Department of Civil Engineering
IIT (ISM) Dhanbad

FINAL YEAR PROJECT

STATISTICAL ANALYSIS OF HEAT WAVES OVER INDIA

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INTRODUCTION

A Heat Wave is a period of abnormally high temperatures, more than the normal maximum temperature that occurs during the summer season in the North-Western parts of India. Heat Waves typically occur between March and June, and in some rare cases even extend till July. The extreme temperatures and resultant atmospheric conditions adversely affect people living in these regions as they cause physiological stress, sometimes resulting in death.

INTRODUCTION-DEFINITIONS

The IMD defines a heatwave as a period when the maximum temperature at a location exceeds the normal temperature by a significant margin.

- **In plains**: a heatwave is declared if the temperature is **at least 40°C** and is **4.5-6.4°C** above the normal temperature
- **In hilly regions**: a heatwave is declared if the temperature reaches **30°C** or higher and shows a similar deviation

(India Meteorological Department, 2016)

A heatwave in India is marked by an increase of **5°C–6°C** from the area's normal temperature when it is typically less than or equal to **40°C**; if the increase reaches **7°C** or more, it is considered a severe heatwave. For regions where the usual maximum temperature exceeds 40°C, a rise of **4°C–5°C** triggers a heatwave declaration, while a **6°C rise** indicates a severe heatwave. If temperatures hit **45°C** regardless of the average maximum, it qualifies as a heatwave condition. **(Shrivastava et al, 2021)**

The WMO also defines a heat wave as when the daily maximum temperature is at least **5°C (9°F)** higher than the average maximum temperature for **five or more** consecutive days. The WHO in India defines sustained high temperatures that exceed local norms, leading to increased heat-related illnesses and health impacts, especially in densely populated and urbanized areas.

(World Meteorological Organization, 2005)

LITERATURE REVIEW

Urbanization and the Urban Heat Island Effect

The urban heat island (UHI) effect intensifies heatwave impacts in cities. Urban centers experience higher temperatures than rural areas due to reduced vegetation, increased concrete infrastructure, and human activities.This research discuss how cities like Delhi, Mumbai, and Hyderabad suffer greater temperature spikes during heatwaves due to the UHI effect, raising public health risks and energy consumption for cooling.

(Shrivastava et al, 2021)

Adaptation and Mitigation Strategies

Adaptive strategies, including early warning systems, public awareness campaigns, and infrastructure upgrades, have been studied as ways to reduce the impacts of heatwaves. The National Disaster Management Authority (NDMA) in India has implemented guidelines for heat action plans, which include community awareness programs, water distribution, and temporary shelters during peak heat periods. These strategies have shown promise in minimizing the adverse effects of heatwaves on vulnerable populations.

(Mathew et al, 2018)

Effects on Agriculture and Livelihoods

High temperatures during the critical growing stages of crops like wheat and rice reduce yields, impacting food security and the livelihoods of farmers. Crop stress due to intense heat also necessitates increased irrigation, placing additional pressure on water resources and increasing production costs.

(**Jangra et al, 2019)**

METHODOLOGY

Step 1: Data Collection and Preprocessing

- The project uses the IMD (Indian Meteorological Department) temperature dataset for the period **2001–2019**. The data contains daily maximum temperatures recorded at various stations across India, specifically focusing on the data for a specific location (15,15).
- The data is stored in a **.mat** file format. The dataset is processed using **MATLAB** for analysis.
- The relevant data is extracted for analysis(15,15).

Step 2: Defining Heatwave Events

Fixed Threshold:
The temperature threshold for heatwaves is defined as 40°C, as per the IMD standards for heatwaves.

Percentile-Based Threshold:
The threshold for a heatwave is considered when the daily maximum temperature exceeds this 90th percentile value.

Heatwave Days:
Heatwave days are identified when the temperature for a given day exceeds the 90th percentile threshold.

OR

Consecutive heatwave days are identified as periods where the daily maximum temperature exceeds the heatwave threshold for at least **three consecutive days.**

Step 3: Statistical Analysis

- Maximum temperature for each day is extracted from the dataset.
- The minimum and average daily temperatures are also calculated for the specified period.
- These values are calculated for the entire dataset as well as for specific heatwave periods which sets the comparison between the temperature distribution during normal days versus heatwave days.

METHODOLOGY

Step 4: Heatwave (Based on Consecutive Days):

- After identifying individual heatwave days, the methodology proceeds to identify consecutive heatwave periods where the threshold is exceeded for **at least three consecutive days**. This is an important criterion for detecting more severe and prolonged heatwaves.
- The consecutive heatwave days are counted, and the total number of heatwave events (>= 3 consecutive days) is calculated.

Step 5: Visualization

Plotting Temperature Data:

- Daily maximum temperatures are plotted over time to visualize general temperature trends.
- The heatwave threshold (90th percentile threshold) is plotted as a reference line.

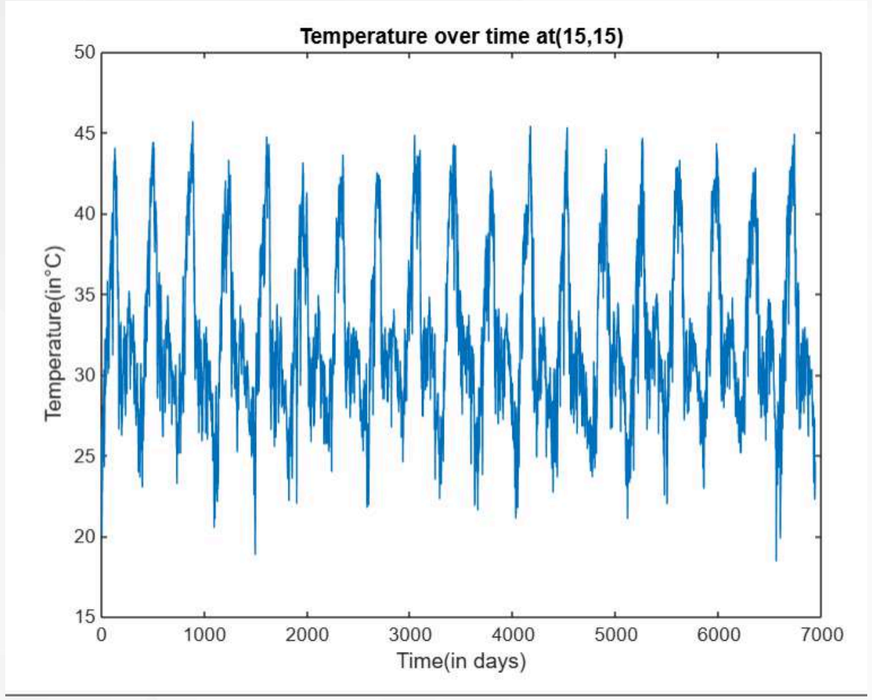
Heatwave Periods:

- Heatwave days and consecutive heatwave periods are highlighted in the plots.
- Specific periods of consecutive heatwaves (3+ days) are marked in a distinct color to show prolonged extreme temperature events.

Comparison of Thresholds:

- The daily maximum temperatures are plotted against both the fixed and 90th percentile thresholds, allowing for a visual comparison of how each threshold identifies heatwave events.

RESULTS

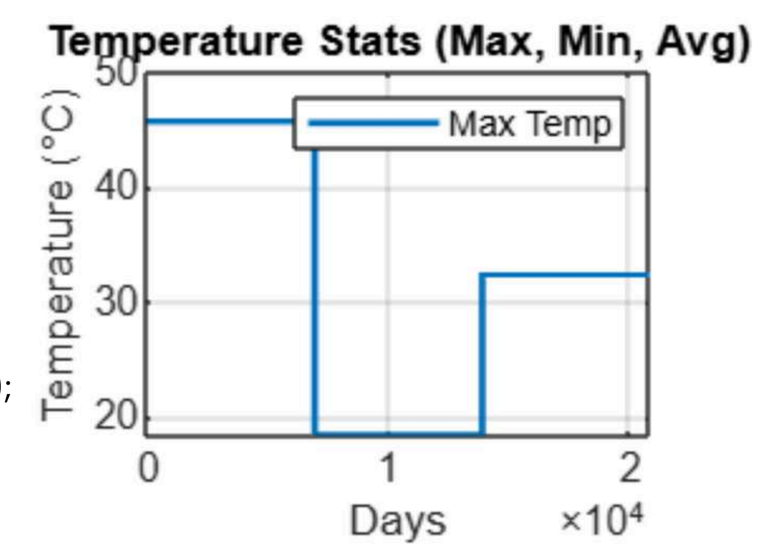


MATLAB CODE FOR SPECIFIED LOCATION

```
load('IMDTemp20012019.mat')
MaxTemp1515=squeeze(IMDTempMAX(15,15,:));
plot(MaxTemp1515)
a=MaxTemp1515(1:10);
plot(a)
plot(MaxTemp1515)
```

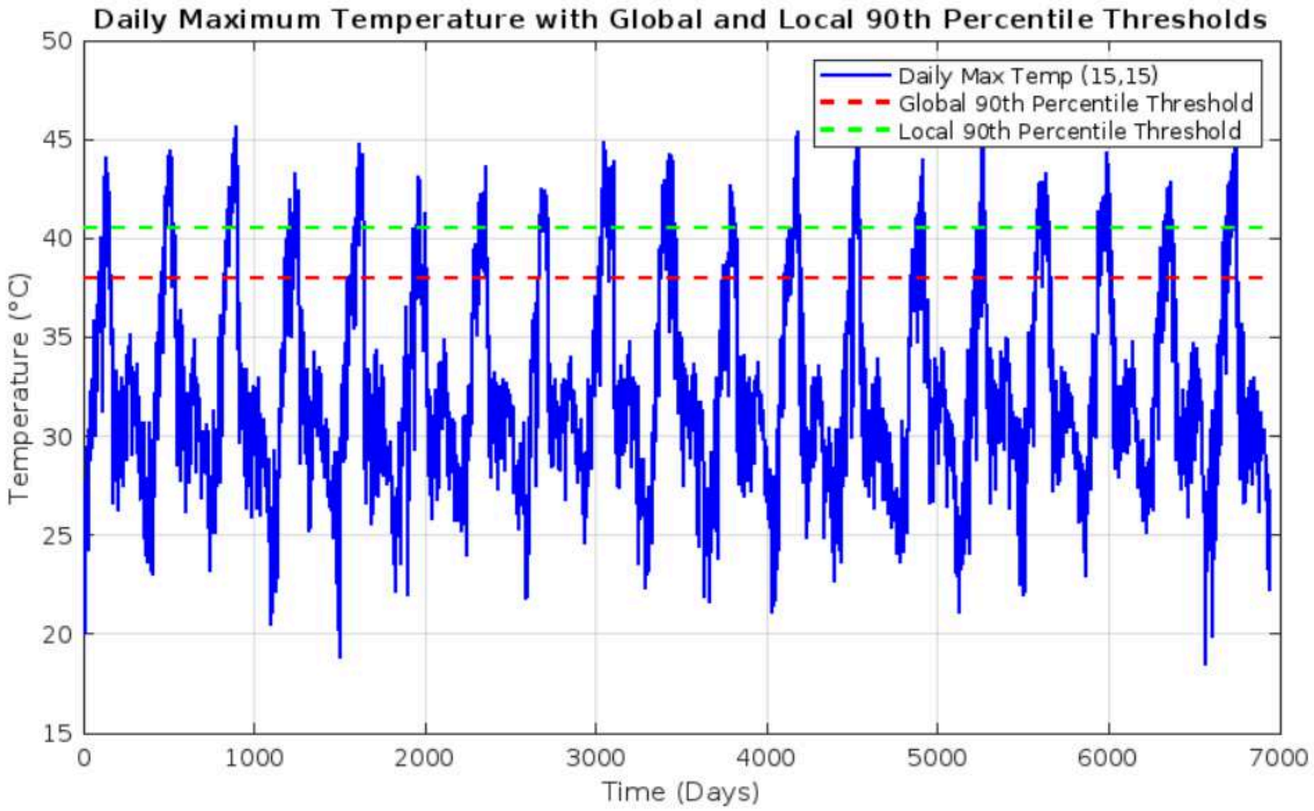
MATLAB CODE FOR MAX,MIN & AVG TEMP:

```
>> max_temp = max(MaxTemp1515); %max temp
disp(['Maximum Temperature: ',
num2str(max_temp)]);
Maximum Temperature: 45.71

>> min_temp = min(MaxTemp1515);
disp(['Minimum Temperature: ',
num2str(min_temp)]);
Minimum Temperature: 18.427

>> avg_temp = mean(MaxTemp1515);
disp(['Average Temperature: ',
num2str(avg_temp)]);
Average Temperature: 32.3967
```



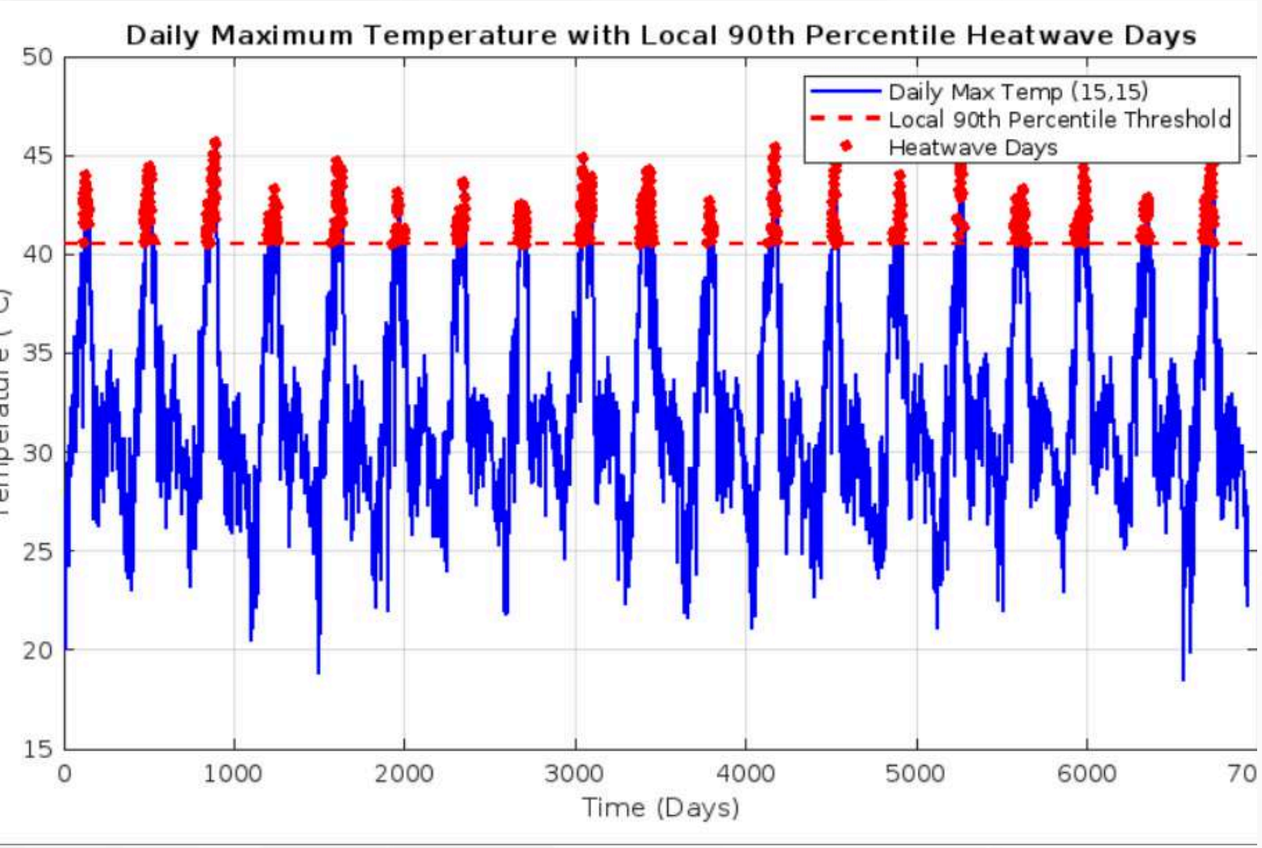

```
>> subplot(2,2,2); //plotting max min and average
on subplot
plot([max_temp * ones(size(MaxTemp1515));
min_temp * ones(size(MaxTemp1515)); avg_temp *
ones(size(MaxTemp1515))], 'LineWidth', 1.5);
legend('Max Temp', 'Min Temp', 'Avg Temp');
title('Temperature Stats (Max, Min, Avg)');
xlabel('Days');
ylabel('Temperature (°C)');
grid on;
```

RESULTS




```
>> global_threshold = prctile(IMDTempMAX(:), 90);
MaxTemp1515 = squeeze(IMDTempMAX(15, 15, :));
local_threshold = prctile(MaxTemp1515, 90);
disp(['Global 90th Percentile Threshold: ',
num2str(global_threshold)]);
disp(['Local 90th Percentile Threshold for (15,15): ',
num2str(local_threshold)]);
load('IMDTemp20012019.mat');
global_threshold = prctile(IMDTempMAX(:), 90);
MaxTemp1515 = squeeze(IMDTempMAX(15, 15, :));
local_threshold = prctile(MaxTemp1515, 90);
figure('units','normalized','outerposition',[0 0 1 1]);
plot(MaxTemp1515, 'b-', 'LineWidth', 1.5);
hold on;
plot(global_threshold * ones(size(MaxTemp1515)), 'r--', 'LineWidth',
2);
plot(local_threshold * ones(size(MaxTemp1515)), 'g--', 'LineWidth',
2);
title('Daily Maximum Temperature with Global and Local 90th
Percentile Thresholds');
xlabel('Time (Days)');
ylabel('Temperature (°C)');
legend('Daily Max Temp (15,15)', 'Global 90th Percentile Threshold',
'Local 90th Percentile Threshold');
grid on;
```

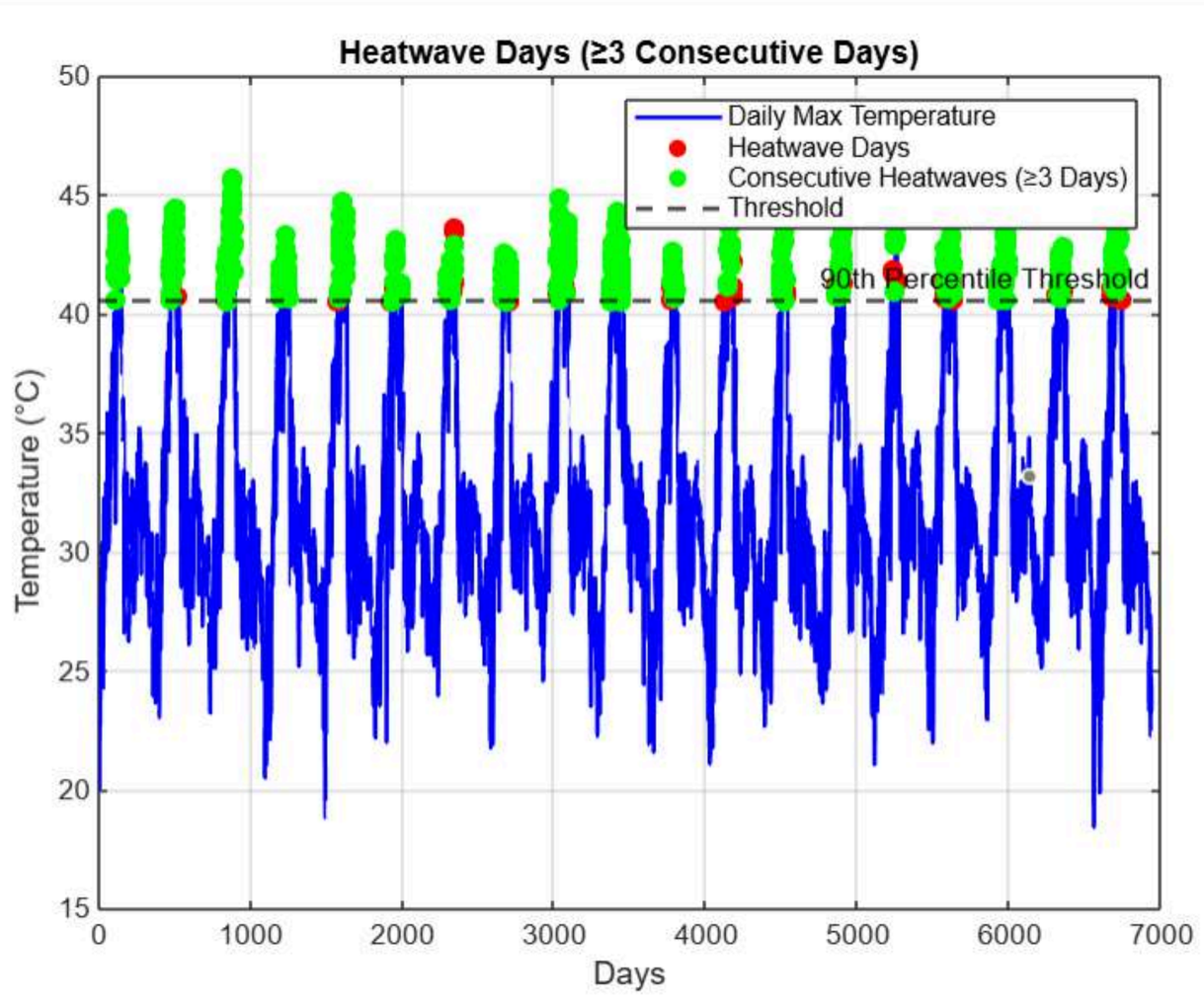
RESULTS



Number of Heatwave Days for location (15,15)

```
>> load('IMDTemp20012019.mat');
MaxTemp1515 = squeeze(IMDTempMAX(15, 15, :));
local_threshold = prctile(MaxTemp1515, 90);
heatwave_days = MaxTemp1515 > local_threshold
num_heatwaves = sum(heatwave_days);
disp(['Number of Heatwave Days for location (15,15): ',
num2str(num_heatwaves)]);
figure('units','normalized','outerposition',[0 0 1 1]);
plot(MaxTemp1515, 'b-', 'LineWidth', 1.5);
hold on;
plot(local_threshold * ones(size(MaxTemp1515)), 'r--',
'LineWidth', 2);  % Plot the local threshold
plot(find(heatwave_days),
MaxTemp1515(heatwave_days), 'ro', 'MarkerSize', 4,
'MarkerFaceColor', 'r');
title('Daily Maximum Temperature with Local 90th
Percentile Heatwave Days');
xlabel('Time (Days)');
ylabel('Temperature (°C)');
legend('Daily Max Temp (15,15)', 'Local 90th Percentile
Threshold', 'Heatwave Days');
grid on;
```

RESULTS



MATLAB CODE FOR HEATWAVE DAYS>=3: DAYS

```
>> load('IMDTemp20012019.mat');
MaxTemp1515 = squeeze(IMDTempMAX(15,15,:));
heatwave_threshold = prctile(MaxTemp1515, 90)
heatwave_days = MaxTemp1515 > heatwave_threshold;
consecutive_count = 0;
heatwave_periods = false(size(heatwave_days));
for i = 1:length(heatwave_days)
 if heatwave_days(i)
 consecutive_count = consecutive_count + 1;
 else
 if consecutive_count >= 3
 heatwave_periods(i-consecutive_count:i-1) = true;
 end
 consecutive_count = 0;
 end
end
if consecutive_count >= 3
 heatwave_periods(end-consecutive_count+1:end) = true;
end
num_heatwave_days = sum(heatwave_periods);
disp(['Number of Heatwave Days (≥3 consecutive): ',
num2str(num_heatwave_days)]);
figure;
plot(1:length(MaxTemp1515), MaxTemp1515, '-b', 'LineWidth', 1.5); hold on;
scatter(find(heatwave_days), MaxTemp1515(heatwave_days), 50, 'r', 'filled');
scatter(find(heatwave_periods), MaxTemp1515(heatwave_periods), 50, 'g', 'filled');
yline(heatwave_threshold, '--k', 'LineWidth', 1.5, 'Label', '90th Percentile Threshold');
xlabel('Days');
ylabel('Temperature (°C)');
```

RESULT & DISCUSSION

Maximum Temp: 45.71 deg cel
Minimum Temp: 18.427 deg cel
Average Temp: 32.396 deg cel
90th percentile Local Temp: 40.5384 deg cel
90th percentile Global Temp: 38 deg cel
Number of heatwaves days >= consecutive3 days: 640

- A heatwave is considered to occur when the daily maximum temperature at a given location exceeds the 90th percentile threshold, and this condition holds for 3 or more consecutive days.

Future Scope:

- This study currently focus on the a single location (15,15). Later It will be done for whole India by iteration.
- Here we have found Heatwaves using 90th percentile later we will focus on to take more factors like EHF(Excessive Heat factor), humidity and other parameters like topography.
- Also, how the climate change is impacting heatwave and frequency of heatwaves is changing over time.

- Using a fixed threshold (40°C) and a dynamic threshold based on the 90th percentile of daily maximum temperatures, we identified heatwave days in the dataset.

- The 90th percentile threshold provided a more location-specific approach, adjusting for seasonal variations, which made it potentially more reliable in capturing local temperature extremes.

- Heatwaves are not only characterized by their intensity but also by their duration. In this study, we focused on consecutive heatwave events of 3 or more days. This threshold is useful for understanding prolonged exposure to extreme temperatures

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THANK YOU