. A comparison of SM data of various methods is shown in Figure 4.



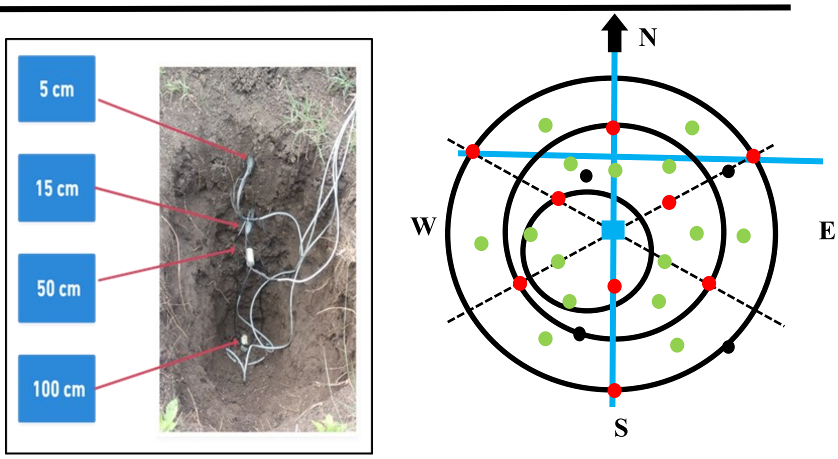


Figure 4: *Taylor Diagram presents the comparison of six different soil moisture data sets (SMOS, SMAP, AMSR2, ERA5, MERRA-2, and GLDAS; represented by distinct symbols) with vali- dation reference to COSMOS-IITM observation in terms of centred Root Mean Square Error (RMSE) Correlation Coefficient and Standard Deviation (Mujumdar et al., 2021)*

Field-scale hydrometeorological observations

The automated system developed at the Centre for Climate Change Research, Indian Institute of Tropical Meteorology (CCCR, IITM), Pune, regularly monitors the meteorological variables like soil moisture and temperature in four different layers of the soil. Collected data for different hydrometeorological variables is stored and communicated via Bluetooth low energy (ble), email, and short message service (SMS). A field photograph is shown in Figure 5 (Technical report, IITM). At the latest around 280 profiles are analysed, starting from March 21, 2022 to November 29, 2023.

Figure 5.: *Low cost soil profile sensors (red dots) at various depths and schematic map with three concentric circles at 5 m, 25 m and 75 m (inner to outer).* The green dots (right-hand side picture) indicates locations at which soil samples were collected and a gravimetric analysis is carried out to infer the volumetric water content.

Research Implications

The surface -subsurface coupling of SM observations from IMD stations across the core monsoon zone (CMZ) of India and COMSOS-IITM, Pune site, has shown an enhanced or near to void of convective activities during succeeding winter and pre-monsoon seasons of the excess and deficit years, respectively.

Figure (6) (Goswami et al., 2023) indicates the soil water dynamics in terms of the ridgeline plots of surface and subsurface SM and soil temperature (ST) as a function of time at the COSMOS-IITM site. This is in line with the above results based on coupling and memory analysis for the same period but only on a much larger extent – CMZ of India.

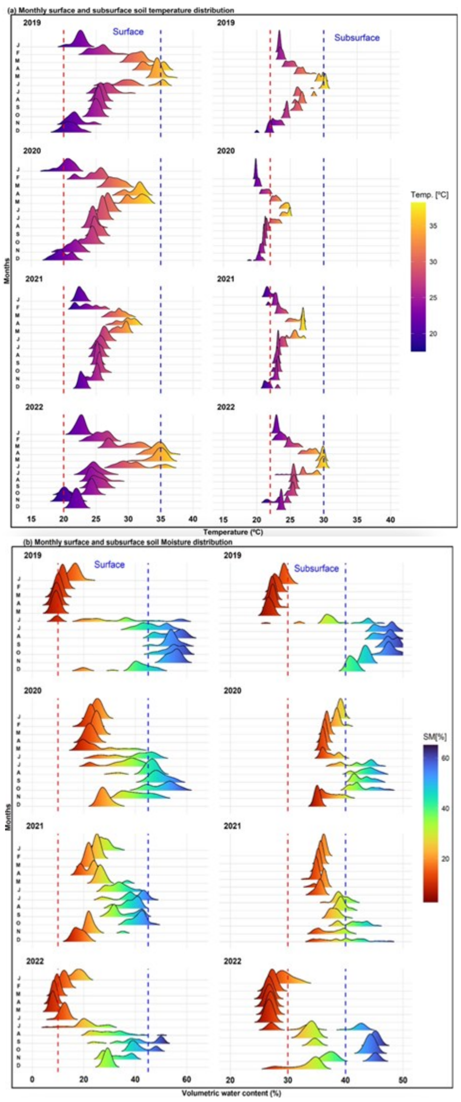


Figure 6: *The density ridgeline plot of surface and subsurface (a) soil temperature (ST, ◦C) and (b) soil moisture (SM, VWC %) for each month of the period between 2019 and 2022, using in-situ measurements at the COSMOS-IITM, Pune. The colour bar (same as x-axis) depicts the variation in ST (SM). The dashed red lines indi*

cate the threshold for extremely dry (warm) SM (ST) conditions, whereas the dotted blue lines, indicate the threshold for extremely wet (cool) SM (ST) conditions.

Also, the role of surface soil moisture variability on the temperature extremes over the Indian region could be emphasized using COSMOS-IITM, Pune site observations with IMD rainfall, and the GLDAS (1948 – 2014), SM observations over India (Ganeshi et al., 2020). Northcentral India could be identified as a hotspot for SM-temperature coupling using Generalized Extreme Value (GEV) distribution to assess the influence of SM on temperature extremes. Based on the results, the duration of temperature extremes (ExTD) could be observed to increase under dry soil moisture conditions.

Further, in a recent study published by Ganeshi et al. in 2023, the critical role of soil moisture variations in shaping temperature extremes has been underscored. Through meticulous sensitivity experiments, researchers examined the effects of increase or decrease in soil moisture by 20% on the frequency, intensity and duration of extreme temperature events across the Indian region. These findings shed light on the intricate relationship between soil moisture dynamics and temperature extremes, offering valuable insights for understanding and managing climate-related risks in the region.

In conclusion, the challenges posed by climate change on agriculture in India necessitate innovative solutions for monitoring soil moisture and its impact on weather patterns. The development of the Cosmic ray soil moisture monitoring system (COSMOS) by IITM Pune offers a promising avenue for accurate and non-invasive assessment of soil moisture, bridging the gap between conventional point-scale measurements and remote sensing techniques.

By leveraging advanced technologies and interdisciplinary research, such as coupling surface and subsurface soil moisture observations, we gain crucial insights into the complex dynamics of the climate system. Moreover, recent studies highlighting the significant influence of soil moisture variability on temperature extremes underscore the importance of integrating soil moisture monitoring into climate risk management strategies. Moving forward, continued collaboration between scientific institutions, policymakers, and agricultural communities will be vital in implementing sustainable practices and mitigating the adverse effects of climate change on agriculture and livelihoods in India.

Acknowledgment

The authors express their gratitude to the Director of the Indian Institute of Tropical Meteorology (IITM, India) for supporting the research efforts. Additionally, the authors acknowledge the funding provided by IITM (under the Ministry of Earth Sciences), which facilitated this study.

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From altered weather patterns to Urban Transformation: India's Climate Story

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Climate change is a pressing issue of the modern era, with its rapid escalation and intensification causing significant impacts worldwide. In India, the effects of climate change have been profound, reshaping the country's environment, society, economy, and urban areas. In 2019, India ranked seventh among the countries most affected by extreme weather events attributed to climate change. This impact was evidenced by the loss of 2,267 lives and an economic damage amounting to 66,182 million US dollars in purchasing power parity (PPP) (Hussain et al., 2024). With a population of 1.4 billion people, India has become the most populous nation globally, representing approximately 18% of the global population (Hussain et al., 2024). This demographic trend has led to an increased rate of natural resource consumption in the country. Given this scenario, it is imperative to implement various climate mitigation strategies, including nature-based solutions, to alleviate the impacts of climate change and support India in achieving its Sustainable Development Goals (SDGs).

From 1970 to 2021, India faced 573 disasters linked to extreme weather, climate, and water events, resulting in the loss of 138,377 lives (IMD Annual Report, 2021). Recent years have seen India experience its highest temperatures and most prolonged dry spells on record. The country is now included in the UN's Global Drought Vulnerability Index, with consecutive drought episodes affecting major rice-producing states like Uttar Pradesh, Bihar, Jharkhand, and West Bengal. India's rapid economic and developmental growth has led to sector-specific CO_2 emissions, with the electricity sector contributing 35.05%, agriculture 23.18%, construction/ manufacturing 15.92%, and transport 8.64% (Tiseo, 2023a). Despite India's relatively low per capita CO_2 emissions at 1.82 metric tons, well below the global average of 4.55 metric tons (World Bank, 2021), it ranked as the fourth-largest emitter in 2017 due to its substantial population and economic size (UNEP, 2019).

The altered weather patterns

In 2021, the average temperature across India was 21.43°C, marking it as the third-highest on record since 1901, following 2016 (21.8°C) and 2009 (21.59°C) (IMD Annual Report, 2021). Figures 1A and 1B illustrate deviations from the average seasonal maximum and minimum temperatures, revealing that certain regions like Assam, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, Himachal Pradesh, Saurashtra, and Kutch experienced maximum temperature anomalies exceeding 2°C.

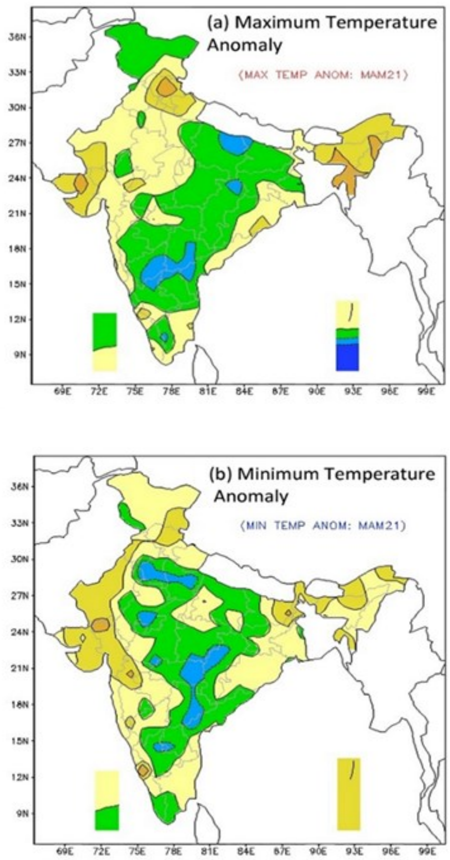

***Fig 1:** Mean seasonal temperature anomalies (°C) (a) maximum (b) minimum (Source: IMD Annual Report, 2021)*

There were observable changes in precipitation patterns as well. In parts of Tamil Nadu, Puducherry, Karaikal, Kerala, and Lakshadweep, the rainfall anomaly exceeded 100 mm. Conversely, regions in Arunachal Pradesh, Assam, Meghalaya, Uttarakhand, Punjab, Himachal Pradesh, and the western parts of Jammu and Kashmir and Ladakh experienced negative rainfall anomalies greater than 50 mm. Moreover, in parts of Arunachal Pradesh, Uttarakhand, Punjab, Himachal Pradesh, and Jammu and Kashmir, the negative rainfall anomaly exceeded 75 mm (Figures 2a and 2b).

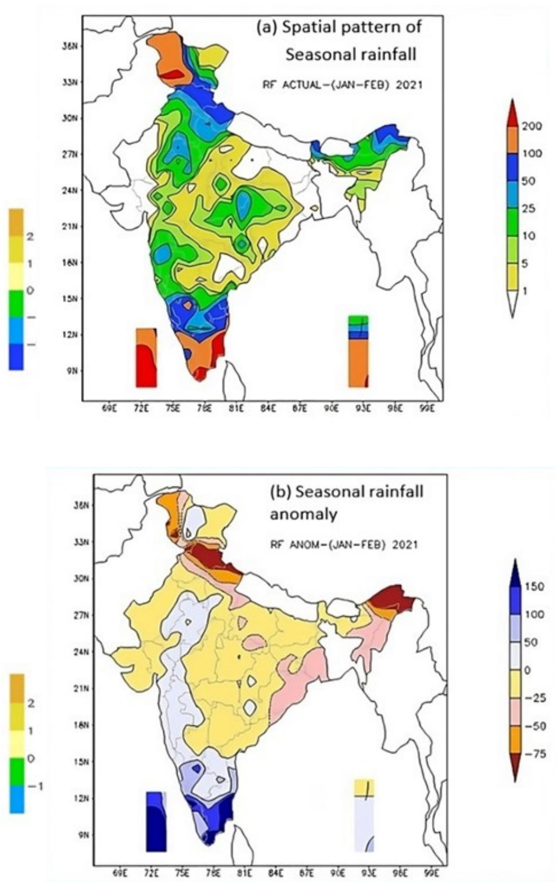

***Fig 2:** Spatial pattern of (a) Seasonal Rainfall Winter (January-February) (b) Seasonal rainfall anomaly (mm) (Source: IMD Annual Report 2021)*

The enhanced impact in Urban systems

Urban transformation in India is influenced by various factors such as population growth, changes in land use, and industrialization, all of which are compounded by the impacts of climate change (Lele et al., 2018; Sonwani et al., 2021a,b,c). Many Indian cities still grapple with foundational issues like physical development, poverty, and environmental degradation. Integrating climate change considerations alongside these fundamental challenges presents a significant obstacle (Ürge-Vorsatz et al., 2018). The construction and expansion of these cities will determine consumption patterns, production practices, and exposure to climate-related risks for decades to come.

Several cities lack adequate services, with inconsistent and insufficient access to essentials like water, sanitation, and drainage. A significant proportion of urban dwellers live in inadequate living conditions, often referred to as "slums." The local environment's health, including air and water quality and solid waste management, is severely compromised and ranks among the poorest globally (Karak et al., 2012; Nixon et al., 2013).

Implementing a well-coordinated urban climate strategy that spans different levels of government, considering India's sprawling urban layouts, and seizing the opportunity to establish sustainable infrastructures with reduced consumption could play a crucial role in shaping India's development path.

In recent years, urban areas have experienced significant societal and technological changes, including a noticeable shift towards adopting low-carbon lifestyles (Roy et al., 2018).

This transition has been facilitated by national-level policies and programs influenced by increasing research on modern-day climate change, encouraging cities to embrace environmentally friendly practices. Initiatives such as the National Mission on Sustainable Habitat, Smart Cities Mission, Solar City Program, and Green Urban Transport Mission promote the implementation of rooftop solar panels, energy-efficient practices, public transportation, pedestrian pathways, bike lanes, and building energy standards (Rajasekar et al., 2018). Simultaneously, efforts to improve drainage infrastructure under the Atal Mission for Rejuvenation and Urban Transformation aim to enhance urban climate resilience (Tewar et al., 2015).

Nature-based solutions (NbS) leverage the benefits of nature to address the effects of urbanization and climate change. These solutions involve interventions that integrate nature into urban spaces to enhance resilience and well-being. One crucial aspect of NbS is Urban Green Infrastructure (UGI), which aligns with NbS principles. UGI, including urban parks, has been shown to mitigate urban temperatures, reducing daytime temperatures by approximately 1°C. Larger parks with significant tree cover have an even more pronounced cooling effect (Bowler et al., 2010).

One significant initiative to address climate change challenges is the Blue-Green Master Plan of Delhi, which aims to enhance the city's sustainability and resilience. This plan focuses on developing a multifunctional blue-green infrastructure that integrates water and vegetation elements. By combining these elements, the plan seeks to tackle environmental issues such as pollution, water scarcity, and inadequate green spaces. Another example is Rajkot, a city in Gujarat, which has developed a comprehensive Climate Change and Environment Action Plan to mitigate the impact of rising temperatures and climate change. This plan focuses on reducing energy consumption, conserving water, monitoring air quality, managing waste, and reducing greenhouse gas emissions. (http://www.vasudha-foundation.org/wpcontent/uploads/Full-Action-Plan-Rajkot.pdf.).

Why does the problem still persist?

In India, there is a noticeable lack of comprehensive understanding regarding the intersection of climate concerns and developmental goals across policy and governance levels. Often, short-term, isolated actions are taken without considering their cumulative impacts, making them vulnerable to the influence of vested interests. There is a gap in adopting a holistic approach that integrates climate change considerations into urban planning at all levels of government. Central government initiatives like the Transit Oriented Development Policy, Green Urban Mobility Scheme, Unified Metropolitan Transport Authorities, and particularly the Smart Cities Mission aim to achieve integrated urban governance. Urban climate action in cities is influenced by the involvement of higher government levels, which cities often rely on for central schemes and policy direction. India's unique socio-economic conditions, diverse geography, and varying climates present challenges in implementing a uniform policy nationwide. In conclusion, India's vulnerability to climate change is now an undeniable reality, contrasting sharply with more developed countries. This susceptibility arises from a complex interplay of fragile ecosystems, precarious economic structures, and widespread poverty within the country (Panda, 2009). Addressing the future challenges of climate change in India is a pressing and multifaceted task that requires a comprehensive approach to mitigate its extensive impacts. Given India's geographic diversity, future climate research should focus on understanding region-specific impacts. It is essential to comprehend how climate change affects different parts of India, considering variations in temperature, precipitation, and extreme events, to develop tailored adaptation strategies. Additionally, future research should prioritize urban planning, infrastructure development, and efficient energy use to boost the climate resilience of cities. Leveraging data, technology, and remote sensing can aid in monitoring climate change and predicting its impacts accurately. Lastly, ensuring that climate policies are aligned with India's development goals and effectively implemented is a crucial aspect of future work.

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Long-term Integrated Greenhouse Gas Observations in India

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GHG observations in India (IITM Projects) started in 2009. CH4 observations in India were used in the top-down models. We estimated India's CH4 emission as 24.2±5.3 Tg per year from 2011 to 2017. This estimation is 19.2% higher than India's CH4 emission (19.55 Tg per year) reported by the Govt of India in its Biennial Update Report 3 (BUR-3) to UNFCCC. (Ref. Janardan et al., 2020). In another top-down estimation using surface observations in India, average CH4 emissions in India during 2010-2015 were 22.0 Tg per year (19.6–24.3 Tg per year). This estimation was consistent with the emissions reported by India's BUR-1 report submitted to UNFCCC. (Ref. Ganesan et al., 2017). India's CH4 emission estimated by EDGAR (v4.3.2-2012) was 32.6 Tg per year, which is approximately 39% higher than the emissions reported by India's BUR-1 (19.8 Tg per year), BUR-2 (20.05 Tg per year), and BUR-3 (19.55 Tg per year). We have deployed various instruments at different locations and ecosystems to understand better fossil fuel (biospheric) GHG emissions (sink) variability in India. We monitor in-situ observations of CO_2, CH_4, CO, and H_2O concentrations; in-situ delta 13C of CO_2 and CH_4; and in-situ delta 13C, 17O, and 18O of CO_2 at different locations in India.

Systematic GHG monitoring started at Sinhagad (SNG) in 2009. SNG is located 200 km east of the Arabian Sea (73.75 E, 18.35 N, 1600 m asl) over the Western Ghats mountains (Fig.1). Routine air sampling at SNG, collected from a 10-meter meteorological tower at weekly intervals, has been operational since November 2009. This site is free from major emission sources and has prevailing light winds from the south and southeast during afternoon hours. The mean wind speed at the sampling time is typically about 0.5 to 1 m s-1, so the samples are free from local influences. The ambient temperature ranges from 25 to 30 dc. The Sinhagad site was inducted with continuous monitoring using an in-situ CRDS

Figure 1: *GHG monitoring at Sinhagad (SNG)*

Figure 2: *GHG monitoring at IITM Pune*

Figure 3: *GHG monitoring at IITM-ART Bhopal*

Picarro instrument in 2022.

GHG in-situ observations at IITM Pune began in 2016. We are monitoring CO2, CH4, CO, and H2O concentrations at high temporal resolution using the CRDS Picarro instrument (Fig.2). The observations are conducted at the top of the 40-meter building. IITM is located in a semi-urban environment on the outskirts of Pune. Observations of CO2 isotopes 13C, 18O, and 17O are also carried out at IITM campus. The IITM Pune site is shown in Figure 2. Calibration of all these measurements is done using WMO standards imported from NOAA Boulder, USA. We recently installed a 72-meter tower in central India with multi-level GHG, isotopes, and AWS instruments (Fig.3). IITM Atmospheric Research Testbed (ART) was established 70 km outside Bhopal city. The tower is installed at the ART campus and has been operational since March 2023. We are measuring CO2, CH4, CO, and H2O concentrations at three different levels on the tower; CO2 isotopes are measured at the surface. Meteorological parameters are measured at eight different levels. CO2 flux using the eddy covariance (EC) technique is measured at two levels. Apart from these variables, we have installed a Net Radiometer (separate short and long wave), Infrared Thermometer, Photosynthetic Active Radiation (PAR), Line PAR, Soil Moisture, soil temperature, electrical conductivity, and soil heat flux plate. For policymakers to create effective mitigation and adaptation plans for climate change, accurate greenhouse gas data is a necessity. Observations help set emission reduction targets, implement regulations, and assess the effectiveness of climate policies in India. India has committed to lowering its greenhouse gas emissions and periodically reporting on its progress as a signatory to international agreements such as the Paris Agreement. Reliable GHG observations are essential for fulfilling these commitments and demonstrating India's contributions to global efforts to combat climate change.

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Atmospheric Polycyclic Aromatic Hydrocarbons: Sources, Inhalation Exposure and Associated Human Health Risk Assessment

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Polycyclic aromatic hydrocarbons (PAHs) are the ubiquitous lipophylic component of persistent organic pollutants (POPs) (Haritash & Kaushik, 2009). They are the most widely investigated organic compounds due to their known carcinogenic and mutagenic nature (Sonwani et al., 2022; Chen et al. 2019). PAHs compounds originated from natural and anthropogenic combustion source such as coal combustion, biomass burning, forest fire, and traffic emission (Kulkarni et al., 2014; Sonwani and Kulshrestha 2018; Sonwani et al. 2021). Atmospheric PAHs mostly found associated with particulate matter and also in vapour phase (Goel et al., 2021; Sonwani et al., 2016; Sonwani and Shukla, 2022).

As the larger PAH molecules (≥4 rings) exert lower vapor pressure and get adsorbed on the particulate matter, whereas the smaller PAH molecules (2–3 rings) generally exist in the vapor phase (Park et al. 2002; Ravindra et al., 2006). Vehicular traffic is one of the major sources of PAHs in the urban ambient atmosphere (Mohanraj et al., 2011), wherein the particulate-bound PAHs are considered to be a serious human health risk (Najmeddin and Keshavarzi, 2019). Several studies have been conducted to identify the particulate matter (PM) levels in the ambient atmosphere of some of several Asian countries including India, but studies related to PAHs determination; source apportionment and related health risk through the various rout of human exposure are still sparse (Gurjar et al. 2010; Karar and Gupta

2006; Jyethi et al. 2014) and need to be considered by atmospheric science researchers. Some of these studies have particularly focused on PAHs owing to their high concentration in the ambient atmosphere and the resultant entailing a serious health concerns, particularly in Delhi (Kulkarni and Venkataraman 2000; Khillare et al., 2012; Sonwani, 2016). It was identified by researchers that, the New Delhi records an excess number of mortality cases (~1600/year) due to respiratory problems due to air pollution with incidence of respiratory ailments being 12 times the national average (Gurjar et al. 2010). The present study was published in Inhalation Toxicology, a journal of Taylor & Francis (Sonwani et al., 2022).

This study was focused on the particulate PAHs, sources, and related health risks for the residents of urban areas of New Delhi. In this study, authors considered and analyzed, sixteen PAH priority PAHs compounds (∑16 PAHs) that were identified by USEPA. Of these, Naph is the only 2-ring PAH, whereas Acy, Acen, Flu, Phen, and Anth are 3-ring PAHs, Flan, Pyr, B[a]A, and Chry are 4-ring PAHs, B[b]F, B[K]F, B[a]P, DBA are 5-ring PAHs, and B[ghi]P and IP are 6-ring PAHs. Out of these ∑16 PAHs, seven have been classified as carcinogenic by USEPA, namely B[a]A, Chry, B[b]F, B[k]F, B[a]P, DBA, and IP (∑7 PAHs). The present study was targeted on Delhi and two important sites have been identified for the sample collection. Figure 1 shows the map of the sampling sites. In this study, two sites were selected, namely Jawaharlal Nehru University Campus (JNU) in the south-west and Mandi

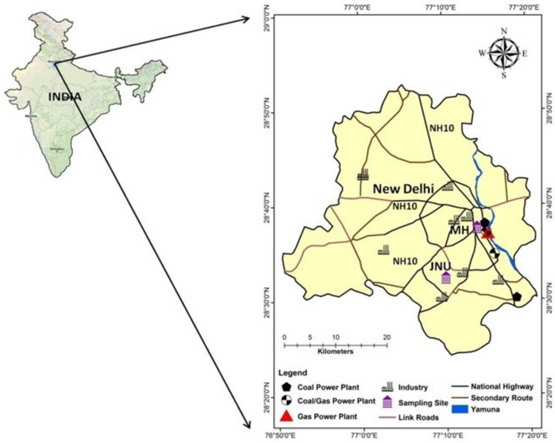

Fig. 1 *Map of the study area showing sampling sites in Delhi*

House (MH) in the central and commercial location of the city. JNU is a closed university campus area situated on the ridge of Aravalli Hills (forested area). It has been considered as the urban background receptor site for air pollutants being largely a residential university with predominant wind direction from N and NW except during the rainy season, when the easterly or south-easterly winds dominate (Sonwani and Kulshrestha, 2019).

Second site, MH is characterized by roads with heavy traffic and a range of administrative offices along with a myriad of commercial and industrial activities in the peripheral area. The sampling of PM_{10} (≤10 μm) was carried out simultaneously for 24 h every week at both the sites during 2013 & 2014. . PM10 samples were collected on Whatman™ Grade GF/A (8" x 10") Glass Microfiber Filter (pre-combusted at 450°C for 12 hours) using Respirable Dust Sampler (Model MLRDS-002, Mars Bio-analytical Pvt. Ltd.). with a particular flow rate of 1.1 m^3min^{-1}. Determination of PAHs was carried with the help of HPLC with UV detector.

Molecular diagnostic ratios (MDR) of PAHs were used for preliminary identification of sources. Final identification of sources was performed with the help of principal component analysis (PCA). A given ratio is characteristic of a particular emission source and is used as a diagnostic tool to identify the origin of PAHs in the ambient atmosphere (Guo, Sheng et al. 2003; Guo, Lee et al. 2003; Fang et al. 2006). Values of different PAH isomer pair ratios show that vehicular emission and coal combustion-related sources are the main sources of PAHs at both the sampling sites in Delhi. DB [ah]A, B[ghi]P, and IP are generally associated with automobile exhausts (Khalili et al. 1995), which further confirms that a major part of PAHs emissions was directly linked to Delhi's vehicular traffic. The final confirmation of the potential sources in Delhi has been identified with Principal Component Analysis (PCA). Its a powerful tool to increase the accuracy of emission source identification by selecting statistically independent source tracers (Guo, Sheng et al. 2003). Results of PCA for the mentioned study have been presented in Table 1. PCA analysis showed that the emissions from vehicles (both gasoline and diesel powered) predominate at MH site as compared with other PAHs emission sources; however, coal combustion and traffic emission are identified as predominant PAHs emission sources at JNU campus, whereas oil combustion and wood burning are also identified as other important sources at JNU. For the health risk assessment, inhalation exposure pathway has been considered and the assessment was based on the possible impact of the selected PAHs compounds present in the ambient atmosphere of Delhi.

Seven carcinogenic PAHs, namely BaP, Chry, BbF, BkF, BaP, DBA, and IP (US EPA 2002) considered to identify the carcinogenic potential.

Out of these, B[a]P is considered to be the most carcinogenic and therefore is generally accepted as a surrogate for the carcinogenicity of the whole PAH fraction. In this study, the mean ∑7 PAHs concentration was found to be 30.63 ± 20.14 ng m^{-3} at JNU and 40.40 ± 32.85 ng m^{-3} at MH. The observed percentage contribution for the two sites was 55% and 60%, respectively. In this study, the health risk is explained on the basis of BaPeq contribution, ILCR, and expected cancer cases with respect to both the sites in Delhi considering toxic equivalency factors (TEFs) values provided by Nisbet and LaGoy, and B[a]P Inhalation Unit Risk value (IUR) provided by CEPA (2004) and WHO (1987). The BaP equivalent concentration (B[a]Peq) is often used to express the carcinogenic risk of PAHs mixture. B[a]Peq was calculated using TEFs listed in Nisbet and LaGoy (1992). B[a]Peq is used to assess the effect of all PAHs species. Moreover, TEF has been used to adapt the effect of PAH species to the equivalent values calculated based on B[a]P (Yang et al., 2005):

$$\text{Total B[a]P}eq = \sum i\,(\text{Ci} \times \text{TEFi})$$

Ci : concentration of a PAHs species i, TEFi: toxic equivalency factor for a PAHs species i

According to the present study, the observed overall mean of B[a]P eq concentrations during the study period were (12.96 ± 9.28) ng m^{-3} and (17.73 ± 19.26) ng m^{-3} at the two sites, respectively. B[a]P value (mean of both sites) recorded in the present study (15.30±15.08 ng m^{-3}) is more than 15 times the annual NAAQS. The total mean B[a]P*eq* concentration in Delhi (15.30 ± 15.08 ng m^{-3}) was found to be higher than Florence, Italy (0.916 ng m^{-3}, Lodovici et al., 2003), Nanjing, China (7.1 ng m^{-3}, Wang et al., 2006), and Hong Kong (0.64 ng m^{-3}, Zheng and Fang 2000).

In the present study, Incremental lifetime cancer risk (ILCR) was calculated due to inhalation of PAHs. Since IUR values are not available for all the individual PAH species, the respective PAHs concentration were converted to B[a]Peq values. WHO (1987) has suggested an IUR of 8.7×10^{-5} ng m^{-3} for B[a]P while California Environmental Protection Agency (CEPA, 2004) recommends a value of 1.1×10^{-3} µg m^{-3}. Regardless of the huge difference between these, both the values are extensively accepted. Thus, we used both the IUR values for B[a]P calculation in the present study. The ILCR values at both the sites fall in the range of 10^{-2} to 10^{-4}, which is higher than the acceptable risk level (10^{-6}). However, they fall in the range of lower than priority risk level (10^{-3}). Result also shows that ILCR values have significant difference at both the sites at $p \le 0.05$ (t-test, p = 0.014 and p = 0.016 at JNU and MH respectively). With respect to the ILCR (considering CEPA and WHO standards), the lower- and the upper-bound values for excess cancer cases in Delhi at a site with busy traffic was found to be much higher (3315 and 26220) than at the urban background site (2423 and

Table: 1. *Results of principal component analysis (Varimax Rotation with Kaiser Normalization) at JNU campus and MH site. Only factor loadings ≥0.4 are shown with loading ≥0.5 in bold.*

	JNU (South Delhi) Principal Components				MH (Central Delhi) Principal Components		
PAHs Species	**PC1**	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**	**PC3**
Naph							
Acy							
Acen				**0.559**			
Flu	**0.704**						
Phen	**0.803**						
Anth	**0.869**					0.418	
Flan			**0.565**			0.481	
Pyr	**0.799**					**0.762**	
B[a]A				**0.867**	**0.517**		
Chry	**0.602**			**0.73**	**0.775**		
B[b]F			**0.588**		**0.513**	**0.74**	
B[k]F		**0.854**			**0.794**		
B[a]P			**0.871**		**0.829**		**0.511**
DBA		**0.651**					**0.938**
B[ghi]P		**0.519**				**0.791**	
IP		**0.777**			0.818		
% of Variance	42.31	21.52	14.91	12.78	55.40	14.12	12.79
Cumulative %	23.77	56.24	70.63	76.42	55.40	69.52	82.32

19210). These excess cancer cases may occur in Delhi due to lifetime inhalation of of PAHs, particularly at the levels found at the sites of the study.

Thus, in the mentioned study, particulate bound PAHs show spatial variations influenced by local emission sources. Molecular Diagnostic Ratio and Principal Component analysis showed the emissions from vehicles (both gasoline & diesel powered) predominate at commercial area in Delhi as compared to other PAHs emission sources however; coal combustion and traffic emission are identified as predominant PAHs emission sources at University campus located at southern part of Delhi, where oil combustion and wood burning are also identified as other important sources at JNU. The excess cancer cases were found to be higher at the MH site than the JNU site in Delhi. Overall, it may also be attributed to the nature of the MH site (traffic intersection point), which increases the risk of health hazard due to inhalation of particulate PAHs. Whereas JNU with dense vegetation and distance from PAH emission sources have less health risk associated with the inhalation of particulate bound PAHs.

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Mr. Avinash N. Parde is currently a PhD student at the esteemed Indian Institute of Tropical Meteorology (IITM) in Pune, India, where his primary focus is pioneering advancements in Data Assimilation, particularly in enhancing Fog forecast accuracy. His expertise encompasses Land surface data assimilation, meteorological data assimilation (including Microwave Radiometer and Radiosonde Profiles), and numerical modeling. Additionally, he plays a pivotal role in the Winter Fog Experiment (WiFEX) campaign, contributing significantly to forecasting fog patterns during the winter months in the Indo-Gangetic Plain (IGP) region. Spearheading the development of the operational Ensemble Probability Fog Forecast System (EPFS) at IITM, he provides probabilistic visibility forecasts across major airports in the IGP region. With a commitment to Scholarly pursuits, he has authored over 12 research articles, including five as the lead author, published in esteemed Q1 journals. He is an active member of prestigious organizations such as iLEAPS, the Indian Meteorological Society (IMS) in Pune, and Vigyan Bharti. His professional journey underscores a dedication to advancing meteorological science and leveraging cutting-edge technologies to address critical challenges in weather forecasting and climate research.

Winter Fog EXperiment (WiFEX) in India

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In recent years, the Indo-Gangetic Plain (IGP), one of the world's most densely populated regions, has frequently experienced prolonged and widespread fog activity during the winter months (December-January), with approximately 60% of days characterized by foggy conditions (Ghude et al., 2017). The widespread fog development over this region is associated with deep and extensive atmospheric subsidence, driven by large-scale forcing, which inhibits cloud formation and enhances radiative cooling of the surface and atmosphere (Ghude et al., 2023). This perpetuates stable stratification and turbulence in a shallower stable boundary layer, facilitating saturation through turbulent mixing of heat and moisture between the surface and adjacent air (Dhangar et al., 2021). As a result, the region is notably more prone to radiation fog. Additionally, the region's unique topography, river systems, agricultural practices, and urbanization further enhances the complexity in fog genesis and contribute to different fog phase transitions for weeks, with partial lifting occurring only in the late afternoon. One recent widespread fog spell engulfed the entire IGP region by white blanket of fog/low-clouds for almost 33 days, as depicted in Figure 1. This fog spell is noted as one of the longest fog spells after 2009-10 and 2019-20 winter seasons. Such prolonged widespread fog diminished solar radiation reaching the surface and ultimately escalated the demand for conventional energy sources and indirectly enhanced the pollution level in shallow boundary layers. While dense fog (Visibility < 200 m) episodes are frequently witnessed in the northern part of India, disrupt rail-road-air traffic and impact millions of lives (Kulkarni et al., 2019). The socio-economic impact due to increasing frequency, intensity, and duration of fog activities over the past four decades in northern India has garnered heightened attention.

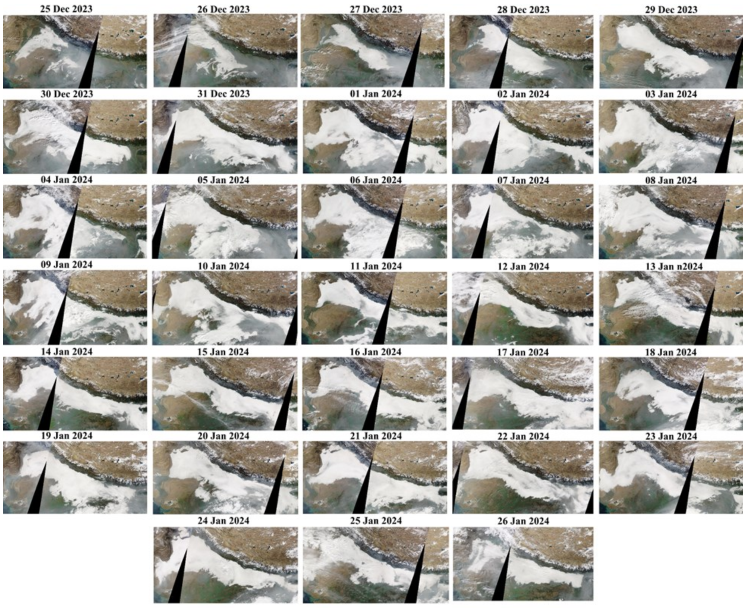

Figure 1. *Fog/low-cloud products from MODIS satellite over the IGP region at 05:30 UTC during 25 December 2023 to 26 Jan 2024.*

By considering the national interests and key research issues, the Ministry of Earth Sciences (MoES), Government of India (GoI), has taken a leading role in comprehending the broad aspects of winter time fog and haze and haze formation over the northern regions of India and in developing a pertinent fog forecasting system to public/private sectors and policy concerns.

In this vein, a brainstorming workshop was organized in September 2015 to discuss the future research which could be pursued by interested institutes, individually or collaboratively. Forty-seven experts from various scientific institutions/universities in India, along with five experts from abroad (participating via webinar), encompassing observationalists and modelers, convened at the workshop to assess its scientific agenda.

These experts endorsed the proposal to conduct a comprehensive field experiment in Delhi over the next five years, aiming to establish linkages between chemical processes, micro-meteorological and boundary layer conditions, and fog microphysical processes. Attention was drawn to

the challenges in the fog prediction with current numerical models. Experts emphasize that the weather prediction models have to be tested and evaluated for several fog episodes and suitable sets of physical parameterization need to be identified to suit the situation and the location of the study. They suggested initiating modeling efforts and improving model capability linking intense measurements from the campaign and specifically designing a modeling framework for the winter fog.

Both the field campaign and modeling experiments were initiated centered around the "Winter Fog Experiment" (WiFEX), conducted at the Indira Gandhi International Airport (IGIA) in New Delhi, India. The WiFEX project aims to investigate various aspects of fog events, shedding light on fundamental questions related to their formation, persistence, dissipation, and the interplay of key factors. The scientific objectives include:

- Analyzing the mechanisms involved in extended-period fog and the subsequent dissipation.
- Exploring the role of microphysical aspects in the fog lifecycle and understanding how boundary layer dynamics influence fog microphysics.
- Assessing the critical values of key parameters such as aerosol concentration, super-saturation, radiative cooling rates, and turbulent mixing for achieving a balance conducive to fog formation.
- Investigating the influence of fog water chemistry and gas–aerosol partitioning throughout the entire fog lifecycle.
- Determining whether there is a hierarchical relationship among these processes
- Assessing the capability of numerical atmospheric models in recreating fog, exploring the necessity of aerosols in the modeling process, and identifying key parameters for effective physical parameterization.

WiFEX commenced as a pilot project (during the winter of 2015-16 December 2015 - January 2016) and continued as an intensive field campaign during subsequent winter seasons (2016-2017, 2017-2018, 2018-19, 2019-20).

The observational campaign involved simultaneous measurements of surface meteorological conditions, surface energy balance, radiation balance, turbulence, thermo-dynamical structure of the surface layer, droplet and aerosol microphysics, aerosol and fog water chemistry, as well as vertical profiles of winds, temperature, and humidity to provide a comprehensive understanding of the fog development environment (Ghude et al., 2017, 2023). The Indian Institute of Tropical Meteorology (IITM) Pune, India Meteorological Department (IMD), Indian Council for Agricultural Research (ICAR) Delhi, Indian Institute of Science Education and Research (IISER) Mohali, and Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Hisar, participated in the observational campaign. The Airport Authority of India (AAI), GMR, IGIA, and Indian Air force (IAF) extended their full cooperation and support for the success of the observational campaign.

For modeling efforts and experimental forecasts, IITM Pune, IMD Delhi, and NCMRWF (National Center for Medium Range Weather Forecasting, Noida) were also involved. Over the course of a 5-year field experiment (2015-2020), real-time deterministic fog forecasts were also conducted over Northern India using the Weather Research and Forecasting (WRF) Model at a 2 km resolution. The model setup included 60 vertically stretched levels, with 20 levels near the surface within the lower 1 km of the atmosphere. Extensive hindcast sensitivity experiments were performed to validate the model configuration, drawing insights from observed fog events during the field campaigns. Optimal physical parameterizations were identified, resulting in improved predictive accuracy, particularly at IGIA (Pithani et al., 2019a, 2019b). The WRF model generated forecasts with a 48-hour lead-time, initialized at 0000 UTC using IITM-GFS initial and boundary conditions. During the winter seasons of 2016–2017, deterministic forecasts relied on liquid water content (LWC) at the model's first level. In contrast, during the subsequent winter (2017-2018), probabilistic forecasts incorporated LWC and model-derived visibility, utilizing 4-member physics ensembles. Details about the deterministic forecast system are provided in Pithani et al. (2020).

Capitalizing the effectiveness of Ensemble Forecast Systems (EFS) in short- and medium-range weather predictions, EFS was implemented for fog forecasting during the winter seasons of 2020–2021 and 2021–2022.

The EFS utilized 21 initial and boundary conditions (ICs/BCs) at 0000 UTC from the Global Ensemble Forecast System (GEFS). The EFS product facilitates probability forecasts of visibility with four different categories (CAT2, CAT3A, CAT3B, and CAT3C) at five main airports in the IGP region. The forecasting domain and detailed workflow of the EFS are depicted in Figure 2. Further details regarding the model setup and framework can be found in Parde et al. (2022).

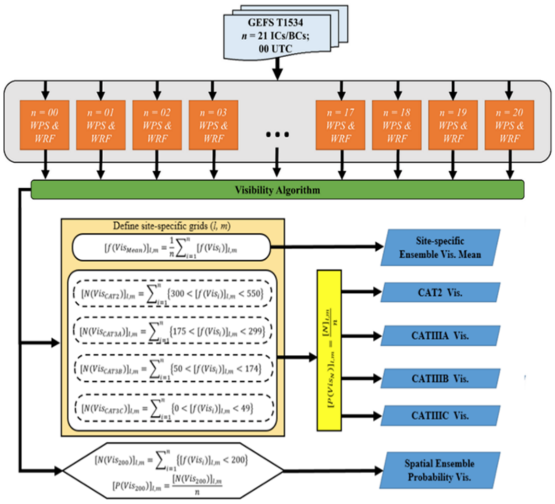

Figure 2. *Schematic flowchart of the operational Ensemble Forecast System (EFS) for fog prediction*

The primary aim of intensive field measurements was to capture the thermo-dynamical and microphysical characteristics of fog events. A total of 89 dense fog events (Visibility < 200 m) were recorded between 2015 and 2020 winter periods. Observations from microwave radiometers (MWR), radiosondes, and tethered balloons highlighted significant variability in the vertical structure of the fog layer and associated thermodynamic features. Profiles of temperature and dew point temperature below 1 km were analyzed for fog, haze, and clear days, revealing that the presence of a deep moist layer is essential for the development of a thick fog layer. The formation of dense and very dense fog over the location was found to be linked to the vertical extent of the moist layer.

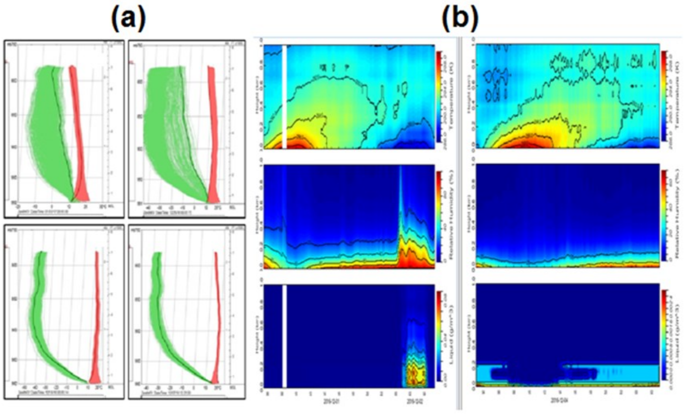

Figure 3. ***(a)*** *Vertical profiles of temperature and dew point temperature during foggy, hazy and clear sky days.* ***(b)*** *Time-height cross-section of temperature, relative humidity and liquid water content during typical foggy and hazy days.*

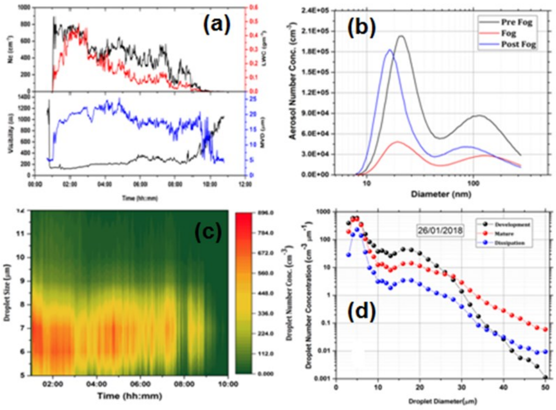

Figure 4. *(a) Evaluation of LWC, droplet number concentration, visibility and mean volume diameter, (b) aerosol size distribution before during and after dense fog, (c) droplet number size distribution during fog period and (d) during development, mature and dissipation phase.*

The MWR the vertical structure of the thick fog layer (~ 400 m) during numerous dense fog events. Substantial temporal variations in fog conditions underscored the dynamic nature of the fog layer.

The features presented in Figure 3 illustrate that a strong low-level temperature inversion (below 400 m) in midnight and rapid humidification, deepening, and persistence of the moist layer typically trigger very dense fog in the early morning hours. Conversely, shallow and sub-saturated moist layers only lead to moderate fog or hazy conditions, even in the presence of a strong low-level inversion at midnight. Significant variations in the temporal and vertical structure of the fog layer indicate its dynamic nature, often eroding from the layer above with nearly 60% humidity. Despite its dynamic behavior, the moist layer remains deep and extensive during dense fog events. The progressive growth of the saturated surface layer in the nocturnal boundary layer pro motes the rapid development and intensification of the initial shallow fog into extremely dense fog. Fog droplets form through aerosol particle nucleation when relative humidity exceeds 100%. Their size distribution evolves during the fog life cycle, influenced by aerosol/CCN number concentration and air mass super-saturation. CCN concentration observations at 5% super-saturation ranged from 1500 to 7000 cm^{-3}, indicating a highly polluted environment. Microphysical properties of fog events exhibit variability in droplet number concentration and effective diameter. Droplet size distribution spans a broad spectrum, with concentrations extending to a diameter of 50 µm, as illustrated in Figure 4 Fog particles grow larger and uniformly increase in number concentration with time, transitioning from non-foggy to foggy conditions. Droplet number concentration decreases between 10 and 30 µm during the mature phase, while larger droplets form, likely through water vapor diffusion or coalescence. Observations show significant droplet numbers exceeding 50 µm and LWC exceeding 0.3 gm^{-3} in two-hour averages. Smaller particles (2-8 µm) exhibit minimal change, while larger droplet concentrations decrease during the dissipation stage, likely due to gravitational settling. These findings highlight the complex interplay of aerosols and different processes throughout various fog event phases. Chemical analysis of aerosols and fog water during foggy conditions in December 2017–February 2018 revealed significant contributions from chloride, nitrate, sulfate, and ammonium to fine aerosol composition, comprising over 97% of total inorganic ionic mass of PM_1 and $PM_{2.5}$. Among trace gasses, SO_2 and NH_3 dominated, with average concentrations of 22.0 ± 12.3 and 25.7 ± 9.1 µg m^{-3}, respectively. NH_4^+ was the primary neutralizer, mainly forming NH_4Cl and NH_4NO_3.

The sulfur oxidation ratio increased under foggy conditions, indicating enhanced SO_2 oxidation and second-

-ry sulfate formation. Carbonaceous constituents showed higher concentrations of secondary organic carbon than primary organic carbon. Aerosol acidity (pH) ranged from 2.19 to 5.83 for PM_1 and 2.55 to 6.54 for $PM_{2.5}$. The average aerosol liquid water content of PM_1 and $PM_{2.5}$ was 169 ± 205

and 324 ± 393 $\mu g\ m^{-3}$, respectively. These parameters significantly influence gas-to-particle partitioning and secondary aerosol formation, particularly in highly humid conditions like wintertime fog.

In the deterministic fog forecast, out of 43 dense fog events (visibility < 200m) during the winters

of 2016-17 and 2017-18, the model accurately predicted 31 fog events. While generally capturing variability in fog onset and lifting over IGIA, deviations in onset, duration, and dissipation were noted in some cases. A significant model case study revealed the WRF Model's limited ability to simulate hydration of water-soluble inorganic ions in subsaturated environments, impacting fog visibility predictions.

Results emphasize the crucial role of chemical processes alongside micrometeorological, thermodynamic, and surface dynamical processes in the fog life cycle. Real-time numerical fog forecasts using WRF during WiFEX 2016–20 achieved approximately 54% accuracy, attributed to issues in initial conditions, boundary layer parameterization, and land surface processes. Compared to single model forecasts, EFS demonstrated higher reliability with a probability threshold > 70% during 2020-21 and 2021-22 winters. However, the diagnostic visibility algorithm in EFS does not include the chemistry information. This was the lacuna of the present EFS. The WiFEX data are expected to serve as a foundation for further research into the physico-chemical parameters affecting fog genesis and its life cycle, thereby addressing the challenges associated with the accuracy of fog forecasting.

Data availability statement

Campaign data is securely housed within the data repository at the Indian Institute of Tropical Meteorology. These datasets adhere to the data sharing guidelines established by the Ministry of Earth Science (MoES), Government of India, and are made publicly accessible. For more details, refer to the guidelines provided at https://ews.tropmet.res.in/wifex/.

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Workshop on "Nature-Based Solutions and Climate Change Mitigation"

The Department of Environmental Science, Hindu College, University of Delhi, Delhi, India, supported by the United Nations Environment Program (UNEP) India Country Office celebrated 50th anniversary of World Environment Day, 5th June, 2023 by organizing a **"Workshop on "Nature -Based Solutions for Climate Change Mitigation".**

The main objectives of this workshop are :

I) To spread basic awareness about Nature-based solutions and climate change mitigation undergraduate students.

ii) To understand about Climate Change Mitigation and Adaptation.

iii) To understand the role of Nature based Solutions in different components of SDGs.

Iv) To encourage the students to come up with their own action plan in terms of Nature based Solutions and Climate Change.

This event was convened by Dr. Pallavi Saxena, Assistant Professor, Department of Environmental Science, Hindu College, University of Delhi with the Patronship of Prof. Anju Srivastava, The Principal, Hindu College, University of Delhi.

The Keynote Speaker of this event was Dr. Alka Bhargava, Senior Policy Advisor, UNEP, TEEB, AgriFood India. Dr. Bhargava talked about her research work on "Sustainable Agriculture for Climate Resilient Landscapes". She explained the different sustainable and nature-friendly techniques in agriculture sector which can help us in solving the problem of climate change in India.To put more light on Climate Crisis and to explain the significant role of NbS in wildlife and biodiversity sector, Mr. Nishant Jain, Senior Program Officer, IUCN, New Delhi, India & Ms. Meenal Pahuja, Conservation Scientist, IUCN, New Delhi, India had delivered their talk on "Harnessing Nature to address the Climate crisis: Decoding the IUCN Global Standard for Nature-based Solutions (NbS)". There was a special session for students "Group Presentation on Different Topics of Nature-Based Solutions" where students had presented their thoughts on different techniques of NbS and Climate Change Mitigation. By taking the theme of SRI 2022 and SRI 2023 session and this workshop, we have announced one special issue on "The Intersection of Air Quality and Atmospheric Chemistry with Sustainable Development" under the section "Earth and Environronmental Sciences" in Discover Applied Sciences, Springer-Nature in October 2023.

This issue is edited by Dr. Pallavi Saxena, iLEAPS SSC Member, Dr. Saurabh Sonwani, iLEAPS Early Career South Asia and Middle Esat Chair Representative, Dr. Langley Dewitt, IGAC Director, Dr. Semeena V. Shamsudheen, IPO, iLEAPS, Dr. Andriannah Mbandi, SSC Member, IGAC and Dr. Cathy Liousse, GEIA Co-Chair. This issue will be completed by 31st July 2024.

iLEAPS built capacity to develop Dust Forecasting System for Qatar for FIFA 2023 World Cup

The staging of the 2022 FIFA World Cup in Doha, Qatar, from November 20th to December 18th, 2022, marked a momentous global event. Recognizing the paramount importance of this occasion, the Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS), in collaboration with the Indian Institute of Tropical Meteorology Pune (IITM) and the Qatar Meteorology Department (QMD) of the Civil Aviation Authority, Doha, undertook a joint initiative.

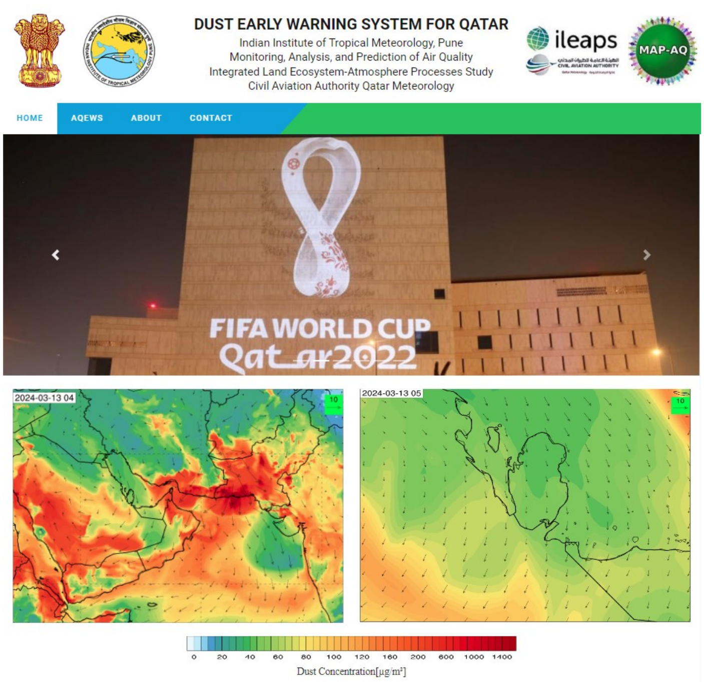
The collaborative effort resulted in the development and implementation of an advanced operational dust forecast system tailored for Qatar and its surrounding regions.

Specifically designed to cater to the unique requirements of the FIFA World Cup, this system provided precise dust forecasts with a lead time of 96 hours.

These forecasts were effectively disseminated through a dedicated website [https:ews.tropmet.res.in/qatar/index.php].

The efficacy of the forecast was evident, successfully capturing pivotal dust events. In the aftermath of this success, iLEAPS orchestrated a program for capacity building, facilitating a visit by their early career scientists (Dr. Rajmal Jat and Praful Yadav) from IITM Pune to QMD in Doha. During this collaborative visit, comprehensive training sessions were conducted, imparting knowledge on the development and implementation of the dust forecast system. A direct outcome of this initiative is the newfound capability of QMD to independently generate daily dust forecasts for the state of Qatar and its adjacent regions.

This collaborative initiative stands testament to the commitment of iLEAPS and its esteemed partners in advancing scientific capabilities and contributing to the success of globally significant events.



iLEAPS Global Colloquium Series 2024

Elena Paoletti is Research Director at the National Research Council of Italy and Responsible of the Florence Branch of the Institute of Research on Terrestrial Ecosystems. She is a forest ecophysiologist with research and teaching experience on air pollution, climate change and vegetation in many countries, e.g. China, Japan,USA, Switzerland. She is member of the Board of the European Forest Institute (EFI), and member of the Management Committee of the International Union of Forest Research Organizations (IUFRO) where also chairs the honors and awards committee and the scientific committee of the IUFRO World Congress in Sweden 2024.She is Editor-in-chief of Science of the Total Environment (IF 2023 = 9.8) and has many other editorial commitments. She is an active mentor of young scientists from all over the world. Elena has published 270 peer-reviewed papers, in journals like Nature Food, Science Advances, Global Change Biology, Environmental Pollution; her Scopus h-index is 56. Her main scientific interest at present is on tropospheric ozone impacts on vegetation, including developing novel tools and approaches for such studies (e.g. free-air systems, epidemiological impacts, protectants), as well as interactions of ozone and urban vegetation.

Abstract: Ozone is a very oxidative gas and is a secondary pollutant, i.e. it is not directly emitted from the sources . Despite significant efforts in reducing the emission of precursors, we will show that tropospheric ozone is still an issue for vegetation health, especially in Asia and Africa. Here we will review the indices (exposure-based such as AOT40 and stomata! flux-based such as PODy) and the approaches (free-a ir systems , epidemiological monitoring, used of anti-oxidants), that have been developed to assess such risks, and summarize the latest results about the effects on biodiversity, stomata! control and carbon sequestration of terrestrial plant ecosystems . Air quality improvement by using urban green infrastructure will be also discussed in terms of species-specific biogenic volatile emissions.

iLEAPS Global Interview Series: Drive with iLEAPS On Wheels of Science

This year, iLEAPS Global Interview Series: Drive with iLEAPS On Wheels of Science has completed its 4th epi-sode with Dr. Juichi Yamagiwa, Director-General, Research Institute for Hu-manity and Nature (RIHN), Japan on 31st January, 2024.

Upcoming Events

- **International Training Cum Workshop:** on "Air Pollution and Climate Change Mitigation by Using Vegetation Based Models": Organizing One Day International Training Cum Workshop on "Air Pollution and Climate Change Mitigation by Using Vegetation Based Models" on 14th March, 2024 at Department of Environmental Science, Hindu College, University of Delhi, Delhi, India supported by United States Forest Service (USFS), US. This event is convened by Pallavi Saxena, SSC Member, iLEAPS.

- **Session in EGU 2024:** Organizing iLEAPS collaborated Sheffield University, UK PICO Session BG8.17 "Urban Ecosystem Dynamics: Challenges and Advances" in EGU 2024, Vienna, Austria on 19th April 2024. This session is convened by Pallavi Saxena, SSC Member, iLEAPS and co-convened by Saurabh Sonwani, iLEAPS Early Career Chair Representative of South Asia and Middle East, Semeena V. Shamsudheen, iLEAPS IPO, Holly Croft, Kadmiel Maseyk, Philip Wheeler, Jill Edmondson from Sheffield University, UK.

- **Session in SRI 2024:** Organizing iLEAPS collaborated Future Earth Finance & Economics KAN Session #3115 on "Heterogenous Role of Urban Blue Green Space on Public Health and Environmental Sustainability" in SRI 2024, in Helsinki, Finland, June 10-14, 2024. This session is convened by Pallavi Saxena, SSC Member, iLEAPS and co-convened by Saurabh Sonwani, iLEAPS Early Career Chair Representative of South Asia and Middle East, Semeena V. Shamsudheen, iLEAPS IPO and Jurgen van der Heijden, senior consultant at TNO, the Dutch Organization for Applied Scientific Research, affiliate with Govern EUR at Erasmus University Rotterdam, member of Future Earth Finance & Economics KAN.

- **iLEAPS-BBURNED workshop in association with IGAC Open Science Conference (iCACGP-IGAC 2024 – Kuala Lumpur):** The international initiatives BBURNED and iLEAPS will host a joint 2-full-day workshop will be held on 14-15 September 2024 in Hybrid / Kuala Lumpur, Malaysia on biomass burning/fires that will be focused on the themes of variability and uncertainty in fire emissions, atmospheric chemistry and processes, and modelling. The workshop aim is to identify fire uncertainty related questions and preliminary/ongoing science and kick off a multidisciplinary special journal issue. Workshop purposes are to i) present cutting-edge interdisciplinary/convergent fire science in sessions related to emissions, chemistry, and modelling, and ii) jointly identify fire uncertainty science questions, including current and future work in this area. Workshop outcomes will include the launch of a multi-journal, multi-disciplinary special issue for papers on the topic of fire uncertainty.

- **GEWEX Open Science Conference:** The 9th Global Energy and Water Exchanges (GEWEX) Open Science Conference, is organized under the auspices of the Global Energy and Water Exchanges (GEWEX) core project of the World Climate Research Programme together with Hokkaido University and Science Council of Japan. The conference will take place from 7 to 12 July 2024 at the Keio Plaza Hotel in Sapporo, Japan. The conference is organized around three themes: 1. Water, Climate, Anthropocene 2. Extremes and Risks Waterr 3. Energy and Carbon Processes

In the context of the conference themes, the sessions will focus on research that contribute to the following areas:

i. Determination of the extent to which Earth's water cycle can be observed and predicted

ii. Quantification of the inter-relationships between Earth's energy, water and carbon cycles to advance our understanding of the system and our ability to predict it across scales

iii. Quantification of the anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle

iv. Extremes in the water cycle and risks to society

Young Scientist Award

Dr. Saurabh Sonwani, Chair, iLEAPS Early Career Scientist, South Asia and the Middle East

Dr. Saurabh Sonwani, iLEAPS Early Career Scientist representative of the South Asia and the Middle East Region has been awarded the "**Young Scientist Award**" for outstanding contribution to Environment and Sustainable Development by the Society for Science of Climate Change & Sustainable Environment (SSCE) at the WNO NEEM Summit 2024. He is currently working as Assistant Professor at Department of Environmental Studies, Zakir Husain Delhi College, University of Delhi, New Delhi, India. This honor reflects his unwavering commitment to Air Quality, Health and Sustainability is impactful work within the environment discipline.

The Neem Summit & Global Neem Trade fair is being organized by collaboration with ICAR-Central Agroforestry Research Institute, Jhansi in New Delhi on 19-20 February 2024. The accolade was bestowed by Dr. Akhilesh Gupta,

Senior Adviser at the Department of Science and Technology, Government of India, and Dr. S K Chaudhary, Deputy Director General, (Natural Resource Management), Indian Council of Agricultural Research.

The event began with the opening of a Trade Fair by Secretary, DARE and DG, ICAR Dr Himanshu Pathak. 22 companies participated in the trade fair from India and abroad who showcased their products. Following this, Secretary, DARE and DG, ICAR Dr. Himanshu Pathak inaugurated the Neem Summit along with Guests of Honour - Dr. P.K. Singh, Agricultural Production Commissioner, and Justice Honorable K.T. Tated, Chairman, Human Rights Commission, Government of Maharashtra, India. This Summit has a special session of WNO and SSCE award ceremony for outstanding contributions in the field of Climate Change, Environment and Sustainability. These SSCE awards were presented by Dr. Suresh Kumar Chaudhari, Deputy Director General (Natural Resource Management), ICAR. Picture taken during the award ceremony .

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Early Career Spotlight

Pooja Pawar has been nominated and selected as one of the Early Career Researchers (ECRs) from INDIA for the world's top decision making body on the environment United Nations Environment Programme (UNEP) - sixth session of the United Nations Environment Assembly (UNEA-6) for her outstanding Ph.D. research work under guidance of Dr. Sachin D Ghude in N2024. She is focussing on air pollution policies globally and over South Asia at the Global Major Groups and Stakeholders Forum and the main UNEA -6. She has been granted full funding support by the Natural Environmental Research Council (NERC) South Asian Nitrogen Hub (SANH).

Ms. Pooja is attending UNEA-6 assembly, scheduled from February 26th to March 1st 2024, at the UNEP headquarters in Nairobi, Kenya, promises to be an invaluable platform for global discourse on upcoming air pollution challenges and solutions.

She actively interacted with international and national experts. In UNEA-6 she has been mentored by Prof. Mark A. Sutton (Director, SANH/INMS/GEF/UNEP) to prepare for Nitrogen science-policy development in global level. She actively interacted with additional secretory MOEFCC (Govt. of India) Shri Naresh Pal Gangwar, Joint Secretary MOEFCC Shri Neelesh Sah, Director Ved Prakash Mishra and Dr. Satyendra Kumar MOEFCC, India.

Spotlight on LMICs – The Future's Juggernaut: Positioning Research as Anchors for Environmental Health

Dr. Gregor Feig

As the global population grows, the well-being of modern human societies continues to be dependent on available natural resources. Many regions are facing and attempting to mitigate the impacts of increasingly frequent and damaging climatic events including heat waves, extended droughts, storms, or changes in rainfall distribution and intensity. An enhanced understanding of fundamental processes should be used to discern best practices, guidelines, regulations, or policy briefs that are the basis of mitigation and/or adaptation measures. However, there are notable knowledge gaps in research with those issues magnified in underrepresented regions.

Dr. Gregor Feig set out to summarize the development of Research Infrastructure (RI) over the last three decades in Southern Africa and take it a step further by assessing how the successful maintenance and further implementation of RIs may turn them into important anchor points for the positioning and long-term development of environmental scientific work in support of environmental sustainability, national commitments, and societal well-being. Dr. Gregor Feig set out to summarize the development of Research Infrastructure (RI) over the last three decades in Southern Africa and take it a step further by assessing how the successful maintenance and further implementation of RIs may turn them into important anchor points for the positioning and long-term development of environmental scientific work in support of environmental sustainability, national commitments, and societal well-being. The study also outlines the importance of understanding the impact on the environment, science, and society that a fully functional RI is able to cause and provides an example of potential key indicators using the Integrated Carbon Observation System as a model:

- Producing standardized high-precision long-term observational data
- Stimulating scientific studies and modeling efforts and providing a platform for data analysis and synthesis
- Communicating science-based knowledge toward society and contributing timely information relevant to the greenhouse gas policy and decision making
- Promoting technical developments
- Ensuring high visibility of the RI

As large amounts of data are required across a broad range of intersecting disciplines to effectively address emerging global challenges, the impact of this study can provide the framework for the use of RIs to mitigate the impact on environmental health.

Dr. Feig is a part of the Integrated Land Ecosystem-Atmosphere Processes Study (ILEAPS) Global Research Network of Future Earth. He has done research in the fields of air quality management, biogeochemistry, climate change impacts and land-vegetation-atmosphere interactions and is focused on the management of observation infrastructure. Dr. Feig is a Manager at the South African Environmental Observation Network (SAEON).

SSC Members: Awards, Honours, and Recognitions

Gemma Purser

Awarded 2024 BIOS Postdoctoral Fellowship among other outstanding postdocs for interdisciplinary research work on "Investigating the role of urban forest soils in mitigating atmospheric volatile organic compound driven air pollution in cities". This will start a collaborative independent research project with Urban Biogeochemistry program at Boston University and Aerodyne Research, Inc. (ARI) to study the interplay between urban green spaces and volatile organic compounds in improving air quality. She will use the funds to conduct soil experiments using advanced mass spectrometer instrumentation at ARI and work with Boston University to further develop her microbial analysis techniques.

Pallavi Saxena

GEIA SSC Member:

Selected as Scientific Steering Committee Member of The Global Emissions InitiAtive (GEIA), a community effort dedicated to emissions information exchange and competence building, was created in 1990 under the International Geosphere-Biosphere Programme (IGBP) and is now an IGAC activity. This position is effective from 20th October, 2023. For more details, please visit https://www.geiacenter.org/leadership

Rachna Kulkarni

IGAC Early Career SSC Member:

Selected as Early Career Scientific Steering Committee Member of IGAC. She is also iLEAPS Early Career Researcher. Rachana is a highly respected independent air quality researcher with a strong focus on understanding the microphysical and chemical properties that influence air quality. She has made significant contributions to the field through her work on the Winter Fog Experiment (WiFEX) project at the IGI Airport in India, one of the busiest and most populated airports in the country. As part of the IGAC project, Rachana ensures that the team is meeting its goals and making meaningful contributions to the scientific community. Her research has been crucial in informing policies and practices related to air quality and public health.

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