Diurnal Variation of Wet Bulb Temperature and exceedance of physiological thresholds relevant to human health

in *South Asia*

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Introduction

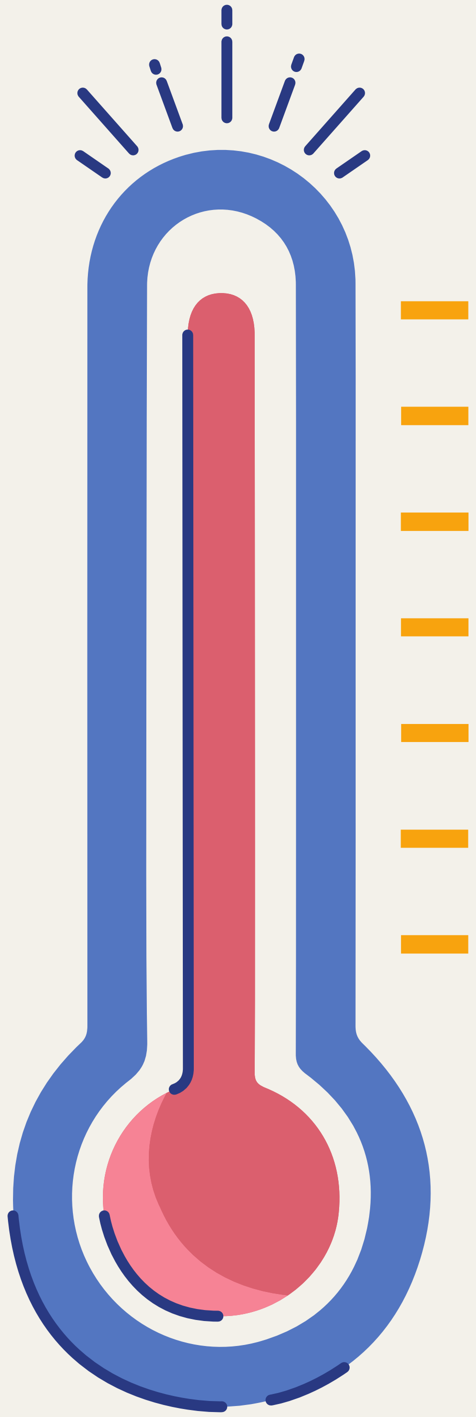
The paper examines daily temperature changes in South Asia and their link to heat-related health risks. It explains when these changes occur and what factors make them dangerous. The study is organized into an introduction that outlines the issue, a methods section describing how the data was collected and analyzed, a results section presenting the key findings, and a conclusion that summarizes the study and offers recommendations for future work.

Metric	Dry Bulb Temperature (TD)	Wet Bulb Temperature (TW)
Definition	Ambient temperature without humidity effects	Temperature considering humidity
Measurement	Standard thermometer	Wet bulb thermometer including evaporation
Peak Time	Afternoon (~2 PM)	Evening (~7 PM)
Health Impact	Indicates general heat conditions	Better indicators of heat stress

ABSTRACT

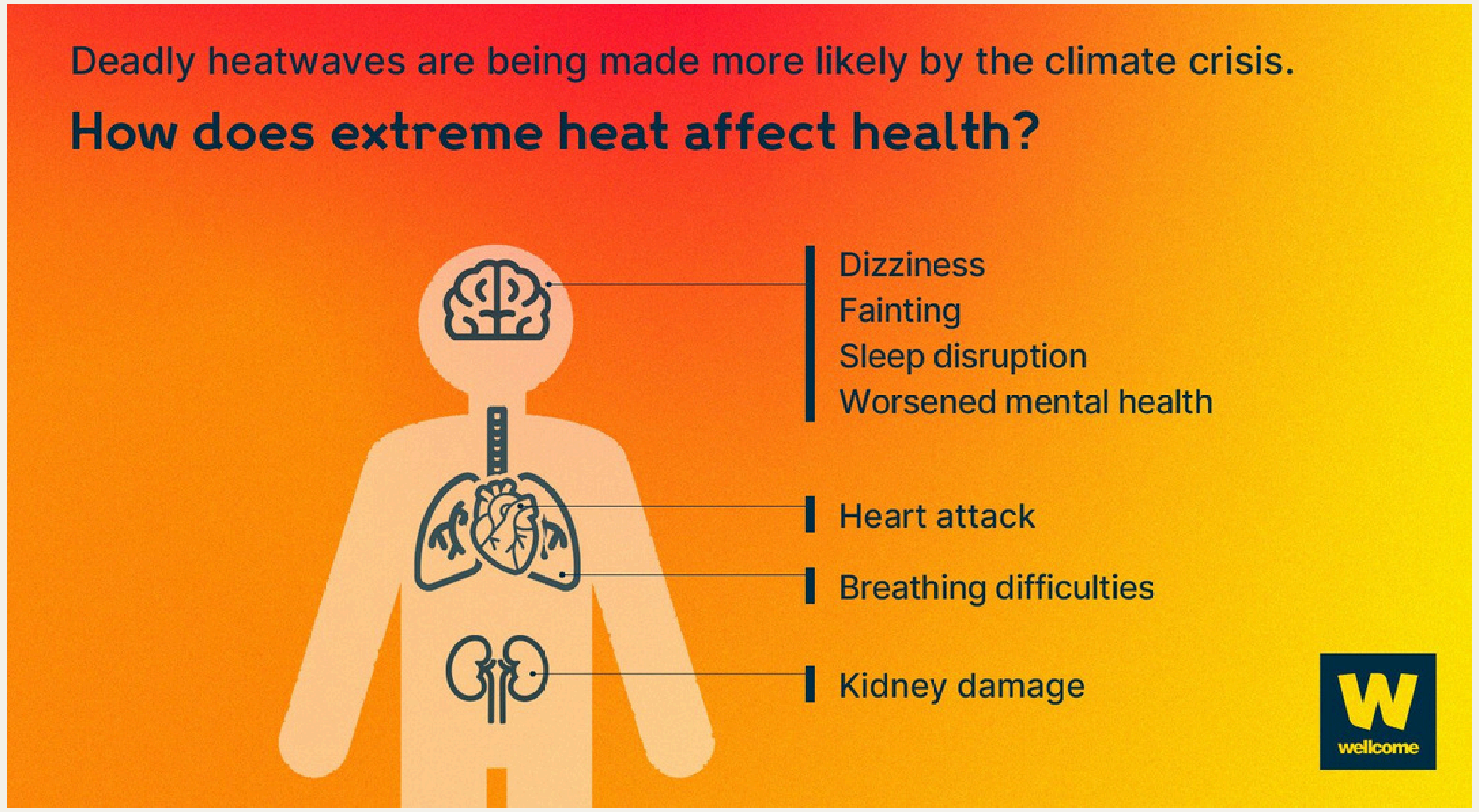
South Asia's Hidden Heat Hazard: Wet Bulb Temperature

- **Heat risk: Dry & Wet bulb temps + personal factors.**
  Heat impact on humans isn't just air temperature (dry bulb). Humidity (wet bulb) and individual health play crucial roles.
- **Wet bulb peak lags dry bulb peak (hours).**
  The hottest "feel-like" temperature (wet bulb) occurs later in the day than the hottest air temperature, extending the danger period.
- **Boundary layer/water content drives wet bulb changes.**
  Atmospheric conditions like how high moist air rises and how much water is in the air directly impact the wet bulb temperature.
- **Evening heat stress exceeds physiological limits.**
  Even after the hottest part of the day, high humidity keeps the "feel-like" temperature dangerously high, stressing the body.
- **⩾ 300 hours of extreme heat stress (1995-2020).**
  Over 25 years, South Asia experienced prolonged periods where heat stress was beyond what humans can handle, showing a serious trend.
- **Physiological thresholds are vital for accurate risk assessment.**
  To truly understand heat danger, we need to measure how the body reacts to heat, not just the air temperature itself.
- **Wet bulb alone is insufficient for hazard evaluation.**
  While wet bulb is important, we must consider both dry and wet bulb temperatures, and personal factors, to fully assess heat risk.



Extreme Heat and Health Risks

- Impacts results from a combination of physiological response & external factors (age, behavior)
- Human thermal stress depends on ambient temperature, humidity, shortwave and longwave radiation and wind speed.
- Temperature and humidity, crucial for heat transfer and sweat evaporation, are reliably measured worldwide. Combined metrics are commonly used to assess heat stress.



But what is Heat Stress?

Heat Stress

The increase in the core body temperature due to insufficient cooling leading to heat exhaustion, and heat stroke etc.

Compensable Heat Stress

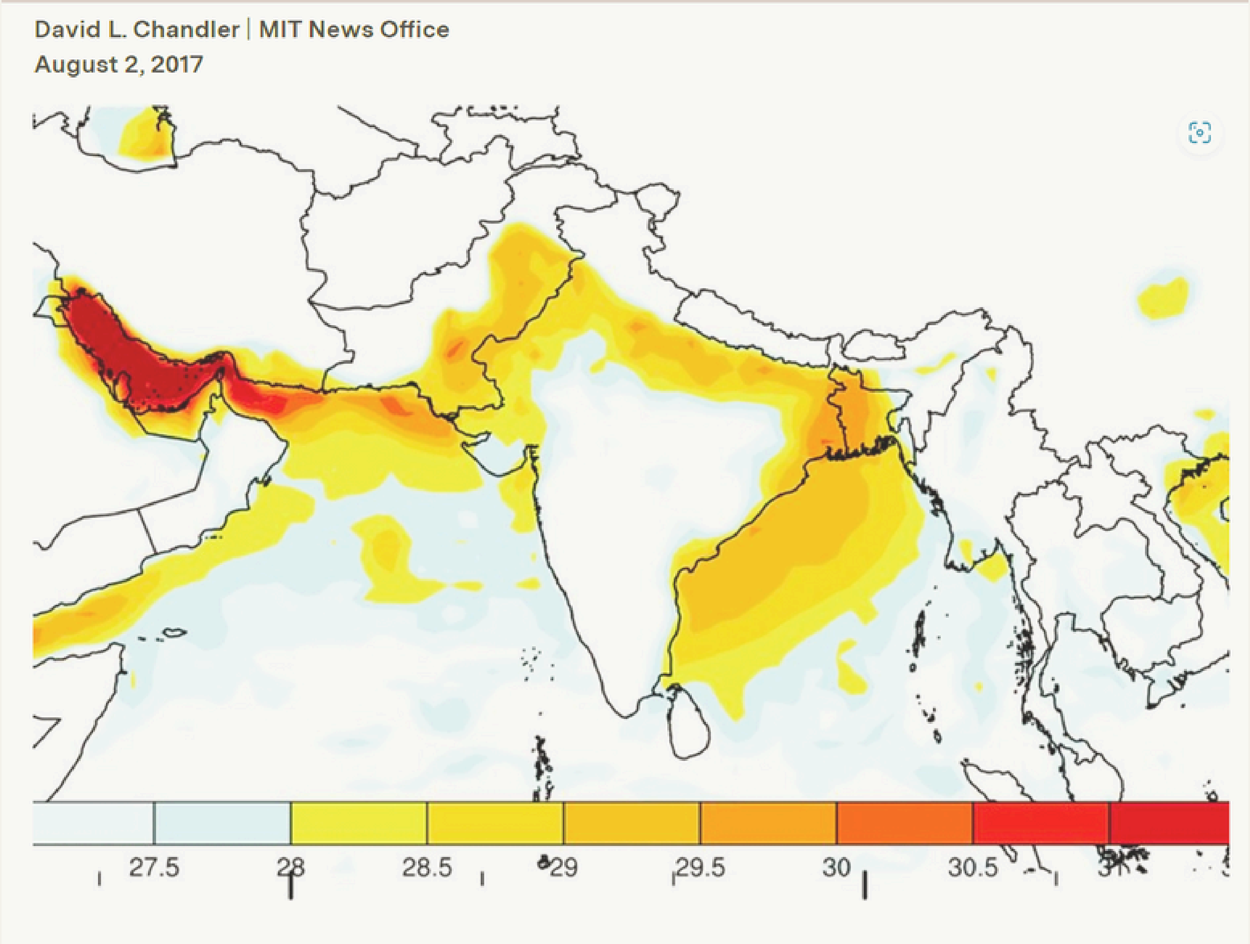
- Body can cool via sweating
- More common in dry environments.

Uncompensable Heat Stress

- Evaporative cooling is insufficient.
- Hot, humid conditions make heat dissipation difficult.

Heatwave Patterns in South Asia

- South Asia is a major hotspot for extreme heat in both current and projected climates.
- The Indian Meteorological Department's heat wave definitions and threshold were primarily based on TD.
- Key regions affected are East Coast of India, Northwest India and Indus River Basin.
- More recent studies use TW as a measure of heat stress and delineate regions that experience extreme TW.



Importance of Study on Extreme TD & TW

- Despite numerous TW-focused studies, most deadly and recent high-impact heatwaves in South Asia occurred under extreme TD conditions.
- Extreme TW may become a growing concern in the coming decades.
- Extreme TD remains highly relevant under both current and future climates.
- Uncompensable heat stress occurs at lower TW than the 35°C adaptation limit, and this threshold further decreases with rising TD.
- Diurnal cycles of TD and TW can help pinpoint times of day that pose the greatest health risk

DATA AND METHODOLOGY

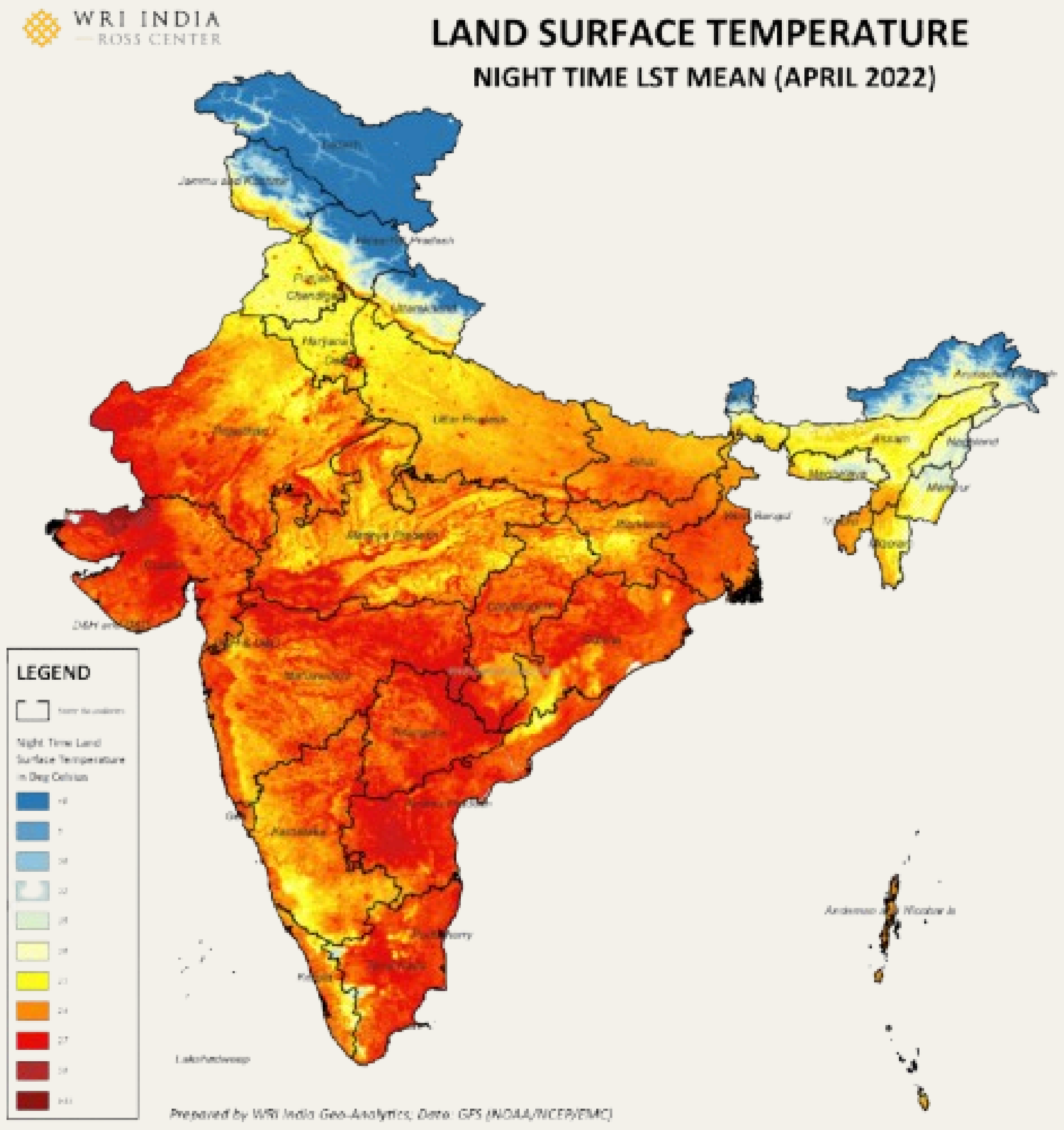
Data Type	Sources	Variable
Surface Meteorological Data	Hadley Centre Integrated Surface Database	Air Temperature Dew Point Temperature Surface Pressure
Radiosonde Data	Integrated Global Radiosonde Archive (IGRA)	Boundary Layer Height Water Vapor Content
Heatwave Mortality Data	Emergency Events Database (EM-DAT) Open Government Data (OGD) Portal National Crime Records Bureau (NCRB)	Mortality Records

Heat Wave: The temperature departure from normal is 4.5°C to 6.4°C above average.

Severe Heat Wave: The temperature departure from normal is ⩾6.5°C above average.

Data Type	Threshold (Daily Max TD)
Regular Days	47.5-52.5th percentile
Extreme	Exceeds 95th percentile

Period: March–June, the heatwave season in South Asia (1995-2020)



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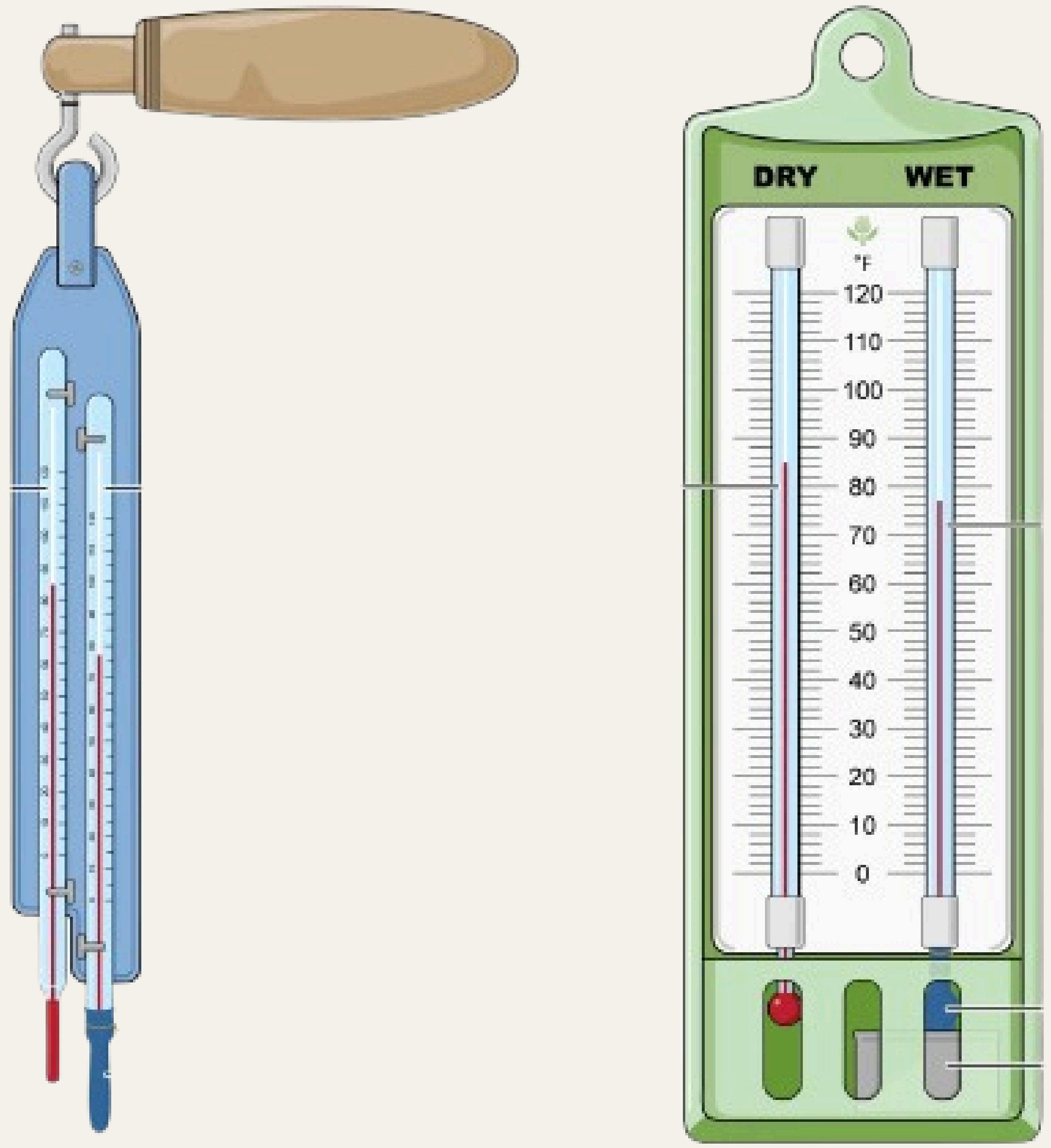
DIURNAL CYCLE ANALYSIS
(Diurnal Wet Bulb Temperature (TW) Patterns)

- Timing of Daily Max/Min TW
- Amplitude of Diurnal Cycle
- Heatwave & Regular Days

Diurnal Range =

median (TW Max) - median (TW Min)



Dry and Wet Bulb Thermometers

Evaluation of Critical TW exceedance

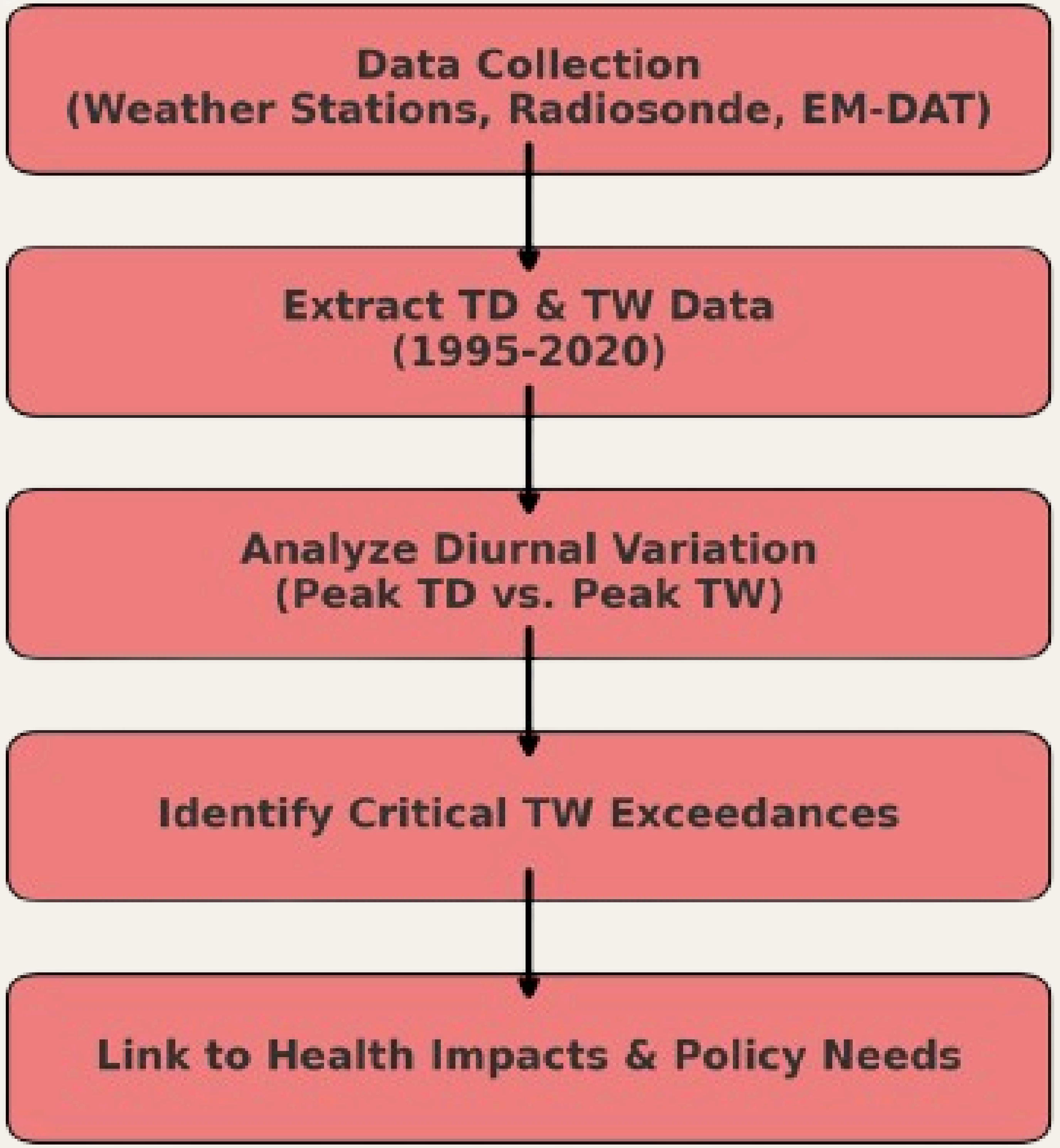
TD	36°C	38°C	40°C	44.04°C	47.48°C	50.57°C
TW	30.34°C	30.96°C	30.45°C	27.82°C	27.12°C	25.75°C

TD and TW values associated with uncompensable heat stress in thermal physiological experiments (Vecellio et al., 2022)

Heat Chamber ((Lu et al., 2016))

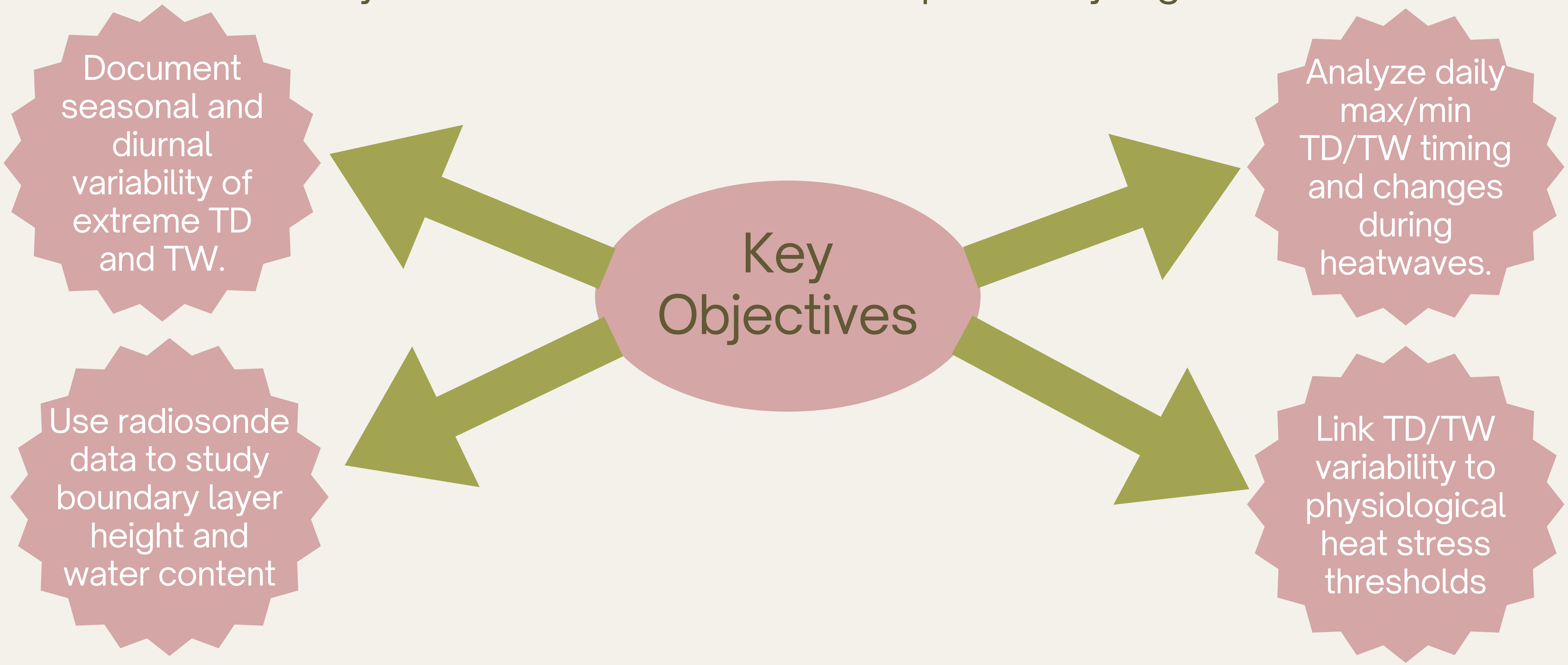
Critical TW Thresholds for Heat Stress: Highest TW value the body can tolerate before heat stress becomes dangerous - **35°C**

Data Collection and Analysis Process



Physiological Data and Hazard Duration

Limited studies on extreme heat impacts in South Asia due to sparse health data. Physiological data can be assessed by TD and TW variations and helps identify regions of health hazards.



Daily TD and TW Variation

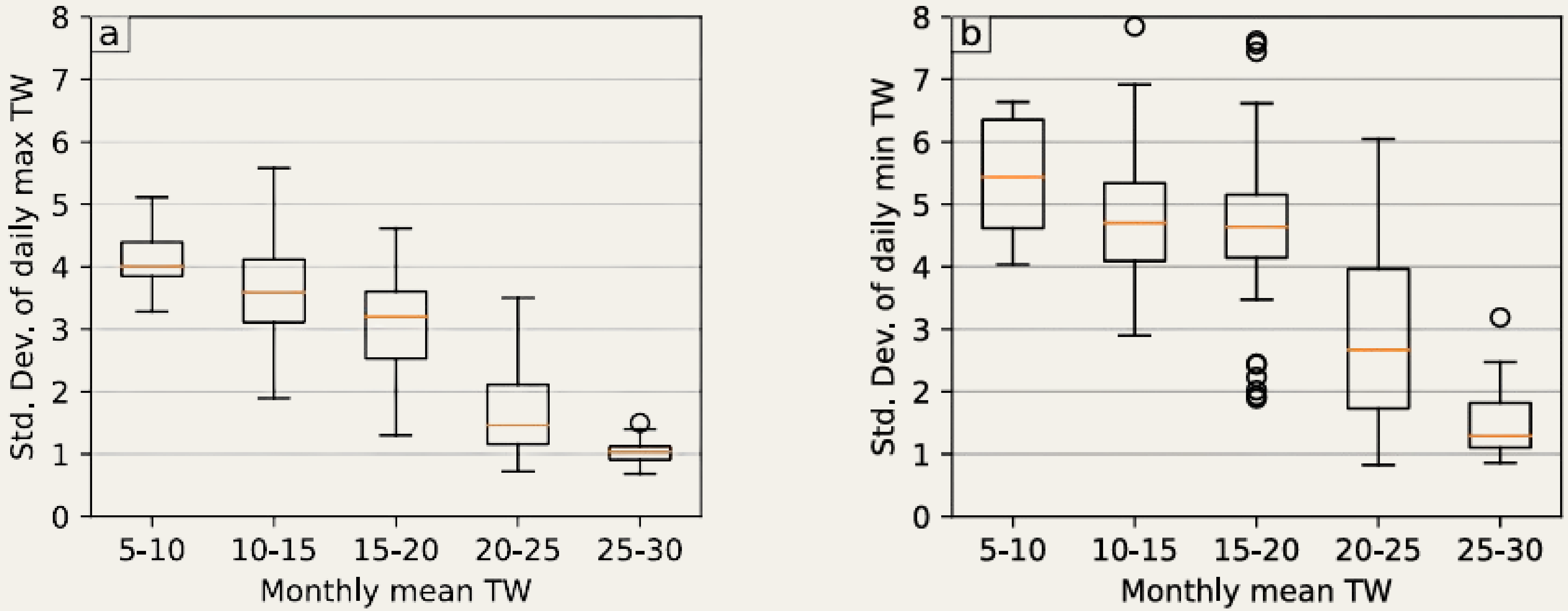


Fig. 3 Relationship between mean and variance of TW. The relationship between monthly mean TW and the respective standard deviation for daily maximum (**a**) and minimum TW (**b**) for all stations in South Asia. The calculation was done for the months March to June, and each month was treated separately Thus, each station contributes four values. The monthly mean bins are in degrees centigrade.

Monthly Distribution of TD and TW in South Asia

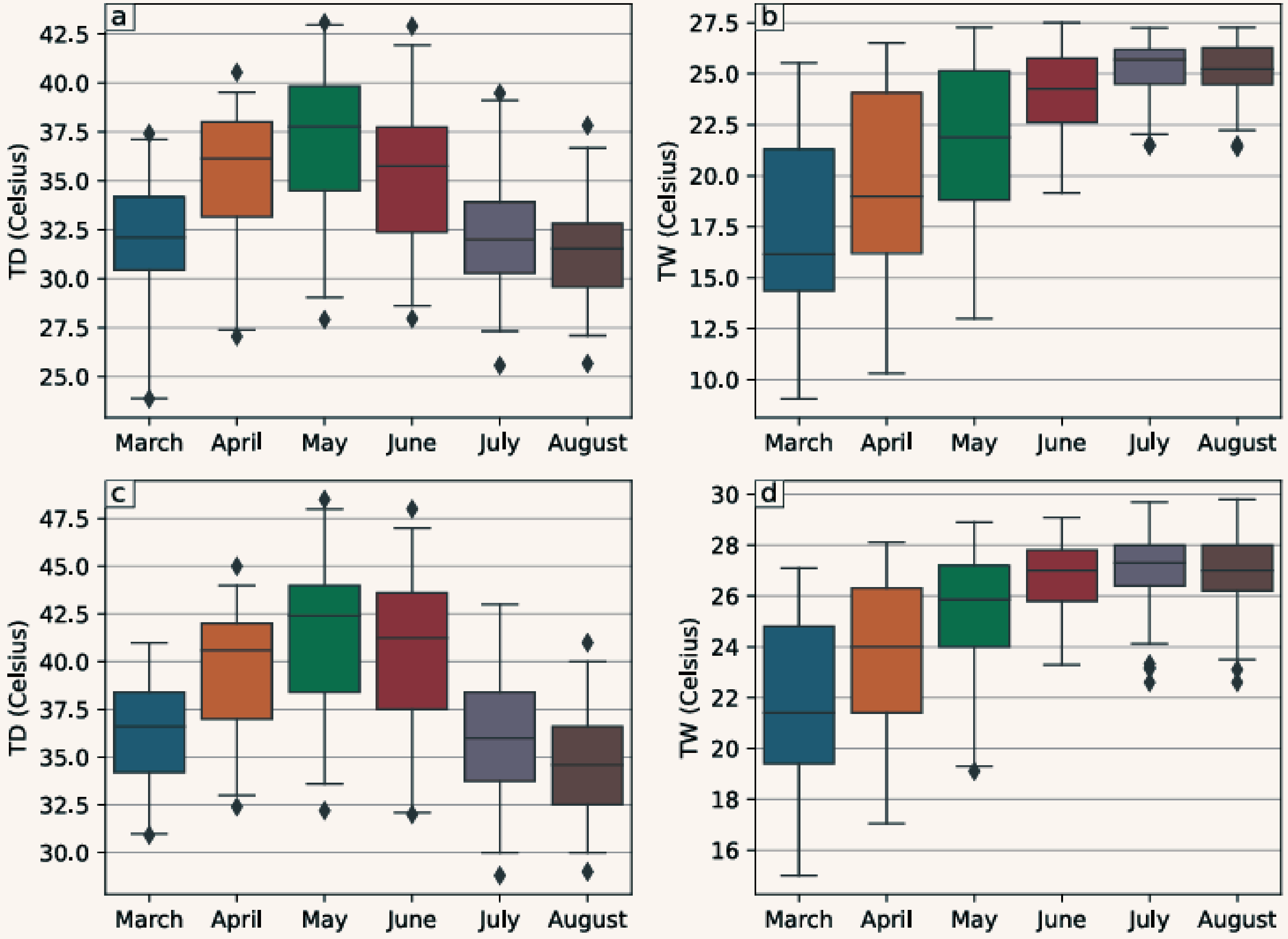


Fig. 1 Seasonal distribution of TD and TW in South Asia. The monthly distribution of the mean (panels **a**, **b**) and 95th percentile (panels **c**, **d**) of TD and TW for all stations in South Asia. The whiskers represent the 1st and 99th percentile of each distribution.

Insights

- This distribution shows that extreme TD peaks in May whereas extreme TW peaks in July.

- This seasonal distribution of TD and TW also supports the fact that extreme TW alone is insufficient to explain the seasonal distribution of health impacts.

- While the daily maximum TW may remain near seasonal norms, the daily minimum TW can drop significantly.

- These patterns indicate that humidity alone is not always the main driver of deadly heat stress, especially during months with the highest mortality (May)

Whether the paper primarily addresses climate change impacts or adaptation, or both?

The paper, The diurnal variation of wet bulb temperatures and exceedance of physiological thresholds relevant to human health in South Asia, primarily focuses on climate change impacts, though it briefly touches on adaptation aspects. Below is a detailed explanation supporting this reasoning:

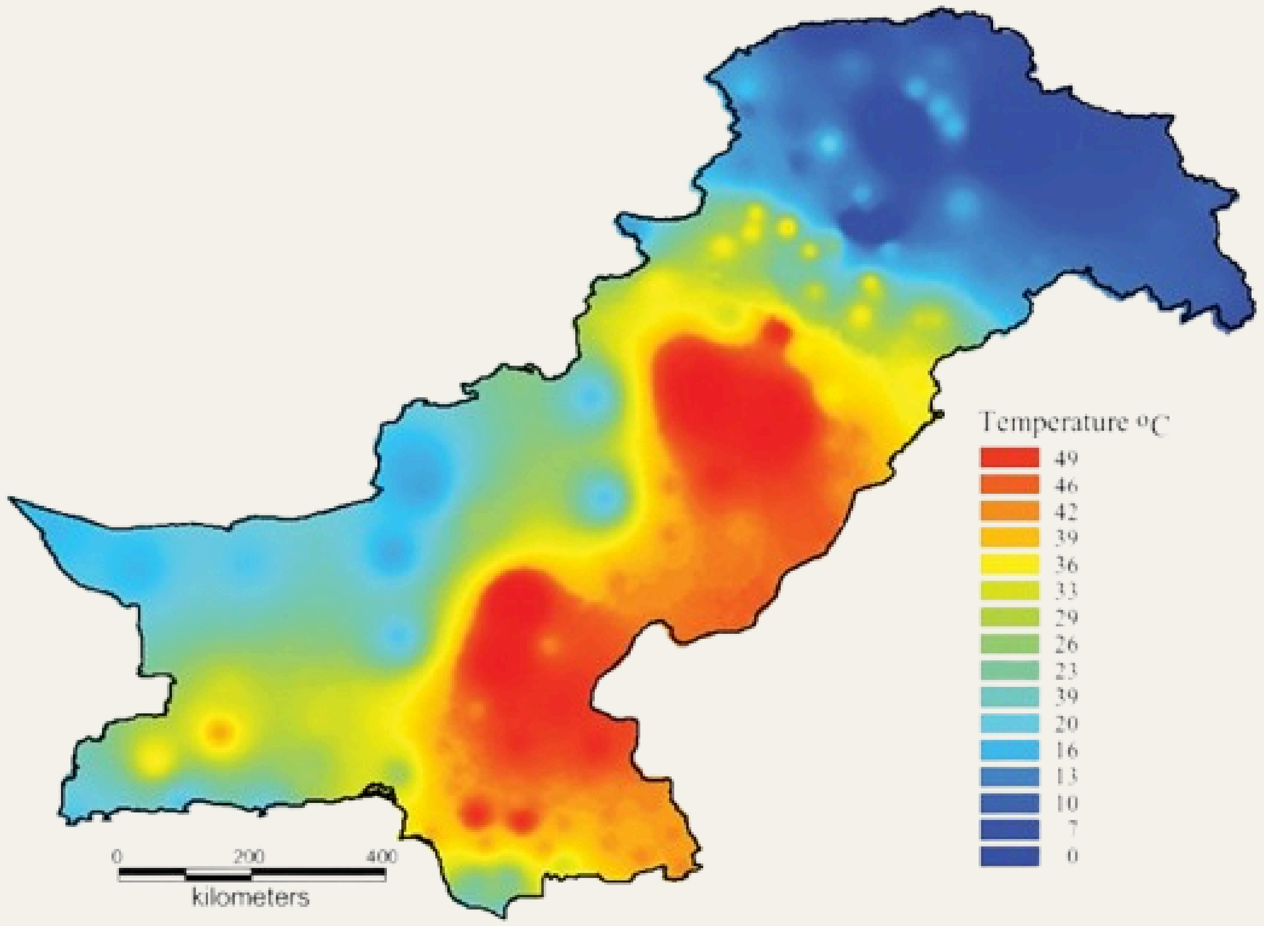
1. Focus on Climate Change Impacts

2. Scientific Analysis of Heat Stress

3. Limited Discussion on Adaptation

4. Conclusion: Impacts > Adaptation

1. Focus on Climate Change Impacts



- The central theme of the paper is extreme heat as a hazard to human health, which is a direct consequence of climate change, based on wet-bulb temperature (TW).

- The paper connects extreme heat to mortality and morbidity, citing documented heatwaves (e.g., *Karachi 2015*) and physiological limits (e.g., uncompensable heat stress at lower TW under high TD). This aligns with impact studies that quantify climate-related health risks.

2. Scientific Analysis of Heat Stress

- It highlights the diurnal variations in TW and their correlation with mortality data but does *not propose specific solutions* for reducing heat-related health risks.

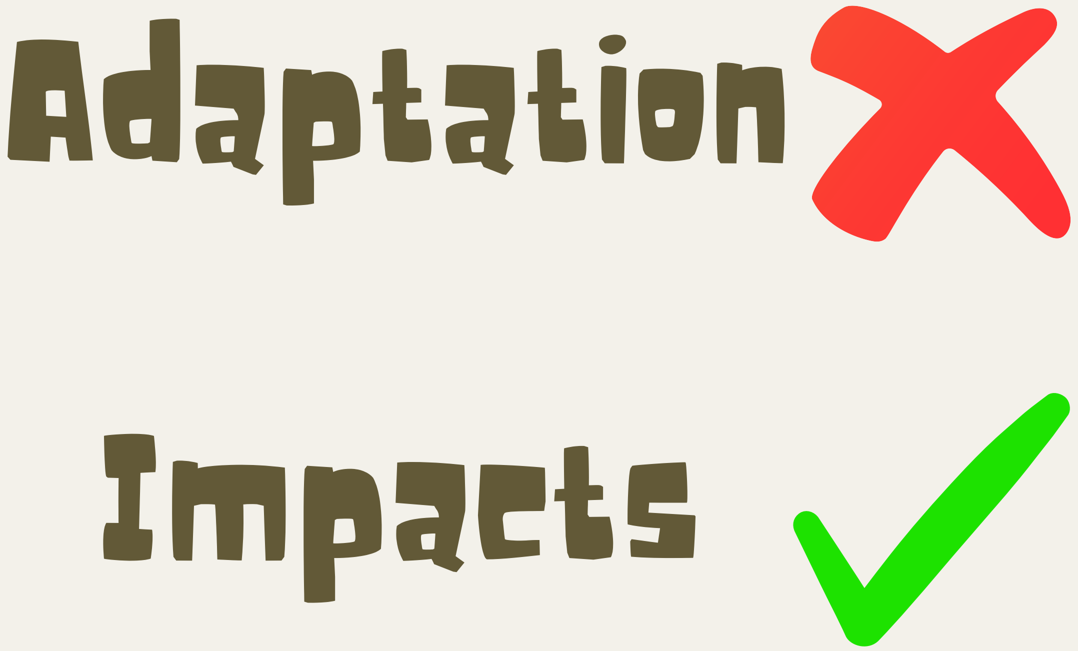
- The study emphasizes that physiological limits are being exceeded more frequently, which signifies a growing health crisis due to climate change impacts.

3. Limited Discussion on Adaptation

- *Public Health Messaging*: The study suggests revising heat advisories to account for evening/night-time heat stress (due to TW-TD phase differences), which is an adaptation strategy to reduce health risks.

- *Data Limitations and Preparedness*: The call for improved meteorological monitoring to identify health hotspots indirectly supports adaptation planning (e.g., early warning systems).

- *Physiological Thresholds:* By proposing context-specific thresholds for South Asian populations (rather than relying on global standards), the study nudges toward localized adaptation measures.



4. Conclusion: Impacts > Adaptation

- The paper is primarily an impacts study with implications for adaptation. It provides evidence of climate-related health risks while offering guidance on adapting public health responses, but its core focus remains on *quantifying the problem rather than solving it*.

- While the paper acknowledges the importance of adaptation in public health responses and suggests adaptation considerations, it does not delve deeply into specific adaptation measures and no detailed policy recommendations or strategies are provided. Thus, *it is best categorized as a study on climate change impacts with some minor adaptation considerations.*

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Thank You

For Your Attention