CLIMATE CHANGE IN INDIA

Content

Guiding Questions

Gathering Data

The main objective of this project is to analyse and understand surface temperature change in India and its different states & union-territories. The required data was obtained from the "Climate Change Knowledge Portal (CCKP)". "The Climate Change Knowledge Portal (CCKP) provides global data on historical and future climate, vulnerabilities, and impacts."[4]

The obtained data contains the monthly and annual temperature data of India and its states & UTs between the period 1901 and 2020. After procuring the data following steps were taken (using Ms Excel) to organise it:-

1. Merge the CSV files (containing temp. data of each state separately) into a single excel sheet.

1. Calculate seasonal temperatures for every state based on the following categorization :-

   The IMD (India Meteorological Department) has broadly categorised seaons in India as: [5]

   - **Winter Season:** January – February
   - **Pre Monsoon/Summer Season:** March – May
   - **Southwest Monsoon/Summer Monsoon Season (named as "Monsoon" in this dataframe):** June - September
   - **Post Monsoon Season:** October - December

Data Wrangling

After gathering and organising the data, further data manipulation and wrangling are done to get it ready for visualization. Since the objective is to study "Temperature Change", we need temperature change data. To calculate "Temperature Change" from the available

"Temperature Values": I calculated the arithmetic mean of the "Temperature Values" (termed as "Baseline mean") between the __baseline period (1961-1990)*__ and subtracted it from the "Temperature Values" for each observation.

The following steps were taken to get the final **"Visualization ready data"**:-

1. Create a copy of the original data to a new dataframe `df`.

1. Calculate `Baseline mean` relative to the period 1961 to 1990.

2. Add a column `Zone`, for __Zonal-classification**__ of states based on the following categorization:

   North: 'Chandigarh', 'Delhi', 'Haryana', 'Himachal Pradesh', 'Punjab', 'Rajasthan' **South:** 'Andhra Pradesh', 'Karnataka', 'Kerala', 'Puducherry', 'Tamil Nadu', 'Andaman and Nicobar', 'Lakshadweep' **East:** 'Bihar', 'Orissa', 'Jharkhand', 'West Bengal' **West:** 'Dadra and Nagar Haveli', 'Daman and Diu', 'Goa','Gujarat', 'Maharashtra' **Central:** 'Chhattisgarh', 'Madhya Pradesh', 'Uttarakhand', 'Uttar Pradesh' **North East:** 'Assam', 'Sikkim', 'Nagaland', 'Meghalaya', 'Manipur', 'Mizoram', 'Tripura', 'Arunachal Pradesh'

3. Transform the dataframe using melt function.

4. Calculate temperature change by subtracting 'baseline mean values' from 'temperature values'.

Note:- * A baseline period is needed to define the observed climate with which climate change information is usually combined to create a climate scenario. The IPCC Data Distribution Centre (IPCC DDC) suggests the period 1961-1990 to be used as the baseline period. This period has generally good observed data and it represents the recent climate to which many present-day human or natural systems are likely to be reasonably well adapted.[6]

** Zonal classification is done by the Government of India through the State Reorganisation Act, 1956. It has been done by considering the cultural, geographical, and demographic diversity of each Indian state, where the six zones are as follows: East, West, North, South, Northeast and Central India.[7]

The columns in the final dataset are:

- **`States`:**

  Description: Names of different states and union territories. **Type:** Object **Unique Values:** Andaman and Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chandigarh, Chhattisgarh, Dadra and Nagar Haveli, Daman and Diu, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, India, Jharkhand, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Puducherry, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal

- **`Zone`:**

  Description: Zone-wise classification of states and U.T.(s) using `zones` function. **Type:** Object **Unique Values:** South, East, North, West, Central, North East, None

- **`Period`:**

  Description: Duration of time. i.e., months, seasons and year. **Type:** Object **Unique Values:** Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec, Winter, Summer, Monsoon, Post Monsoon, Annual

- **`Year`:**

  Description: Year **Type:** int32 **Unique Values:** 1901 to 2020. i.e., [1901, 1902,1903, ... , 2018, 2019, 2020]

- **`temp_change`:**

  Description: Change in temperature relative to `Baseline mean` **Type:** float64

- **`Baseline mean`:**

  Description: Arithmetic temperature mean relative to baseline period 1961-1990 **Type:** float64

Temperature change in Indian States and Union Territories

1. Which ten States/UTs suffered the most due to temperature change in the last decade?

Observation:

- Lakshadweep suffered the most from temperature change in the last decade. Lakshadweep is a tropical archipelago (an extensive group of islands). Andaman and Nicobar Islands is another archipelago on the list. It is already well known that islands are more vulnerable to and threatened by the effects of climate change.
- Tamil Nadu, Kerala and Puducherry are all coastal regions in the southern part of the country. Climate change threatens coastal areas, which are already stressed by human activity, pollution, invasive species, and storms.
- Himachal Pradesh, Uttarakhand, Delhi, Chandigarh and Haryana are regions in the north of India. North India has been witnessing frequent heatwaves and high temperatures in the recent past.

2. Which ten States/UTs suffered the least due to temperature change in the last decade?

Observation:

- Tripura, Mizoram, Meghalaya, Manipur and Assam form most of the North-East and are among the states which experienced the least temperature change in the country.
- West Bengal, Jharkhand, Orissa and Bihar are eastern states of India while Chhattisgarh lies in the central part.

3. What was the overall trend of temperature change in Indian States & UTs in the last decade?

Observation:

In the last decade (2011-2020):-

- All States & UTs have a positive temperature change which means all of them witnessed an increase in temperature in the last decade.
- Southern and northern regions have witnessed greater changes in temperature than the central or western parts, whereas Eastern and North-Eastern states have experienced lower changes.

- Lakshadweep witnessed the highest temperature change of 0.87 °C and Tripura experienced the least change at 0.07 °C.
- 22 out of 33 (≈ 67%) States & UTs have experienced a temperature change of more than 0.5 °C. Out of these States & UTs, there are 7 southern, 6 northern, 5 western, 2 central and 2 north-eastern states.

__*Note:-*__ Data for the states of 'Jammu and Kashmir' and 'Telangana' was unavailable.*

4. What is the zone-wise temperature change scenario (in the last decade)?

Observation:

- The southern zone experienced the maximum temperature change. All the states in this region touch the coastline of India. Lakshadweep and Andaman & Nicobar Islands also lie in this region. Islands and coastal regions are relatively more vulnerable to the effects of climate change.
- The northern zone is second on the list. The northern region has been witnessing frequent heatwaves and high temperatures in the recent past.
- The western and central parts witnessed temperature changes greater than 0.5 °C.
- The eastern and north-eastern states have experienced the least change in terms of temperature. The northeastern part of India is known for its diverse and most

extensive lush forest cover. The India State of Forests Report (ISFR) 2021, released by the Ministry of Environment, revealed that the forest cover in the eight north eastern states accounts for 23.75% of the total forest cover of the country.[8]

Temperature change in India

5. What is the trend of temperature change in India?

Observation:

- It is evident from the bar graph that the value for temperature change has continuously increased between 1901 and 2020. A positive change in temperature means that the temperature has risen.
- The maximum annual temperature change (Mean Annual Temperature Change) of 1.12 °C was witnessed in 2009, while the minimum was experienced in 1917 with a change of -0.88 °C.
- A relatively erratic increase in temperature can also be noticed in the graph in the last two decades (2001-2020).
- Hence, it can be concluded that India has seen a continuous rise in temperature between 1901-2020.

6. What is the outline of seasonal temperature change in India?

Observation:

- In the graph, the Monsoon season has a relatively smoother line with fewer fluctuations and small peaks.
- Winter, summer and post-monsoon have more fluctuant lines than monsoon.
- Winter has witnessed the most erratic changes in temperature with abruptly high peaks.
- In addition, the hottest winter with maximum temperature change was in 2009 and the summer of 2010 was the second hottest season.

The Climate Spiral

Conclusion

In this project, I examined and analyzed how the surface temperature changed in India between 1901 and 2020. I tried to visualize temperature change in India and find trends and patterns of the same and how it varies over different states and union territories.

I found that all States & UTs in India have experienced a continuous increase in temperature in the last decade. 22 out of 33 (≈ 67%) States & UTs have experienced a

temperature change of more than 0.5 °C. Island groups (Lakshadweep and Andaman & Nicobar) are the most impacted by temperature change. Southern and northern regions have witnessed maximum changes, whereas Eastern and North-Eastern states have experienced the least. The temperature change trend in India (as a whole) shows a continuous temperature rise, particularly in the last few decades. A look at the seasonal temperature change reveals that the winters witnessed the most erratic temperature changes followed by summer, post-monsoon and monsoon.

The IPCC Working Group II's report titled 'Climate Change 2022: Impacts, Adaptation and Vulnerability' [10] goes into depth regarding all climate-related threats to agriculture and food systems in parts of Asia. The study also mentions that under RCP8.5 (high emissions scenario), at the end of the century, Lucknow and Patna are among the cities predicted to reach wet-bulb temperatures of 35 degrees if emissions continue to rise, while Bhubaneswar, Chennai, Mumbai, Indore and Ahmedabad are all identified as at risk of reaching wet-bulb temperatures of 32-34 degrees with continued emissions. Overall, Assam, Meghalaya, Tripura, West Bengal, Bihar, Jharkhand, Odisha, Chhattisgarh, Uttar Pradesh, Haryana and Punjab will be the most severely affected, but if emissions continue to increase, all Indian states will have regions that experience wet-bulb 30 degrees or more by the end of the century.

The conclusion is that India is already experiencing a warming climate. Unusual and unprecedented spells of hot weather are expected to occur far more frequently and cover much larger areas. Under 4°C warming, the west coast and southern India are projected to shift to new, high-temperature climatic regimes with significant impacts on agriculture.

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