Document No. STI-FF/06/2025

# HEATWAVES

## Impacts and Implications on the Developing World

(A NAM S&T Centre - SAMA Fact File for Dissemination of Information on Science, Technology and Innovation in NAM and Other Developing Countries)

## FROM THE DG'S DESK

Warmest Greetings to our Esteemed Readers!

I am pleased to present the latest Fact File titled "Heatwaves: Impacts and Implications on the Developing World" brought out by the NAM S&T Centre in collaboration with the South Asian Meteorological Association (SAMA), New Delhi.

As climate change intensifies, heatwaves are becoming a pressing global issue, particularly impacting developing countries. This Fact File outlines the alarming rise in the frequency and intensity of heatwaves, highlighting their detrimental effects on health, agriculture, water resources and economic stability, especially for vulnerable populations.

Key findings indicate that extreme heat events can lead to increased mortality rates, reduced agricultural productivity and heightened water scarcity. The Fact File emphasizes the urgent need for tailored "Heat Action Plans" and effective early warning systems to mitigate these impacts. Urban areas, particularly in South Asia are especially vulnerable due to the "Urban Heat Island Effect", highlighting the necessity for localized strategies such as early warning systems and public awareness campaigns.

I would like to take this opportunity to extend my heartfelt thanks to the Editor AVM (Retd.) Prof. Ajit Tyagi and other contributors, including Dr. Poulomi Chakravarty, Prof. Someshwar Das, Dr. Swagata Payra and Dr. Mohan Kumar Das from the South Asian Meteorological Association (SAMA) for their valuable insights.

I hope our readers will find the information on such an important topic interesting and useful.

Amitava Bandopadhyay

**(Amitava Bandopadhyay)**

## Overview

Heatwaves are a growing global threat with increasing frequency, intensity and duration due to climate change. They pose significant risks to human health, agriculture, water resources, energy supply and economies, particularly in developing countries. While there is no universally accepted definition of a heatwave, it is generally understood as periods of unusually hot and dry or hot and humid weather lasting at least two to three days, with significant impacts on human and natural systems. The absence of a universal definition reflects the variability in extreme heat conditions across different regions and climates [1]. Hence, region-specific thresholds and criteria based on local meteorological and health data are necessary. Typically, high pressure/Anticyclone causing subsidence keeps hot air close to ground, clear skies, dry weather, winds from hotter regions and El Niño are favorable conditions for the development of heatwaves. In recent decades, global warming has become a major contributing factor in the increase in the frequency and intensity of heatwaves. The year 2023 was the warmest year on record and 2014-23 was the warmest decade ever [2]. The decade saw a dramatic acceleration in climate change with rising greenhouse gas concentrations causing record ocean and land temperatures. This year, from January to September 2024, the global average surface air temperature was 1.54°C higher than the pre-industrial level, with an uncertainty margin of ±0.13°C. This increase was partly driven by a warming El Niño event, based on data from six international sources analysed by the WMO (Fig 1).

## Global, Regional, National and Local Heatwave Occurrences

### Global

Globally, heatwaves have become more frequent and severe, impacting multiple continents. The 2010 Northern Hemisphere summer heatwaves included severe heat waves that impacted most of the United States, Kazakhstan, Mongolia, China, Hong Kong, North Africa and the European continent, along with parts of Canada, Russia, Indochina, South Korea and Japan. In the year 2010, heatwave killed ~55,000 people in Russia. In 2023, Europe recorded some of the highest temperatures, with Southern Europe reaching 48°C [3]. North America, particularly the

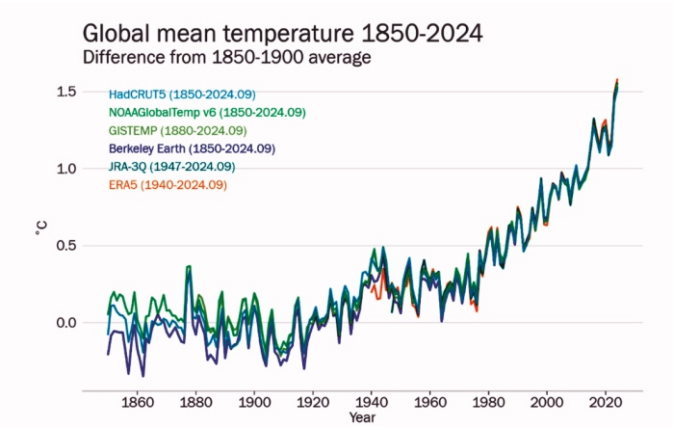


**Figure 1:** Global mean temperature anomalies for January – September 2024 relative to the 1850–1900 baseline, based on six international datasets.

*Image credit: WMO News Release*

Pacific Northwest saw unprecedented heat while North Africa recorded temperatures above 50°C. In South and Southeast Asia, temperatures exceeded 45°C leading to widespread health crises and agricultural damage. These events underscore the global scale of the heatwave crisis, driven by climate change. In the southern hemisphere, Australia, Africa, Argentina and Chile in South America experienced heatwaves in 2023 [4,5] as shown in Fig 2.

## Regional

Regionally, South Asia and Southeast Asia are among the most affected by heatwaves. South Asia with its high population density and agricultural reliance has seen a marked increase in the frequency and intensity of the heatwaves. Southeast Asia also experiences extreme heat with temperatures rising above 44°C leading to significant health and agricultural impacts [6]. In Africa, particularly in North and East Africa, heatwaves have become more severe, worsening existing challenges like drought and food insecurity. South America is similarly affected with prolonged heatwaves disrupting agriculture and energy systems.

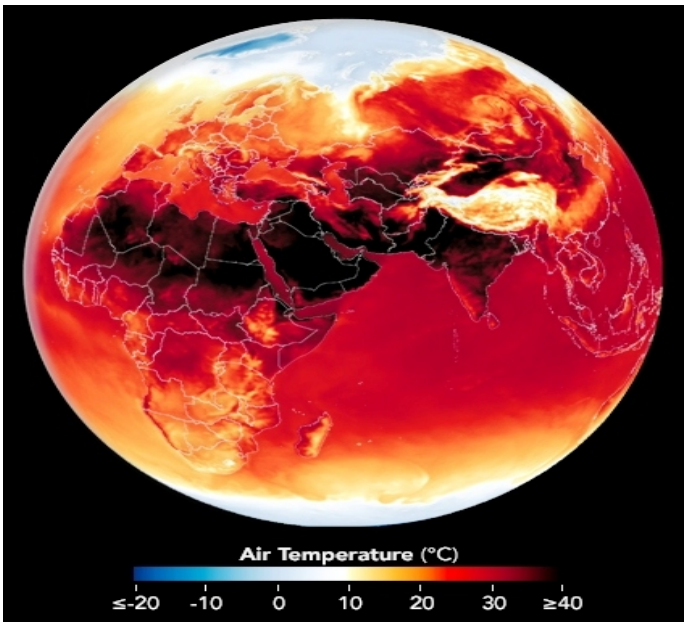


**Figure 2:** Global Heatwaves June 2024

*Image credit: NASA*

## National

At the national level, South Asian countries have been among the hardest hit. India, Pakistan, Bangladesh and Nepal have recorded extreme temperatures with Turbat and Pakistan reaching 54.0°C in 2017.

These heatwaves have resulted in significant mortality rates and economic losses. Southeast Asia, Thailand, Malaysia and Vietnam have also faced extreme heat, leading to widespread health emergencies and disruptions in agricultural productivity. North and East Africa continue to experience severe heatwaves, worsening drought conditions and food shortages. Morocco and Algeria recorded temperatures above 50°C in 2023, leading to severe impacts on agriculture and water resources. These extreme conditions have exacerbated existing challenges related to drought and food insecurity. Southern Europe, particularly Spain and Italy faced record highs of 48°C in 2023 causing significant crop damage, increased energy demand and public health crises. The Pacific Northwest America experienced another record-breaking heatwave in 2023 exacerbating challenges like wildfires, power outages and health emergencies.

## Local (City and Ward Level)

Urban areas are particularly vulnerable to heatwaves due to the Urban Heat Island (UHI) effect which causes cities to be significantly warmer than their rural surroundings. In South Asia, cities like Ahmedabad, India have implemented localized Heat Action Plans (HAPs) that include early warning systems, public awareness campaigns and cooling centers to reduce heat-related mortality.

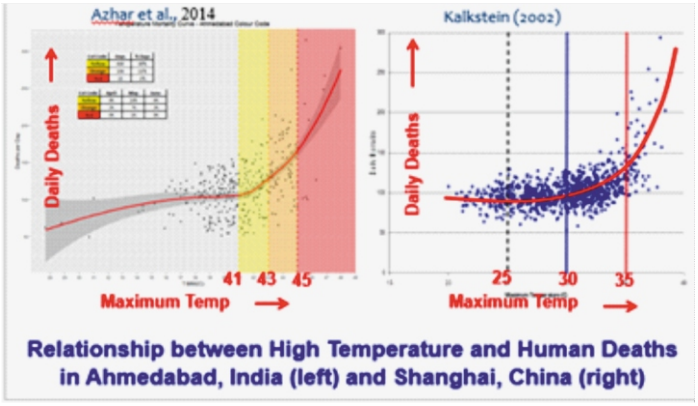


**Figure 3:** Relationship between High Temperature and Human Deaths in Ahmedabad, India and Shanghai, China

*Image credit: [7, 8]. It requires location/city specific heat wave warning thresholds. However, many cities lack such infrastructure, leaving them more exposed to extreme heat.*

## Impact of Heatwaves on Developing and Least Developed Countries

The Developing and Least Developed Countries (LDCs) have contributed least to the emissions of greenhouse gases, but they are most vulnerable countries to the effects of global warming and climate change and they have least capacity to adapt to these changes. Countries in Africa, South Asia and Southeast Asia are most vulnerable to heatwaves as a result of low adaptive capacity. The low capacity is due to extreme poverty, frequent natural disasters, extreme weather events and heavy rainfall. Heatwaves have far-reaching impacts across various sectors. Important among these are:

**1. Health**: Heatwaves cause significant health issues, including heat exhaustion, heatstroke, dehydration and exacerbation of pre-existing conditions. In South Asia, heat stress-induced deaths are projected to reach 85 per 100,000 by 2100.

**2. Agriculture**: High temperatures reduce crop yields, increase water demand, cause soil degradation and impacts food security. In South Asia and Africa, agricultural productivity has declined by 10-20% due to extreme heat.

**3. Water Resources**: Heatwaves exacerbate water scarcity by increasing evaporation rates and reducing water availability, particularly in drought-prone regions like Africa and South Asia.

**4. Energy**: Increased demand for electricity for cooling during heatwaves leads to power shortages and outages, especially in regions with inadequate infrastructure.

**5. Biodiversity:** Heatwaves will impact the population that are dependent on forest species for subsistence needs an economy that is based on forest products. Nature reserves become less effective as the vegetation and animal species that they seek to protect will no longer be in the preferred bio-climatic region.

**6. Food and Livelihood Security**: It may be strained if people lose their crops and livestock due to extreme heat.

## Small Island Developing States (SIDS)

Small Island Developing States (SIDS) face unique challenges due to their geographic and climatic conditions. The combination of extreme heat, rising sea levels and limited freshwater resources makes these islands particularly vulnerable. The impacts of heatwaves are compounded by other climate-related events, such as tropical storms and marine heatwaves, making it essential for SIDS to develop comprehensive adaptation strategies that address the full spectrum of climate risks. Marine heatwaves can (and increasingly do) negatively impact this complex ecosystem by causing coral bleaching, harmful algal blooms, death of kelp, seagrass, mortality of oceanic invertebrates and location shift of fish species.

## Approaches to Tackle Heatwaves in the Global South

Effective management and mitigation of heatwaves require a multi-faceted approach that encompasses both immediate and long-term strategies. **Heat Action Plans (HAPs)** are critical tools that need to be developed and implemented at local, regional and national levels. These plans should be integrated into city planning and disaster management frameworks and regularly updated based on new data and experiences. Key components of HAPs includes early warning systems, public awareness campaigns, capacity building and adaptive measures to reduce heat exposure.

## Heatwave Prediction

Prediction of heatwaves should cover different timescales from days to centuries, deterministic predictability, probabilistic forecasts (up to 10 days) and seasonal outlooks (several months ahead), ensemble modelling at high temporal and spatial resolutions, Machine Learning (ML) algorithms and Artificial Intelligence (AI), onset and persistence of marine heatwaves 12 months in advance based on climate models and state of El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD), etc. The predictions should cover district-wise warnings, and city-specific thresholds for issuing alerts. The warning system should include heat index forecasts and location-specific forecast systems for enhancing the effectiveness of heatwave management efforts. Determining heat thresholds is vital for addressing challenges of extreme heat events. Defining these thresholds involves setting specific meteorological criteria signalling the start of heat wave. The early warning thresholds must be location specific based on meteorological and health data. Using all-cause mortality and maximum temperature data, thresholds of maximum temperatures have been worked out by many cities. Threshold curves for Ahmedabad and Shanghai (Fig 3), Colour coded alerts (Fig 4) based on severity should be disseminated through multiple channels. Effective communication of warnings can help mitigate the impacts of heat waves. For example, cities like Ahmedabad in India have successfully reduced heat-related mortality through such methods. At locations where health data is not available, Percentile-based technique established by the World Meteorological Organization (WMO) and World Health Organization (WHO) is recommended to estimate maximum temperature thresholds for summer-heat early warning systems. Using percentile method in a joint study carried out by India Meteorological Department (IMD), Indian Institute of Public Health (IIPH, Gandhinagar) and Ministry of Health and Family Welfare (MoHFW), Government of India determined maximum temperature threshold for 96 Indian cities. Seasonal and monthly maximum temperature thresholds were determined for heat wave warnings using 75% percentile (Heat Alert), 85% percentile (Severe Heat Alert) and 95% percentile (Extreme Heat Alert Day). IMD uses Colour Code (Fig 4) in their heatwave warnings, Yellow (Heat Alert), Orange (Severe Heat Alert) and Red (Extreme Heat Alert).

| Colour Code | Action | Alert Level |
|---|---|---|
| Yellow Alert | Be Updated | Heat alert |
| Orange Alert | Be Updated | Severe Heat Alert |
| Red Alert | Take Action | Extreme Heat Alert |

**Figure 4:** Heatwave Warning Alert

We need to develop impact-based warning systems. The weather and climate models should be able to forecast the frequency, intensity, geographic spread and duration of heatwaves. We need to develop climate-adaptive and gender-sensitive heat action plans at the ward level for various South Asian cities.

Forecasting extreme heat for mountainous regions remains challenging due to inadequate representation of mountains in the models and lack of observations over remote areas. There are problems in forecasting in the small island countries because their areas are considerably less than the grid resolution of typical forecast systems. High quality meteorological data on surface and upper atmosphere conditions are needed for assimilation in the model and for bias correction to improve the accuracy of heat forecasts.

## Management of Heatwaves

Communicating even perfect forecasts of extreme heat is not guaranteed to the most vulnerable communities and/or to improve disaster preparedness (Table 1). More work is required to develop guidance on early warnings, public outreach, early actions and dissemination of information, as well as to produce well-designed education and communication materials for vulnerable and marginalized groups (Fig 5).

Table 1: Heat Action Plan - Key Features

| Heat Action Plan: Key Features |
|---|
| Vulnerability Analysis |
| Early Warning System |
| Inter-agency coordination |
| Public awareness and community outreach |
| Capacity building among health care professionals |
| Infrastructure Development |

Additionally, investments in resilient infrastructure are essential, particularly in urban areas where the urban heat island effect exacerbates extreme temperatures. Adopting

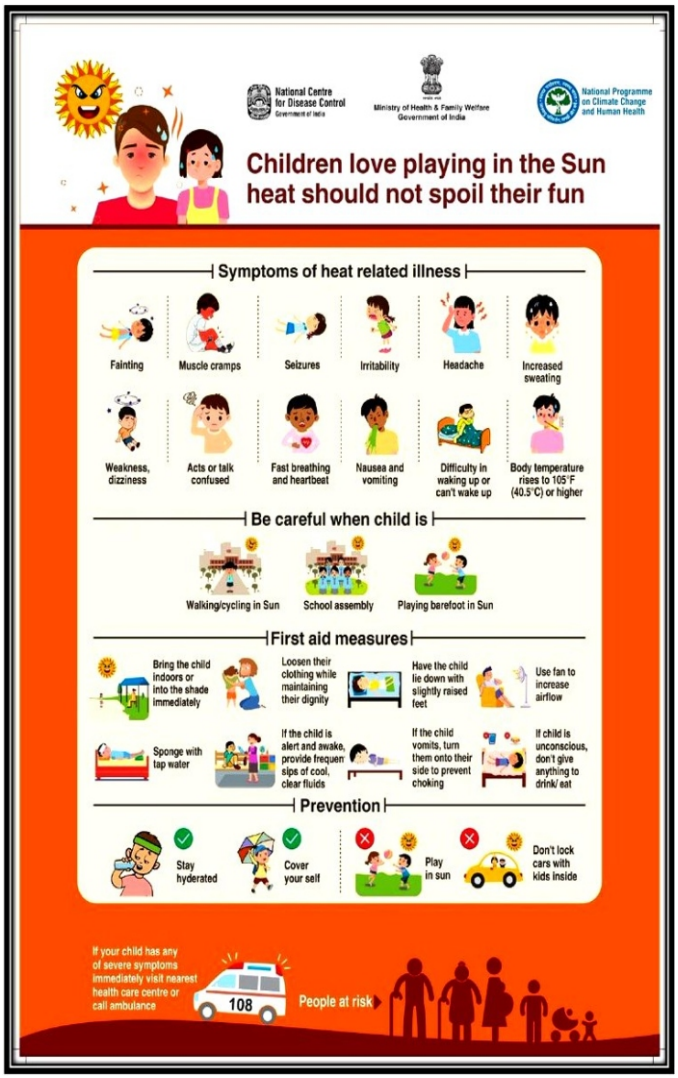


**Figure** 5: Public Awareness Poster on Heatwaves

*Image credit: WHO*

green building codes, increasing urban green spaces and implementing cool roofs can significantly reduce temperatures and improve overall resilience. Furthermore, there is a pressing need for international collaboration to share best practices, innovations and resources, especially in regions like Africa and SIDS which lack adequate infrastructure to cope with the increasing threat of heatwaves. In addition to strengthening public health systems to respond to heat-related mortality and morbidity, improving water management to address scarcity, and enhancing energy infrastructure to cope with rising demand are also crucial for building long-term resilience against the escalating impacts of climate change-induced heatwaves. This calls for specific thresholds to be developed in consultation with sector specialists and implementing seamless warning systems for developing sectors (Agriculture, fishery, dairy, water, energy and transportation / logistics). This includes seasonal, monthly and extended range (medium and short range) for effective management of heatwaves.

## Conclusion

The increasing frequency, intensity and duration of heatwaves across developing countries underscore the urgent need for coordinated action. Regions like South Asia, Southeast Asia, Africa and SIDS are particularly vulnerable facing significant health, agricultural, water and energy challenges.

Developing and implementing effective Heat Action Plans, improving early warning systems, investing in resilient infrastructure and capacity building are critical steps to enhance preparedness and resilience against heatwaves.

## Reference


1. WMO-WHO. (2015). Heatwaves and Health: Guidance on Warning-System Development. Retrieved from WMO.
2. Intergovernmental Panel on Climate Change (IPCC). (2023). Sixth Assessment Report. Retrieved from IPCC.
3. World Meteorological Organization (WMO). (2023). State of the Global Climate. Retrieved from WMO.
4. Voiland A, (2024). In the Grip of Global Heat. NASA Earth Observatory. https://earthobservatory.nasa.gov/images/152995/in-the-grip-of-global-heat.
5. World Meteorological Organization. (2024, November 11). 2024 is on track to be hottest year on record as warming temporarily hits 1.5°C. https://wmo.int/news/media-centre/2024-track-be-hottest-year-record-warming-temporarily-hits-15degc.
6. A Preliminary Study to Estimate Temperature Threshold for Heat Wave Warning in India (2019), National Disaster Management Authority, Government of India.
7. Azhar, G. S., Mavalankar, D., Nori-Sarma, A., Rajiva, A., Dutta, P., Jaiswal, A., & Hess, J. J. (2014). Heat-related mortality in India: excess all-cause mortality associated with the 2010 Ahmedabad heat wave. *PloS one*, *9*(3), e91831.
8. Sailor, D. J., Kalkstein, L. S., & Wong, E. (2002). 7.1 The potential of urban heat island mitigation to alleviate heat-related mortality: Methodological overview and preliminary modeling results for Philadelphia, Proceed. 4th Sympo. on the Urban Environment, vol. 4, pp. 68–69, Norfolk, Va. May 2002 (http://www.5dstudios.com/clients/gcca/wp-content/uploads/2012/05/UHI-and-mortality-sailor.pdf).



**Contributors:**

Dr. Poulomi Chakravarty; AVM (Retd.) Prof. Ajit Tyagi; Prof. Someshwar Das; Dr. Swagata Payra and Dr. Mohan Kumar Das

**South Asian Meteorological Association (SAMA), New Delhi**



**Editor:** AVM (Retd.) Prof. Ajit Tyagi **Editorial Adviser:** Mr. Madhusudan Bandyopadhyay **Editorial Assistant:** Ms. Nidhi Utreja
**Compilation & Design:** Mr. Pankaj Buttan **Published by:** Dr. Amitava Bandopadhyay, Director General, Centre for Science & Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), Core 6A, 2nd Floor, India Habitat Centre, Lodhi Road, New Delhi-110003 (India)
**Phone:** +91-11-24645134, 24644974 **Email:** namstcentre@gmail.com **Website:** https://namstct.org