



京都大学防災研究所
Disaster Prevention Research Institute
Kyoto University

国際共同研究(一般)

2024IG-02

インド北東部プレモンスーン シビアストーム災害の予測と 気候変動影響評価の革新

Innovation in Predictability and
Climate Projection of Hazards due to
Extreme Severe Storms Developing
over the Northeastern India in
Premonsoon Season

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研究代表者 ラフル マハンタ

Coordinator Rahul Mahanta

International Collaborative Research (Project No. 2024IG-02)

Project Title : Innovation in predictability and climate projection of hazards due to extreme severe storms developing over the Northeastern India in premonsoon season

Principal Investigator : MAHANTA Rahul

Affiliation : Department of Physics, Cotton University

Name of the DPRI Contact Person : Prof. Tetsuya Takemi

Research Period / Duration of Stay : Apr. 1, 2024 – Mar. 31, 2026

Research Location / Location of Stay : Northeastern India

Number of the Participants in the Project: 20 (DPRI: 3 / non-DPRI: 17)

Anticipated Impact on Research and Education

This collaborative project has significantly advanced monsoon science and predictive hazard modeling for the Northeast Indian subcontinent. By integrating intensive international field campaigns with advanced numerical modeling, the project has provided essential training for the next generation of researchers, including graduate students and early-career scientists. These activities have not only enhanced international cooperation in hydroclimatological research but also fostered a robust scientific foundation for regional disaster resilience and climate adaptation.

Research Report

(1) Purpose

This research advances a fundamental paradigm shift in Asian meteorology by redefining the "premonsoon" of Northeastern India as the early establishment of the Asian monsoon rather than a transitional phase. This reclassification is scientifically justified by the region's intense land-atmosphere coupling, where active evapotranspiration serves as an intrinsic moisture source that drives internal moisture recycling and fuels convective development. The strategic importance of this study is framed by Japanese Prime Minister Kishida's 2023 statement, which identified Northeastern India as a priority for India-Japan collaborative efforts. By integrating observational data via initiatives like AsiaPEX, the project addresses the high degree of uncertainty in climate projections for this hotspot, aiming to significantly improve the predictability and mitigation of lethal hazards such as lightning and flash floods through enhanced early warning capabilities.

(2) Summary of Research Progress

3.1 Tier 1: Hazard Analysis and Database Development

The project established a technical foundation for multi-decadal hazard assessment by developing a comprehensive 25-year (2001–2025) storm-event database. To

overcome the scarcity of long-term instrumental records in the Eastern Himalayan foothills, the team utilized a methodology involving the manual extraction of reports from regional newspapers, such as The Assam Tribune, The Sentinel, and Nagaland Page, validated against ERA5 reanalysis data. This rigorous process identified 408 confirmed severe events, revealing that April is the peak month for thunderstorm activity and that lightning remains the region's deadliest hazard. Furthermore, the analysis documented a post-2000 escalation in humid heatwaves across the Northeast India–Bangladesh corridor and identified 39 distinct cloudburst events ($\geq 100 \text{ mm h}^{-1}$) through the SOHMON rainfall monitoring network.

3.2 Tier 2: Meteorological Innovation and Intensive Observations

Progress in observational science focused on the characterization of Mesoscale Convective Systems (MCSs), identifying over 300 annual events with a notable increase in intensity during the May–June transition to the mature monsoon. Intensive four-times daily rawin-sonde observations were conducted at Guwahati during the 2024 and 2025 premonsoon seasons to capture high-resolution thermodynamic profiles. A primary scientific highlight from these observations was the identification of a thick, highly heated humid airmass in the lower troposphere with an equivalent potential temperature exceeding 370 K. Additionally, disdrometers deployed on the Meghalaya plateau provided critical ground-truth data for the validation of satellite-based precipitation estimates, particularly for the Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar.

3.3 Tier 3: Advanced Predictive Modeling and HPC Implementation

The computational component of the project involved the deployment of the Weather Research and Forecasting (WRF) model on Google High-Performance Computing (HPC) for big data processing and multi-scale simulations. This technical infrastructure enabled the integration of satellite data assimilation and sensitivity experiments for microphysics and electrification schemes. To refine the modeling of the premonsoon-to-monsoon transition, the team incorporated high-temporal resolution GNSS precipitable water data obtained from a newly utilized station in Itanagar, Arunachal Pradesh.

International workshops and collaborative synergy in our research project are summarized as follows:

- **Workshop on Coordinated Observations and Modelling Strategies for Premonsoon Severe Storms (March 5, 2025):** This event established a collaborative research roadmap and identified critical gaps in thunderstorm dynamics and radar observations between experts from India, Japan, and Bangladesh.
- **Workshop on Disasters due to Premonsoon Severe Local Storms over the Northeastern Indian Subcontinent:** This series of five technical sessions

facilitated a multi-national exchange on long-term climate variability, cloudburst risks, and disaster prevention strategies for the region.

- **Extreme Events in a Changing Climate: Bridging Prediction, Risk, and Resilience in the Eastern Himalayas (February 14–15, 2026):** This workshop enhanced regional cooperation across five nations by focusing on science-based policy development and the integration of AI-based forecasting for Himalayan weather extremes.

(3) Summary of Research Findings

Rising Hazard Trends: Empirical analysis confirms a significant 20-year increase in the frequency and severity of premonsoon heavy rainfall and lightning events.

MCS Intensity: Premonsoon MCSs exhibit higher intensity and an earlier diurnal development cycle compared to systems observed during the mature monsoon phase.

The TTL Discovery: Intensive rawin-sonde observations revealed unique atmospheric structures in the Tropical Tropopause Layer (TTL)—specifically a nearly isentropic layer with weak wind speeds representing convective detrainments—which were successfully reproduced and validated both in sonde and WRF model outputs.

Topographic Modeling Constraints: Accurate simulation of convective storms in the Eastern Himalayas requires localized, high-resolution microphysics and electrification schemes to account for the complex mountainous topography.

(4) Publications of Research Findings

Prolay Saha, R. Mahanta, and B. N. Goswami (2023a): Present and future of the South Asian summer monsoon's rainy season over Northeast India. *npj. Clim. Atmos. Sci.* , 6, 170.

Prolay Saha, R. Mahanta, P. V. Rajesh and B. N. Goswami (2023b): Persistent Wet and Dry Spells of Indian Summer Monsoon Rainfall: A Reexamination of Definitions of “Active” and “Break” Events. *J. Climate* , 36, 261-277.

Unashish Mondal, Sreelekshmi S., S. K. Panda, Anish Kumar, Someshwar Das, Devesh Sharma (2023): Diurnal variations in lightning over India and three lightning hotspots: A climatological study. *J. Atmos. Sol. Terr. Phys.* , 252, 106149.

Unashish Mondal, S. K. Panda, Someshwar Das and Devesh Sharma (2022): Spatio-temporal variability of lightning climatology and its association with thunderstorm indices over India. *Theor. Appl. Climatol.* , 149, 273-289.

Terao, T., S. Das, S. Dutta, A. Fukushima, H. Kamimera, M. Kiguchi, et al. (2023): AsiaPEX: Challenges and Prospects in Asian Precipitation Research. *Bulletin of the American Meteorological Society* , 104, E884.

Kumar, Anish, S. K. Panda, Unashish Mondal, Devesh Sharma, and Someshwar Das (2023): Assessment of model time step and domain resolution of WRF model to simulate the lightning over Bihar and Rajasthan, India. *Model. Earth Syst. Env.* , 9, 3959-3984.

Murata, F., T. Terao, Y. Yamane, A. Fukushima, M. Kiguchi, M. Tanoue, H. Kamimera, H. J. Syiemlieh and L. Cajee (2024): Validation of spaceborne precipitation radar data by rain gauges and disdrometers over the complex topography of the northeastern Indian subcontinent. *J. Meteor. Soc. Japan* , 102, 309-329.

Mondal, U., S. K. Panda, T. Terao, K. Manush, S. Devesh (2024): Evaluating the performance and detection efficiency of Weather Research Forecasting model with lightning parameterization schemes for identifying lightning hotspots over Northeast region in India. *Clim. Dyn.* , 62, 10381-10404.

Kamimera, H., Y. Yamane (2025): Weather Radar Networks and Their Use in Monitoring Severe Storms in the Northeast Indian Subcontinent: Status and Expectations.

Someshwar Das (ed.), *Severe Storms* , 107-126.

Saha, P., (2025): Post-2000 Escalation of Humid Heatwaves and Emerging Cloudburst Risks across the South Asia. *Asian Journal of Engineering Geology* , 3, (in-press), 157-158.

Murata, F., T. Terao, H. J. Syiemlieh and L. Cajee, S. S. Kundu, S. A. Choudhury, S. Md. S. Hossain, Md. S. H. Bhuiyan and Md. M. Islam (2026): Linking rainfall microphysics to intensity using the Dm-R-Nw relationship over the northeastern Indian subcontinent: Implications for GPM DPR retrievals. *SOLA* , 22, 24.

Akshara, N. G., Arunkumar R., S. K. Panda, T. Terao, A. Sharma, U. Mondal and D. Sharma (2026): Regional Shifts in Precipitation Patterns and Indices in North East India. *Asian Journal of Engineering Geology* , 3, (in-press).

Gogoi, A. K., S. K. Panda, Arunkumar R., T. Terao, R. Mahanta (2026): Seasonal Changes in Precipitable Water and Its Influence on Total Precipitation: Linkages with Climate Modes over the Northeastern Region of India. *SOLA* , 22, 26. This research was supported by the General Collaborative Research (Project No. 2024IG-02) of the Disaster Prevention Research Institute, Kyoto University.