



Weather Services and Effectiveness of Heat Wave Warnings

Dr. M Mohapatra, DGM, IMD

**India Meteorological Department
Mausam Bhavan, Lodi Road,
New Delhi-110 003**



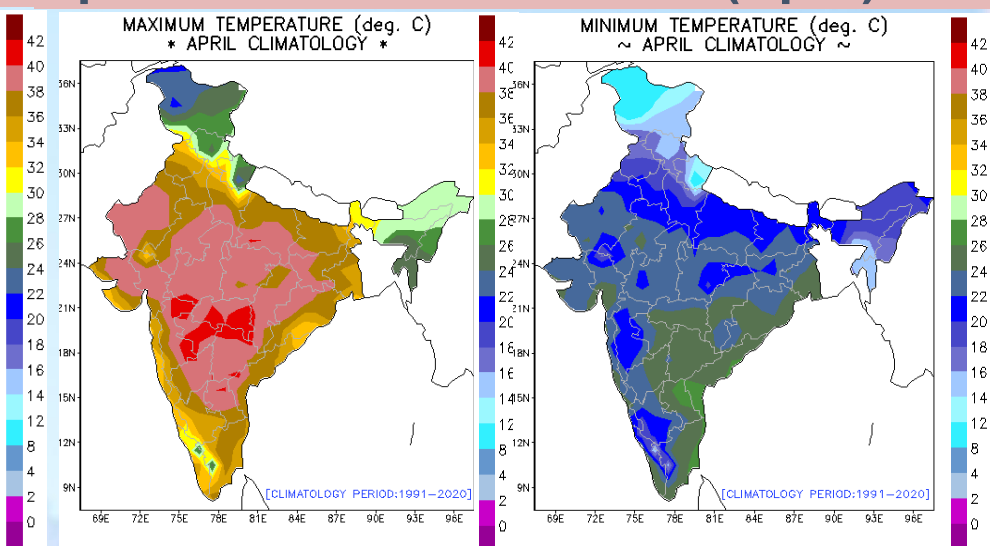
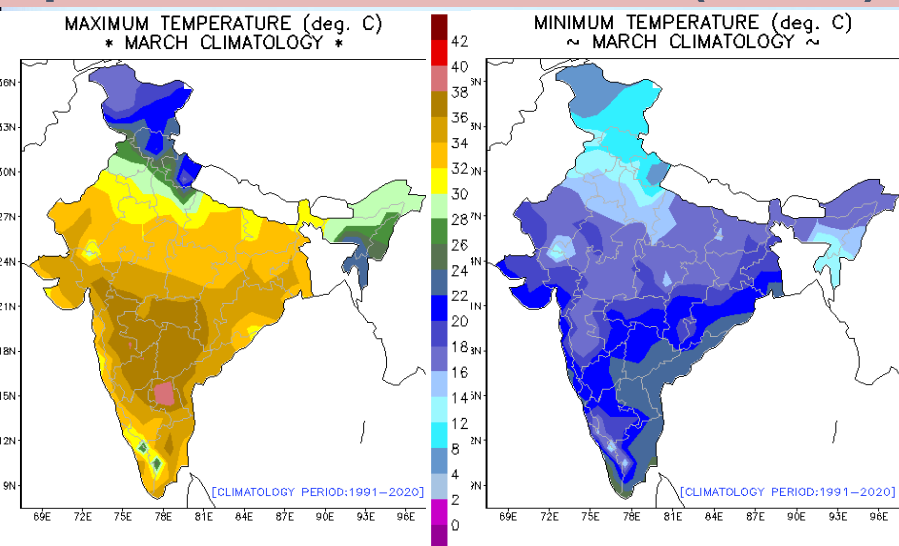
Heat Wave/Warm Night Criteria

- Heat wave Criteria for plain region
- Max. temp. $\geq 40^{\circ}\text{C}$
 - a. Based on Departure from Normal
 - Heat Wave: Departure from normal is 4.5°C to 6.4°C
 - Severe Heat Wave: Departure from normal is $>6.4^{\circ}\text{C}$ or more
 - b. Based on Actual Maximum Temperature
 - Heat Wave: When actual maximum temperature $\geq 45^{\circ}\text{C}$
 - Severe Heat Wave: When actual maximum temperature $\geq 47^{\circ}\text{C}$
- Criteria for describing Heat Wave for coastal stations: Actual max. temp $\geq 37^{\circ}\text{C}$
 - Heat Wave: Departure from normal is 4.5°C to 6.4°C
 - Severe Heat Wave: Departure from normal is $>6.4^{\circ}\text{C}$ or more
- Criteria for describing Heat Wave for Hill stations: Actual max. temp $\geq 30^{\circ}\text{C}$
 - Heat Wave: Departure from normal is 4.5°C to 6.4°C
 - Severe Heat Wave: Departure from normal is $>6.4^{\circ}\text{C}$ or more
- Warm Night: It should be considered only when max. temp. $\geq 40^{\circ}\text{C}$.
 - Warm Night: Minimum temperature departure from normal is 4.5°C to 6.4°C
 - Very Warm Night: Minimum temperature Departure from normal is $>6.4^{\circ}\text{C}$ or more

If above criteria are met at least in 2 stations in a Meteorological sub-division for at least two consecutive days and it declared on the second day.

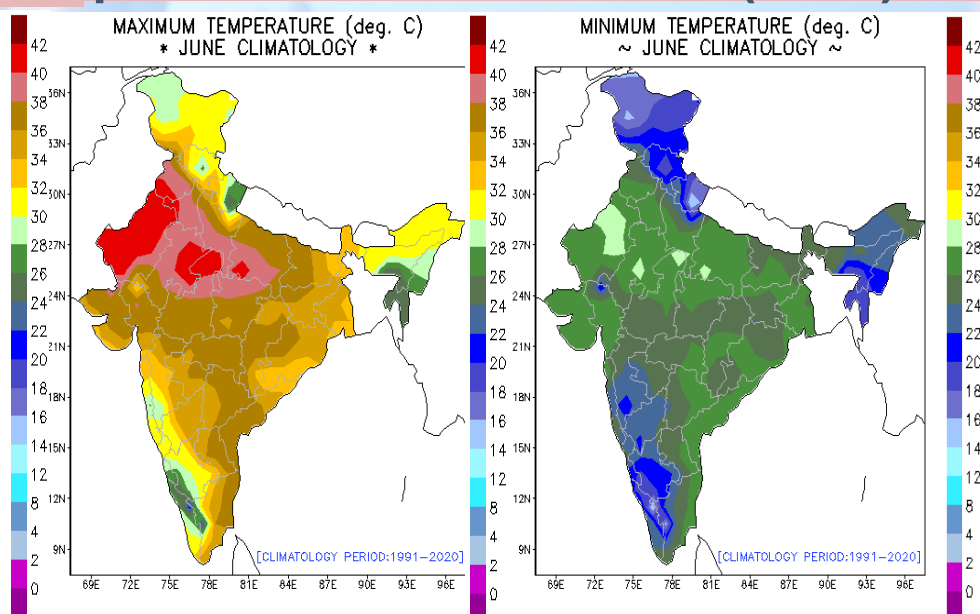
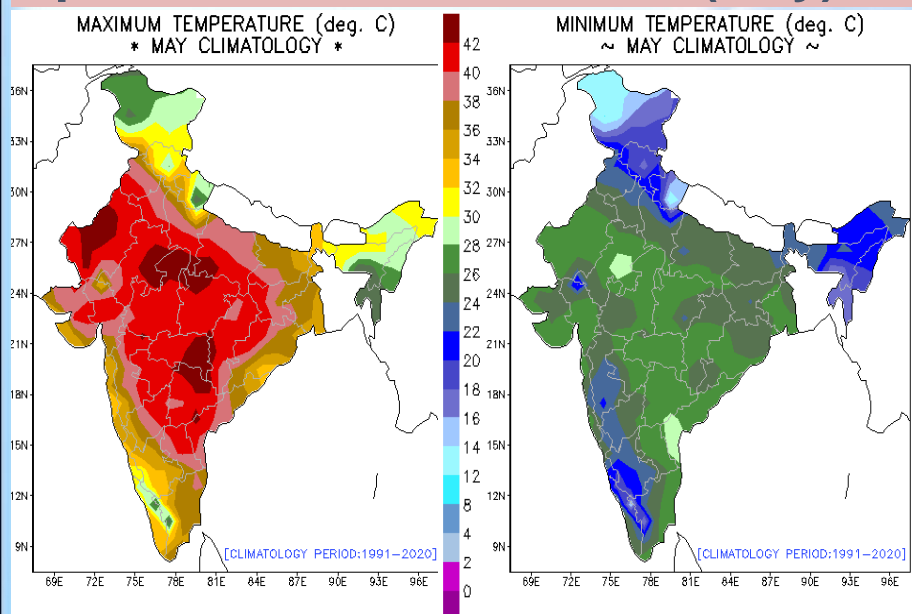
Spatial Patterns of Normal (March)

Spatial Patterns of Normal (April)

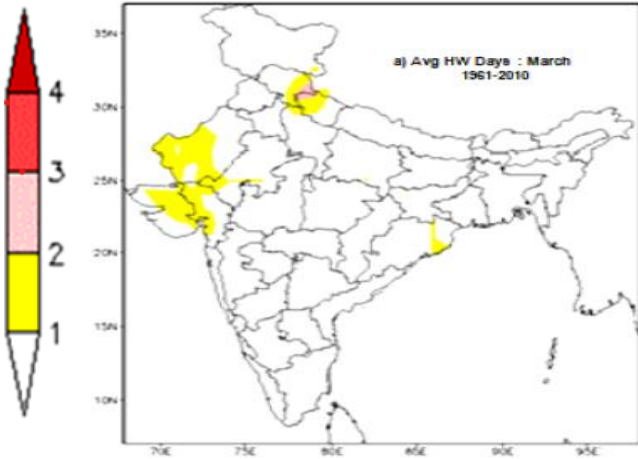


Spatial Patterns of Normal (May)

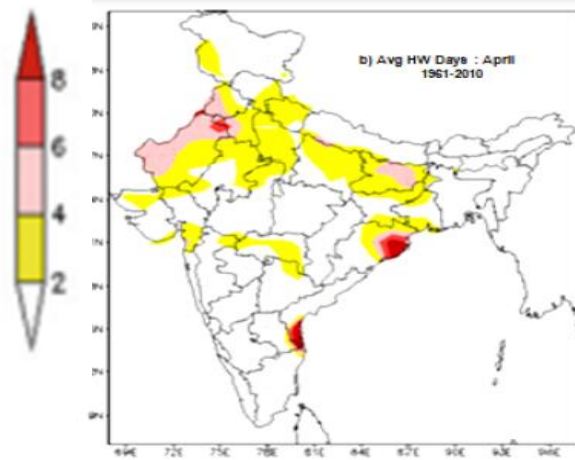
Spatial Patterns of Normal (June)



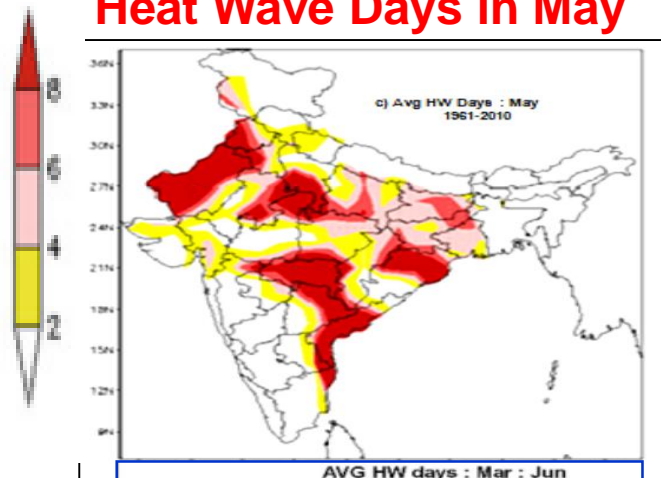
Heat Wave Days in March



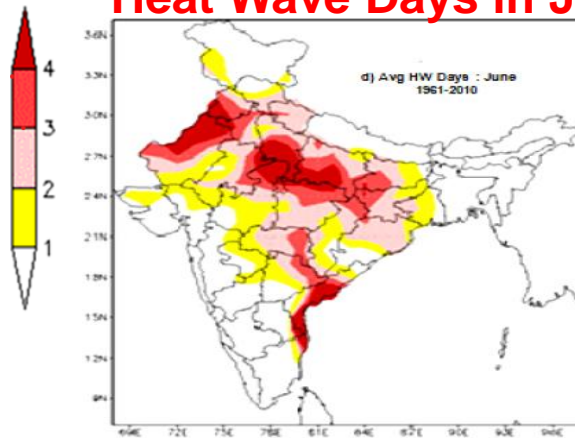
Heat Wave Days in April



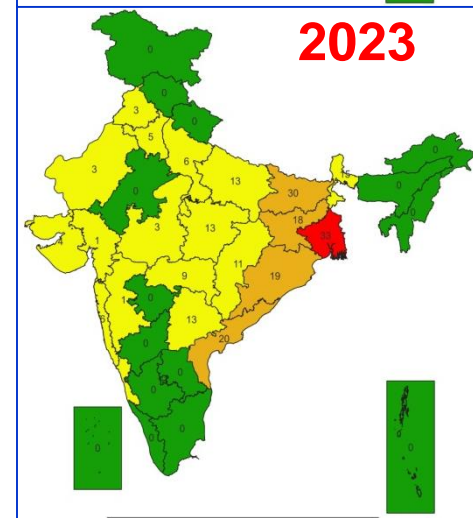
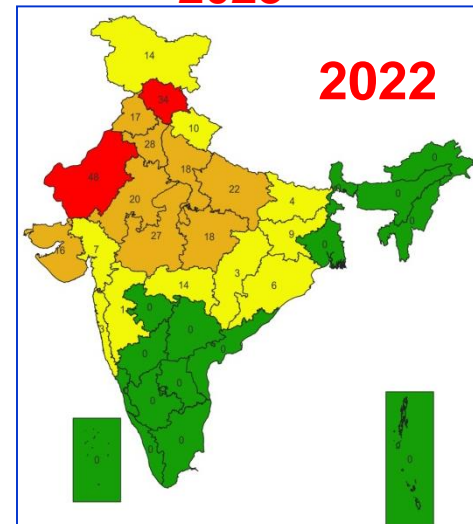
Heat Wave Days in May



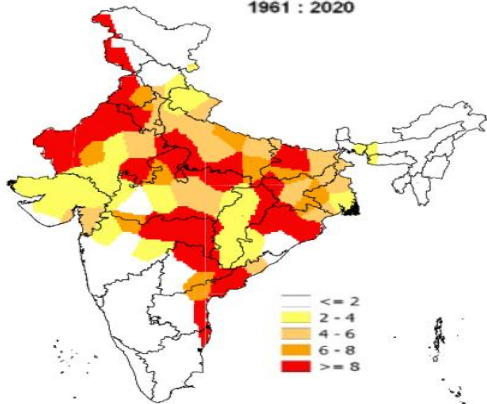
Heat Wave Days in June



Actual Heat Wave Days in Mar-Jun, 2022 and 2023



AVG HW days : Mar : Jun
1961 : 2020

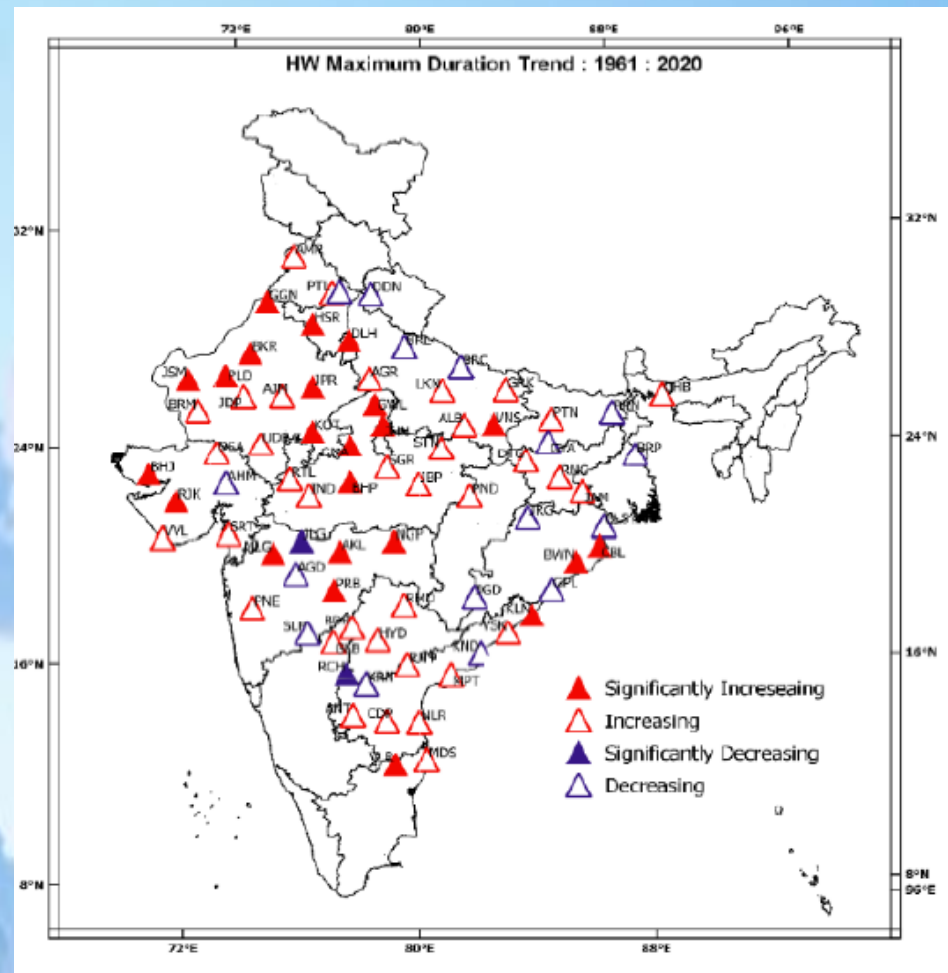
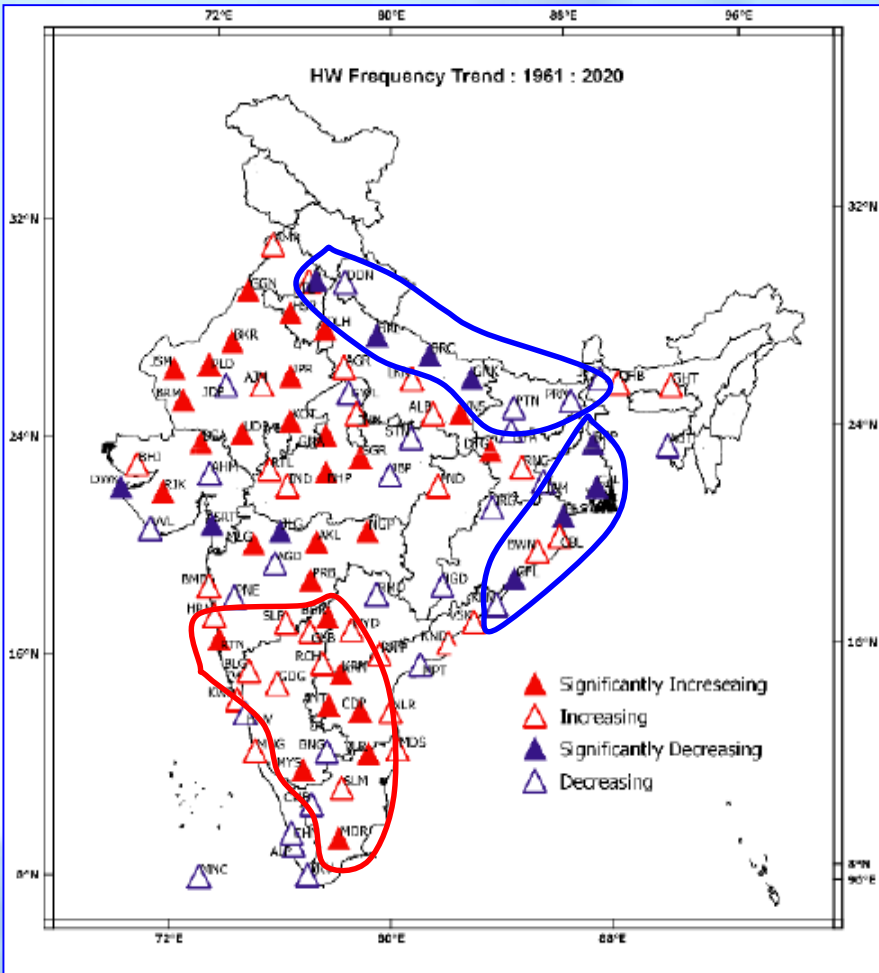


No. of Heat Days

- No Heat days
- 1 to 15 days
- 16 to 30 days
- More than 30 days

Trend in Heat wave frequency during March-June for the period 1961-2020

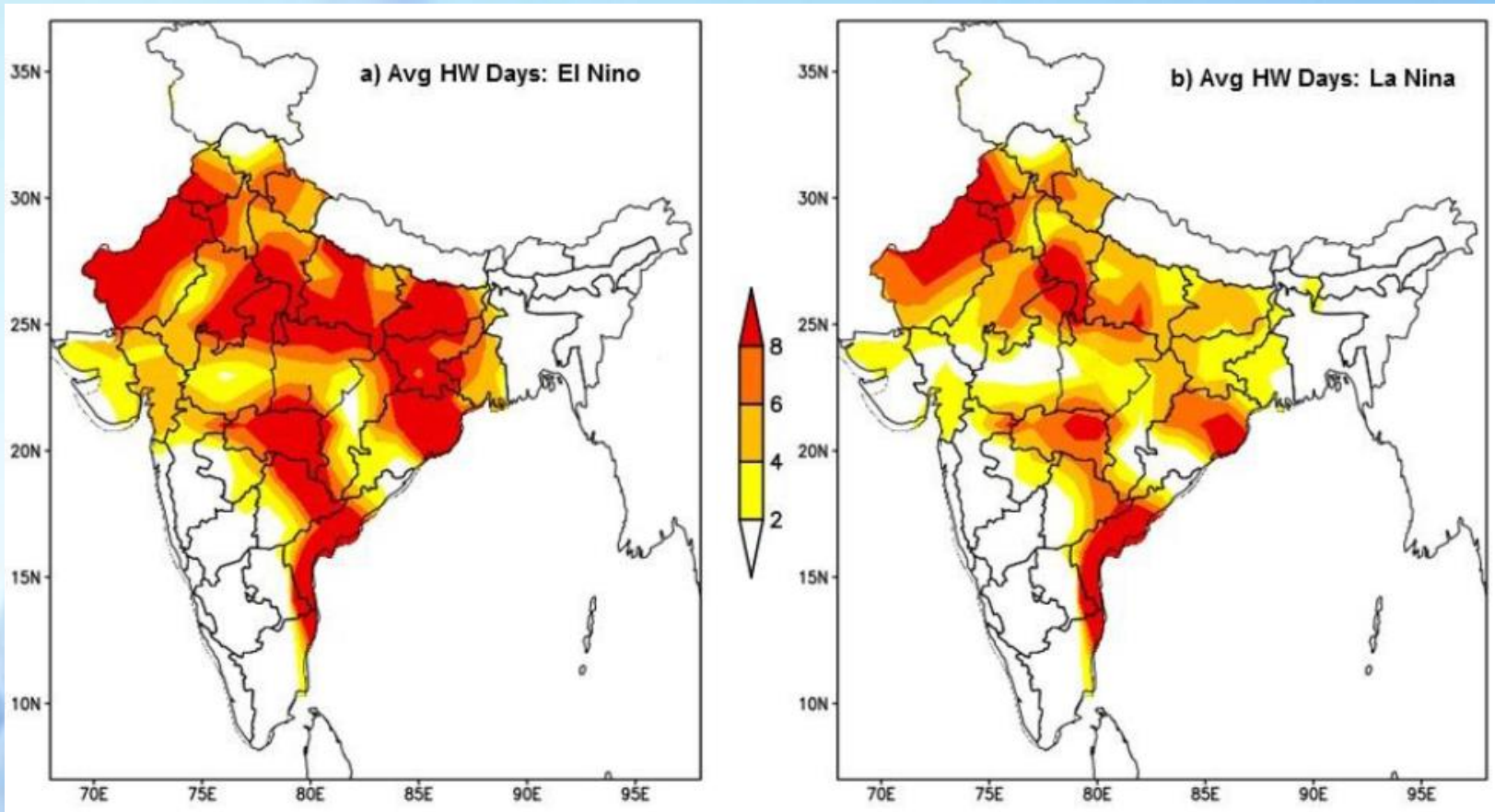
Trends in Maximum Duration of Heat Wave days during March-June for the period 1961-2020



Rajeevan et. al, (2023) IMD Met Monograph



Average HW days during a) the El Nino years and b) La Nina years during the period 1961-2020



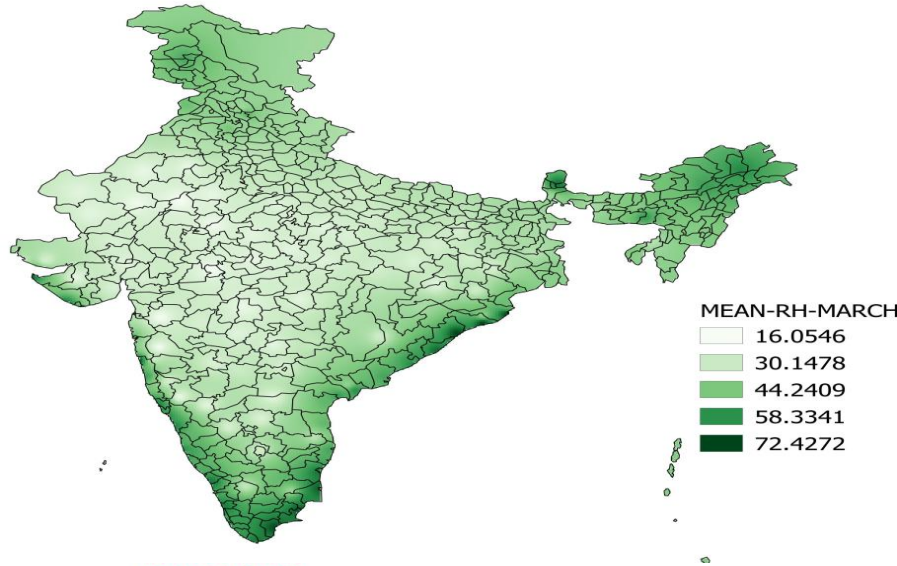
shows the average heat wave days during a) El Nino years and b) La Nina years, which clearly shows that heat wave days are **much more during the El Nino years** than La Nina years.

Rajeevan et. al, (2023) IMD Met Monograph

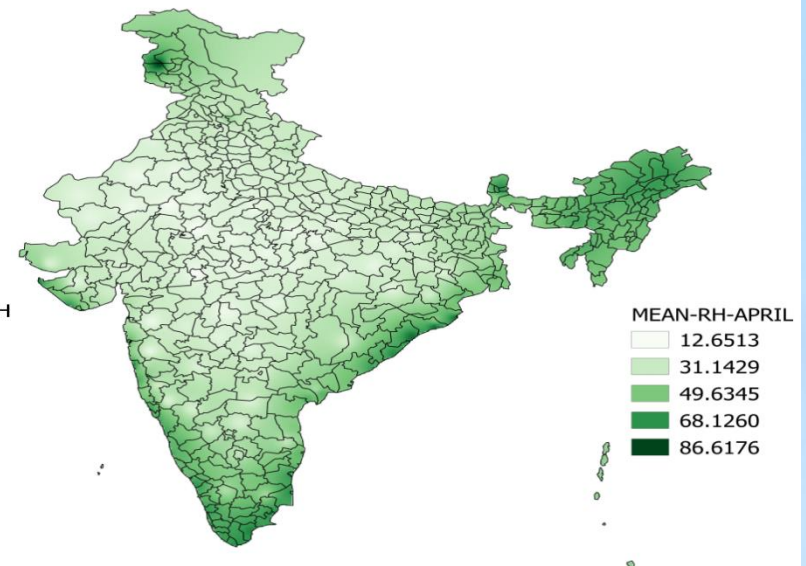


Monthly mean Relative Humidity (%)

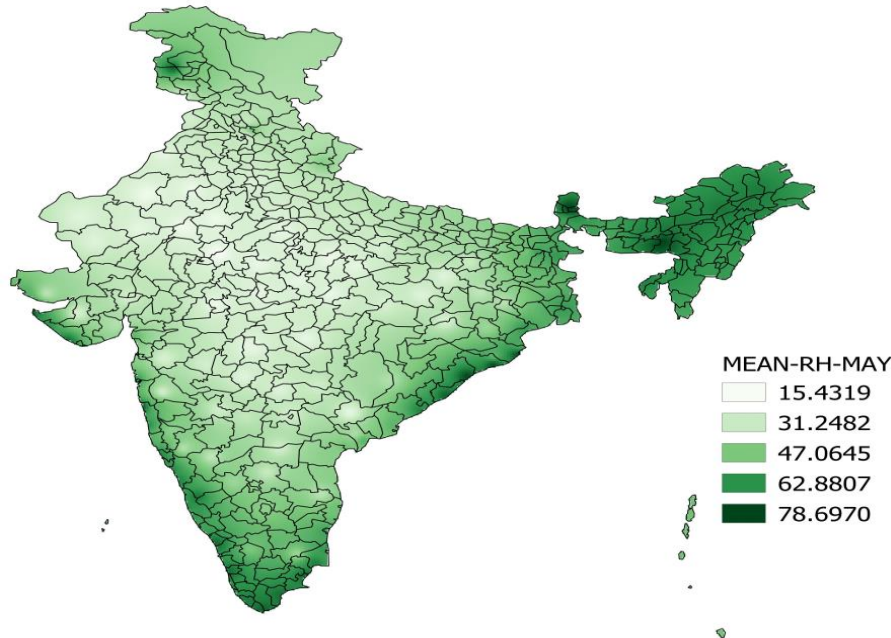
MEAN RH (MARCH)



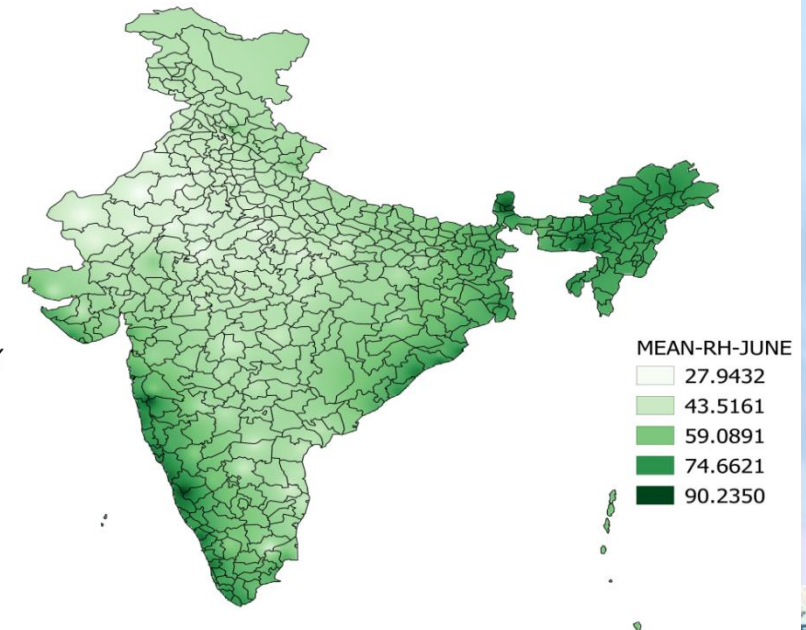
MEAN RH (APRIL)



MEAN RH (MAY)

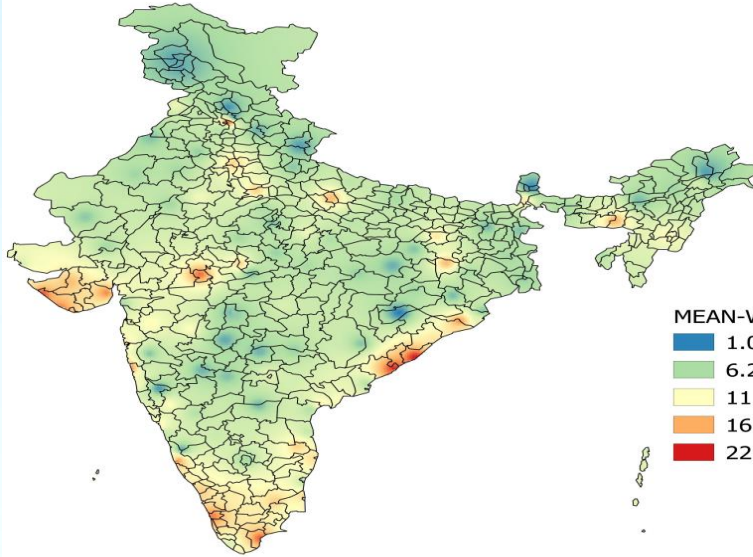


MEAN RH (JUNE)

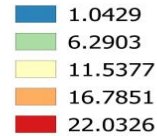


Monthly mean Wind Speed (Knots)

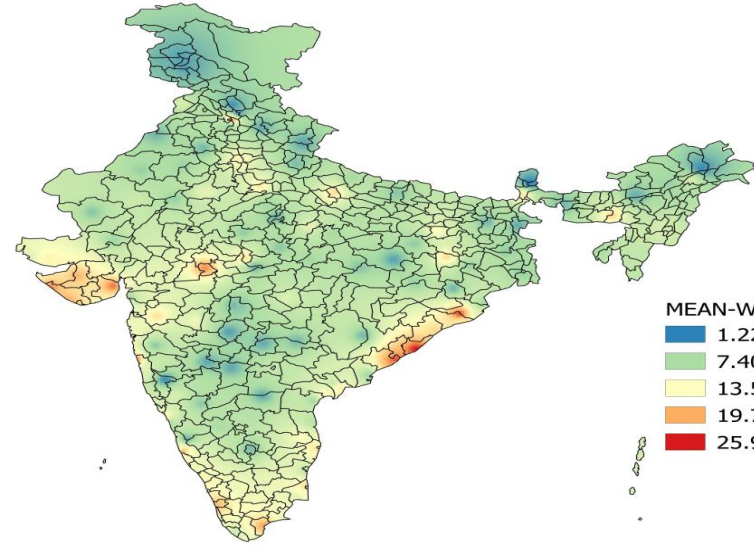
MEAN WIND SPEED (MARCH)



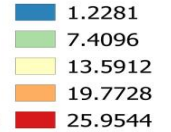
MEAN-WS-MARCH



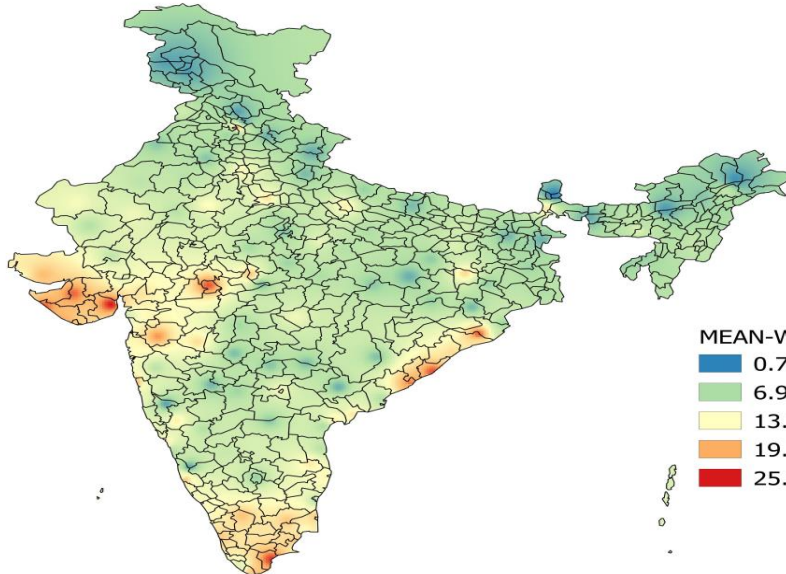
MEAN WIND SPEED (APRIL)



MEAN-WS-APRIL



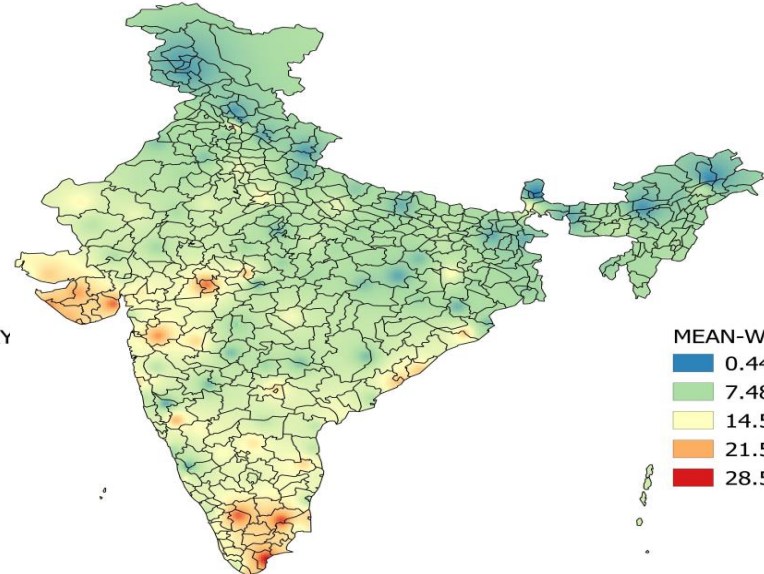
MEAN WIND SPEED (MAY)



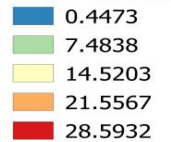
MEAN-WS-MAY



MEAN WIND SPEED (JUNE)

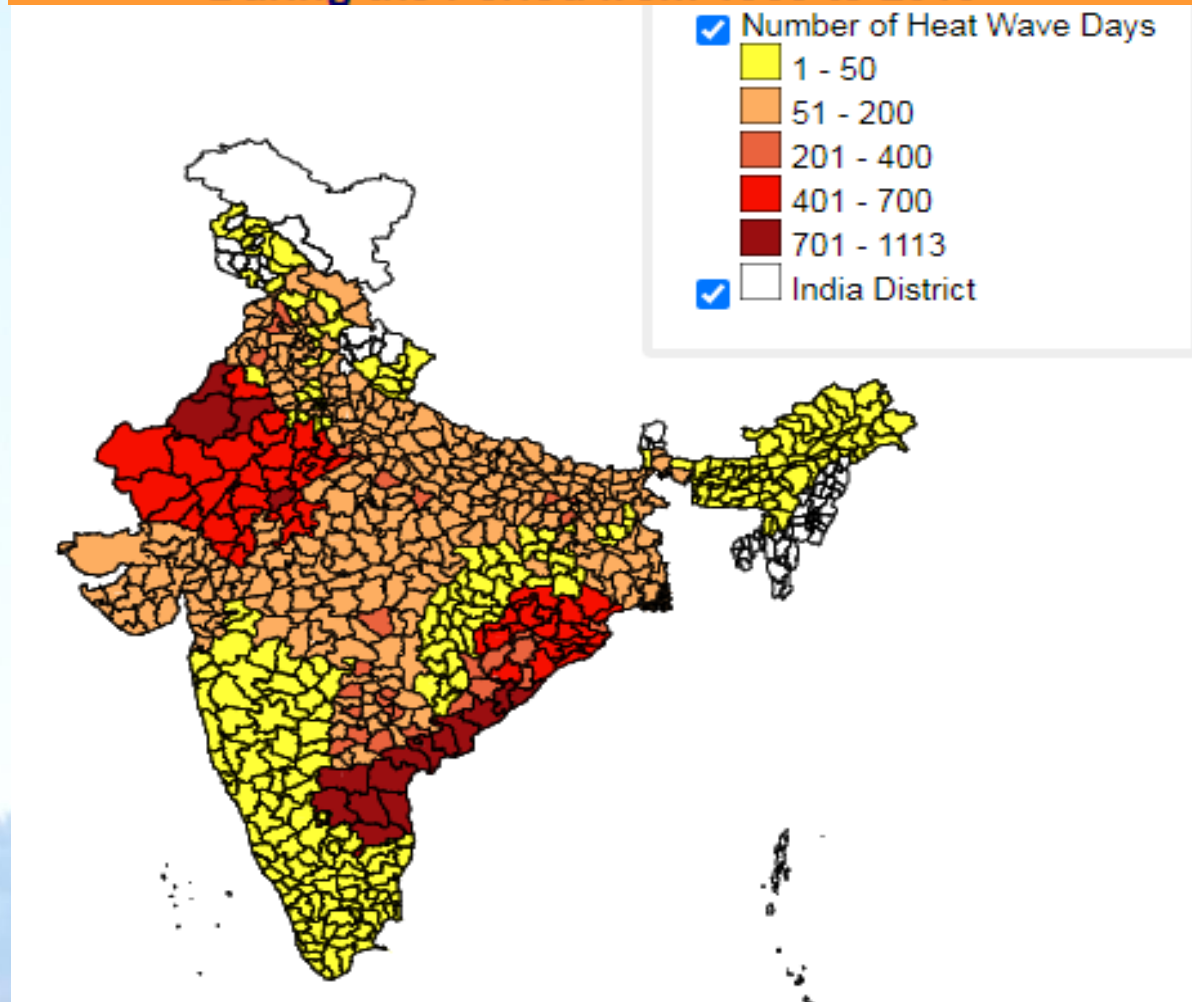


MEAN-WS-JUNE



Vulnerability due to heat wave

Total Number of Disasterous Heat Wave Days in Annual During the Period from 1969 to 2019



(Based on data from IMD Publication Annual Disaster Weather Report.
Disclaimer: Considered the events with atleast 1 human death as per media reports.)



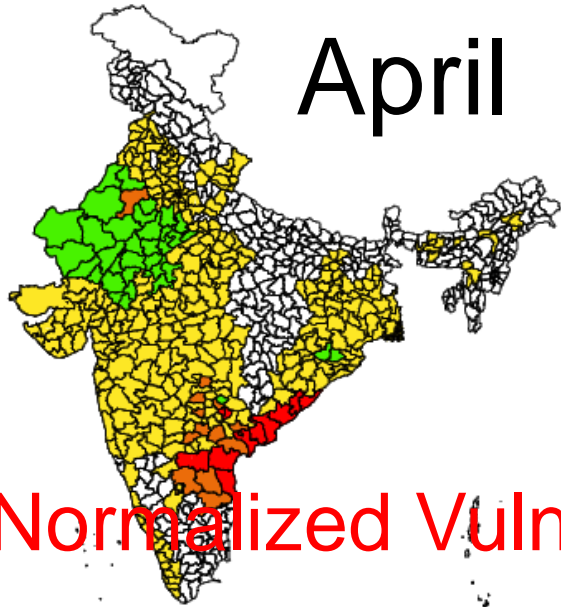
14-Feb-24

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

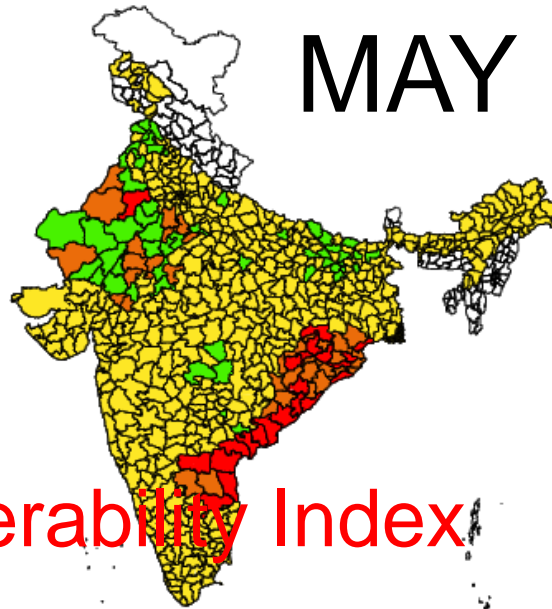


Vulnerable Zones due to heat wave

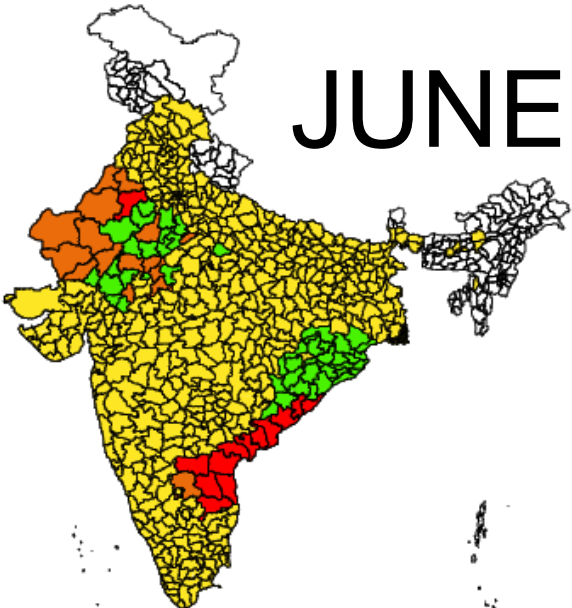
April



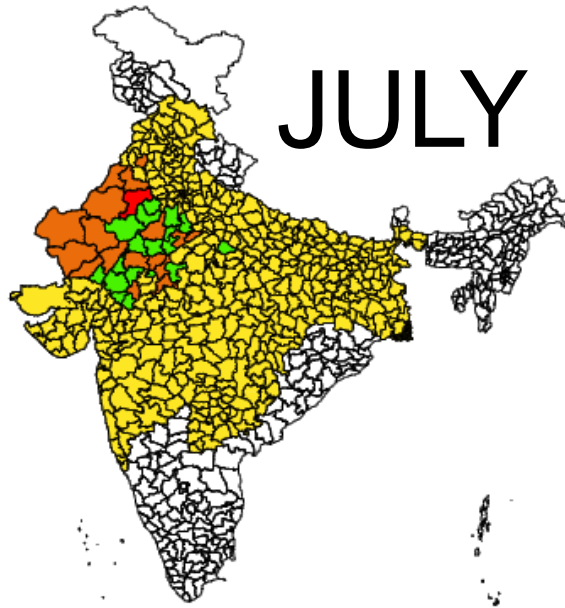
MAY



JUNE



JULY



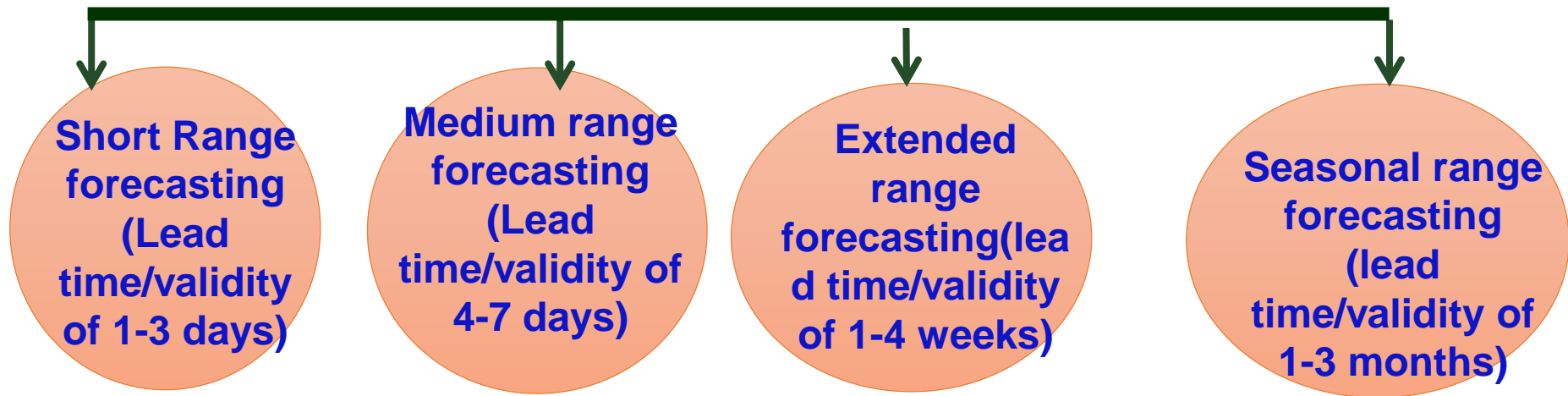
The Normalized Vulnerability Index standardizes the disaster values to the range between 0.0 to 1.0 following formula is used:

$$\text{Normalized Value} = \frac{\text{Actual Indicator Value} - \text{Minimum Indicator Value}}{\text{Maximum Indicator Value} - \text{Minimum Indicator Value}}$$

- Normalized Vulnerability Index
 - Nil (0)
 - Low (> 0 and <= 0.25)
 - Moderate (> 0.25 and <= 0.50)
 - High (> 0.50 and <= 0.75)
 - Very High (> 0.75 and <= 1)
- India District



Heat Wave Forecast and Warning Process



SEAMLESS HEAT WAVE FORECASTING FROM SEASON TO DAYS

An array of Numerical Models are used for forecasting

Warnings to: MHA, NDMA, SDMA, Chief Secretaries, State Emergency Operation Centres (SEOC), District Authorities, Health Department, Agriculture Department, Indian Railway, Road Transport and press & electronic media and Heat Action Plan Authorities at City, District and State levels.

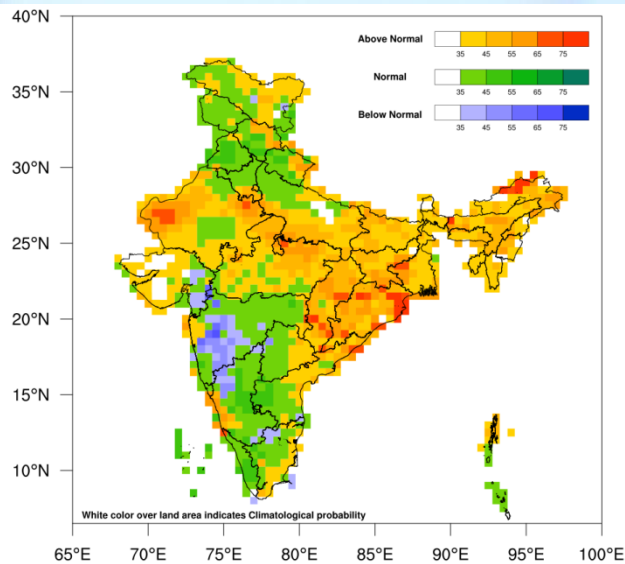
through: website, e-mail, Common Alert Protocol, whatsApp, facebook, twitter

IMD monitoring and forecasting of Heat wave :

- **IMD has a big network of surface observatories covering the entire country to measure various metrological parameters like Temperature, Relative humidity, pressure, wind speed & and direction etc.**
- **Based on daily maximum/minimum temperature station data, climatology of maximum/minimum temperature and other parameters is prepared based on the data of 1991-2020**
- **On a given day, the temperature and other parameters are compared with pentad normal values of the stations to find out departure/ deviation from normal maximum/minimum temperature etc of the day for a particular station.**
- **Thereafter, IMD declared a heat wave and/or warm night over the region as per its definition.**
- **Based on numerical models and observed date utilising a decision support system, IMD issues daily forecast of temperature and other parameters and accordingly the heat wave forecast upto 5 days, extended range forecast upto 4 weeks on every Thursday and monthly and seasonal forecast for every month and season in the begining of month/season.**
- **Accordingly, Impact based forecast in colour coded form and information about impact expected with action suggested in disseminated to all stake holders.**

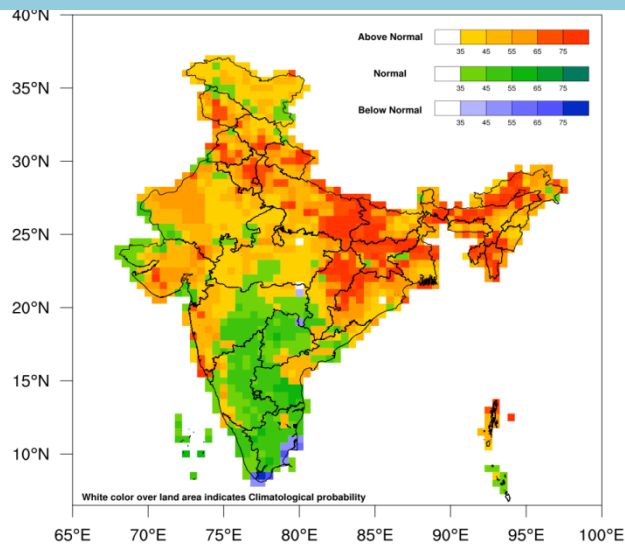


Seasonal Forecast (An example): Probabilistic Forecast for the Maximum Temperature March to May season 2023 .



During the upcoming hot weather season (March to May (MAM)), above-normal maximum temperatures are likely over most parts of northeast India, east and central India and some parts of north west India. Normal to below normal maximum temperatures are most likely remaining parts of the country.

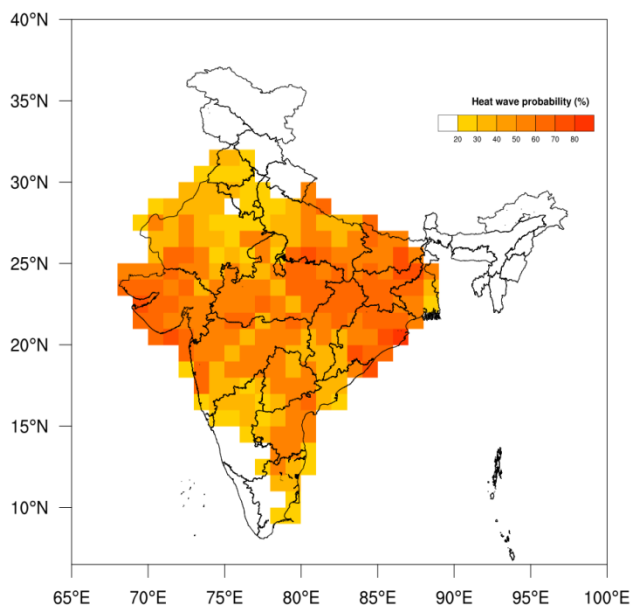
Probabilistic Forecast for the Minimum Temperature March to May season 2023 Based on the Multi Model Ensemble Forecasting System.



minimum temperatures are very likely over most parts of the country except south peninsular India where normal to below normal minimum temperatures are likely.

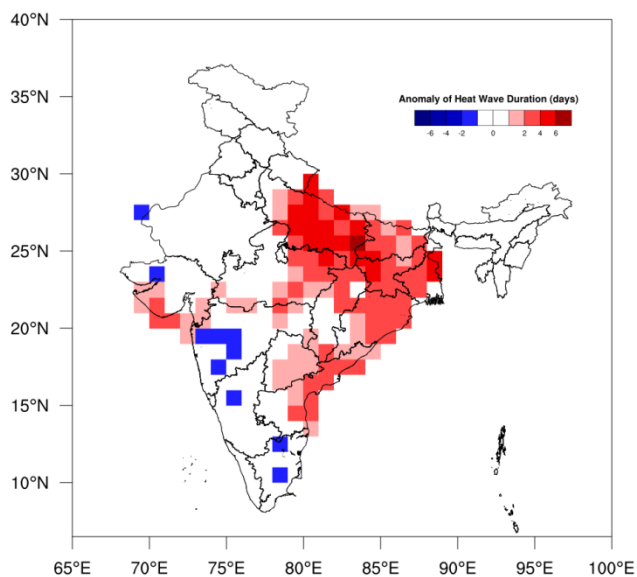
The white shaded areas within the land area represent climatological probabilities. . (*Tercile categories have equal climatological probabilities, of 33.33% each).

Heat wave outlook for March to May season 2023 based on the Multi Model Ensemble Forecasting System.



Enhanced probability of occurrence of Heatwave during March to May season is likely over many regions of Central and adjoining Northwest India.

Heatwave outlook for May, 2023



Above-normal heat wave days are expected over most parts of Bihar, Jharkhand, Odisha, Gangetic West Bengal, east Uttar Pradesh, coastal Andhra Pradesh and some parts of North Chhattisgarh, east Madhya Pradesh, Telangana and coastal Gujarat during May 2023

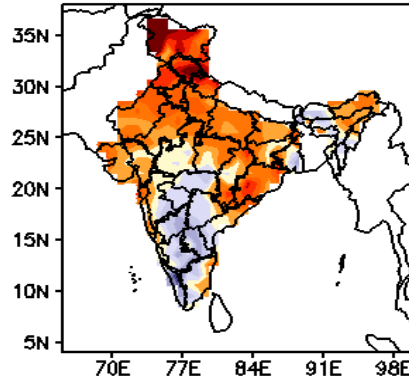
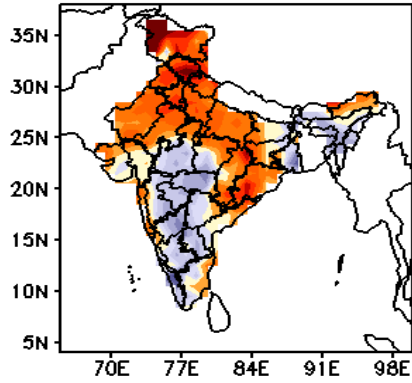


Extended Range Forecast of maximum temperature (Tmax) anomaly for 4 weeks

MME forecast Tmax anomaly (Deg C)

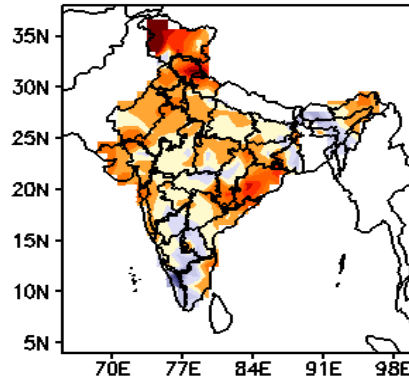
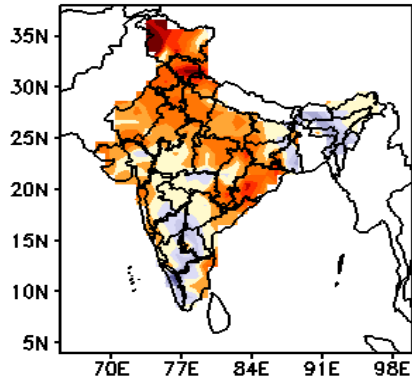
(Week1: 01Apr-07Apr)

(Week2: 08Apr-14Apr)



(Week3: 15Apr-21Apr)

(Week4: 22Apr-28Apr)

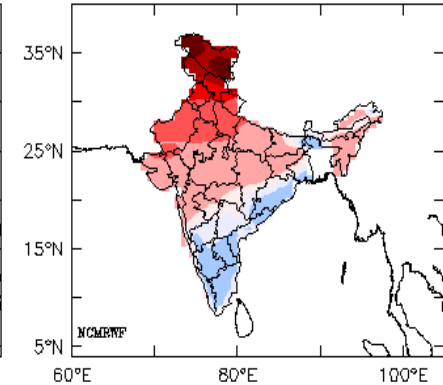
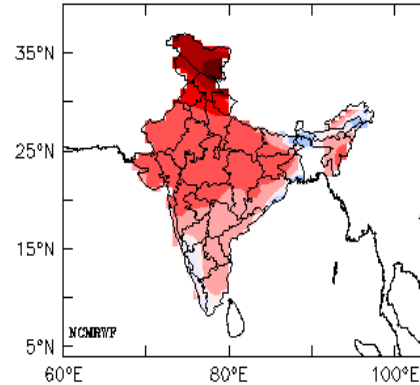


NCMRWF CNCUM Experimental Extended Range Forecasts-20220331

Tmax Anomaly (deg C)

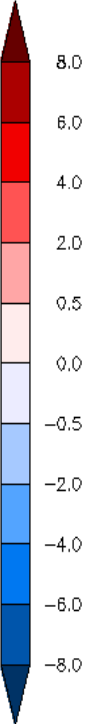
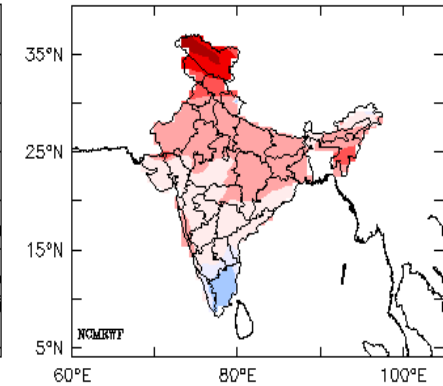
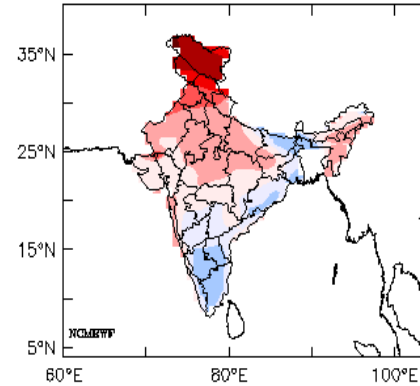
(Week1: 01APR-07APR)

(Week2: 08APR-14APR)



(Week3: 15APR-21APR)

(Week4: 22APR-28APR)



Heat Wave Impact Based Forecasting by IMD

- Heat Wave and Warm Nights are characterized by abnormally high surface air maximum (minimum) temperatures.
- Co-existence of Heat Waves/Warm Nights aggravate their impact.
- Humidity aggravates the impact of hot weather by affecting the perspiration mechanism.
- Hot and dry winds aggravate the impact of heat waves.
- Persistence of abnormal temperatures and above conditions lead to cumulative effect.

IMDs Colour Coded Impact based forecast uses the following:

- a) Absolute Maximum Temperatures, their departures and percentile status.
- b) Absolute Minimum Temperatures, their departures and percentile status.
- c) Relative Humidity Forecast.
- d) Wind Speed Forecast.
- e) Persistence of Above.



objective Heat Wave IBF

Hot Weather Hazard Analysis for entire country considering different meteorological parameters

Operational Experimental Heat Index

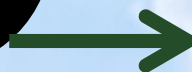
GIS based Heat Wave forecast and warning Services products

GIS based Socio Economic exposure products

Percentile based extreme temperature information.

Vulnerability Atlas with respect to Heat Waves for India.

DSS



Impact & Action Suggested

Colour code	Alert	Warning	Impact	Suggested Actions
Green (No action)	Normal Day	Maximum temperatures are near normal.	Comfortable temperature. No cautionary action required.	No cautionary action required
Yellow Alert (Be updated)	Heat Alert	Heat wave conditions at isolated pockets persists on 2 days	Moderate temperature. Heat is tolerable for general public but moderate health concern for vulnerable people e.g. infants, elderly, people with chronic diseases	(a) Avoid heat exposure. (b) Wear lightweight, light coloured, loose, cotton clothes. (c) Cover your head: Use a cloth, hat or umbrella
Orange Alert (Be prepared)	Severe Heat Alert for the day	i. Severe heat wave conditions likely to persist for 2 days. ii. With varied severity, heat wave is likely to persist for 4 days or more.	High temperature. Increased likelihood of heat illness symptoms in people who are either exposed to sun for a prolonged period or doing heavy work. High health concern for vulnerable people e.g. infants, elderly, people with chronic diseases.	a) Avoid heat exposure— keep cool. Avoid dehydration. (b) Drink sufficient water- even if not thirsty. (c) Use ORS, homemade drinks like lassi, torani (rice water), lemon water, buttermilk, etc. to keep yourself hydrated
Red Alert (Take Action)	Extreme Heat Alert for the day	i. Severe heat wave likely to persist for more than 2 days. ii. Total number of heat/severe heat wave days likely to exceed 6 days.	Very high likelihood of developing heat illness and heat stroke in all ages.	Extreme care needed for vulnerable people.



Heat Wave Warning

In medium range (upto 5 days) issued twice a day

Heat Wave Warnings for Next 5 Days

DAY-1:- Heat Wave to severe heat wave conditions very likely in some pockets over Bihar and West Bengal and heat wave conditions in isolated pockets over Odisha, Jharkhand, Konkan & Goa and Coastal Andhra Pradesh.

DAY-2:- Heat Wave conditions very likely in isolated pockets over Odisha, West Bengal and Bihar.

DAY-3:- Heat Wave conditions very likely in isolated pockets Gangetic West Bengal.

DAY-4:- NIL.

DAY-5:- NIL.

IMPACT & ACTION SUGGESTED:

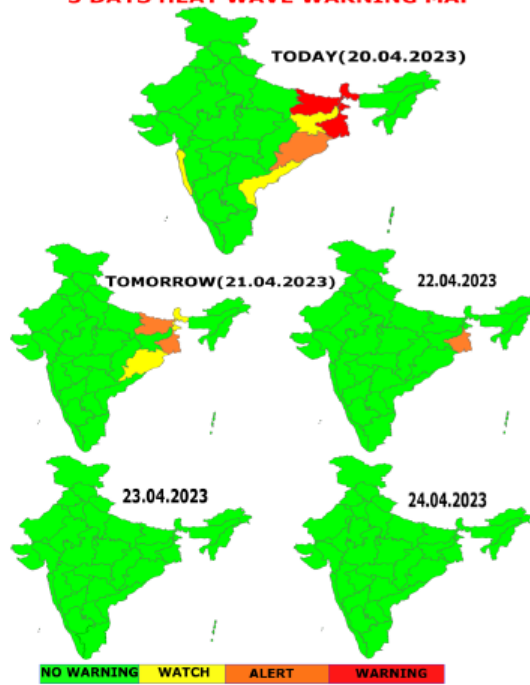
Yellow alert Areas: (1) Moderate temperature, Heat is tolerable for general public but moderate health concern for vulnerable people e.g. infants, elderly, people with chronic diseases.

(2) Avoid heat exposure, Wear lightweight, light coloured, loose, cotton clothes, Cover your head, Use a cloth, hat or umbrella.

Orange alert Areas: (1) High temperature, Increased likelihood of heat illness symptoms in people who are either exposed to sun for a prolonged period or doing heavy work. High health concern for vulnerable people e.g. infants, elderly, people with chronic diseases.

(2) Drink sufficient water- even if not thirsty, Use ORS, homemade drinks like lassi, torani (rice water), lemon water, buttermilk, etc. to keep yourself hydrated.

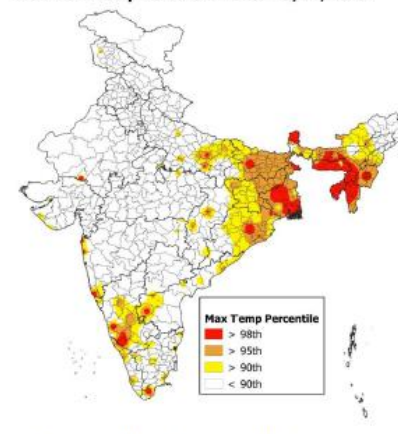
5 DAYS HEAT WAVE WARNING MAP



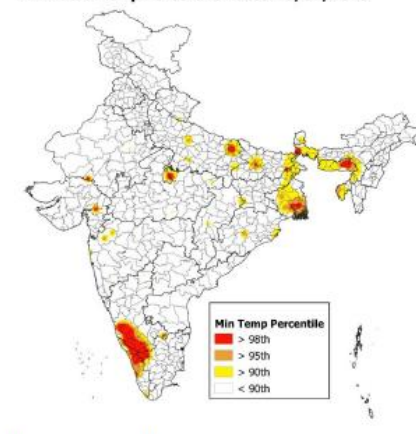
For Districtwise heat wave warning visit:
<https://mausam.imd.gov.in/responsive/districtWiseHeatwaveWarning.php>

“Due to humid air and high temperature, hot and discomfort weather very likely over Kutch and Kerala today.”

Maximum Temp Percentile Dated 19/04/2023



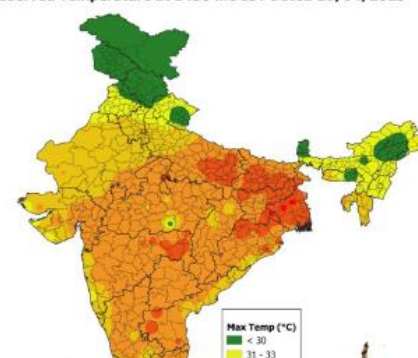
Minimum Temp Percentile Dated 20/04/2023



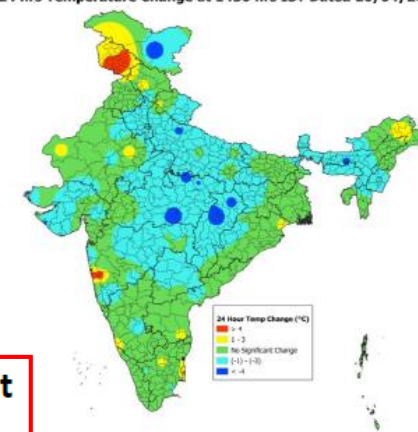
(The percentile analysis uses all the days on record for the current month.)

Annexure 4

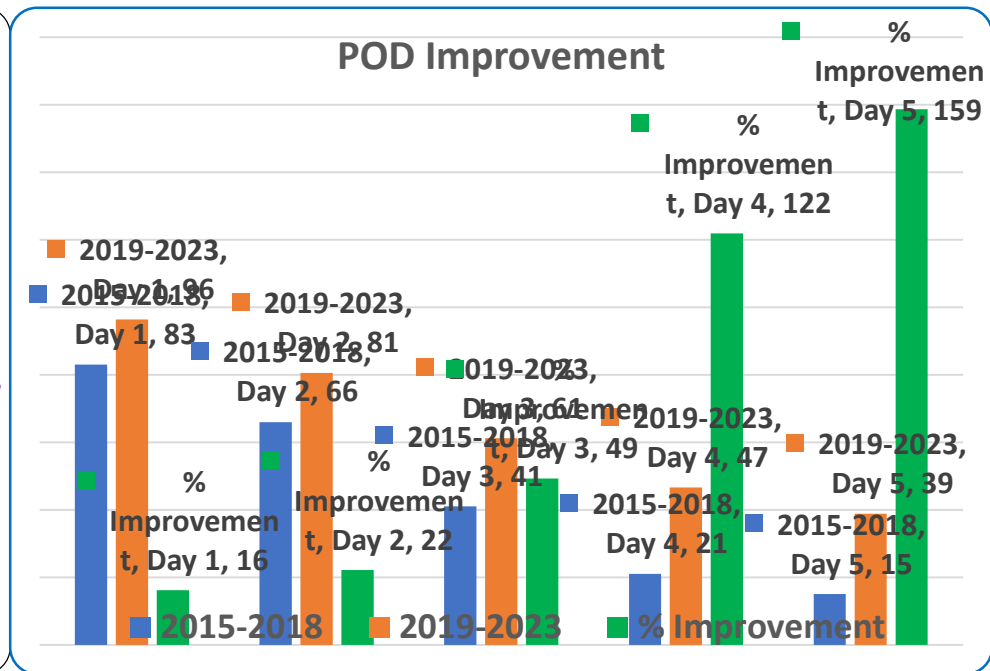
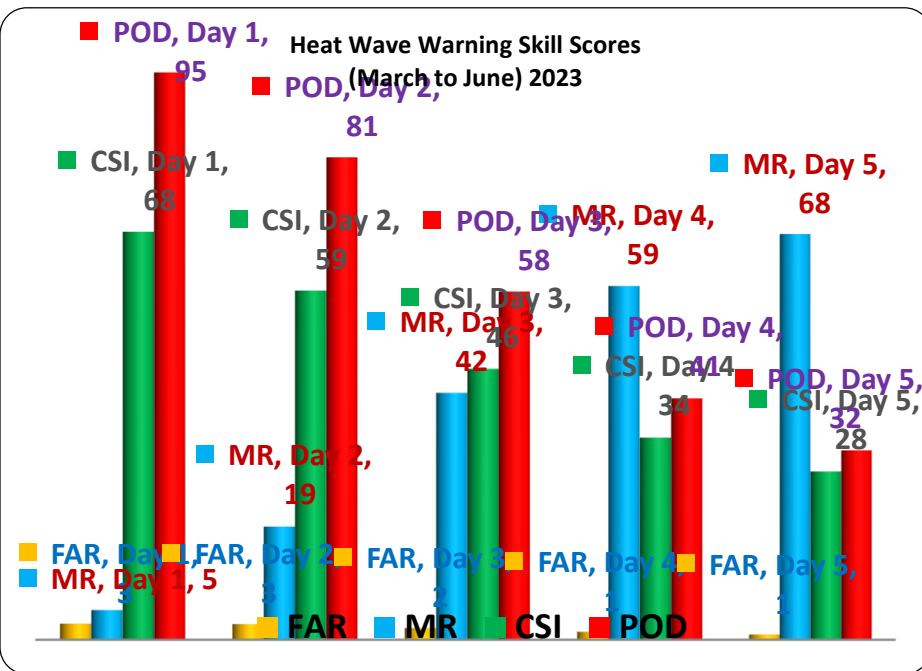
Observed Temperature at 1430 hrs IST Dated 20/04/2023



24 hrs Temperature Change at 1430 hrs IST Dated 20/04/2023



HEAT WAVE FORECASTING SKILLS 2023



- **POD: Probability of Detection**
- **There is significant improvement in recent five years compared to previous five years**

Heat Hazard Analysis

Heat Wave hazard analysis for entire country for four hot weather months (MARCH, APRIL, MAY & JUNE) considering the Maximum Temperature, Minimum Temperature, Humidity, Wind and Duration.

This will lead to identification of hazard scores based on different meteorological parameters aggravating impact of Heat Waves. These scores could in future be utilized as threshold to generate Heat Wave impact based alerts for the specific locations.

(1) Severe Heat Wave/Heat Wave Consideration:-

For Each Day of Month, If

Max Temp < Normal => **0 Weight**

Max Temp > Normal but no HW => **1 Weight**

Heat Wave => **2 Weight**

Severe Heat Wave => **3 Weight.**

If Max Temp > Normal then if,

Min Temp < Normal => **0 Weight**

MinTemp > Normal but no WN => **1 Weight**

Warm Night => **2 Weight**

Very Warm Night => **3 Weight.**

(2) RH Consideration:-

1. Average RH for East Coast for each Month is calculated.

2. This average RH of east coast is considered as threshold below which **weight of 0** is assigned to stations in each month.

3. The RH range above this threshold for any station is divided into three parts and are given the **weightage of 1, 2 & 3** respectively for any Heat Wave/Severe Heat Wave event.

4. RH is calculated individually for Days when Max Temp > Normal or for Heat Wave and Severe Heat Wave events.

(3) Wind Speed Consideration:-

1. Wind Speed of 2 kts is considered as threshold below which **weight of 0** is assigned to stations in each month.

2. Wind Speed above this threshold is divided into three parts and are given the **weightage of 1, 2 & 3** respectively for any Heat Wave/Severe Heat Wave event.

3. Wind Speed range is calculated individually for days when Max Temp > Normal or for Heat Wave and Severe Heat Wave events.

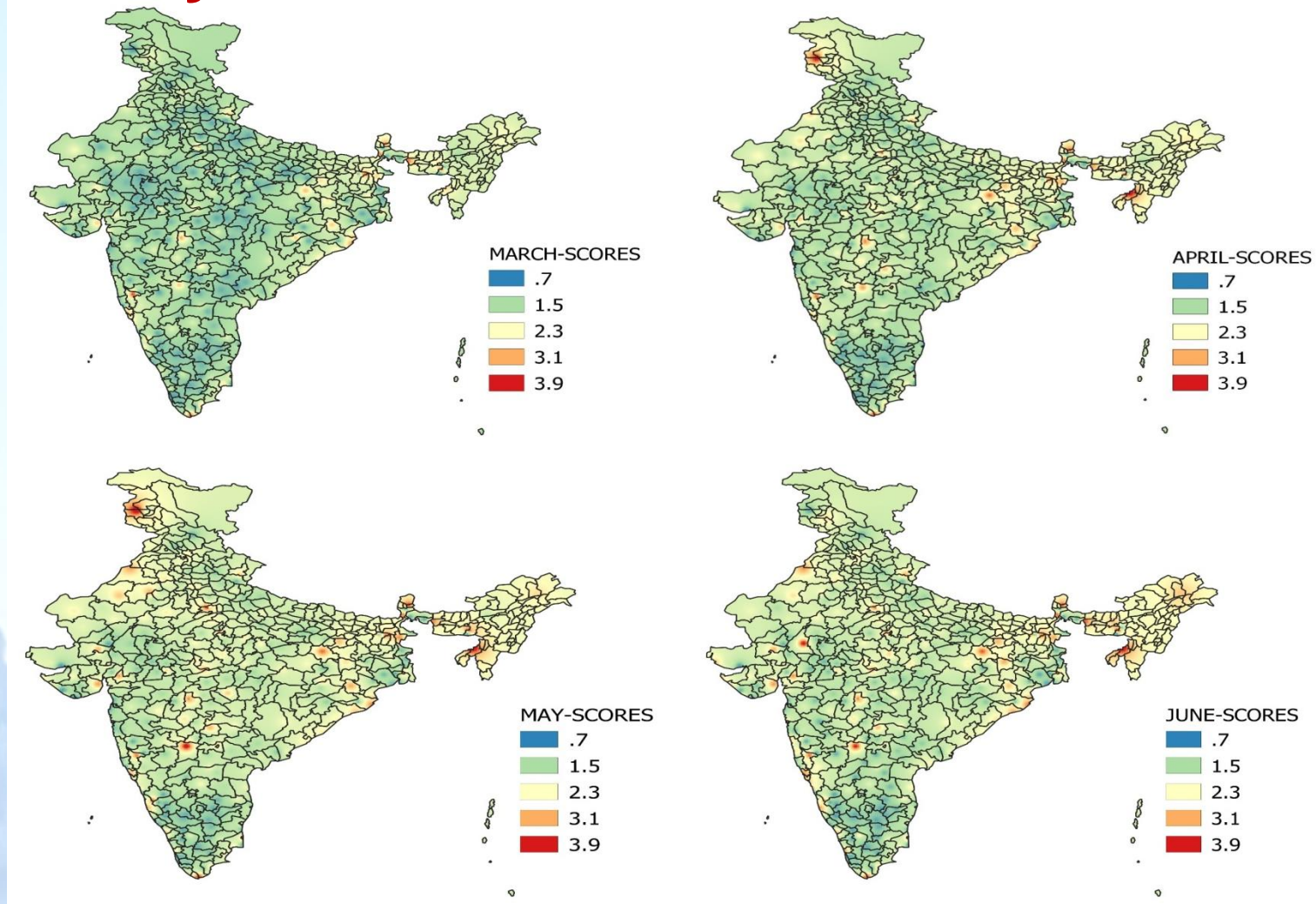
(4) Duration of Heat Wave Spell Consideration:-

1. Each day is identified as day 1,2,3 or 4th and above day of Severe/Heat Wave spell.

2. If day is identified as Day 1 then **weight of 0** is assigned for Day 2 **weight of 1**, for Day 3 **weight of 2** and for day 4 & above **weight of 3** is assigned.

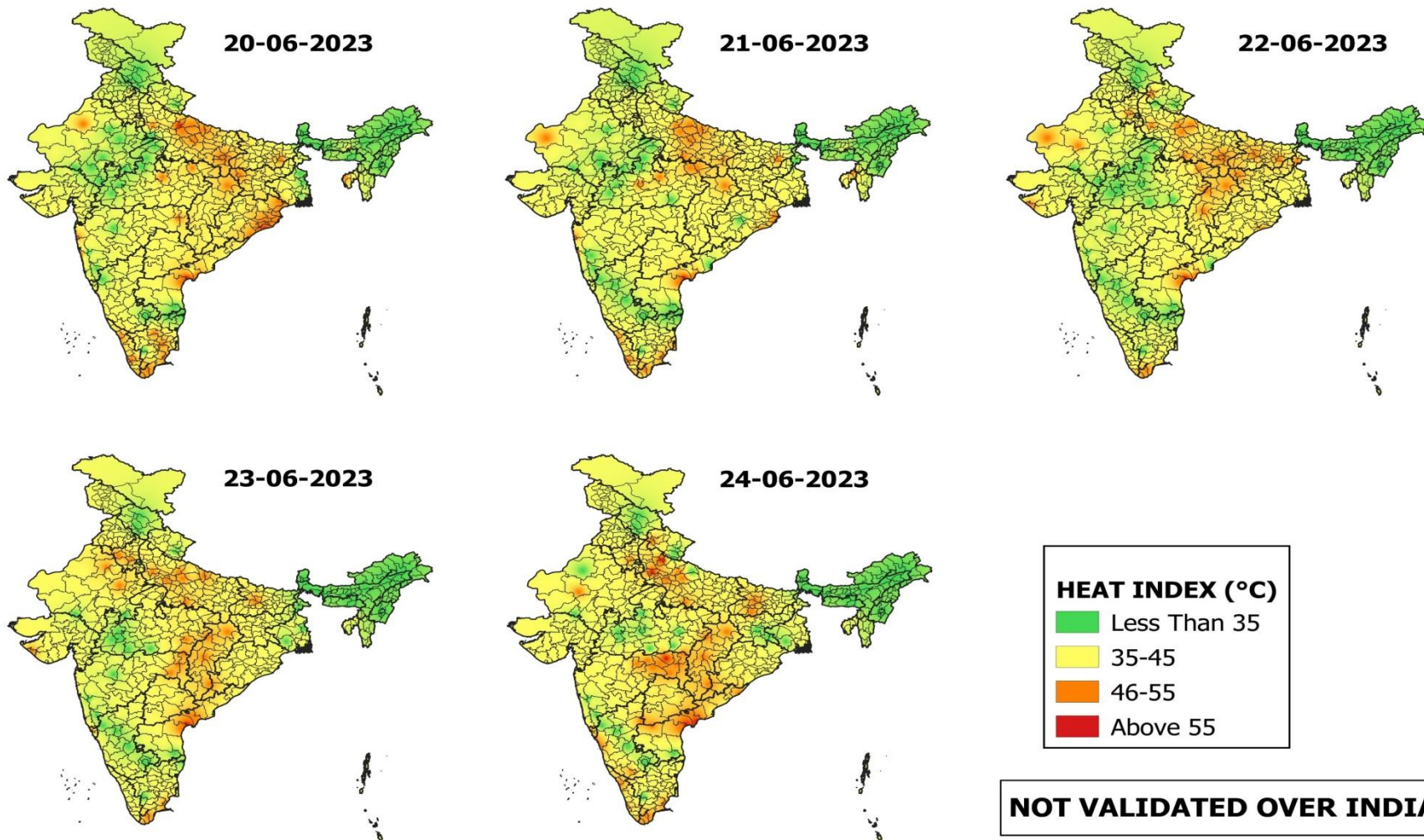
Srivastava, A., Mohapatra, M. & Kumar, N. (2022) Hot weather hazard analysis over India. Scientific Reports 12, 19768.

Monthly mean Hot Weather Hazard Scores



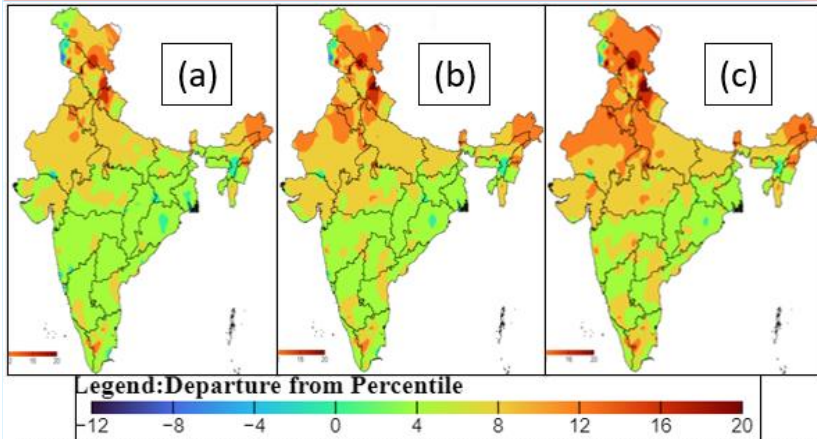
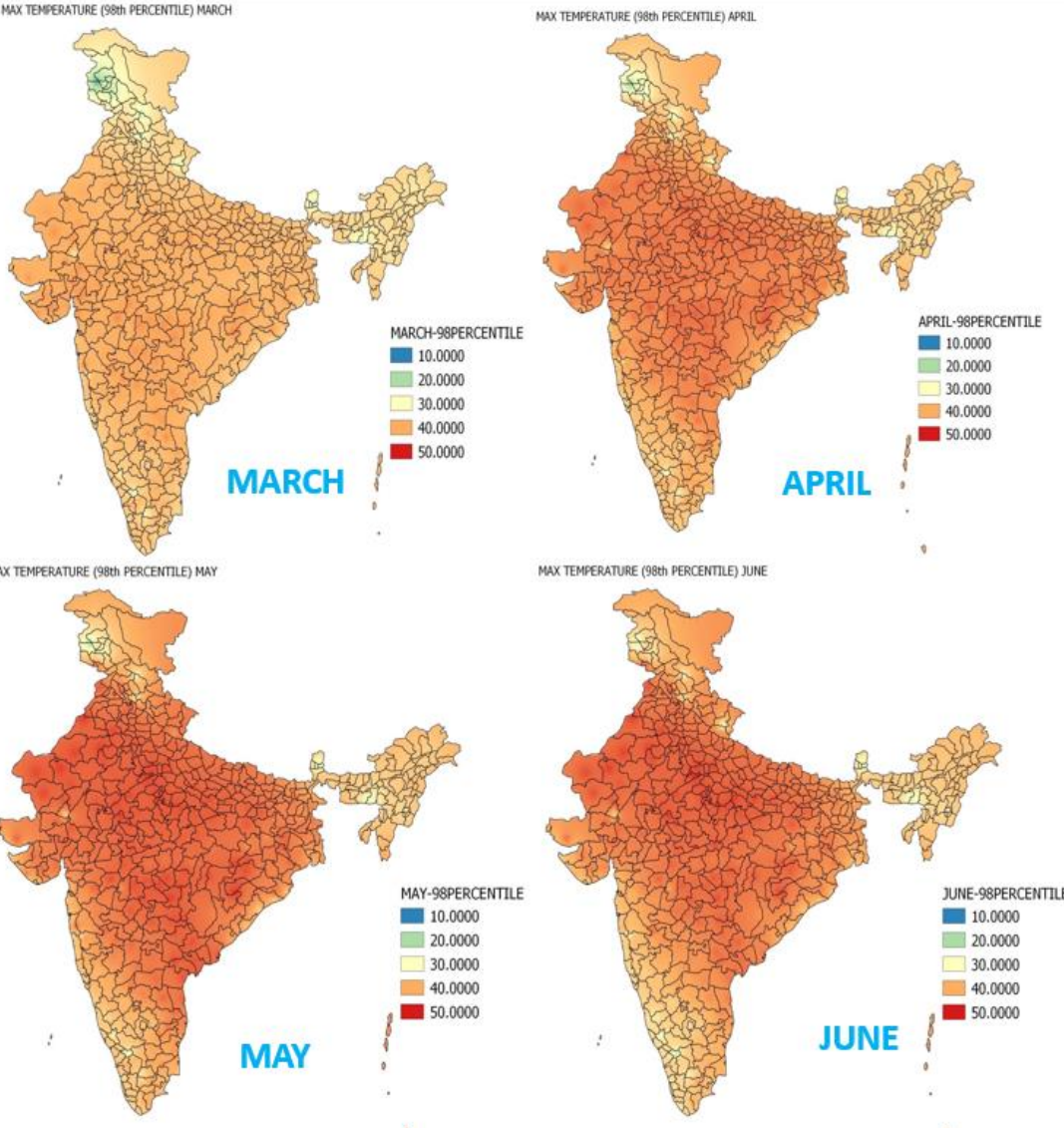
Heat Index forecast started in 2023

HEAT INDEX (EXPERIMENTAL FORECAST) DATED 20-06-2023



Percentile based extreme temperature information.

Observed Max Temp Difference from Monthly a) 90 Percentile; b) 95 Percentile; c) 98 Percentile.



98 percentile Temperatures for March, April, May and June.



GIS based important Heat Wave Products

Observed Max Temperatures

Forecasted Max Temperatures (up to 5 days)

Observed Min Temperatures

Forecasted Min Temperatures (up to 5 days)

Observed Severe/Heat Wave

Forecasted Severe / Heat Wave (district wise up to 5 days)

Observed Warm/Very Warm Night

Forecasted Warm/very Warm Night

90/95/98 Percentile of Max Temperatures

Forecasted Warm/very Warm Night

Observed Relative Humidity & Wind Speed

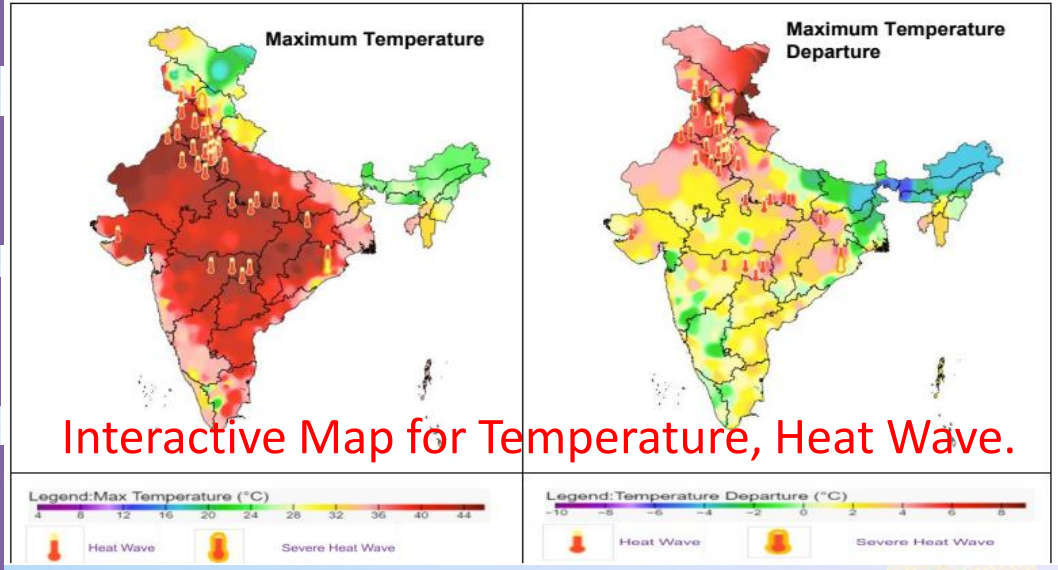
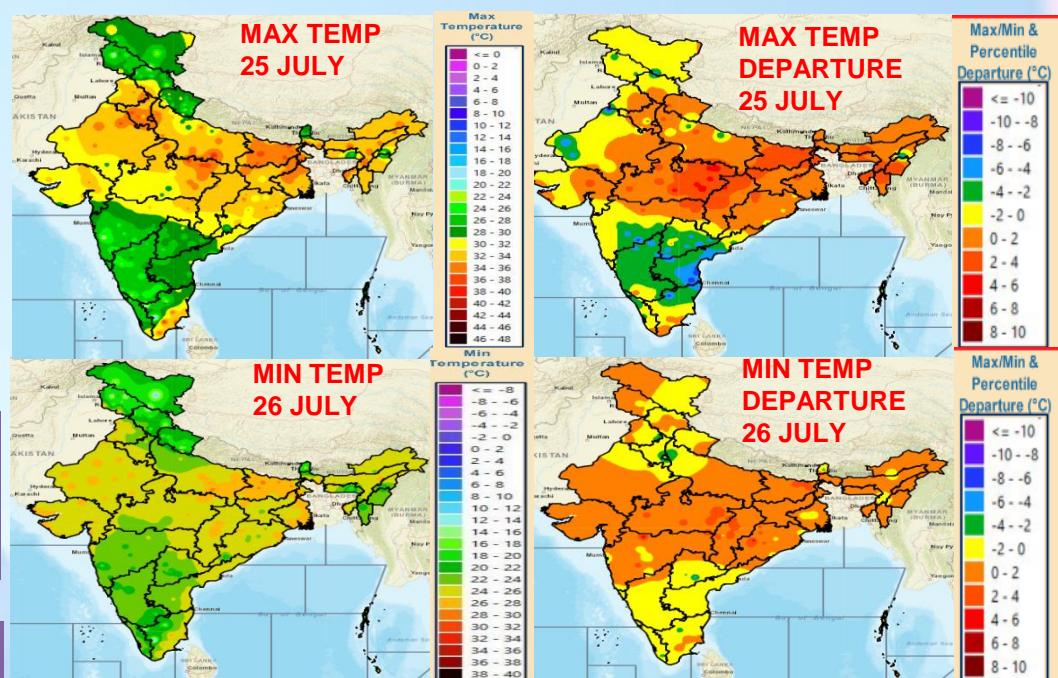
90/95/98 Percentile of Min Temperatures

Exposures to Socio-Economic parameters

Forecasted Relative Humidity & Wind Speed

Hot Weather Hazard Analysis

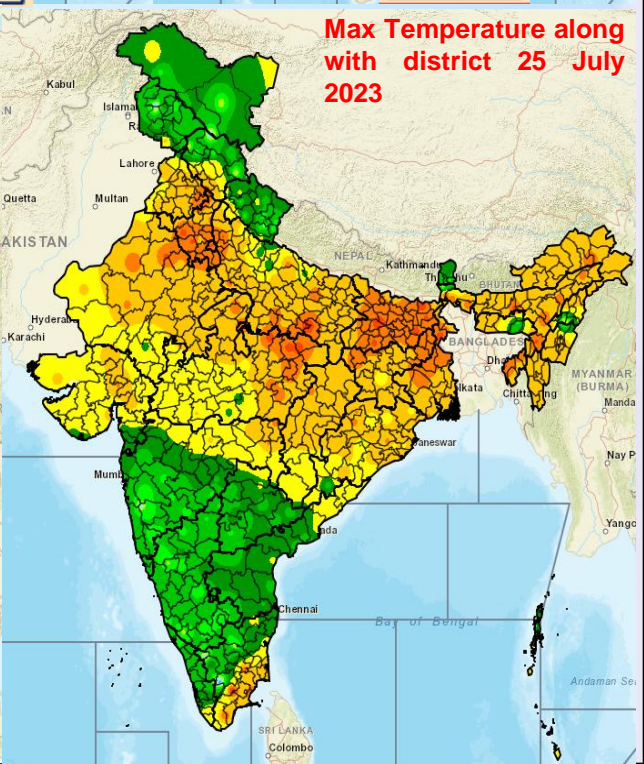
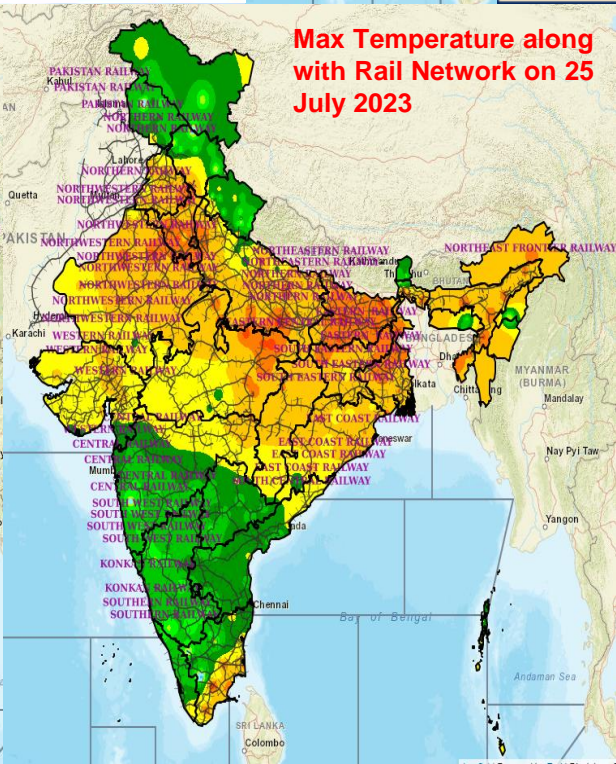
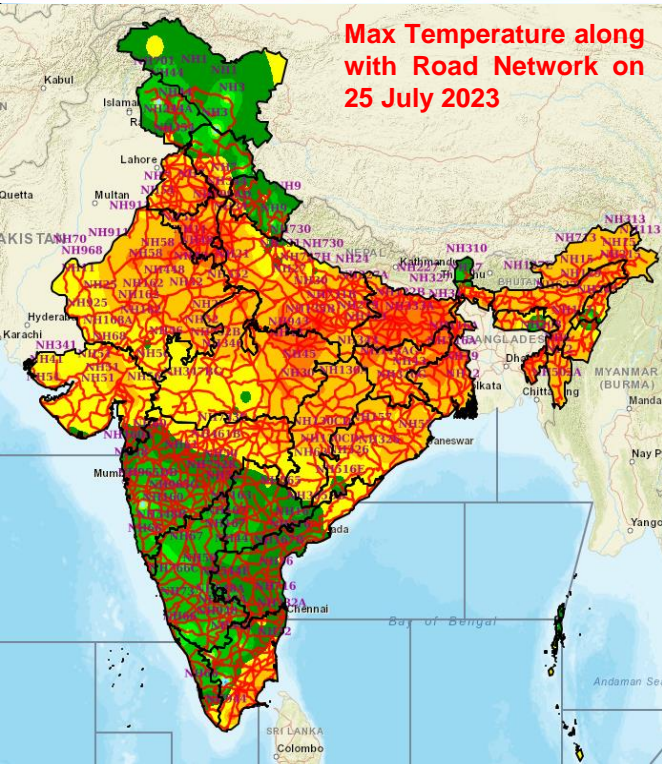
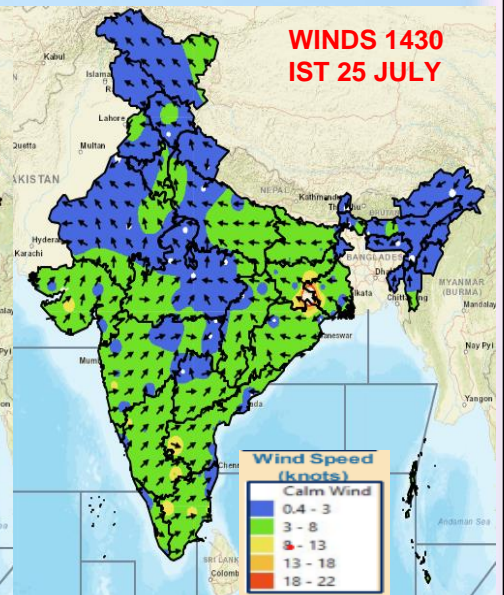
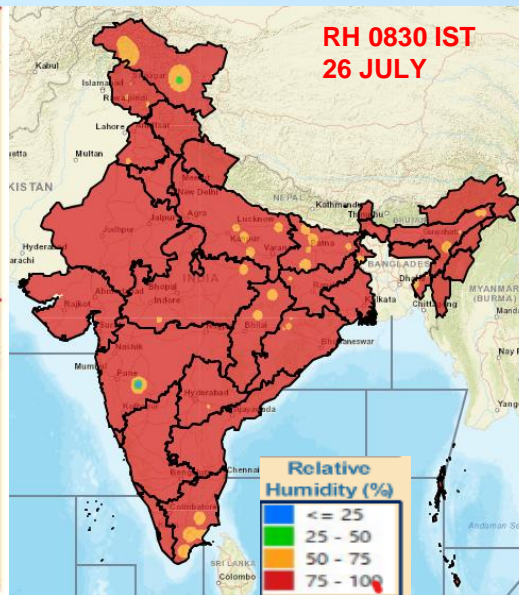
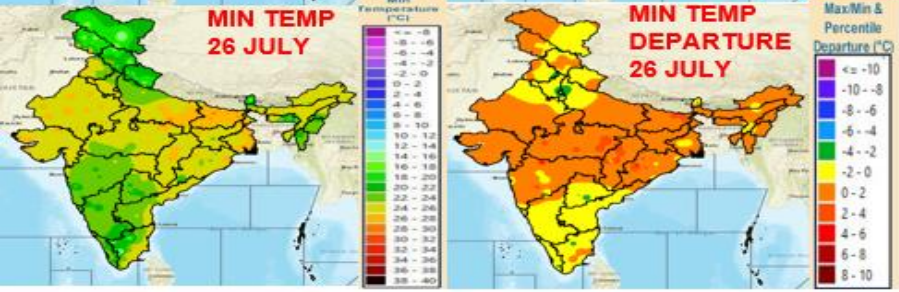
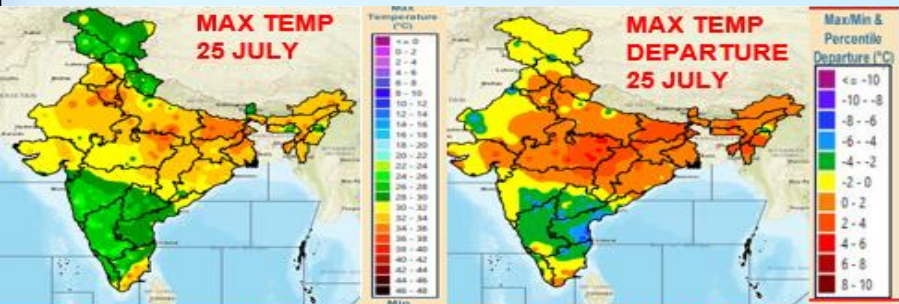
Forecast of Heat Index



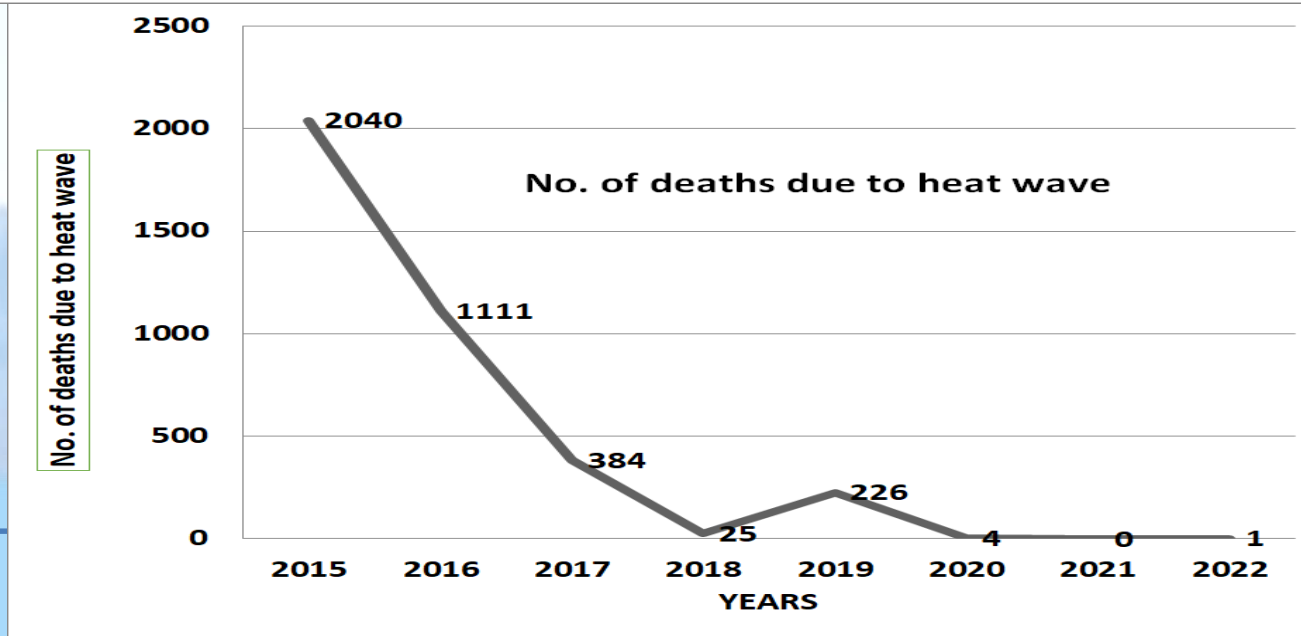
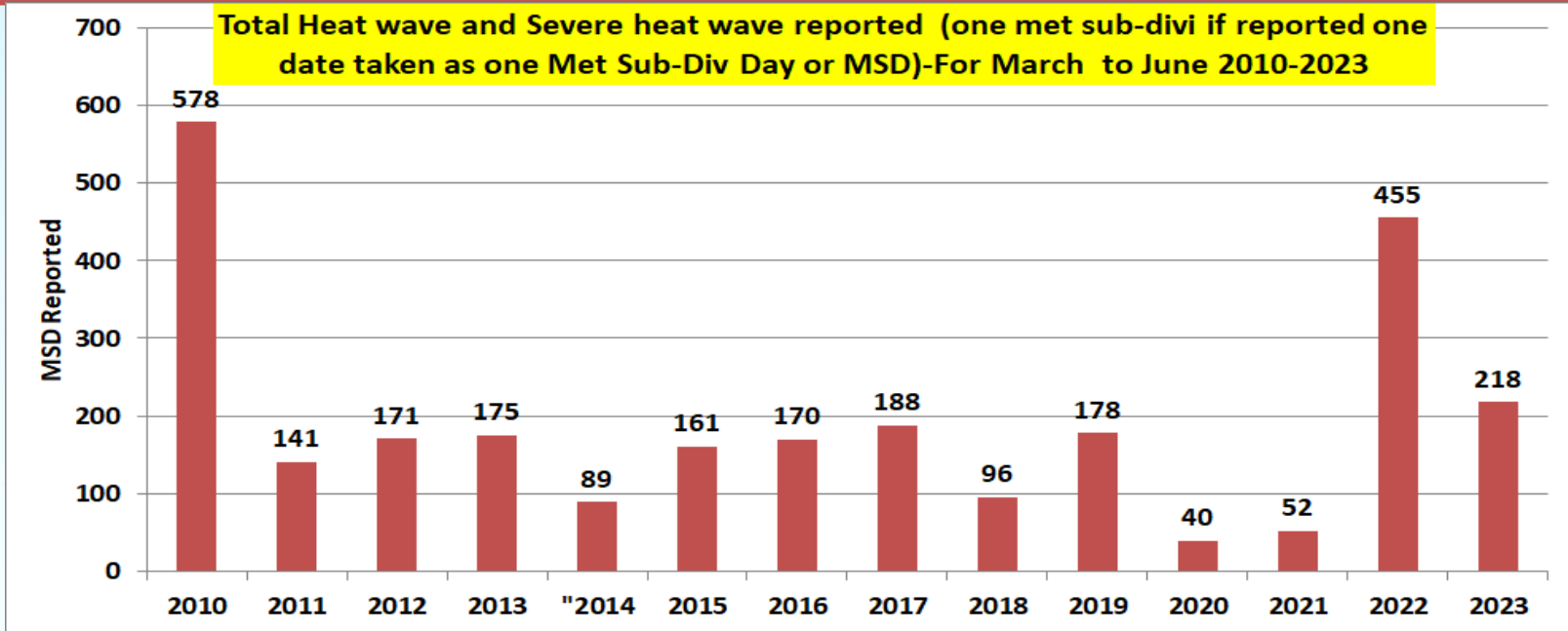
Interactive Map for Temperature, Heat Wave.



GIS based important Heat Wave Products (contd)



Heat Wave days and No. of deaths due to heat wave



IMD's requirement for Impact based Forecasting (IBF) of Heat Waves:-

- **Multistakeholder team having experts from academia/research as well as operational setup from specific sector.**
- **Easy accessibility of data from the sectors.**
- **The aim of the team would be to devise methods and threshold for targeted region wise sector specific impact based forecasting services.**

Coordination by NDMA and depending on priority following tentative sector could be considered.

Heat Wave + Health.

Heat Wave + Agriculture.

Heat Wave + Forest Fire.

Heat Wave + Transport.

Heat Wave + Energy.

Heat Wave +

IBF requires domain expertise from the specific sector in addition to meteorological expertise. These teams could be tapping this multisectoral expertise in generating targeted forecast and warning services.



THANK YOU



14-Feb-24

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

