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Managing Monsoons in a Warming Climate

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ACRONYMS

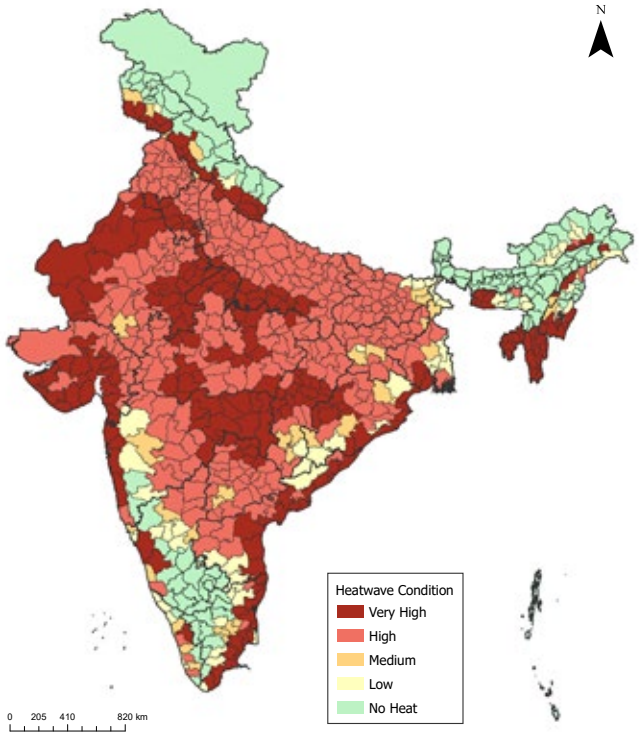
DDMC	District Disaster Management Committees
ECMWF	European Centre for Medium-Range Weather Forecasts
ENSO	El Niño–Southern Oscillation
ERA5	Fifth generation ECMWF Reanalysis
FSB	Financial Stability Board
GDP	Gross Domestic Product
HRO	Heat Risk Observatory
HW	Heatwave/s
IE	Incessant Erratic (rainfall)
ICAR	Indian Council of Agricultural Research
IITM	Indian Institute of Tropical Meteorology
ILO	International Labour Organization
IMD	India Meteorological Department
IMDAA	Indian Monsoon Data Assimilation and Analysis
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
ISRO	Indian Space Research Organisation
JF	January, February
JJAS	June, July, August, September
LLM	Large Language Models
LULC	Land Use and Land Cover
MAM	March, April, May
MAMJ	March, April, May, June
NASA	National Aeronautics and Space Administration
NCMRWF	National Centre for Medium-Range Weather Forecasting
NDC	Nationally Determined Contributions
NOAA	National Oceanic and Atmospheric Administration
NRSC	National Remote Sensing Centre
OND	October, November, December
SEDAC	NASA Socioeconomic Data and Applications Center
SST	Sea Surface Temperature
TCFD	Task Force on Climate-Related Financial Disclosures
USGS	United States Geological Survey
WMO	World Meteorological Organization

Executive Summary

Global warming has caused a significant rise in global surface temperatures over the past few decades, which has also increased atmospheric humidity. This trend has led to a higher incidence of heatwaves around the world, particularly in tropical areas. Heatwaves—meteorological extreme weather events—are most commonly observed in India during the summer months (March, April, May or MAM). Long-term projections indicate that Indian heatwaves could cross the survivability limit for a healthy human resting in the shade by 2050; if the intensity and prevalence of heatwaves in India continue to increase, they could potentially impact around 500 million people (Debnath, Bardhan, and Bell 2023). Forecasts suggest that if the pledges made in the 2015 Paris Agreement are not fulfilled, the global temperature is likely to rise beyond 3°C by the close of the 21st century (Singh, Yadav, and Kumar Goyal 2024). This will have disastrous implications for India in terms of extreme weather events.

As India is trending toward hotter summers, the northeastern, eastern, central, and north-western parts of India are expected to witness heatwaves in the coming decades. The first tranche of the Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report indicates that the Indian subcontinent will experience calamitous consequences if the global temperature breaches the 3°C mark, increased dry spells, intensification of extreme rainfall by more than 20 per cent, and an exponential surge in heatwave and cyclonic events.

Figure ES1. More than 84 per cent of the districts in India are heatwave hotspots



Source: Author's analysis

Climate change is rapidly altering Indian districts' risk of experiencing slow onset events in contrast to their prior experience of 0.6°C rise in the last hundred years (India Meteorological Department, Pattanaik et al. 2019). Our study undertook a first-of-its-kind, multi-decadal, regional, climatological assessment to map heatwave hotspots and understand how its attributional in triggering extreme rainfall events. We used spatial and temporal modelling to develop a district-level seasonal assessment to explain the complexities and non-linear trends and patterns associated with heatwaves and extreme rainfall events. First, we developed a region-specific temperature thresholds roster on a multi-decadal time scale to identify district-level hotspots. Thereafter, we conducted a seasonal climatological analysis using coarse-grain resolution temporal maps to identify micro-seasonal variations.

Our study also aimed to generate empirical evidence on how temperature rise is aggravating extreme rainfall events. We hypothesise that India is witnessing an extended summer season in the monsoon seasons beyond rainy days. We believe that, overall, India is witnessing an extended summer-like condition in the June, July, August, and September (JJAS) months. In particular, we found that districts located in the plains and in hilly regions are witnessing these trends-which has deterrent impacts on lives, livelihoods and economic sectors. These trends align with findings from various studies that show that land surface temperatures across India have been rising (Naveena et al. 2021).

Table ES1. Overall region-specific district heatwave hotspots

Region	District hotspots
Coast	Sivaganga, Nellore, Ahmedabad, Morbi, Pudukkottai, Thanjavur, Kanchipuram, Villupuram, Gandhinagar, Kheda
Plains	Anupgarh, Jaisalmer, Bikaner, Pratapgarh, Botad, Mahoba, Hanumangarh, Ganganagar, Hamirpur, Bundi
Hills	Haridwar, Udam Singh Nagar, Unakoti, West Tripura, Jammu, Sepahijala, Samba, Khowai, Gomati, South Tripura

Source: Author's analysis

We also conducted a land sensitivity assessment that found that more than 55 per cent of land use and land cover (LULC) change in India is concentrated in hotspot districts. We believe that anthropocentric activities are contributing to this large-scale change in climatic patterns. Table ES1 lists the region-wise extreme heatwave hotspots.

In this study, we also provide an empirical assessment of heat stress by identifying hotspots at the district level and undertaking a cascading mapping of incessant and erratic rainfall events across these hotspots. Some of the hotspot states that have been witnessing both extreme heatwaves and erratic incessant rainfall events are Gujarat, Rajasthan, Uttarakhand, Himachal Pradesh, Maharashtra, Uttar Pradesh, Meghalaya, and Manipur. Through our analysis, we found that more than 84 per cent of Indian districts can be considered extreme heatwave hotspots, of which around 70 per cent have witnessed incessant and erratic rainfall more recurrently in the last three decades in the monsoon season JJAS. Further, in October, November, and December (OND), more than 62 per cent of heatwave-prone Indian districts have been witnessing erratic and incessant rainfall. The increase in atmospheric temperatures and humidity increases the likelihood of heatwaves globally, especially in tropical regions. Heatwaves—one of the most dangerous extreme weather events—are most common during the summer months (March, April, May, June or MAMJ) in India. These events occur due to prolonged periods of high and above-normal temperatures and become particularly hazardous when accompanied by high humidity. This combination severely impacts various sectors. Based on our analysis, we make the following recommendations:

Estimates by the International Labour Organization (ILO) suggest that ***India is on the brink of losing more than 40 million jobs by 2030*** due to extreme heatwaves.

Establishing a Heat Risk Observatory (HRO)

India needs to establish a heat risk observatory (HRO) to map heat risks. The HRO is a risk-informed decision-making (investment, policy and planning decisions) toolkit for decision-makers at the district and city levels and an initiative of the National Resilience Programme. Such an observatory can help in identifying, assessing, and projecting chronic and acute heat risks at a hyper-granular level to better prepare against heat-related extremities such as urban heat islands, water stress, vector-borne diseases, crop loss, and biodiversity and ecosystem collapse. We suggest that the HRO will enable heatwaves index–based emergency surveillance. IPE Global and Esri India are already devising India's first "Multi-Hazard Risk Atlas" for Mumbai city for the Government of Maharashtra, which will be integrated into its state-of-the-art command and control centre. This tool will have all the intrinsic components of an HRO. Furthermore, an HRO will help limit the underestimation of economic, social, health, and financial losses due to heat stress.

Devising risk financing instruments to mitigate heat risk and extreme rainfall events

To address the socio-economic risks posed by extreme rainfall and other extreme events, India must adopt a proactive approach that integrates blended finance strategies. The Reserve Bank of India is closely monitoring El Niño trends and monsoonal patterns because these phenomena have significant implications for the exchequer. By blending public and private capital, India can better understand and assess the financial risks associated with monsoonal variability through the mandatory reporting of the Task Force on Climate-related Financial Disclosures (TCFD) as stated by the Financial Stability Board (FSB). This will enable lenders, insurers, and regulatory authorities to make risk-informed business decisions, foster resilient value chains, and minimise loss and damage. Moreover, embracing blended finance mechanisms enhances sectoral resilience and facilitates the establishment of effective risk-transfer mechanisms, providing a much-needed financial cushion for absorbing shocks from climatological disruptions such as extreme heat and rainfall events.

Appointing heat-risk-champion within district disaster management committees to enhance citizen engagement and drive behavioural change

Although disaster departments are responsible for managing heatwaves-related preparedness, they often fail to implement a coordinated response, which hinders their ability to map and address the most critical issues effectively. In turn, it becomes difficult for them to align efforts with community organisations and other stakeholders and

help insulate communities against the growing magnanimity of heat stress. Further, it is crucial to incorporate the dissemination of credible heat-related information into community planning. Thus, appointing a heat risk champion within district disaster management committees (DDMC), who can prioritise and unify the heat-risk mitigation efforts at the district level, will accelerate heat resilience in communities. Globally, such models of appointing city-level heat risk officers are known to mainstream heat-risk management better.

India urgently needs national and subnational strategies to heat-proof its population and economy. If a 1.5°C warmer climate is inevitable, we must brace for its impacts and ensure that we have the means to rebuild better and faster when disaster strikes. India is aggressively pursuing its Nationally Determined Contributions (NDCs) goals and enhancing its carbon sink, but it still needs a razor-sharp focus when managing extreme heat and rainfall events. As heatwaves intensify in a fast-changing climate scenario, managing heatwaves and extreme rainfall events should become a national imperative.

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[1]The Financial Stability Board is an international body that monitors and makes recommendations about the global financial system. It was established in the 2009 G20 Pittsburgh Summit as a successor to the Financial Stability Forum. The Board includes all G20 major economies.

[2]Arsht-Rock created and piloted the world's first chief heat officer (CHO) positions. CHOs are officials focused on delivering a unified response to extreme heat to safeguard their cities.

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