Regional Workshop on Framework and Toolkit Development
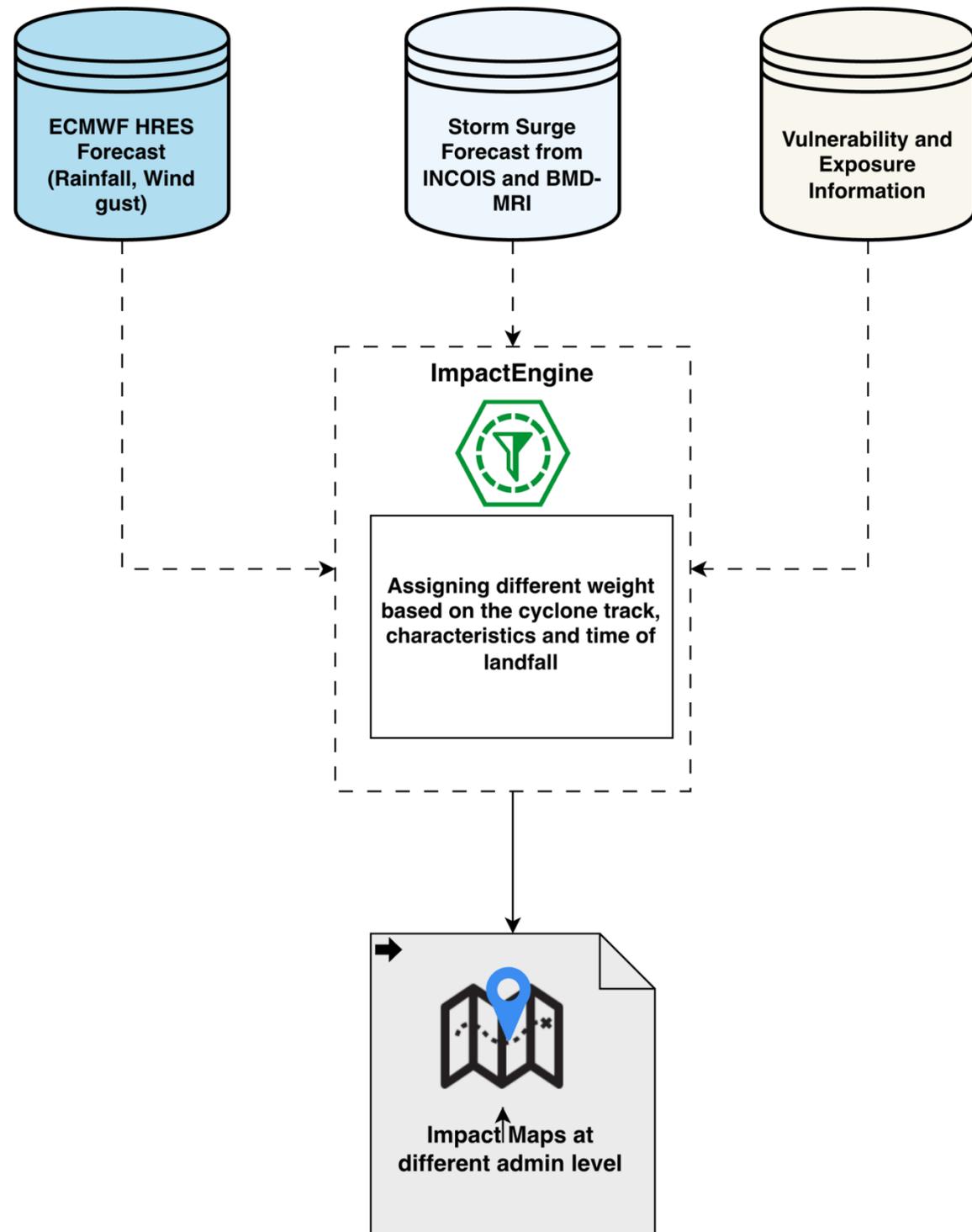
Terminologies and core concepts of IBF/IF, understanding the implications for temperature-related hazards

Raihanul Haque Khan

Impact Forecasting for Cyclone

Impact =Vulnerability $\times$ Exposure$\times$ Hazard

Hazard = (W1$\times$Wind gust + W2 $\times$Rainfall + W3 $\times$Storm surge)

Where,

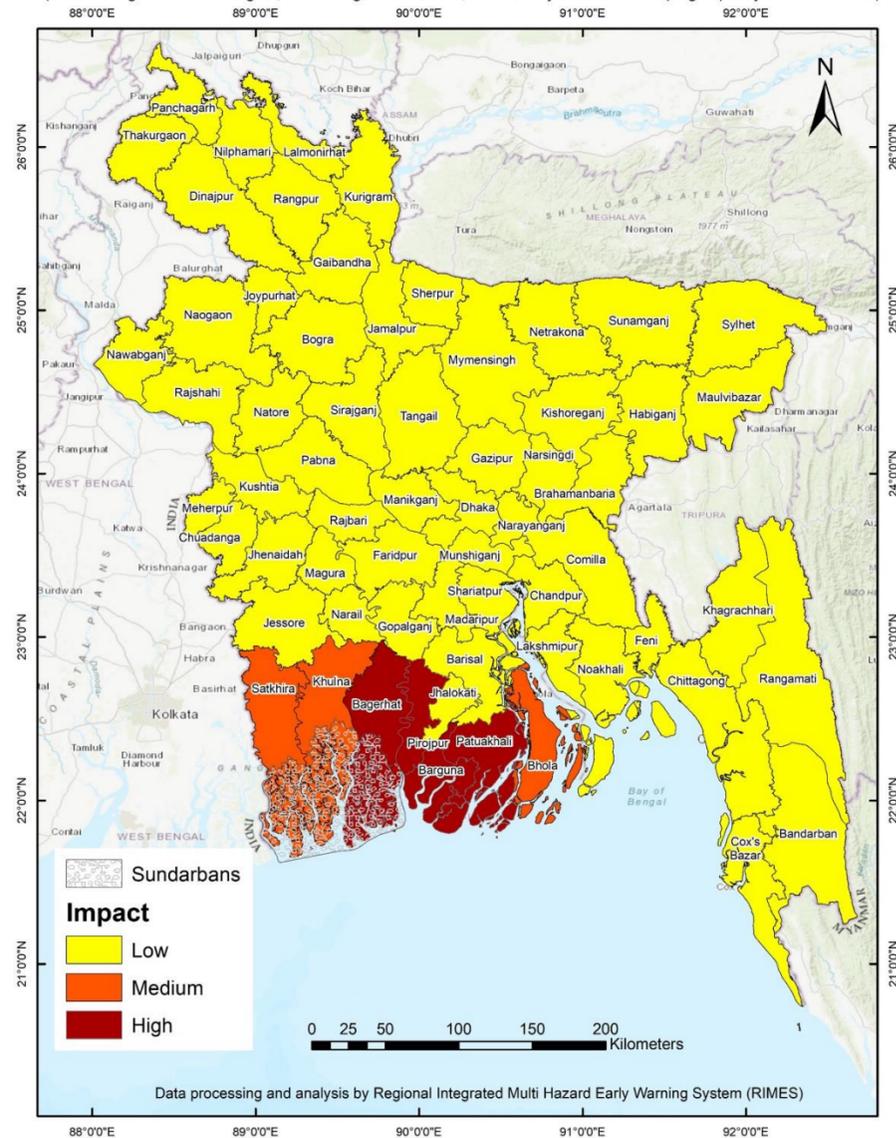**W1 is the weight for wind gust**

W2 is the weight for rainfall

W3 is the weight for storm surge
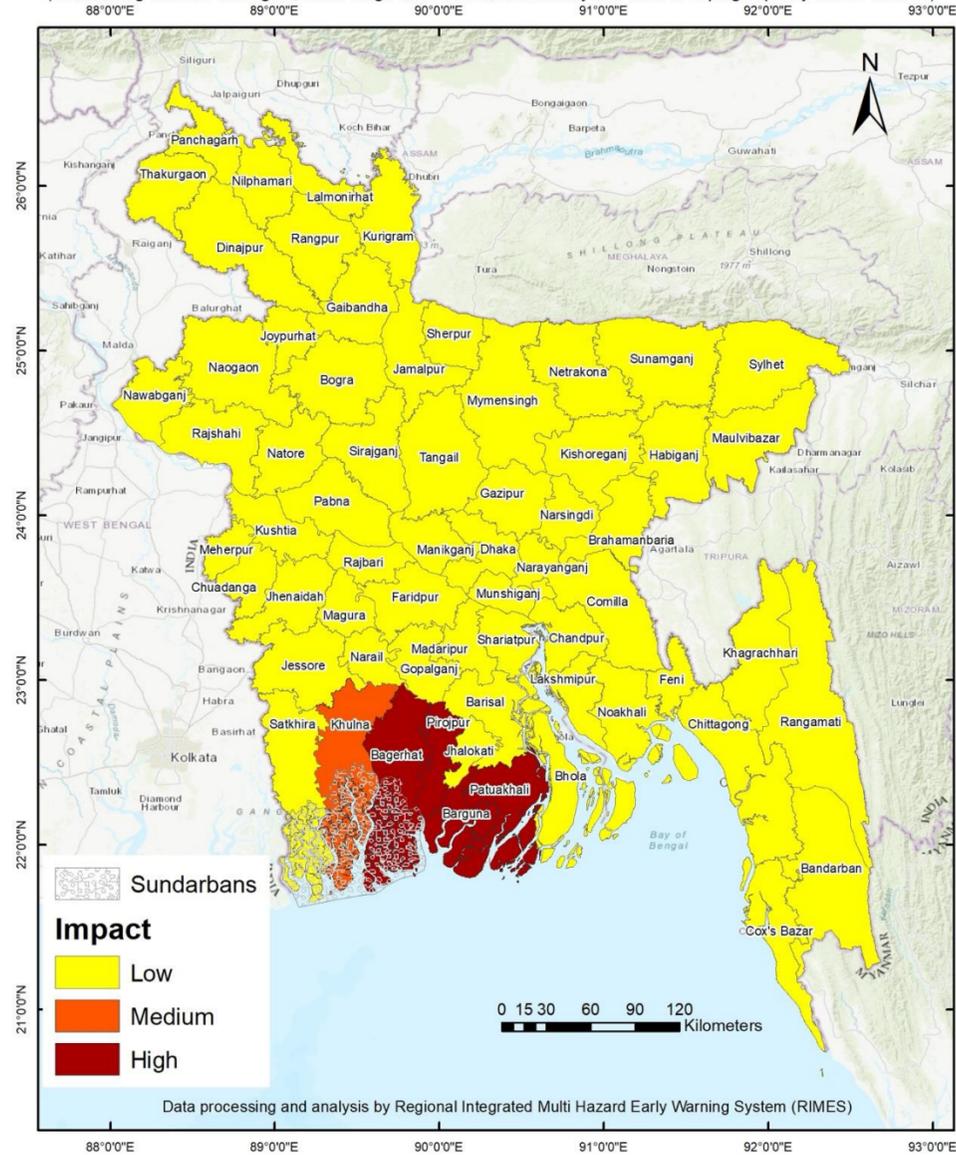
Impact Forecasting for Cyclone

Potential Impact Map during the passage of Cyclone 'Remal' based on ECMWF 25.05.2024 valid for 26.05.2024
(Considering forecast Wind gust, Storm surge and Rainfall; Vulnerability and Lack of coping capacity across districts)

Data processing and analysis by Regional Integrated Multi Hazard Early Warning System (RIMES)
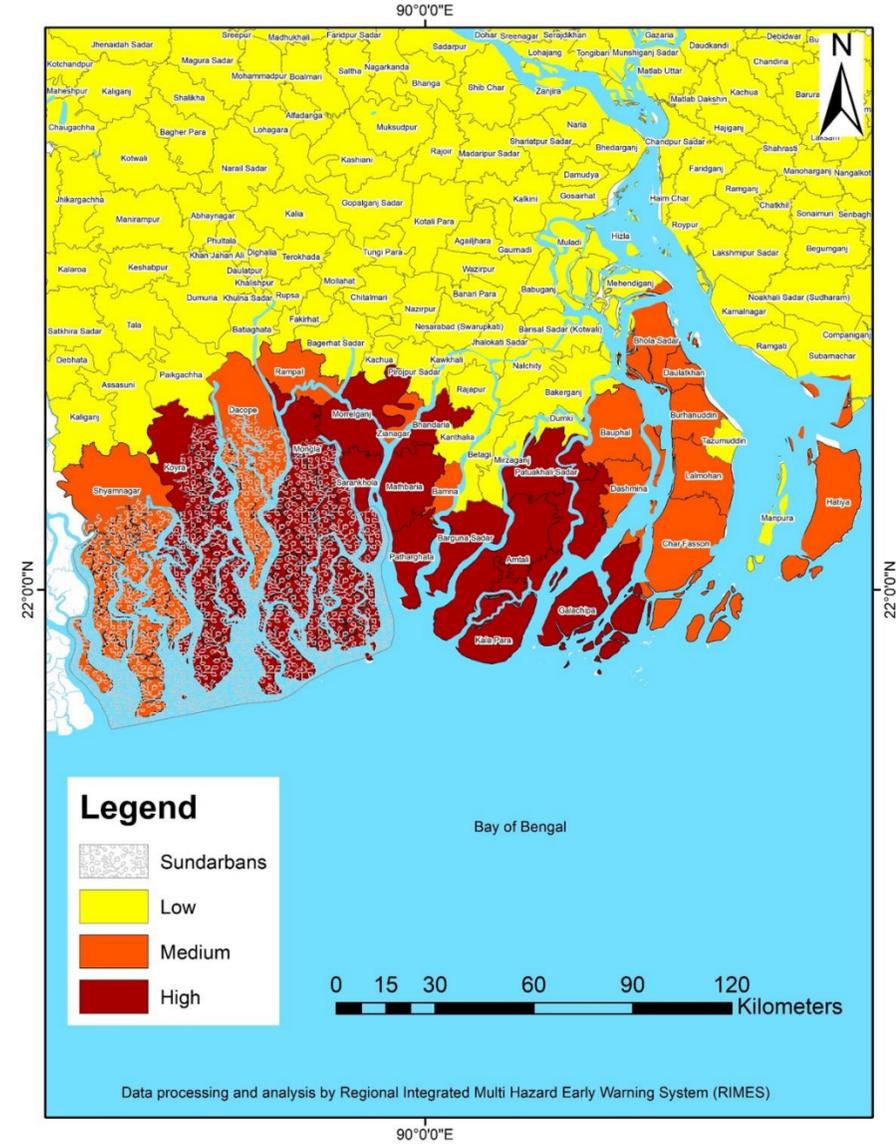
Sundarbans

Impact
- Low
- Medium
- High

Potential Impact Map during the passage of Cyclone "Remal" based on ECMWF 25.05.2024 valid for 27.05.2024
(Considering forecast Wind gust, Storm surge and Rainfall; Vulnerability and Lack of coping capacity across districts)
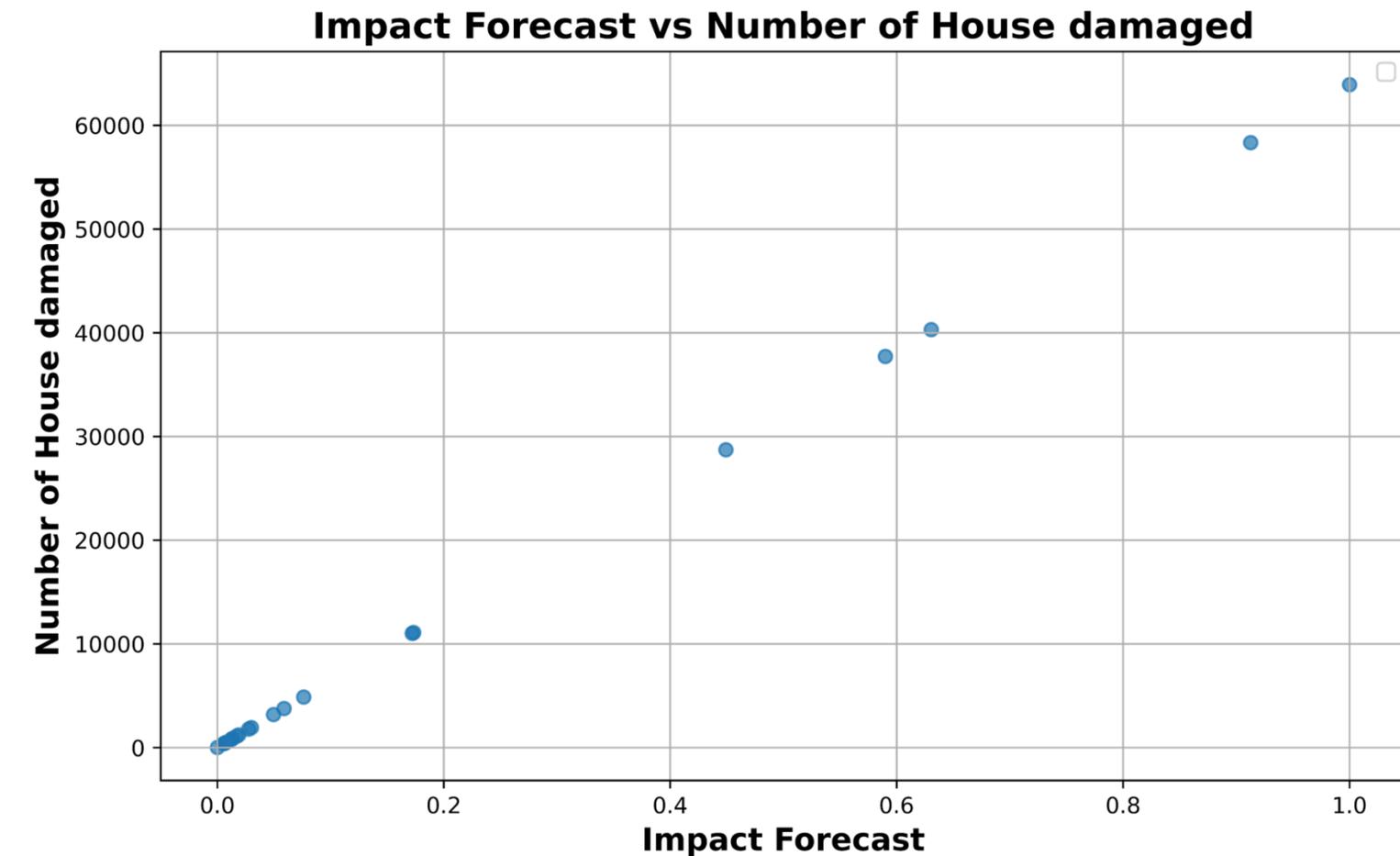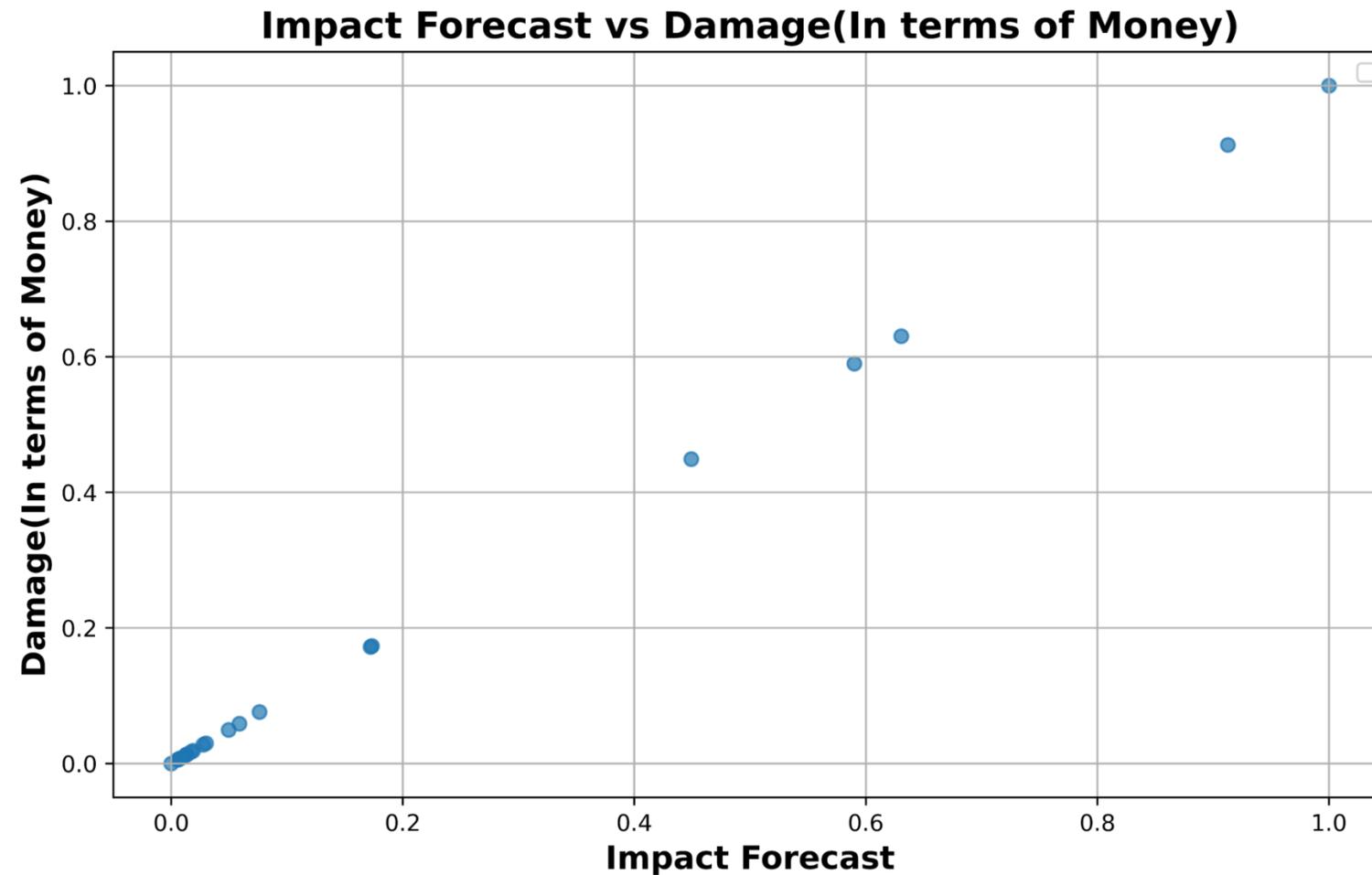
Data processing and analysis by Regional Integrated Multi Hazard Early Warning System (RIMES)

Sundarbans

Impact
- Low
- Medium
- High

Potential Impact Map during the passage of Cyclone 'Remal' based on ECMWF O00 UTC 25.05.2024 valid for 00 UTC 27.05.2024
(Considering forecast Wind Gust, Storm Surge and Rainfall; Vulnerability and Lack of Coping Capacity across Upazilas)

Data processing and analysis by Regional Integrated Multi Hazard Early Warning System (RIMES)

Legend
- Sundarbans
- Low
- Medium
- High

Impact Forecasting for Cyclone

Impact Forecast vs Damage(In terms of Money)

Damage(In terms of Money) vs Impact Forecast

Impact Forecast vs Number of House damaged

Number of House damaged vs Impact Forecast

Significant correlation between forecast and actual damage data at district level!

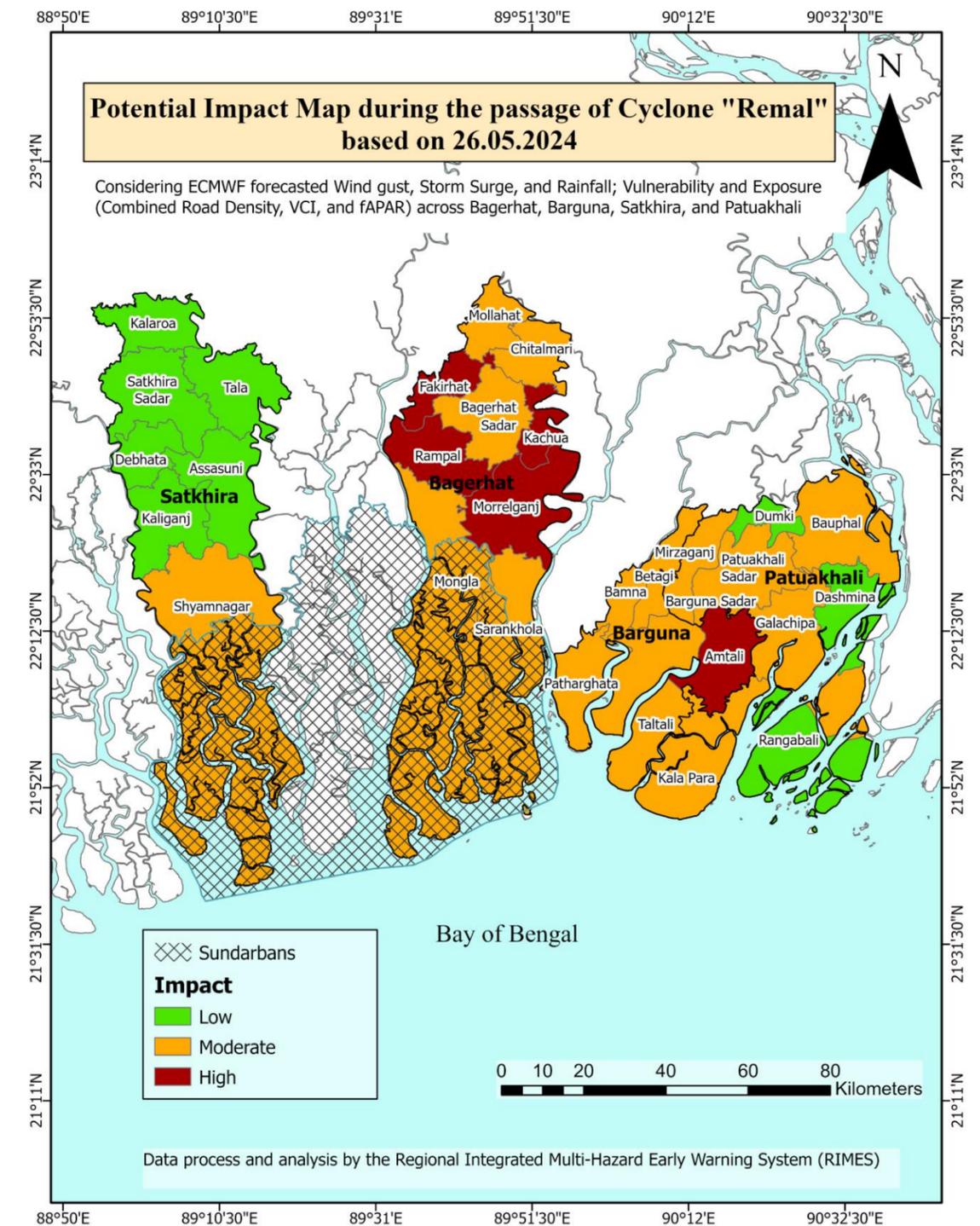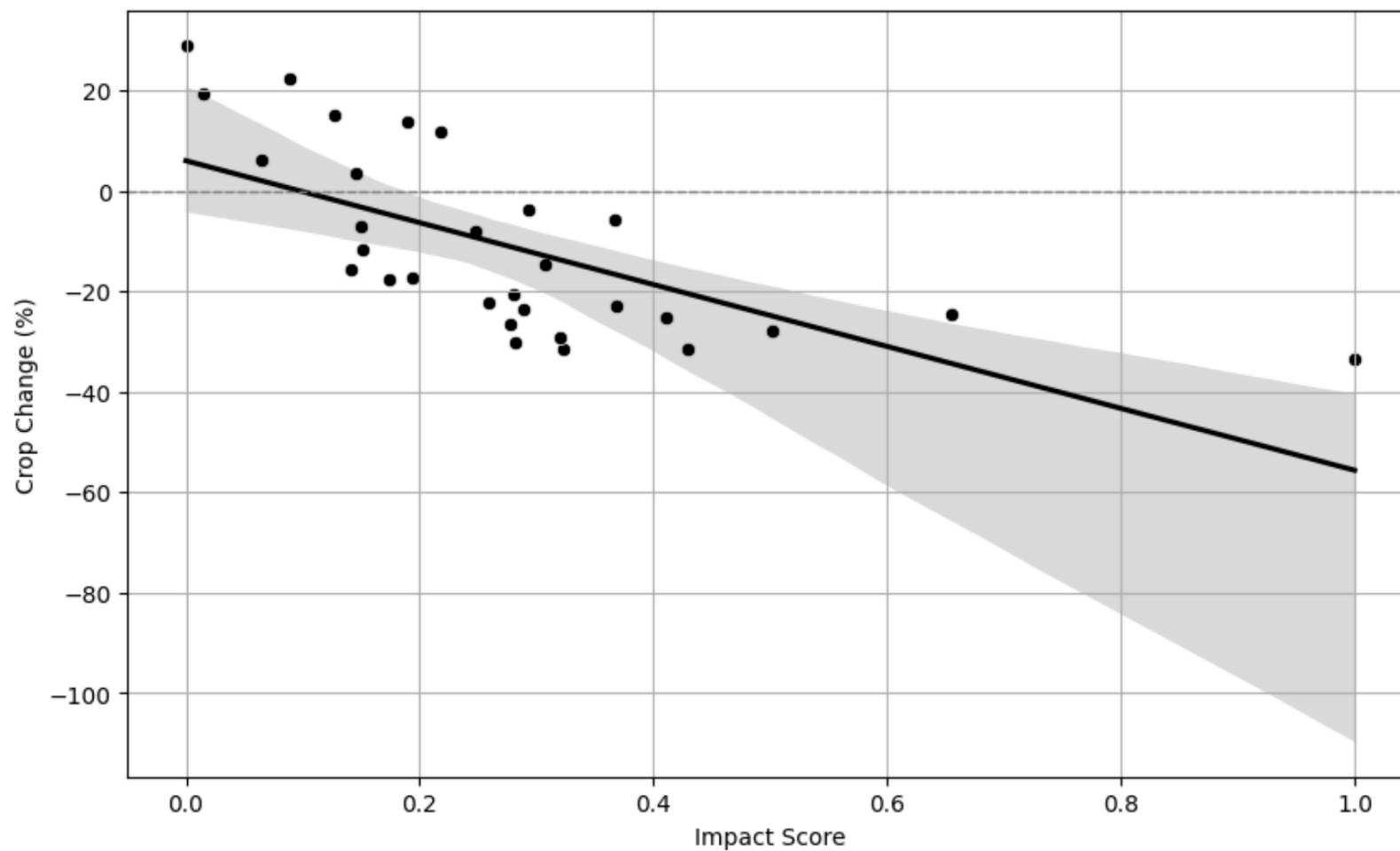# Impact Forecasting for Cyclone: Case of Cyclone REMAL

- Vulnerable but Prepared - Katcha Households who took Forecast-Based Actions Saved **USD 795 Each**, Compared to Just USD 1.50 for Those Who Didn't.

- **Around 15 Times the Return on Investment** from Forecast-Based Early Actions During Cyclone Remal for both cash-supported beneficiary and the people who just got the forecast (but not cash support)

- Households which took Forecast-Based Actions **faced 28% less Agriculture Loss**, from USD 87 to USD 63 due to early actions.

Impact Forecasting for Cyclone

Integration of Satellite products(VCI, FAPAR) as exposed crops has proven to be very high accurate and relevant for agricultural impact.

Potential Impact Map during the passage of Cyclone "Remal" based on 26.05.2024

Considering ECMWF forecasted Wind gust, Storm Surge, and Rainfall; Vulnerability and Exposure (Combined Road Density, VCI, and fAPAR) across Bagerhat, Barguna, Satkhira, and Patuakhali

Bay of Bengal

Sundarbans

Impact
- Low
- Moderate
- High

Data process and analysis by the Regional Integrated Multi-Hazard Early Warning System (RIMES)

Impact Forecasting Toolkit for Cyclone

Impact Forecasting Toolkit
Paving the way towards Impact Forecasting

What is for the temperature related hazards?

Weather forecast

A hot, humid day tomorrow with periods of intense heat expected in the afternoon and evening.

↑

Hazard

Impact-based forecast

High temperatures ranging from 38°C to 41°C expected tomorrow between 12:00 and 15:00 potentially leading to increased risk of heat-related illnesses across the south-east.

↑

Hazard + Vulnerability

Impact forecast

High likelihood of significant heat-related illnesses among slum populations and residents in neighborhoods of X, Y and Z municipalities. Public cooling centers are now open at City Hall and all public libraries. Community volunteers are being mobilized to check on elderly neighbors.

↑

Hazard + Vulnerability + Exposure

Rainfall Forecast from BMD

Rainfall: Light to moderate rain/thunder showers with lightning flashes and temporary gusty wind is likely to occur at a few places over Rangpur, Mymensingh, Dhaka, Barishal, Chattogram & Sylhet divisions and at one or two places over Rajshahi & Khulna divisions with moderately heavy falls at places over Mymensingh & Sylhet divisions.

What does it mean for users?
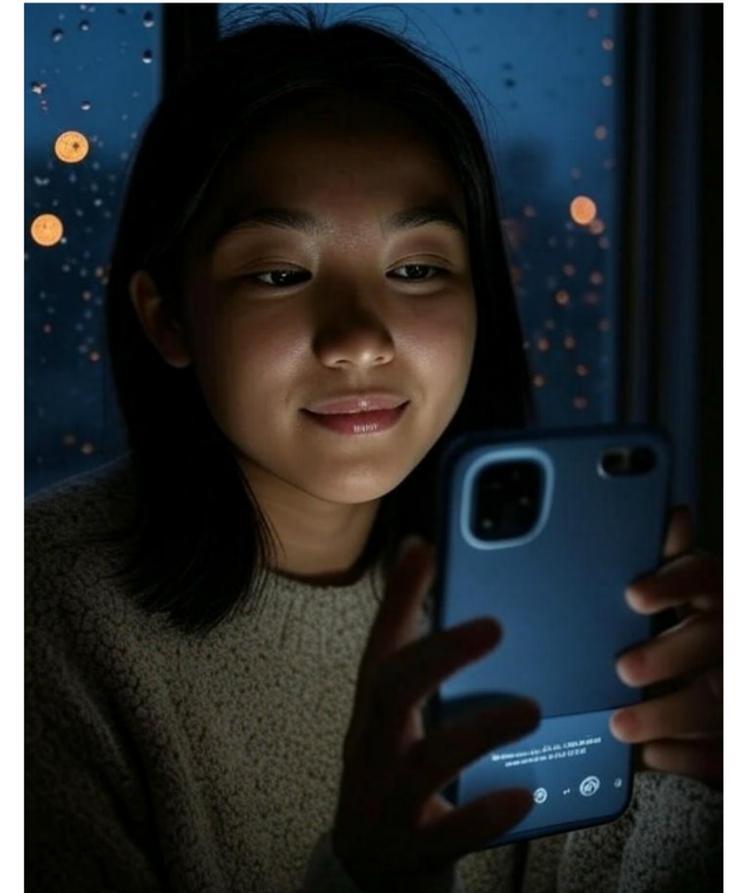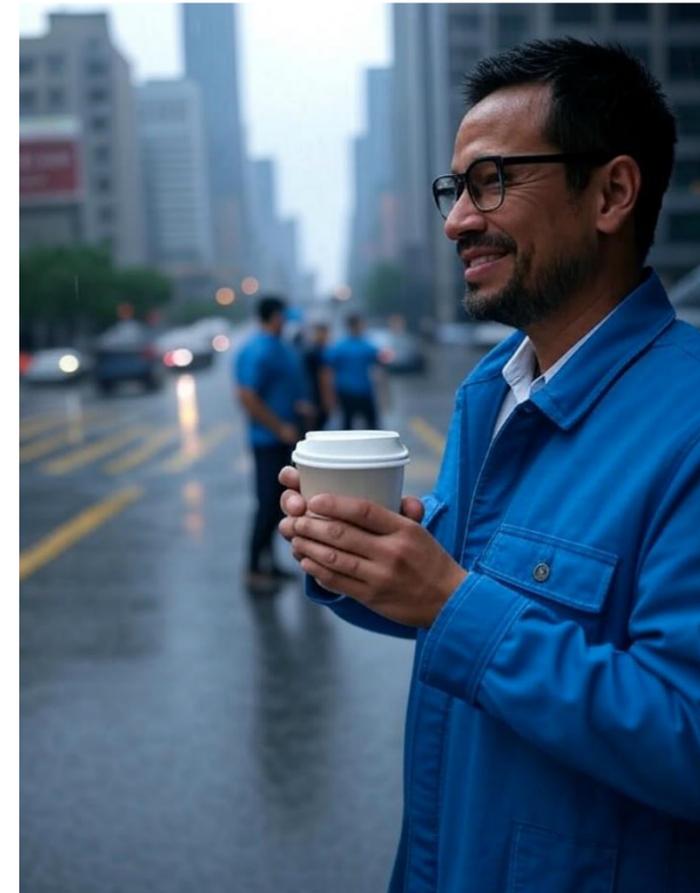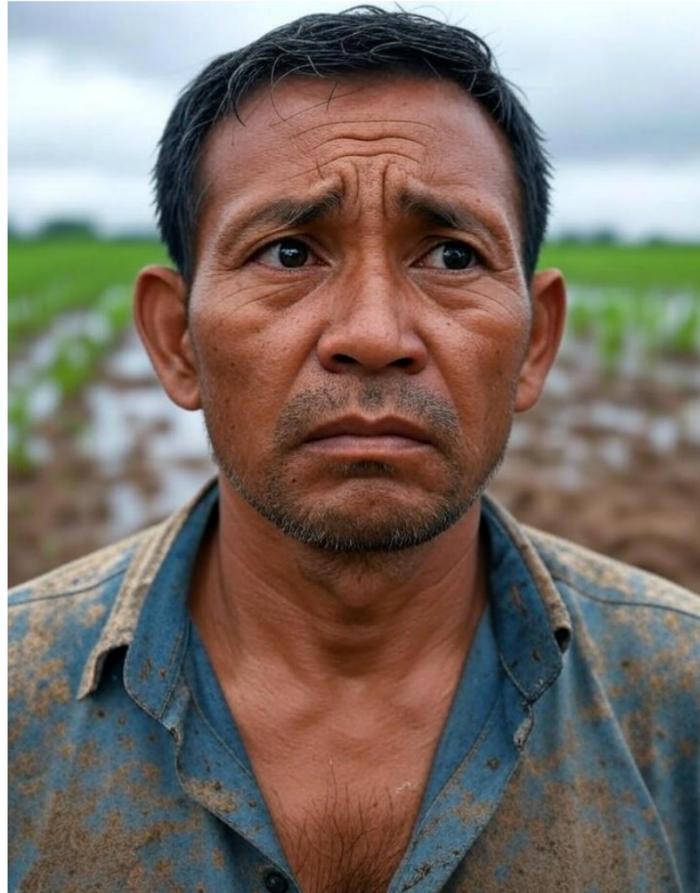
Cooking Impact-based and Impact Forecast

Must know these Ws

When

Who

Where

What

Cooking Impact-based and Impact Forecast

Who: Forecasters should specify to whom the information is targeted.

For example, health departments may be most concerned with heat levels that affect public health, while livestock-poultry industry may focus on THI trends and heatwave duration

Cooking Impact-based and Impact Forecast

What: The forecast should contain details about the hazard to be expected with possible impact for Who.
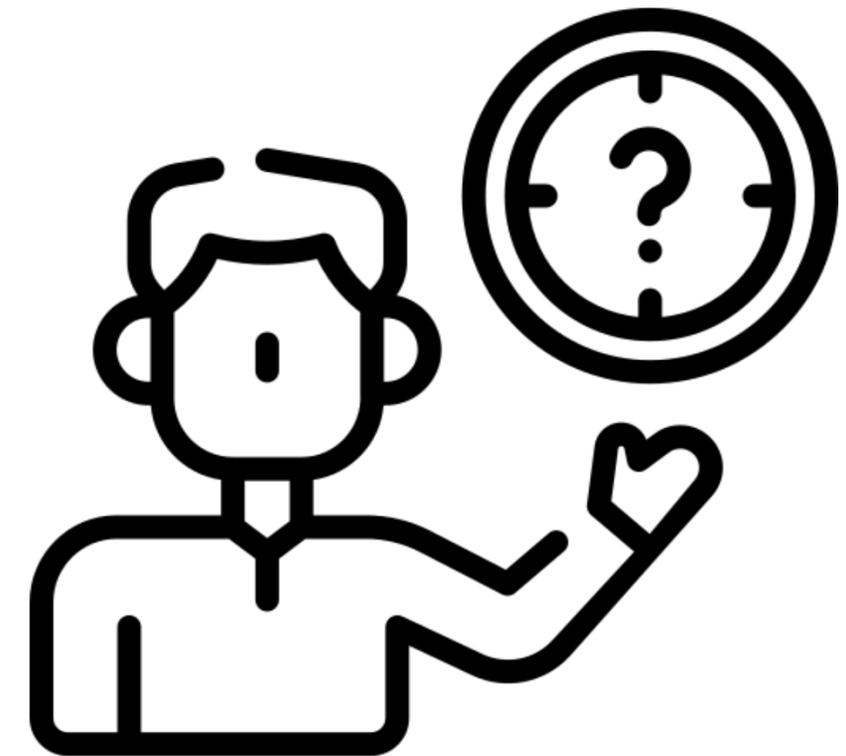
For instance, extremely high temperatures during heatwaves can lead to increased power consumption, as cooling systems work harder to maintain comfortable indoor conditions.

Cooking Impact-based and Impact Forecast

When: The users just don't only want to know the hazard they also want to when it will onset, duration and end. So forecasters need this ingredient too in their forecast

For example, the forecast should include "temperatures will rise to 40°C by 2:00 pm" or "expect heatwave to intensify during the afternoon tomorrow."

Cooking Impact-based and Impact Forecast

Where: Without the specific location, the whole forecast might not get the attention to the stakeholders. This may vary depending on 'Who' and Why.

For example, extremely high temperatures are to be expected due to a heatwave in X city, or power outages may occur due to increased demand from air conditioning during the intense heat in X city.
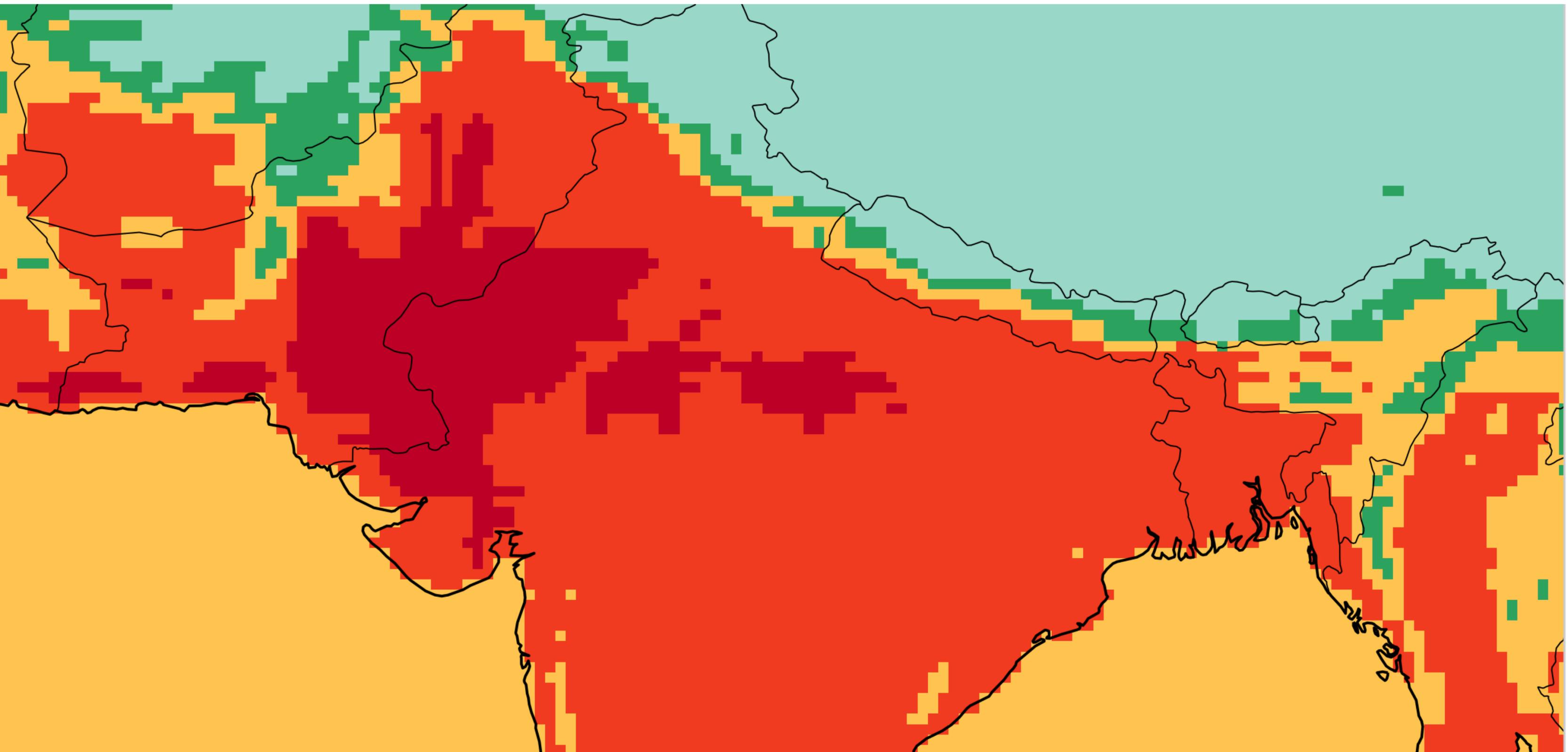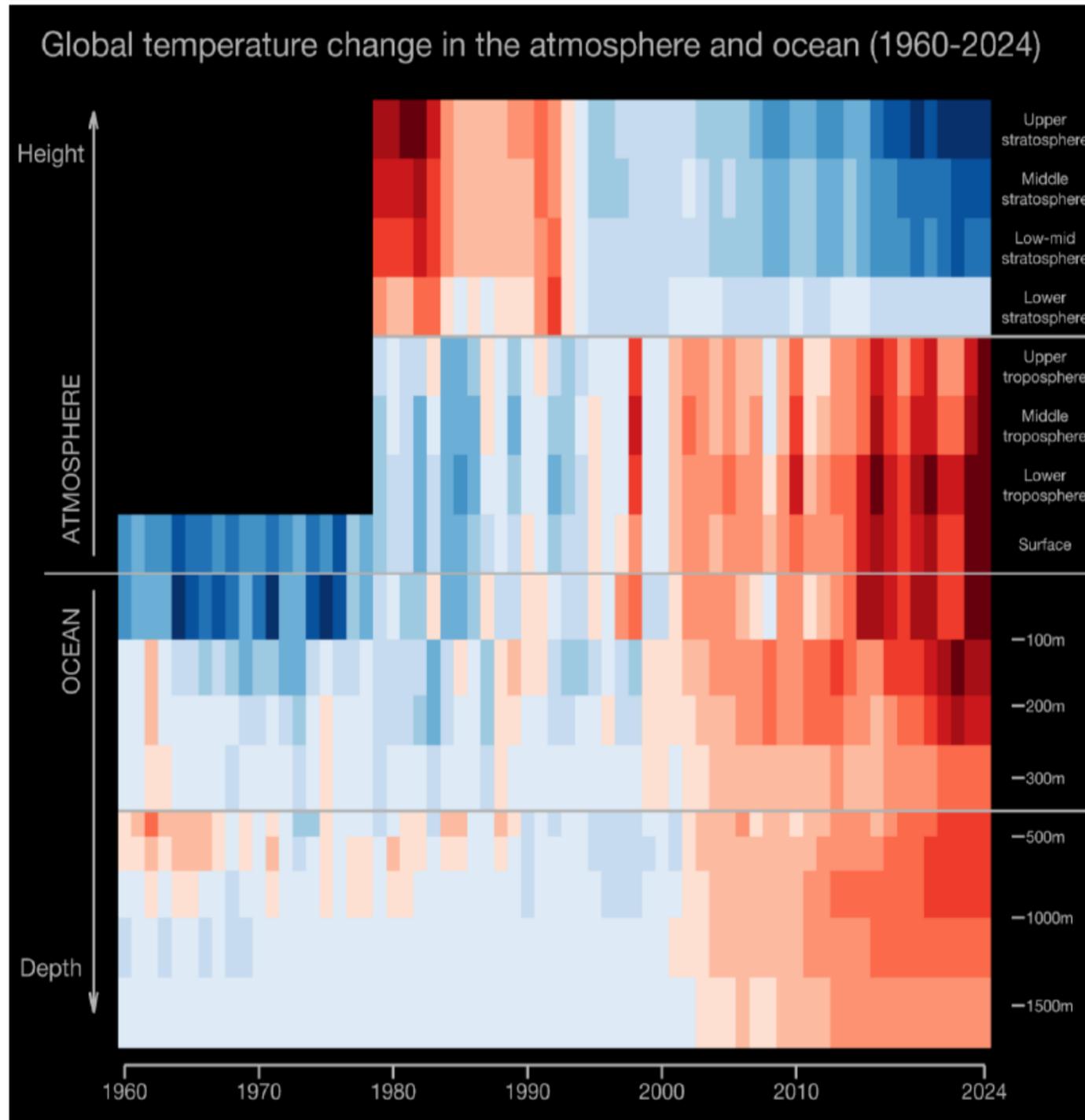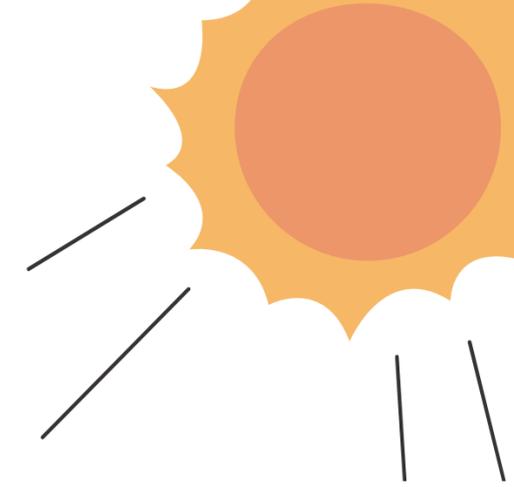
Combining H × V × E → Impacts
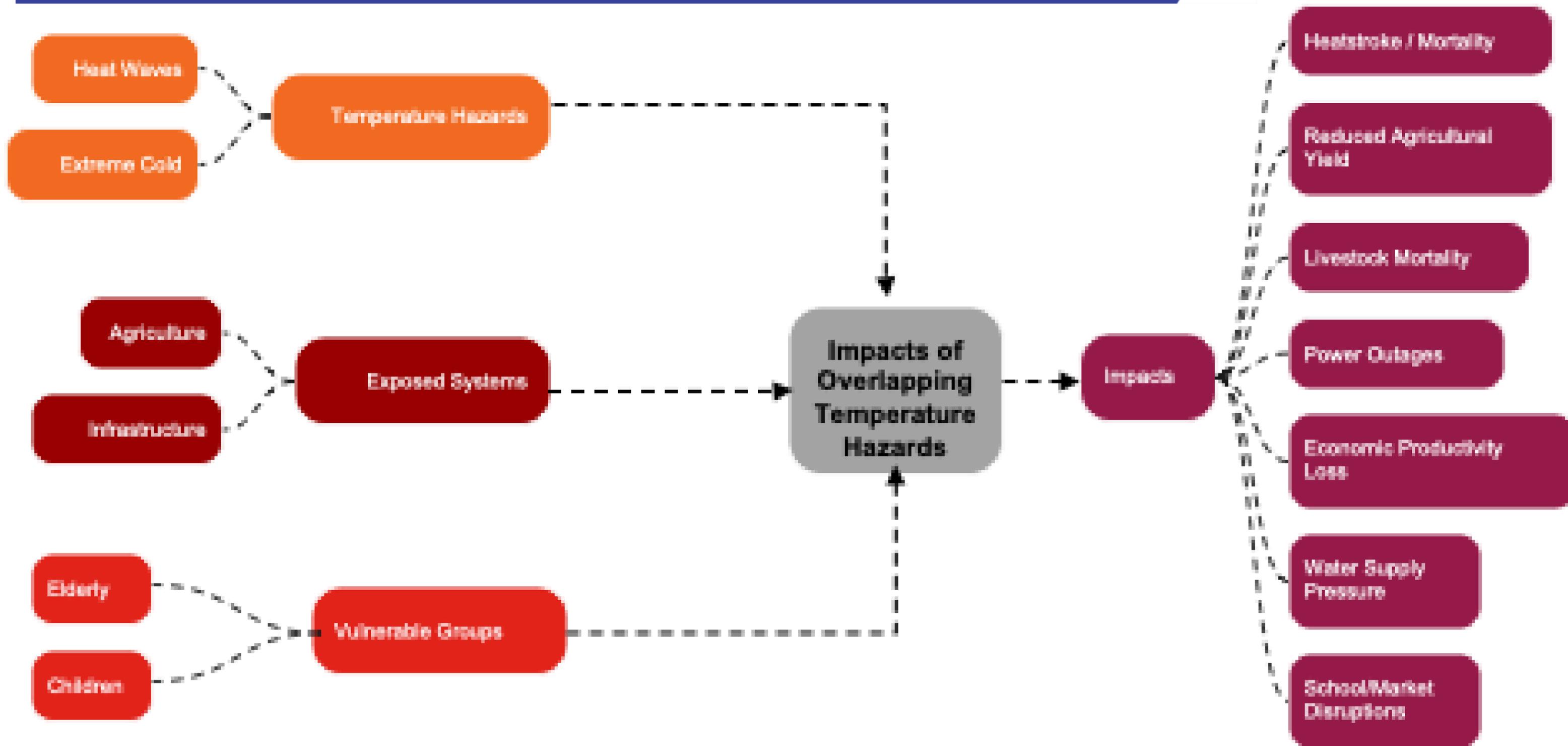
Hazard!

Global Temperature Change

Global temperature change in the atmosphere and ocean (1960-2024)

- Warming stripes for the surface and ocean depths (1960-2024), and for different layers of the atmosphere (1979-2024).
- Anomalies relative to the 1981-2010
- Global surface temperature: HadCRUT5
- Global average temperatures: RSS
- Stratospheric temp.: Steiner et al. (2020)
- Ocean data are from MOSORA

Hawkins et al. (2025)

Temperature-Related Hazards in South Asia

1 **Extreme Heat & Heatwaves**

- Heat Stress
- Urban Heat Island (UHI) effects
- Impacts: Dehydration, mortality, power demand surge, crop stress, reduced labor productivity

2 **High Wet-Bulb & Thermal Stress**

- Wet-Bulb Globe Temperature (WBGT)
- UTCI
- Physiological Equivalent Temperature (PET)
- Impacts: Severe physiological strain

3 **Droughts & Soil Moisture Deficits**

- Agricultural drought
- Groundwater depletion
- Zones Affected: Pakistan, Northwest India, Sri Lanka

4 **Glacier Melts & Temperature-Driven Hazards**

- Glacial Lake Outburst Flood (GLOFs)

Temperature-Related Hazards in South Asia

5 **Marine Heatwaves**

- High sea surface temperatures
- Coral bleaching
- Impacts: Bay of Bengal, Arabian Sea

6 **Winter Temperature Extremes (Cold Stress)**

- Cold waves
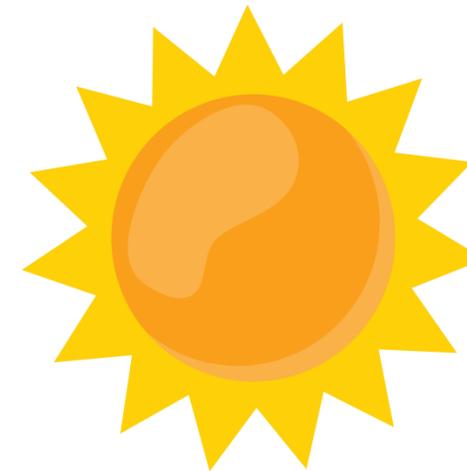- Mist/fog

7 **Fire Weather Conditions**

- Forest fires

8 **Frost / Sub-Freezing Temperature Events**
Elevation-dependent; crop damage in foothills of Himalayas

9 **High-Mountain Wind-Chill / Severe Cold Stress**
Frequent in Nepal, Bhutan, northern Pakistan, Hindu Kush

Hazard Type	Key Indicators	Datasets Commonly Used
Heatwave	Tmax Anomaly, Heat Index	ERA5, IMDAA, BMD
Thermal Stress	WBGT, UTCI	ERA5-Heat, Station obs
Glacier melt	Temperature trends	CMIP6, Satellite altimetry
Marine heatwave	SST anomalies	NOAA OISST, ESA CCI

Temperature-Hazard Activities

- Watches/ Monitoring
- Warnings/Alerts
- Advisories
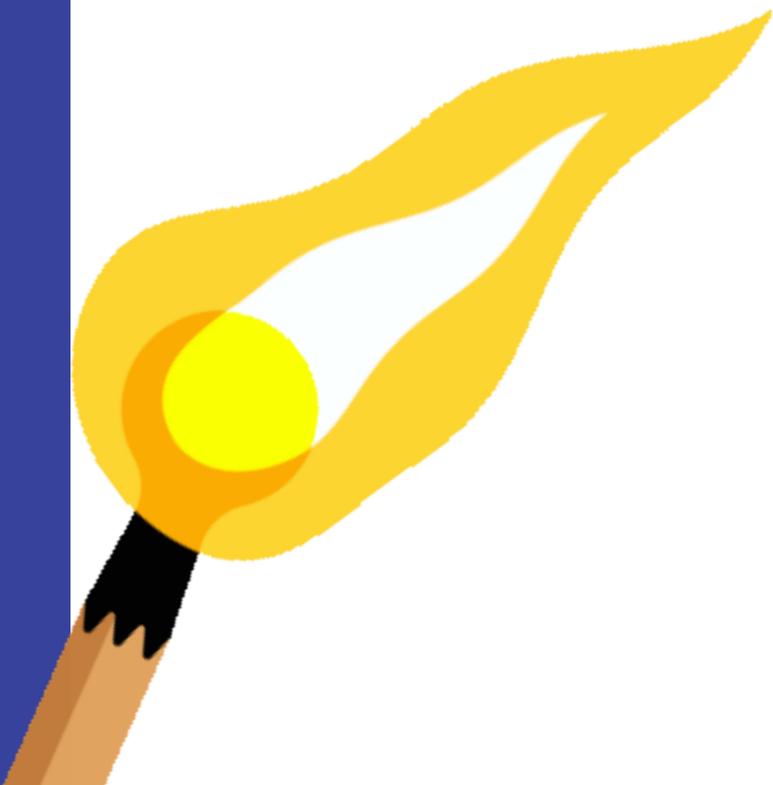
Impacts of Extreme heat

India: 733 Deaths

Pakistan: 568 Deaths

Bangladesh: ~33 million children affected

Source: United Nations Office for Disaster Risk Reduction and World Meteorological Organization (2025). Global Status of Multi-Hazard Early Warning Systems. Geneva, Switzerland.
Centre for Research on the Epidemiology of Disasters (CRED). (2025). 2024 Disasters in Numbers. Brussels, Belgium: CRED.
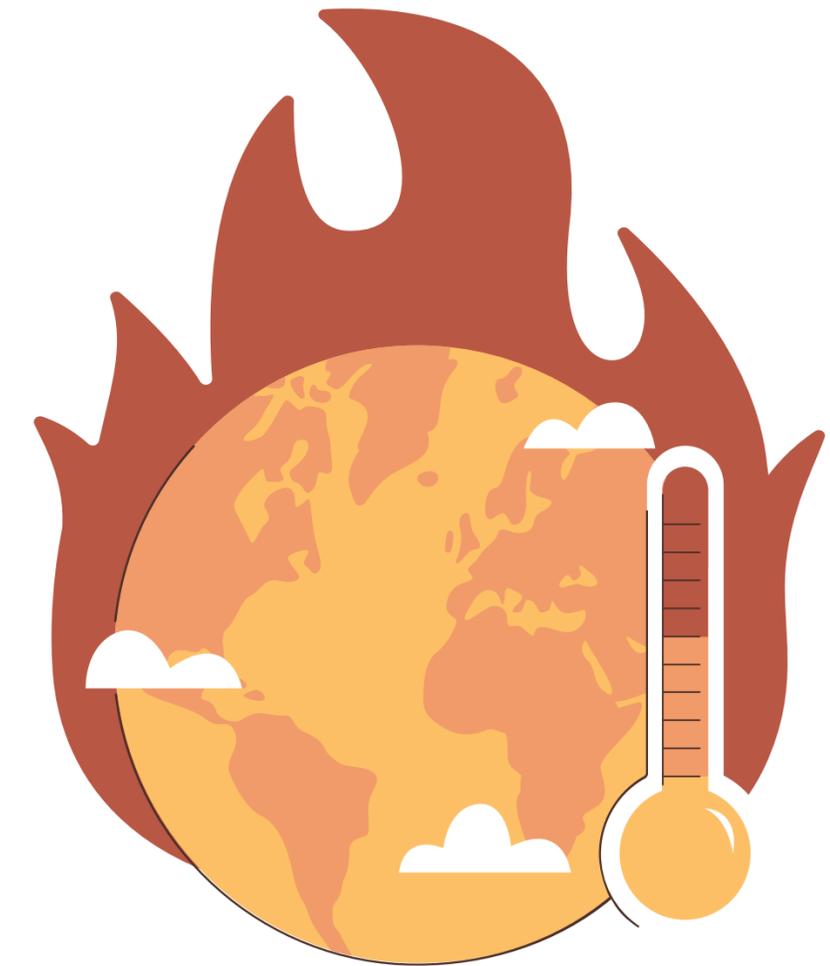
Universal Thermal Climate Index
Pakistan-India-Bangladesh
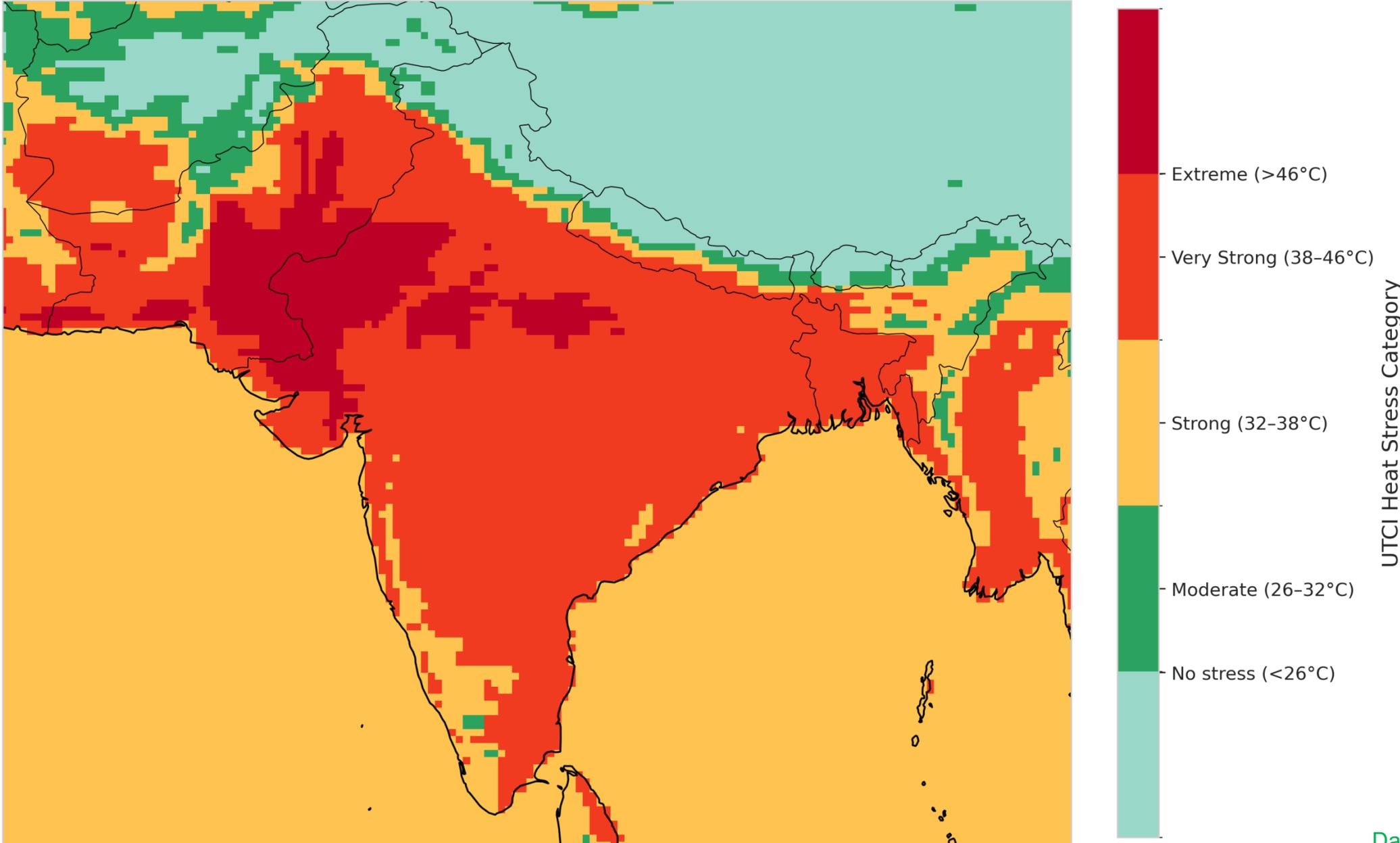
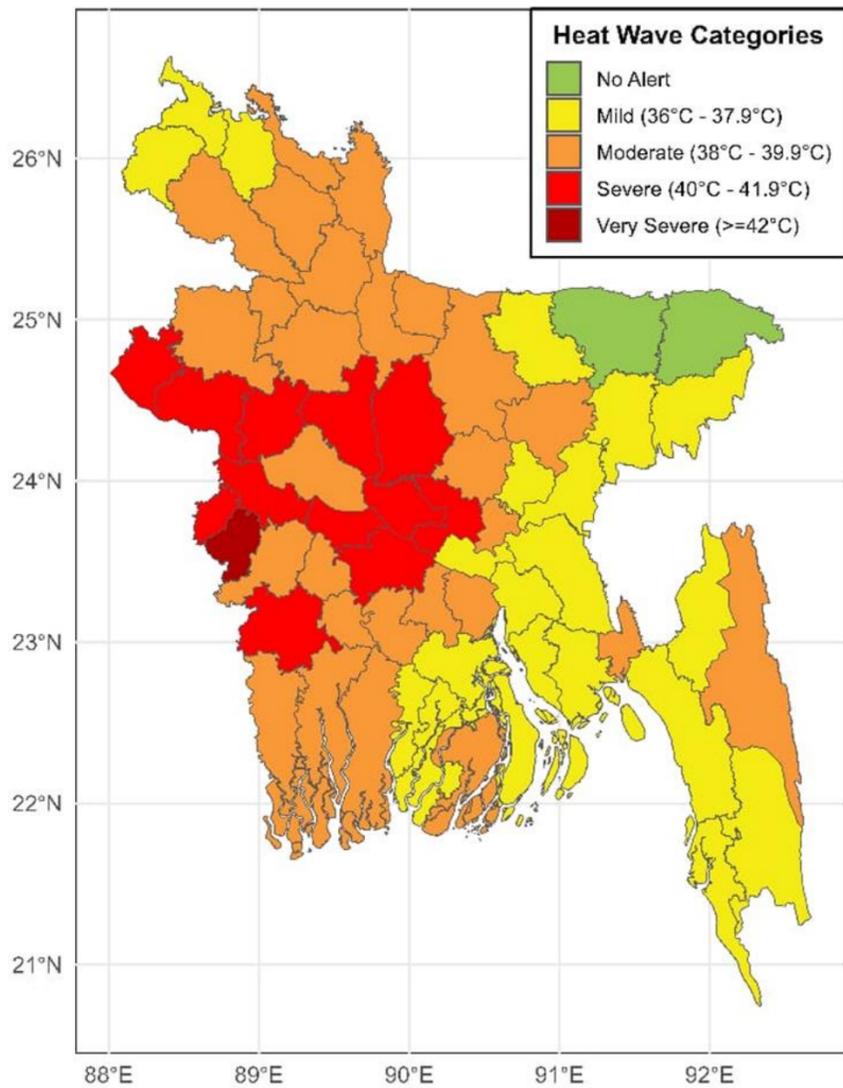UTCI Heat Stress Categories (Mean Daily Max UTCI)
May 2024

UTCI Heat Stress Category

- Extreme (>46°C)
- Very Strong (38–46°C)
- Strong (32–38°C)
- Moderate (26–32°C)
- No stress (<26°C)

Color-coded Heat Wave Forecast
Bangladesh Meteorological Department

Forecast Issued on 08 May 2025

Heat Wave Categories
- No Alert
- Mild (36°C - 37.9°C)
- Moderate (38°C - 39.9°C)
- Severe (40°C - 41.9°C)
- Very Severe (>=42°C)

Govt. of the People's Republic of Bangladesh
Bangladesh Meteorological Department
Storm Warning Centre
E-24, Agargaon, Dhaka-1207

Phone: 41025730, 41025731
FAX : 41025727, 41025728
Web Site: www.bmd.gov.bd
Email: mfo@bmd.gov.bd
swc@bmd.gov.bd

Date: 08.05.2025

ALERT MESSAGE FOR HEAT WAVE

The prevailing mild heat wave condition over Khulna division may spread at many places over the country and it may continue as moderate to severe heat wave at places during next 72 hours commencing from 02:00 PM of today (08 May 2025).

8.5.25

(Kh. Hafizur Rahman)
Meteorologist
For Deputy Director
08, 1330 BST

TO
1. HON'BLE ADVISER, MINISTRY OF DISASTER & RELIEF, FAX 9545405
2. CABINET SECRETARY, FAX 9566539
3. PRINCIPAL SECRETARY TO THE HON'BLE CHIEF ADVISER FAX 9141377
4. SECRETARY, MINISTRY OF DEFENCE, FAX 9119935
5. IGP, BANGLADESH POLICE, FAX 9563502
6. SECRETARY TO THE HON'BLE CHIEF ADVISER, FAX 8128799
7. SECRETARY, MINISTRY OF AGRICULTURE, FAX 9540555
8. SECRETARY, MINISTRY OF DISASTER MANAGEMENT AND RELIEF, FAX 9566559/9545405
9. SECRETARY, MINISTRY OF WATER RESOURCES, FAX 9576773
10. JOINT SECY. (W&D), MOD, FAX 9110935, 11. SSE, FAX 8113351/9113651, 12. CPP, FAX 933 8401, 13. DOM, 9851615
14. MEQ, FAX 8754270, 9885633, 15. SHIPPING MINISTRY, FAX 9566311, 9582037, 16. NDRCC, FAX 9543148, 9540567
17. BIWTA, FAX 9551072, 18. BTV FAX, 8312927, 19. BETAR FAX 8117830, 20. FFWC, FAX 9557386, 21. UNB, FAX 9344556
22. BSS, FAX 9557929, 23. MMO CTG, FAX 031-2500988, 24. CDMP, FAX 9830854, 25 COAST GUARD, FAX 9140992
26. PORT AUTHORITIES, MONGLA 04662-75224, 27. PORT AUTHORITIES, CHITTAGONG 710593, 28. BSS, 9557929, 9551032
29. HON'BLE CHIEF ADVISER'S, ARMED FORCES DEPT (AFD), FAX 8754399, 8115900, 8823233
30. BANGLADESH ARMY, FAX 8754455, 31. BANGLADESH AIR FORCE, FAX 8753911, 32. REUTERS, 8312936
BIWTC, 9563653, 34. ATN, 8111876/9139983, 35. UNHCR, 8829557, 36. SPARRSO, 8113080, 37. UNDP, 8123196
38. CHANNEL 1, 9343674, 39. RTV, 913/0879-80, 40. EKKA HD, 9891609, 41. PORT AUTHORITIES, PAYRA, FAX 031-2510889
42. D.C CON'S
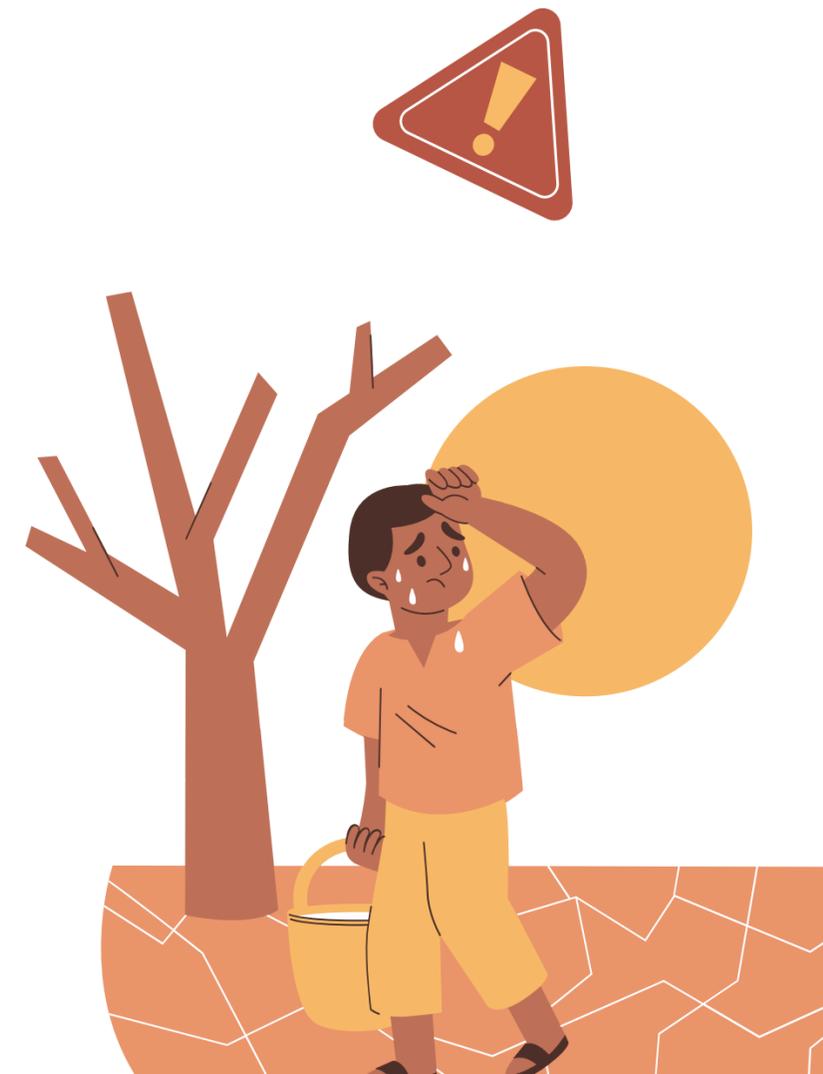
Heat Index

1 **Temperature**

2 **Humidity**

The Heat Index Equation

The computation of the heat index is a refinement of a result obtained by multiple regression analysis carried out by Lans P. Rothfusz and described in a 1990 National Weather Service (NWS) Technical Attachment (SR 90-23). The regression equation of Rothfusz is
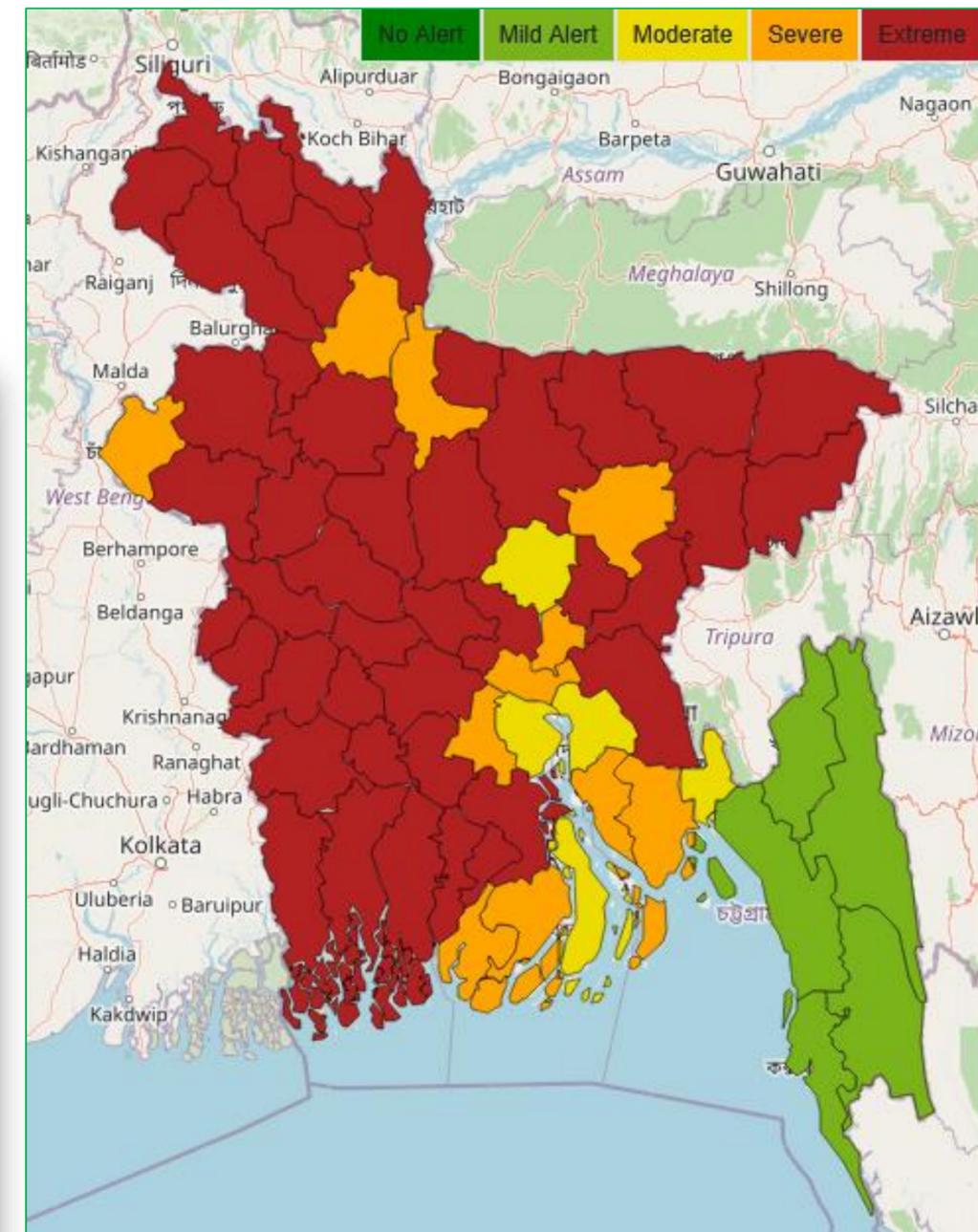
$HI = -42.379 + 2.04901523*T + 10.14333127*RH - .22475541*T*RH - .00683783*T*T - .05481717*RH*RH + .00122874*T*T*RH + .00085282*T*RH*RH - .00000199*T*T*RH*RH$

where T is temperature in degrees F and RH is relative humidity in percent. HI is the heat index expressed as an apparent temperature in degrees F. If the RH is less than 13% and the temperature is between 80 and 112 degrees F, then the following adjustment is subtracted from HI:

$ADJUSTMENT = [(13-RH)/4]*SQRT\{[17-ABS(T-95.)]/17\}$

where ABS and SQRT are the absolute value and square root functions, respectively. On the other hand, if the RH is greater than 85% and the temperature is between 80 and 87 degrees F, then the following adjustment is added to HI:
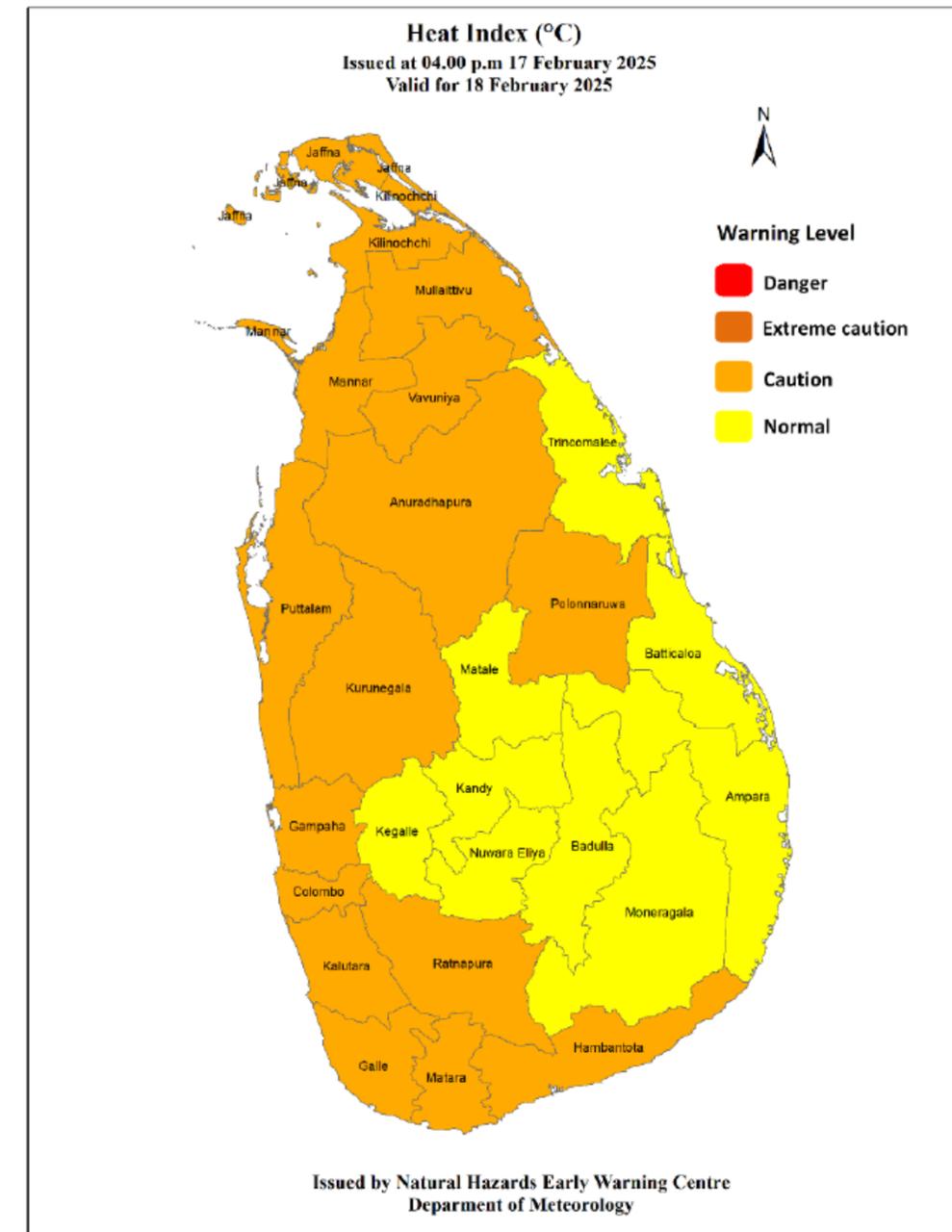
$ADJUSTMENT = [(RH-85)/10] * [(87-T)/5]$

No Alert | Mild Alert | Moderate | Severe | Extreme

Bangladesh Meteorological Department
Supported By: RIMES

Heat index Advisory: SRI LANKA

| 1 | **Temperature** |
| 2 | **Humidity** |

Heat Index	Level of warning	
27–38	**Normal**	
39–45	**Caution**	fatigue is possible with prolonged exposure and activity. Continuing activity could result in heat cramps.
46–52	**Extreme Caution**	heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke.
over 52	**Danger**	heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.

Heat Index (°C)
Issued at 04.00 p.m 17 February 2025
Valid for 18 February 2025

Warning Level
- Danger
- Extreme caution
- Caution
- Normal

Issued by Natural Hazards Early Warning Centre
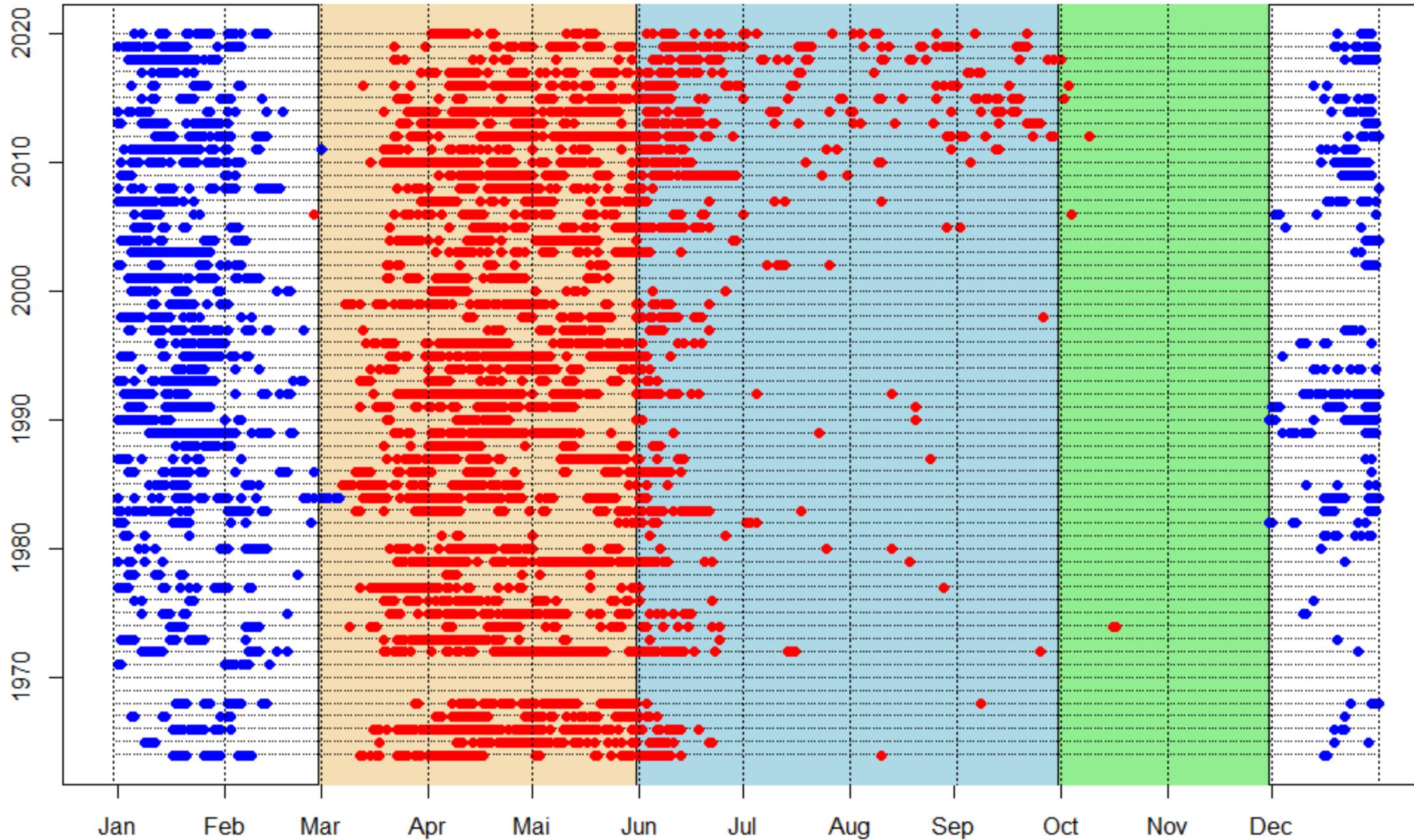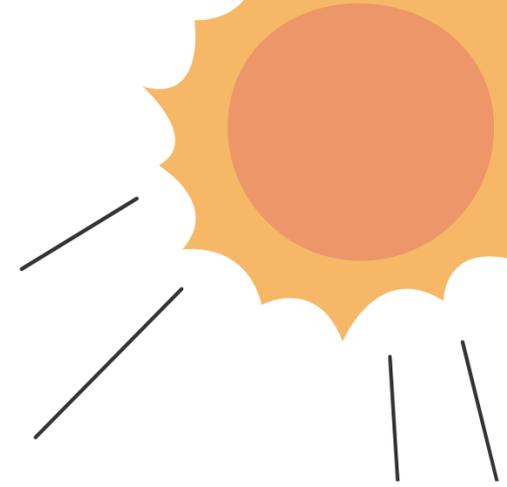Deparment of Meteorology

Natural Hazards Early Warning Centre issued
At 4.00 p.m. 17 February 2025, valid for 18 February 2025

Bangladesh: Climate of Heat Wave Days in March-May During 1981-2025
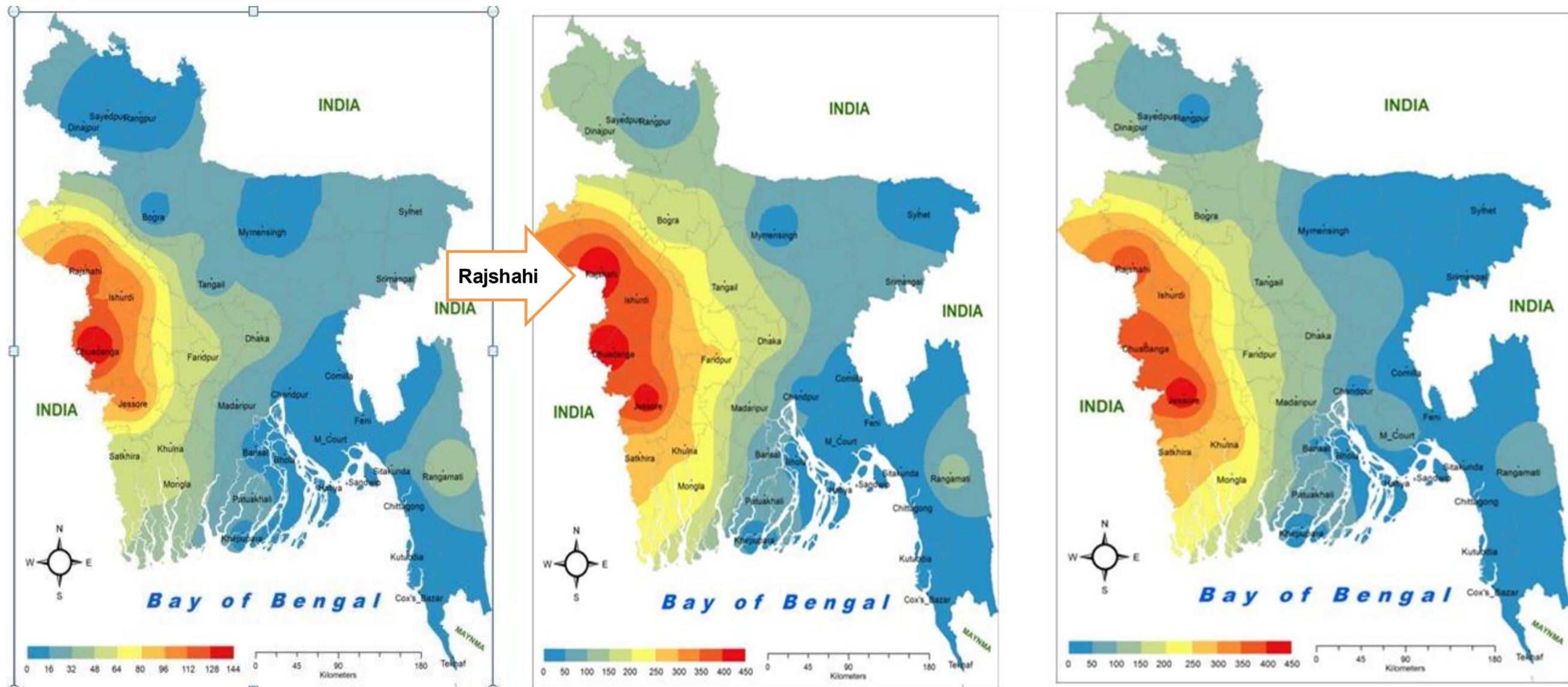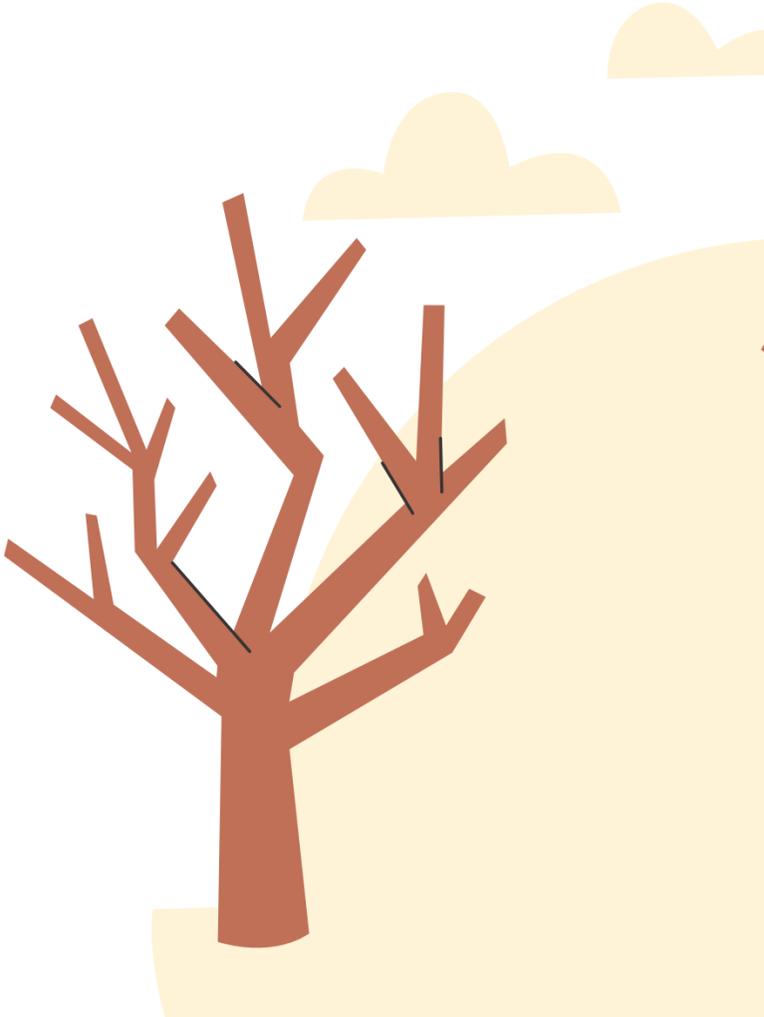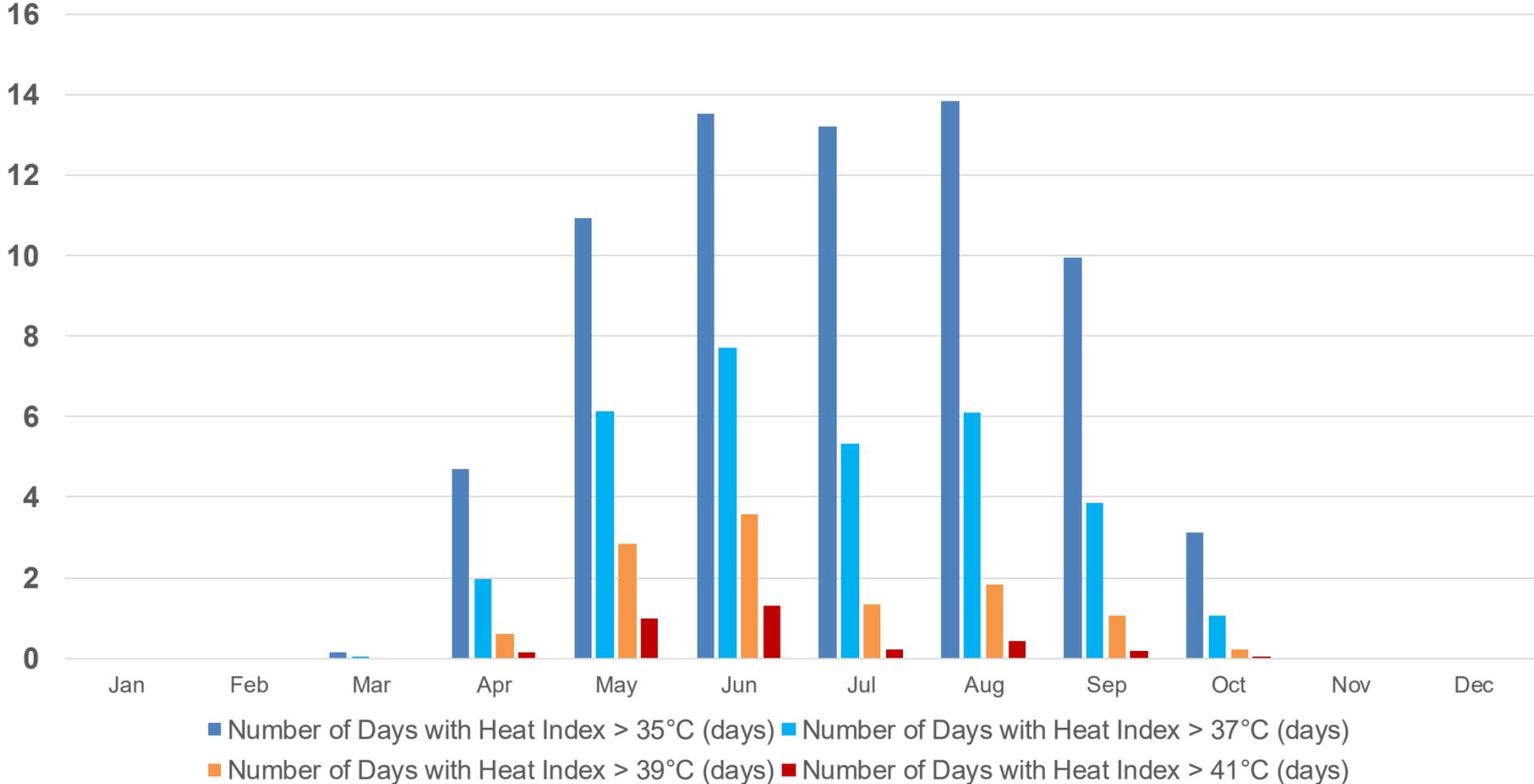
Number and heatwave (red) and coldwave (blue) days in Rajshahi

Heat Index at Rajshahi, Bangladesh during 1991-2020
Data: ERA5

Number of Days with Heat Index at Rajshahi

Legend:
- Number of Days with Heat Index > 35°C (days)
- Number of Days with Heat Index > 37°C (days)
- Number of Days with Heat Index > 39°C (days)
- Number of Days with Heat Index > 41°C (days)

Nepal: Observed Annual Number of Frost Days (Tmin < 0'C)

Observed Annual Number of Frost Days (Tmin < 0°C) Annual Trends with Significance of Tr...
per Decade Nepal 1950-2024
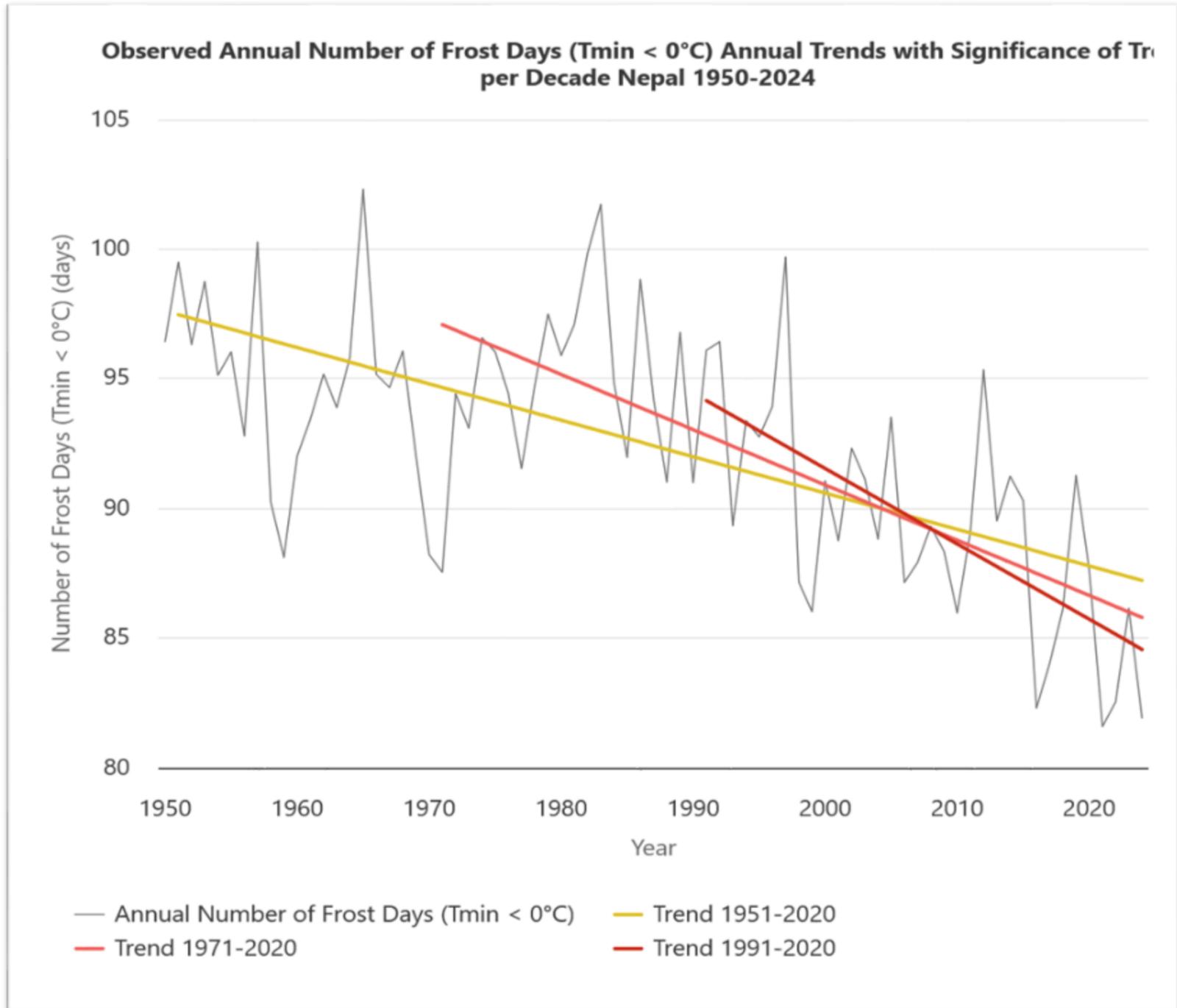
Urban Heat Island over Dhaka, Bangladesh
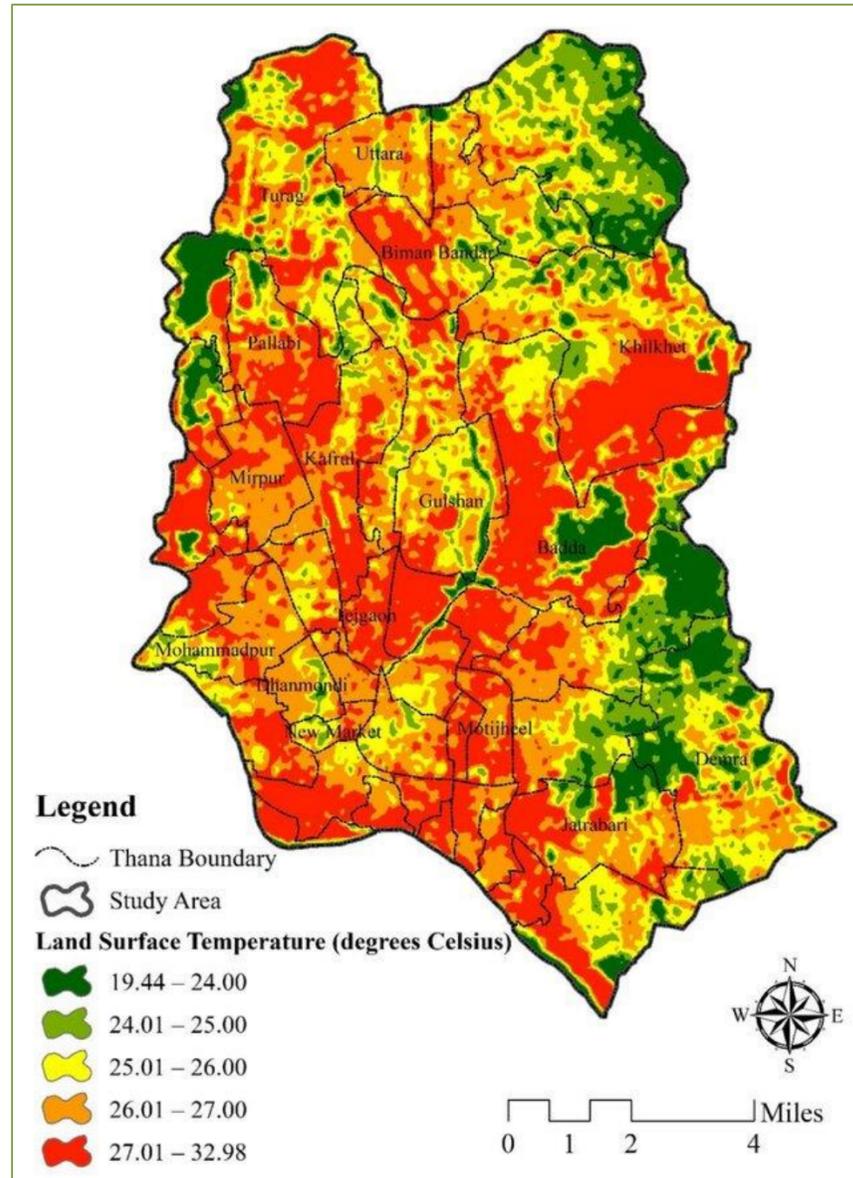
Bangladesh: Avg. Land surface temperature distribution over Dhaka Metropolitan Area (DMA). Abrar et al. (2022)
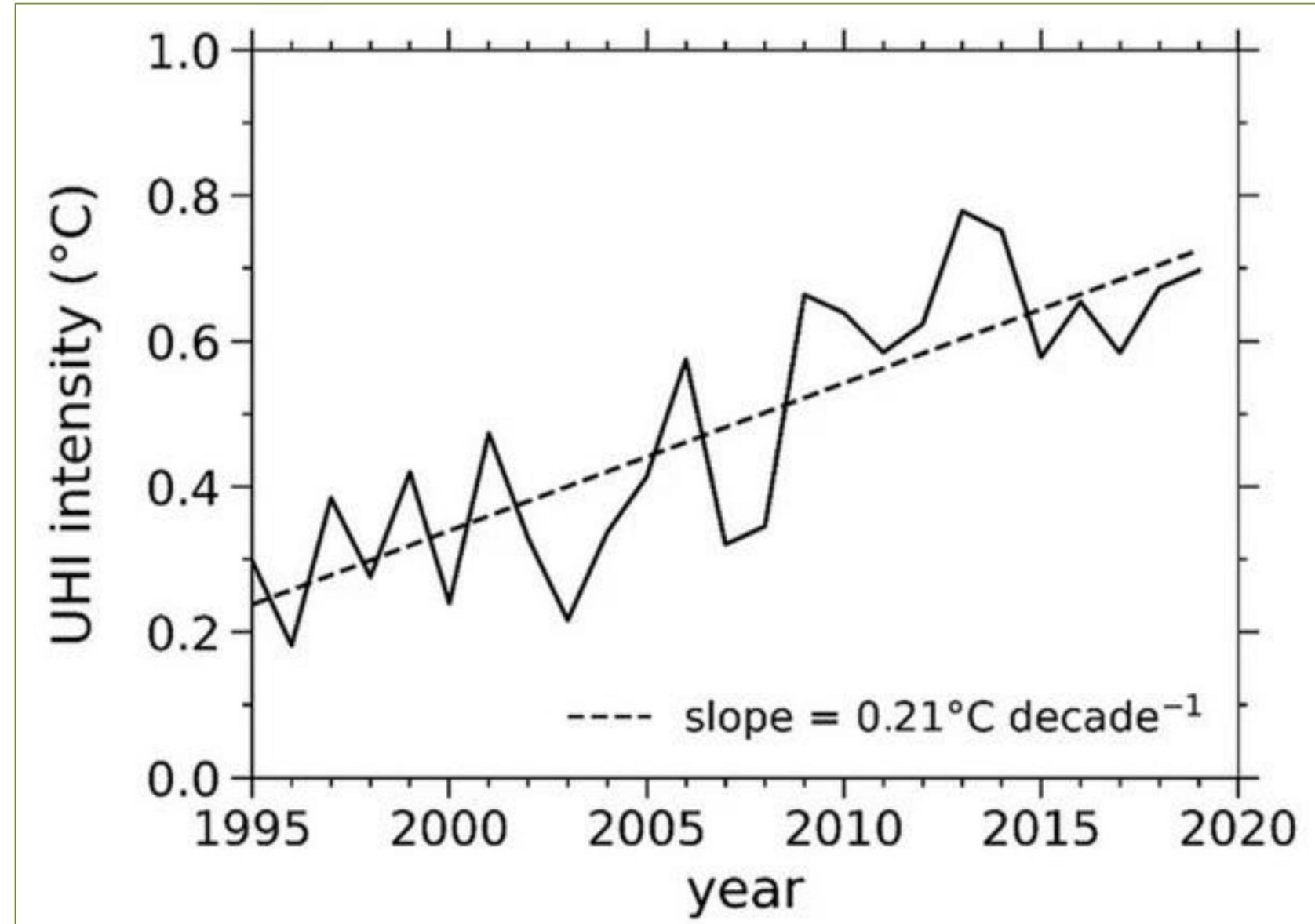
Tabassum et al. (2024)

Universal Thermal Climate Index

$$UTCI(T_a, T_{mrt}, w, RH) = T_a + offset(T_a, T_{mrt}, w, RH)$$

- Air temperature at 2m (Ta),
- Relative humidity (RH)
- Wind speed (w)
- Globe Temperature or Radiation as Mean radiant temperature (Tmrt)

- Angle factors, fa
- The surface projection factor, fp
- solar elevation angle γ

UTCI Dynamic Physiological Response

Bröde et al. (2009)
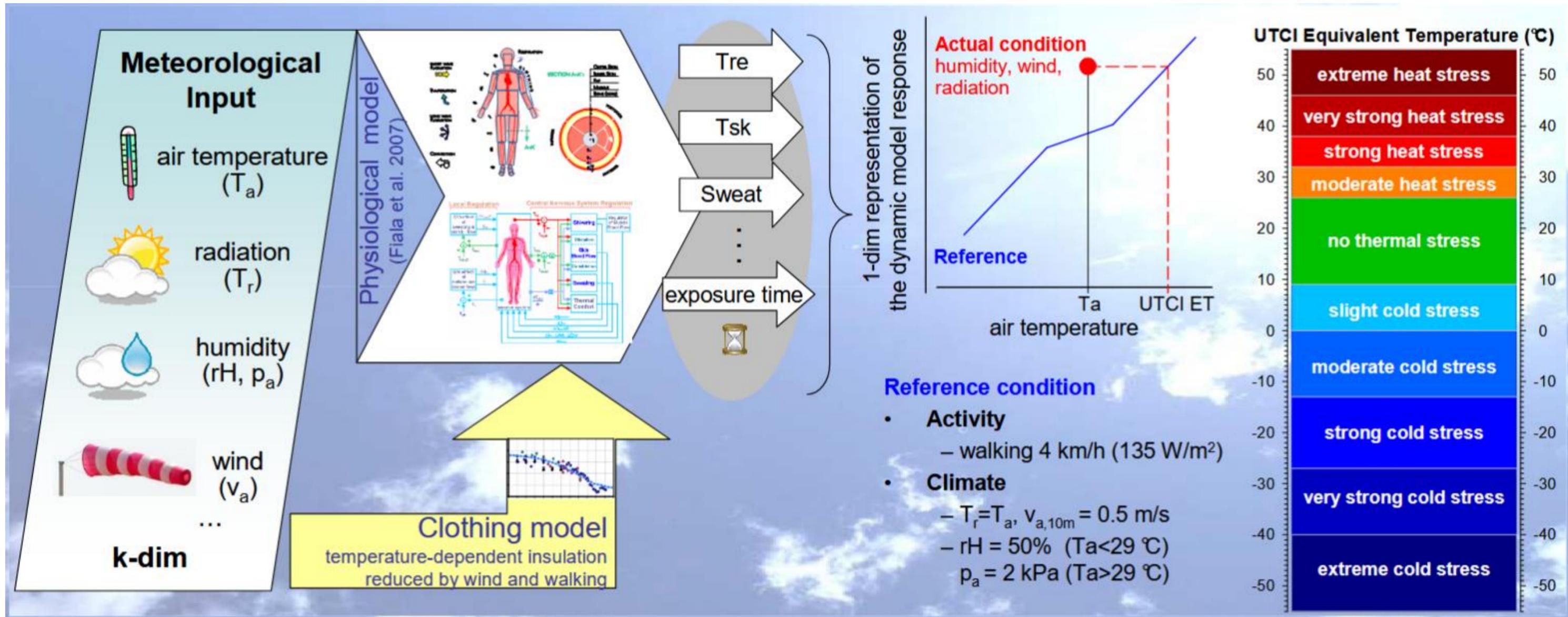
UTCI at Rajshahi, Bangladesh

UTCI Thermal-Stress Days: Rajshahi Station (Daily Max)
Each dot = 1 day

Legend:
- Extreme (>46°C)
- Moderate (26–32°C)
- Strong (32–38°C)
- Very Strong (38–46°C)

Data Source: ERA-Heat

UTCI at Rajshahi, Bangladesh

Annual Heat-Stress Days during March–September: Rajshahi Station (Daily Max UTCI)
Trend Line for Each Category

Extreme (>46°C)
Moderate (26–32°C)
Strong (32–38°C)
Very Strong (38–46°C)

Days per Year

Year

Data Source: ERA-Heat
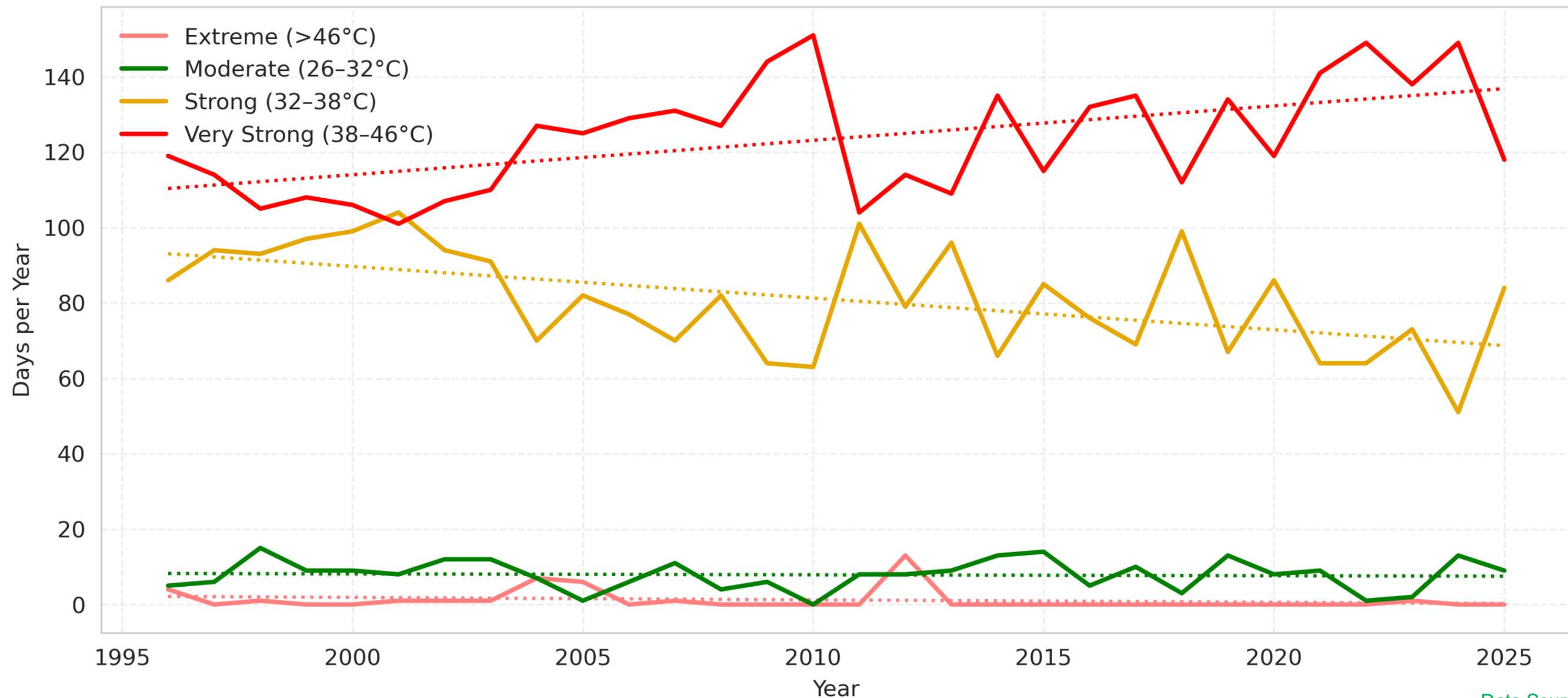
UTCI Sensor Setup at Gana Unnayan Kendra(GUK), Hatibandha, Rangpur, Bangladesh

- **One set of sensor set at Field level – one outdoor and one indoor**

- **2 reading daily at 12:00 pm and 3:00 pm**
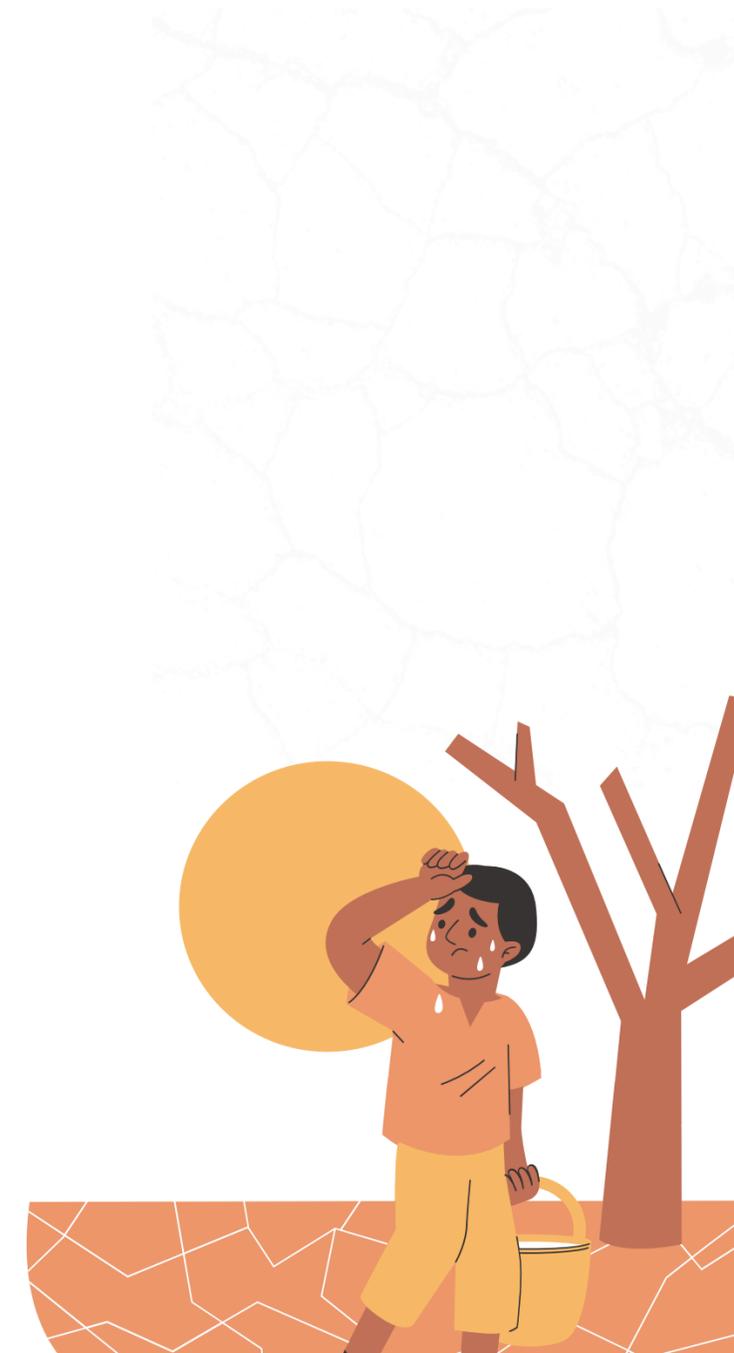
Observed UTCI at Hatibandha, Rangpur, Bangladesh

Forecasting UTCI using ECMWF-IFS Data

$$UTCI(T_a, T_{mrt}, w, RH) = T_a + offset(T_a, T_{mrt}, w, RH)$$

$$\text{MRT}^* = \left\{ \frac{1}{\sigma} \left[f_a\, L_{surf}^{dn} + f_a\, L_{surf}^{up} + \frac{a_{ir}}{\varepsilon_p} \left(f_a\, S_{surf}^{dn,diffuse} + f_a\, S_{surf}^{up} + f_p\, I^* \right) \right] \right\}^{0.25}$$
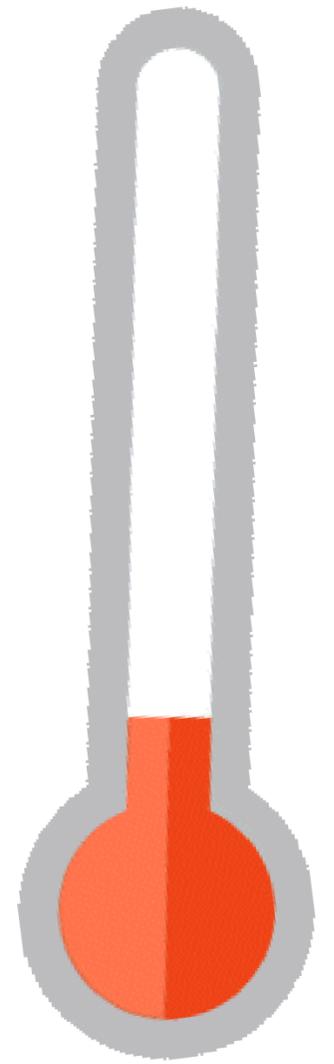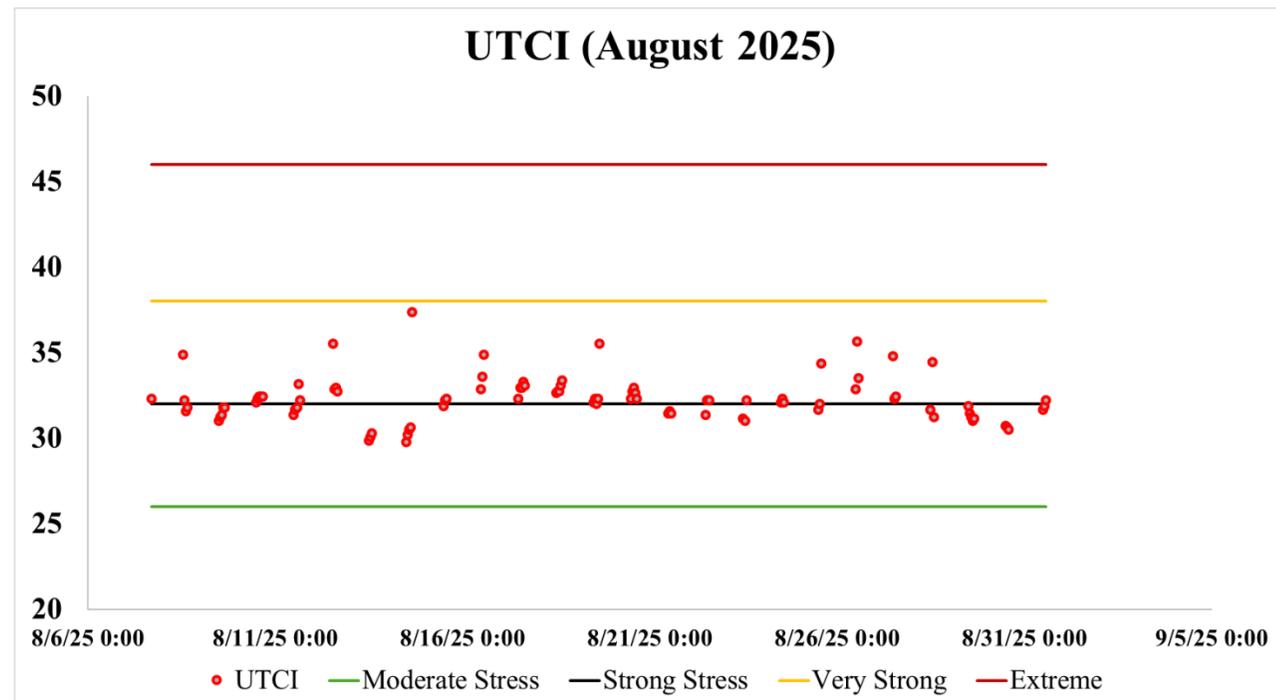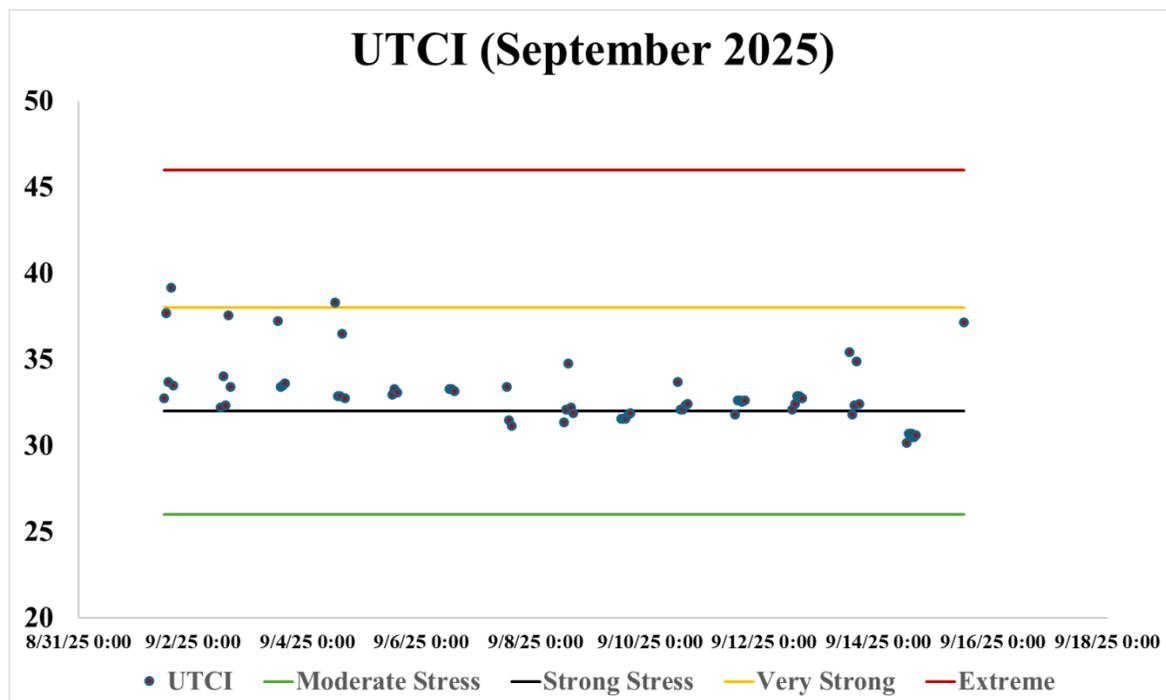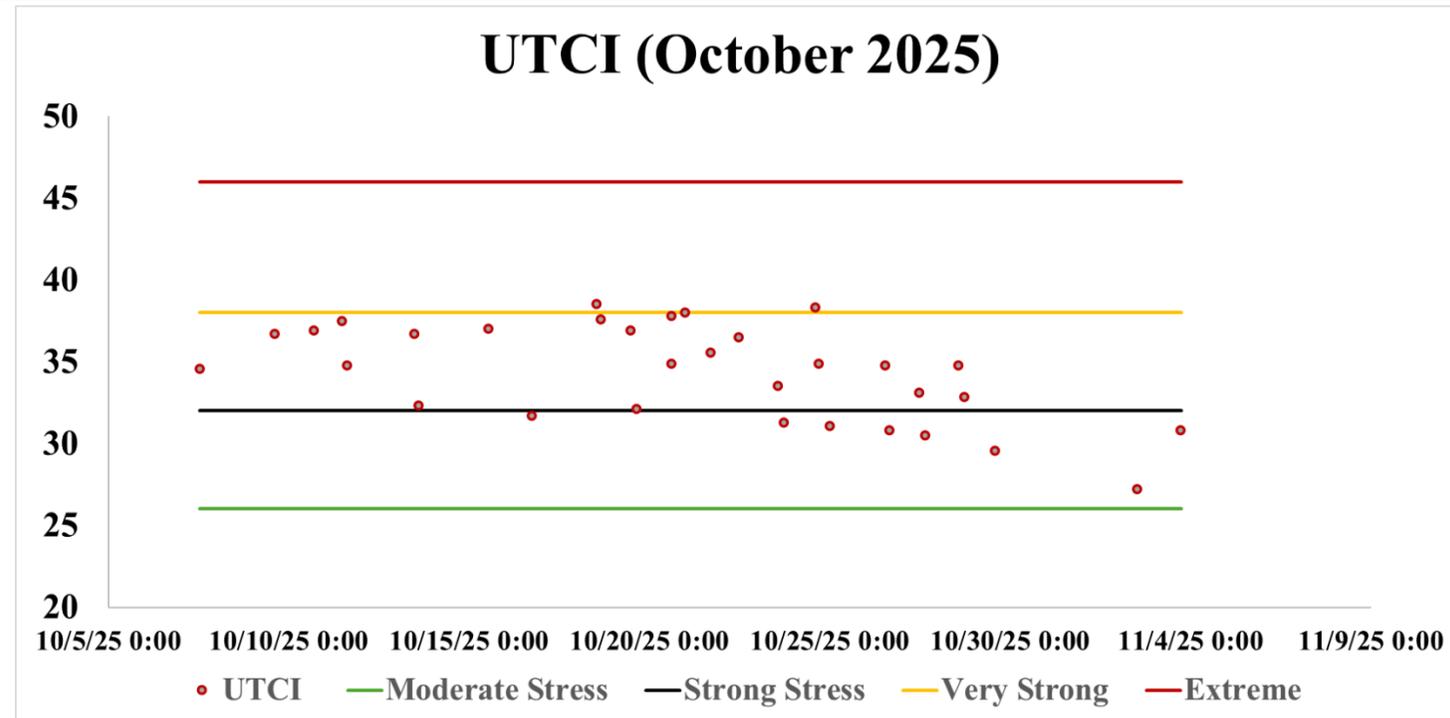
Short Name	Name	Symbol/equation	MARS code
SSRD	Surface Solar Radiation Downwards	$S_{surf}^{dn} = S_{surf}^{dn,direct} + S_{surf}^{dn,diffuse}$	169.128
SSR	Surface net Solar Radiation	$S_{surf}^{net} = S_{surf}^{dn} - S_{surf}^{up}$	176.128
SSRC	Surface net Solar Radiation for Clear-skies	$S_{surf,clear}^{net}$	210.128
FDIR	DIRect solar radiation at the surface	$S_{surf}^{dn,direct}$	21.228
CDIR	Clear-sky DIRect solar radiation at the surface	$S_{surf,clear}^{dn,direct}$	22.228
STRD	Surface Thermal Radiation Downwards	L_{surf}^{dn}	175.128
STR	Surface net Thermal Radiation	$L_{surf}^{net} = L_{surf}^{dn} - L_{surf}^{up}$	177.128
STRC	Surface net Thermal Radiation for Clear-skies	$L_{surf,clear}^{net}$	211.128
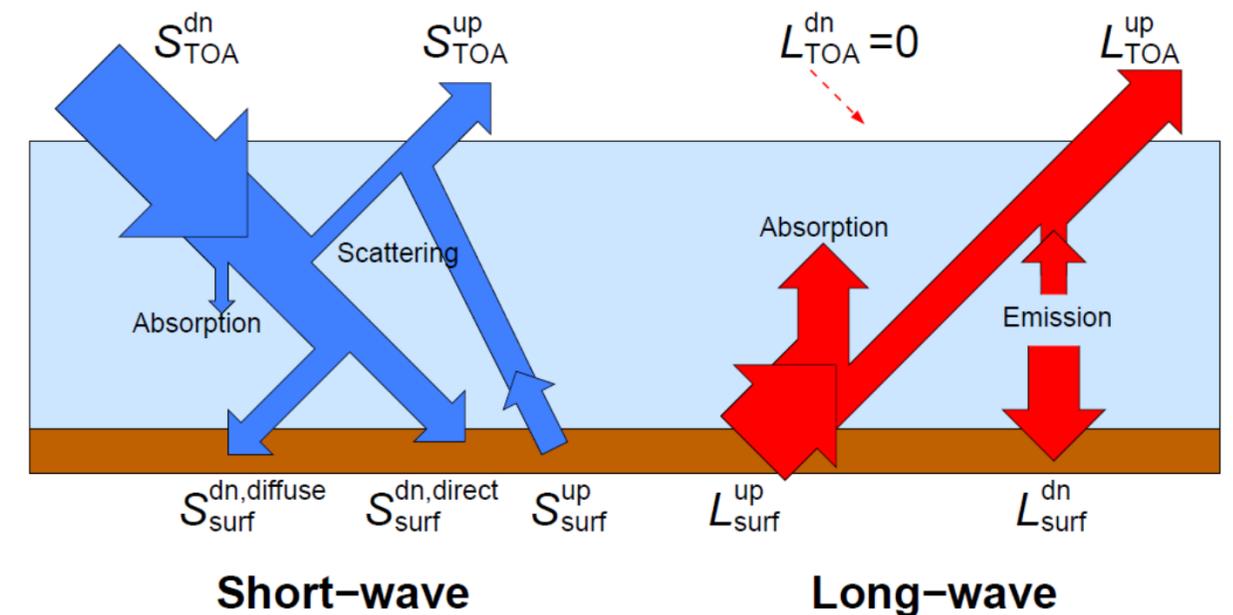
Recommendation

1. Temp. forecast data using for estimating HI and UTCI needs bias correction

2. WBGT, UTCI monitoring sensors should be calibrated

3. Forecasts should be evaluated against observations and community consultations

Instructions

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Vulnerability!

Understanding Vulnerability

Vulnerability = **Sensitivity + Lack of Coping capacity**

✓ Who is more affected when temperature rises or drops?
✓ Which systems fail first?
✓ Which livelihoods are sensitive to temperature anomalies?
✓ If the temperature vulnerability is **multi-sectoral?**

Highly vulnerable, Moderate exposure

Low vulnerable, Moderate exposure
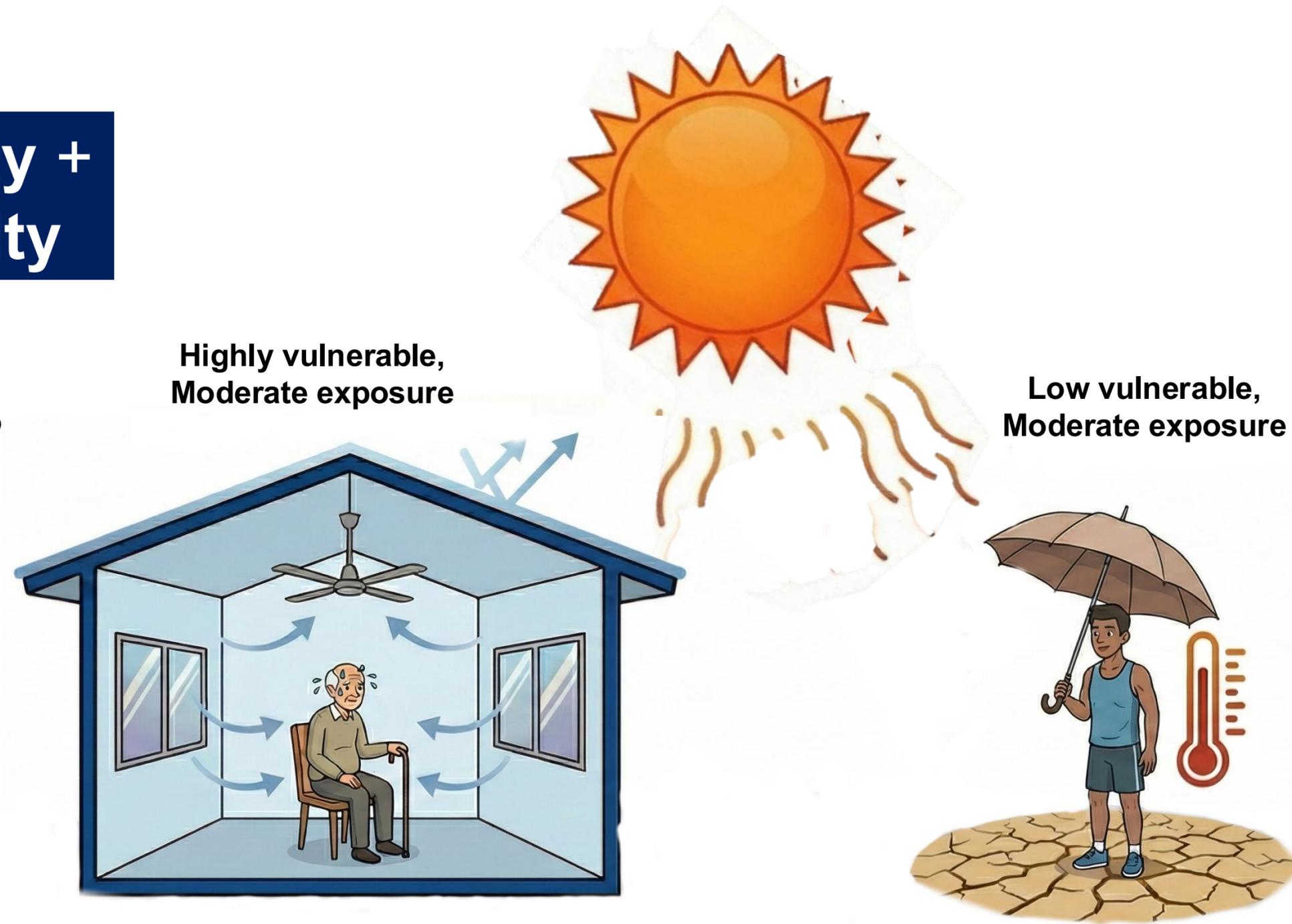
Vulnerability assessments often look at age and income, among other data, and are sometimes overlaid with analysis of tree canopy cover, rooftop albedo and daytime and/or nighttime temperatures.

Low % of 65 and older

Low nighttime temperature (°F/°C)

High nighttime temperature (°F/°C)

High % of 65 and older

Low % of ages 65 and older

Low nighttime temperature (°F/°C)

High nighttime temperature (°F/°C)

High % of ages 65 and older
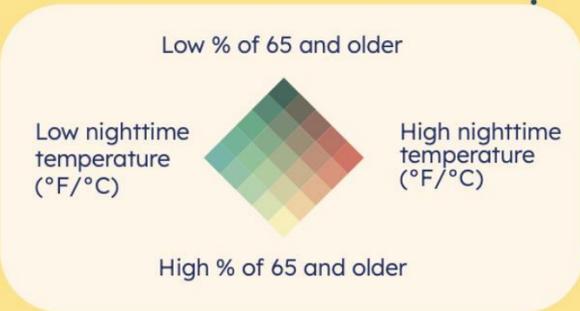
Power/Energy
- High cooling dependency
- Grid fragility / load pressure

Economy & Labor
- Daily wage earners
- Outdoor workers
- Informal settlements

Human Health
- Age group (elderly, children)
- Chronic illness prevalence
- Poor housing / ventilation
- Access to cooling/heating

Urban / Environment
- High-density settlements
- Poor quality housing
- Limited tree cover

Agriculture
- Crop heat sensitivity
- Irrigation dependency
- Water availability

Livestock
- Poultry density (mortality risk)
- Cattle heat stress sensitivity
- Fodder crisis

Calculation of Vulnerability

Example of Cyclone Impact Forecasting

Dimension	Category	Component	Sub-Component	Indicator	Weight
Vulnerability	Poverty and Development	Poverty	Poor People	Poor People	4.5
			Extremely Poor People	Extremely Poor People	5
			Unsustainable Livelihood Household	Population dependent on Agriculture	4
				Number of Day Laborers (Non-agricultural and agri)	3
				Population involved in Fisheries	4.5
				Animal Husbandry	3
	Other Vulnerable Group	Other Vulnerability	Women Headed Households	Female headed Households	2.5
			House Structure	Non-Permanent Housing Structure	5
			Elderly Population	Dependent Population	3.5
			Population (age <15)		
			Population with Disability	Population with Disability	4.5
	Social-Economics Vulnerability	Economical Dependency	Unemployment Rate	Unemployment Rate	1.5
	Natural	Epidemic	Population (age <5)	Children under 5 years	3.5
Lack of Coping Capacity		Communication	Adult Literacy Rate	Lack of Literacy Rate	2
				Lack of Female Literacy Rate	2
			Internet Users	Individuals without access to Internet	3.5
			Mobile Phone Users	Individuals without Mobile Phone	4
	Infrastructure	DRR	Cyclone Shelter	Number of Cyclone Shelters (currently operational)	5
		Access to health care	Community Clinic and Health Center Density	Number of community clinics/health centers (currently operational)	3
		Access to water	Fresh Water	Lack of Fresh water access	4
		Embankment	Embankment Condition	Current condition of dam (non-fragile, fragile, absent)	4
	Institutional	Preparedness and Response	CPP volunteer	Number of Cyclone Preparedness Programme (CPP) Volunteer	5
			Early Warning	Disaster Prone HH Received Early Warning	3.5

Define Purpose and Scope

Clarify focus hazard, identify area and population, define objectives.

Engage different stakeholders including meteorological services, health departments, local government, social welfare, and community groups.

Engage Key Stakeholders

Select Vulnerability Indicators

Choose indicators covering different dimensions including demographic health, socio-economic, and infrastructure dimensions.

Collect data from different sources such as census, municipal records, health databases, and field surveys.

Collect and Compile Data

Assign Weights to Indicators

Consult experts to determine the relative importance of each indicator.

Convert all indicators to a comparable 0–1 scale using min–max normalization.

Normalize Indicator Values

Calculate Composite Vulnerability Index

Multiply normalized indicator values by their assigned weights.

Classify index values into Very Low, Low, Moderate, High, Very High.

Categorize Vulnerability Levels

Validate with Stakeholders

Review initial results with local authorities and community representatives.

Prepare maps, charts, and summary reports. Use results for early warning, planning, and targeted interventions.

Communicate and Apply Results
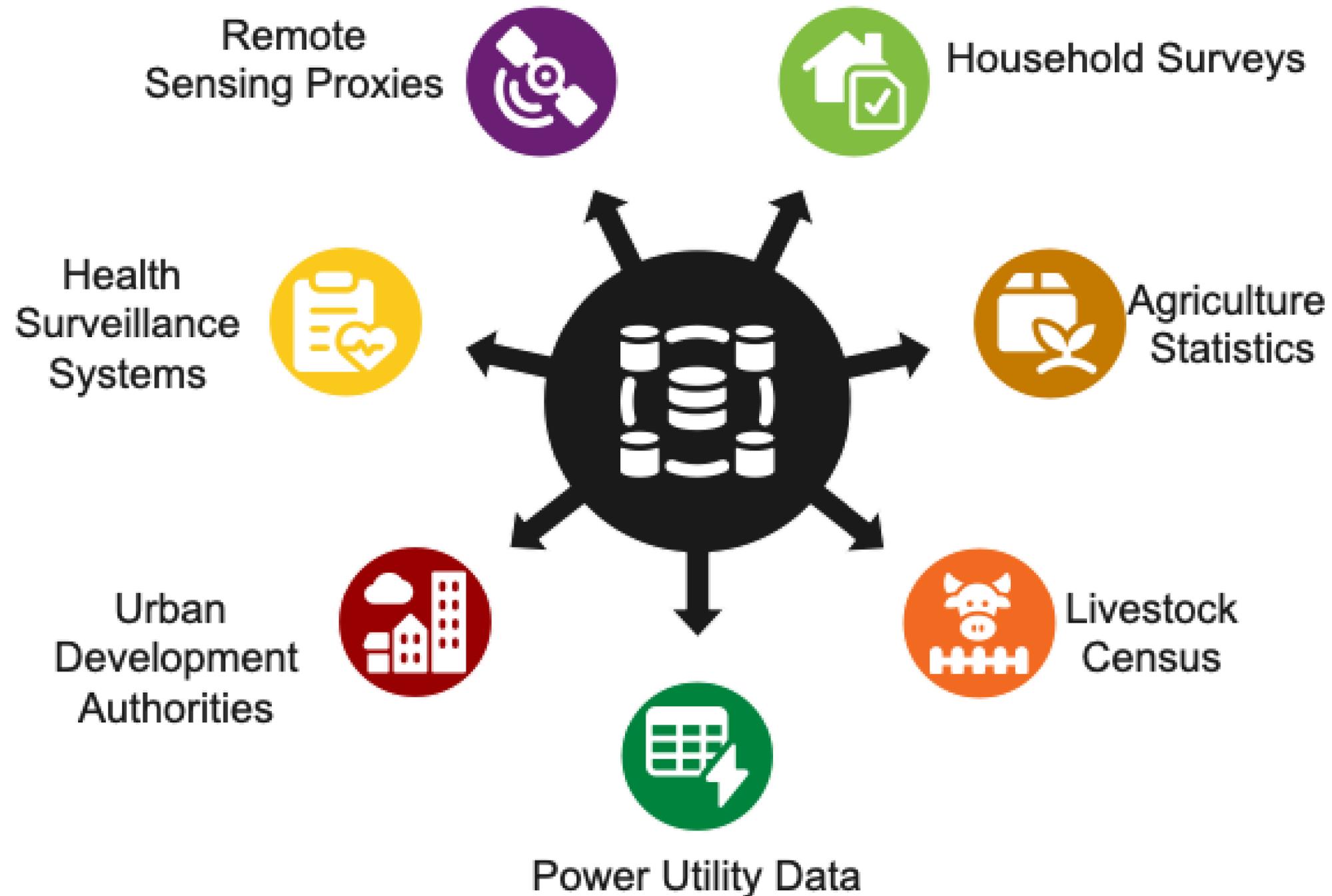
With v_i being the value of the indicator, v_{min} the minimum value of this indicator and v_{max} the maximum value of this indicator.

$$nv_i = \frac{(v_i - v_{min})}{(v_{max} - v_{min})}$$

$$VI_0 = \sum_i w_i * nv_i$$

With the vulnerability index on the scale from 0 to 1, w_i is the weight of the indicator i, and nv_i the normalized value of the indicator i.

Examples of vulnerability indicators

Category	Core Indicators	Why It Matters	Additional Potential Indicators
Demographic Sensitivity	**Children under 5 Elderly >65**	Highest physiological susceptibility due to impaired thermoregulation, dehydration risk, and dependency.	• Pregnant women • Single-person elderly households • Population living alone
Health Status	• Chronic illnesses (cardiac, respiratory, renal, diabetes) • People with disabilities	Chronic and mobility-related conditions reduce heat/cold tolerance and restrict action-taking ability.	• Medication-dependent population (diuretics, beta-blockers, psychiatric medicine) • Mental health conditions
Socio-economic Vulnerability	**Poverty rate Unemployment rate**	Financial constraints limit access to cooling/heating, safe housing, healthcare, and information.	• Informal settlement residents • Energy-poor households (cannot afford AC/heater operation) • Households without social protection support
Migration & Social Exclusion	• Migrants/immigrant population	Limited access to cooling/heating, services, or warning information; often live in poor housing.	• Linguistically isolated groups • Seasonal migrant workers • Homeless/unsheltered population
Occupational Exposure	• Outdoor workers (construction, agriculture, transport, street vendors)	Direct & prolonged exposure to heat/cold; limited workplace safety provisions.	• Workers with high physical exertion • Night-shift workers • Factory/warehouse workers in poor ventilation
Housing & Built Environment	• Heat-sensitive or cold-sensitive housing (tin roof, slum housing, non-insulated) • Social/low-cost housing	Poor thermal performance of buildings intensifies indoor heat/cold stress.	• Households without cross-ventilation • Poorly insulated walls/roofs • Multi-family high-density units
Urban Form & Density	**High Population Density**	Traps heat, restricts airflow, worsens both heat & cold vulnerabilities (depending on housing conditions).	• Urban heat island hotspots • Areas with low vegetation or shade • Street canyons / narrow lanes
Access to Cooling/Heating	• Households without cooling devices (fans, AC) • Households without heating devices (heater, warm clothing)	Limited cooling/heating capacity drastically increases risk of heatstroke or frostbite/hypothermia.	• Energy-unreliable households (frequent outages) • Communities with no public cooling/heating centers
Water & Basic Services	• Households lacking potable water	Hydration is essential for thermoregulation; water scarcity elevates heat-related illness risk.	• Areas with limited sanitation • Communities with irregular water supply
Health & Emergency Services Access	• Distance to nearest health facility	Determines timeliness of response during heat or cold emergencies.	• Ambulance service availability • Community health volunteers density

Vulnerability Data Sources(Example)

Remote Sensing Proxies

Household Surveys

Health Surveillance Systems

Agriculture Statistics

Urban Development Authorities

Livestock Census

Power Utility Data

Group Work
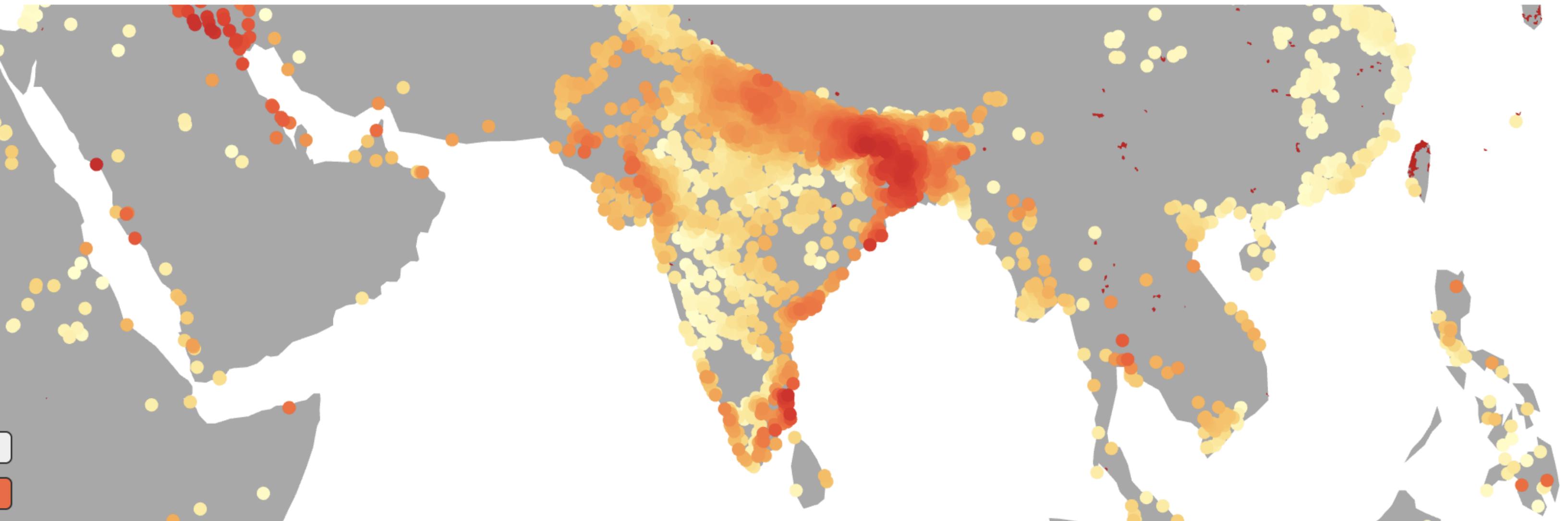
Exposure!

Understanding Exposure

Low Exposure, High Vulnerability

High Exposure, Low Vulnerability

Temperature Exposure

- Population Concentration
- Agricultural Zones
- Livestock Zone
- Power-Dependent Areas
- Environmental Factors
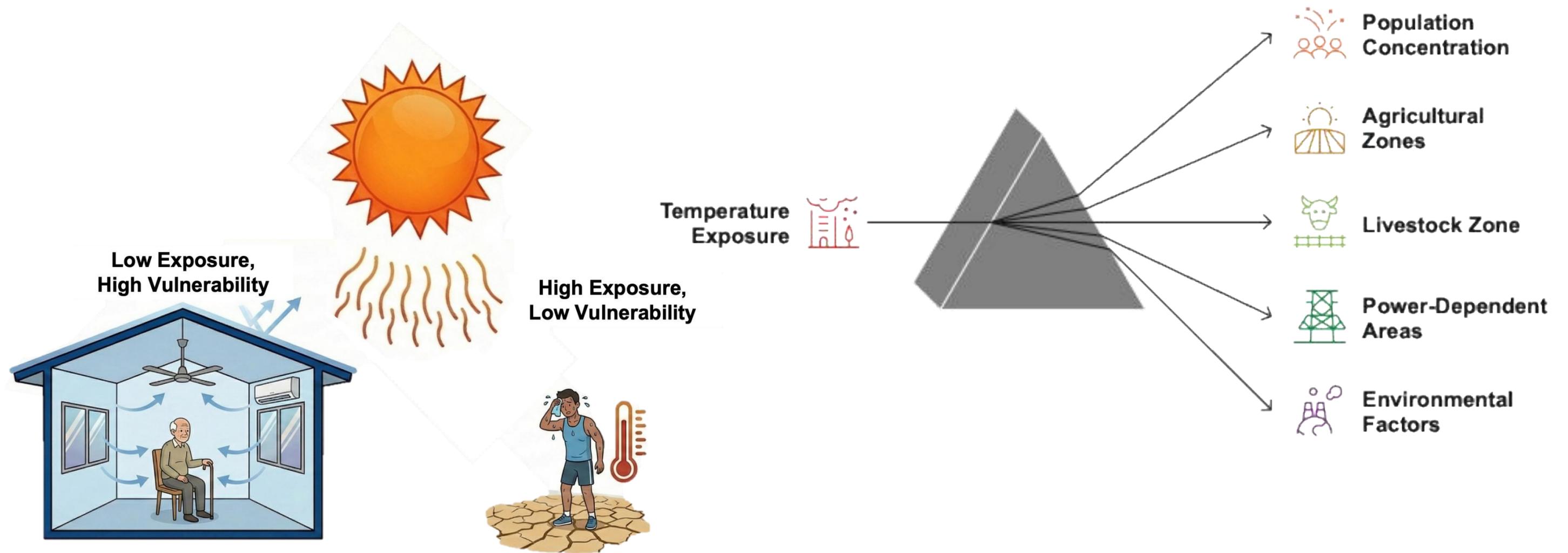
Exposure = "What is physically located in harm's way?"

Heat Exposure

Number of hours (averaged per person per year) during which high heat would have posed at least a moderate heat stress risk if undertaking light outdoor physical activity

Potential Exposure Indicators

Population & Social Exposure
- Population density
- Schools, hospitals
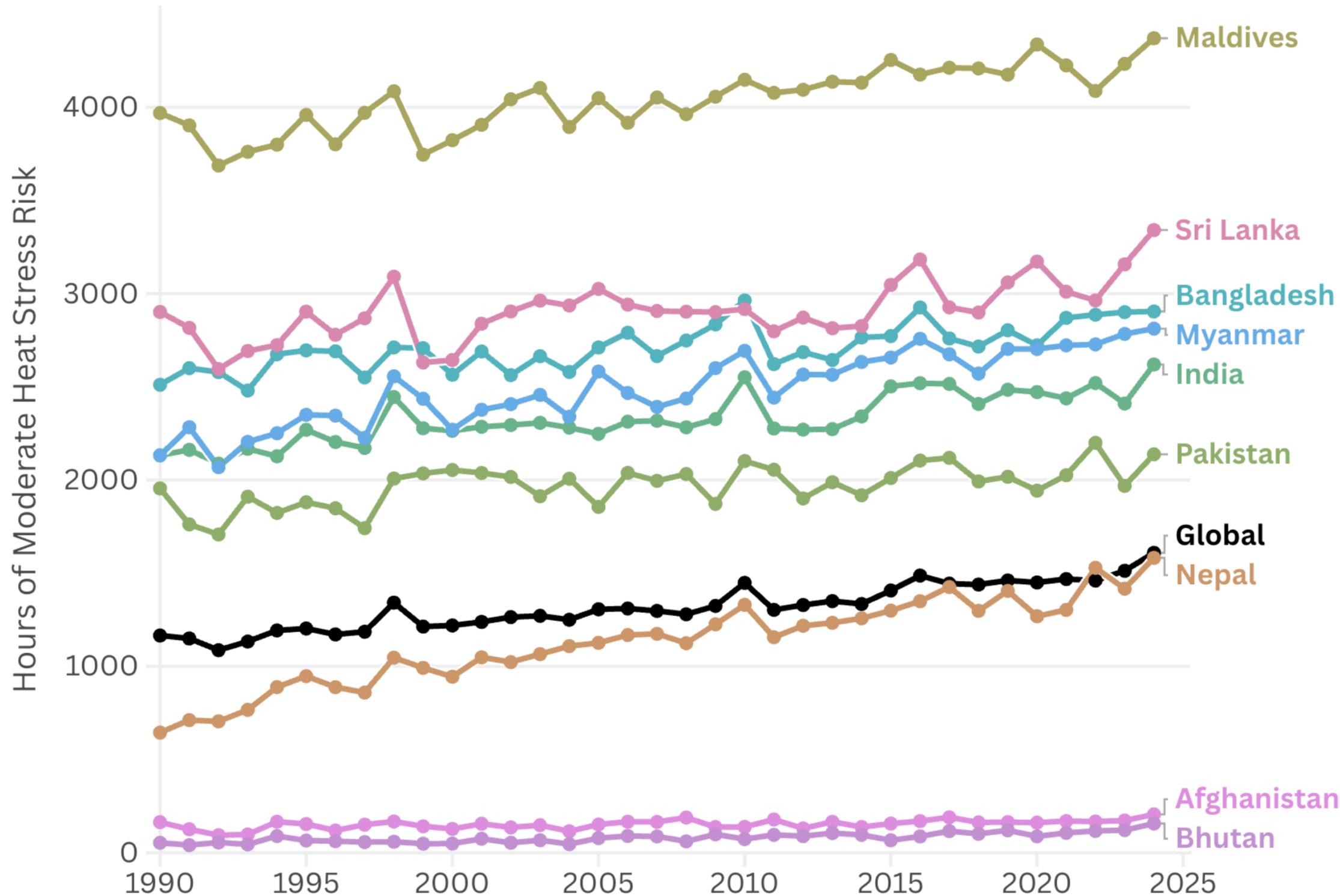- Informal settlements

Agriculture & Livestock Exposure
- Rice/wheat/vegetable zones
- Poultry hotspots
- Irrigated vs rain-fed areas
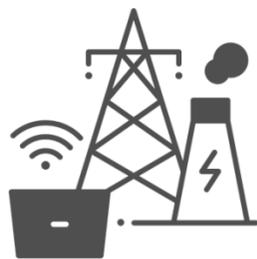
Energy/Infrastructure Exposure
- Power load hotspots
- Water pumping stations
- Cold storage, markets

Environmental Exposure
- NDVI / vegetation cover
- Built-up density
- AQI / CO_2 hotspots
- Urban heat island cores
- Frequency of heatwave

Examples of Exposure indicators

Category	Exposure Indicators	Why It Matters	Examples for Heat / Coldwave
Population Presence	Real-time population in hazard zone (day/night population shifts)	Exposure increases when more people are present during the hottest or coldest hours.	Heat: people outdoors in afternoon peak Cold: early morning commuters
	Seasonal migration / temporary settlements	Exposure varies with agricultural seasons, festivals, or labor migration.	Heat: brick-kiln workers, migrants Frost: seasonal workers in highlands
Outdoor Activity Patterns	Number of people working outdoors at hazard time	Direct exposure related to sun/heat intensity or morning frost.	Heat: construction, transport workers Frost: tea garden pluckers, farmers
	Duration of outdoor exposure (hours spent outside)	Longer exposure magnifies physiological stress.	Heat: outdoor labor 12–3 PM Frost: pre-dawn outdoor routines
Commuting & Mobility	Number of people commuting during peak hazard hours	Commuters face high exposure, especially with no shaded or heated shelters.	Heat: walking/cycling at noon Frost: unheated early-morning transport
	Crowding in open public spaces	High-density gatherings intensify exposure.	Heat: markets, religious gatherings Frost: morning queues, transit hubs
Environmental Exposure Conditions	Surface temperature of key locations (roads, open fields)	Asphalt, tin roofs, and bare fields amplify temperature exposure.	Heat: hot asphalt, playgrounds Frost: frozen fields, icy roads
	Urban microclimate variation (UHI intensity)	Local heat/cold pockets shift throughout the day.	Heat: peak UHI late afternoon Frost: valley cold sinks at dawn
Energy & Utility Status	Power outages (temporary and localized)	Loss of AC/heating instantly increases exposure.	Heat: AC failure leads to rapid overheating Frost: loss of heating increases hypothermia risk
	Water supply interruptions	Lack of water increases dehydration risk during heatwaves.	Heat: water scarcity during peak heat Frost: frozen pipes reduce access
Shelter & Service Availability	Opening/closing of cooling or heating centers	Exposure decreases when shelters open; increases when unavailable.	Heat: cooling centers open afternoon Frost: warming centers at night
	Availability of shaded/heated public transport stops	Temporary closures or crowding affect real-time exposure.	Heat: no shade at bus stops Frost: unheated waiting areas
Local Activity & Hazard Amplifiers	Heat-generating activities	Industrial operations, traffic peaks increase heat exposure.	Heat: industrial heat emissions Frost: none (generally inversely)
	Wind speed & nighttime cooling failure	Low wind reduces heat dissipation; high wind increases cold exposure.	Heat: no ventilation at night Frost: wind chill increasing exposure
Temporary Population Groups	Tourists, pilgrims, visitors	Short-term population spikes increase the number exposed.	Heat: tourist hotspots Frost: religious/seasonal gatherings

Data Sources for Exposure

GIS Data

National geographic information systems and national census data.

Agriculture Data

Information from agriculture and livestock departments.

Remote Sensing Data

Data from different satellites for different indicators

Power Utilities Data

Load curves and other data from power utilities.

Environmental Data

Air quality index and CO_2 maps from environmental agencies.

Urban Planning Data

Information from urban planning authorities.

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