THE DISTINCT RESPONSE OF INDIAN LAND RAINFALL AND ITS TELECONNECTION TO NORTHERN PACIFIC CLIMATE VARIABILITY

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Outline

- ❑ **Introduction**
- ❑ **Data and Methodology**
- ❑ **Climate Classification of Indian subdivisions**
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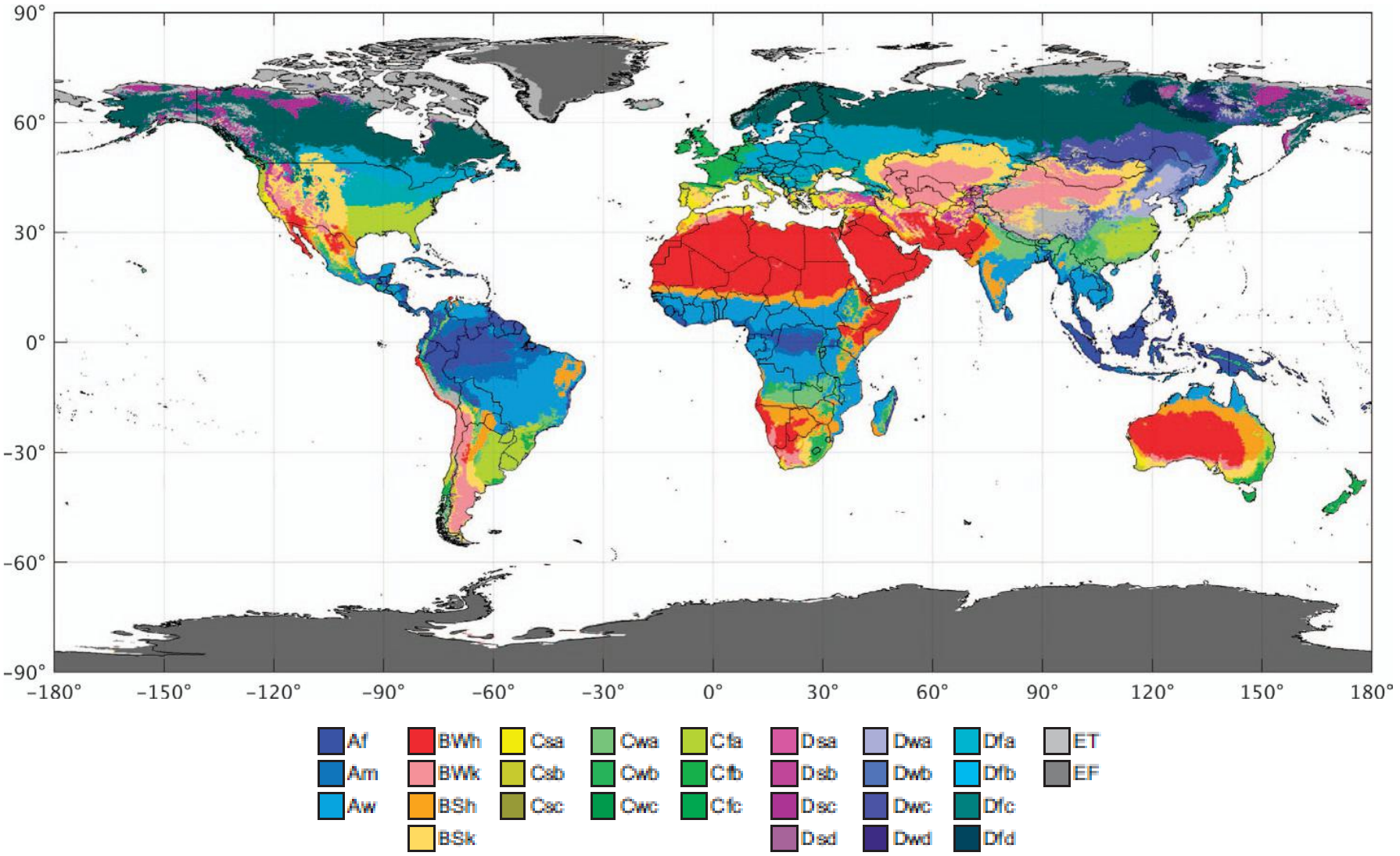
In recent period climate change and global warming is a burning topic worldwide. Global warming is an alarming phenomenon that is characterized by a drastic increase in the average global temperature in earth's atmosphere. Studies shows that, since 1950, the average temperature has risen at the fastest rate in recorded history.

Many studies shows that climate change is significantly impacting India, leading to increased extreme weather events, rising sea levels, and threats to agriculture, water resources, and ecosystems, with the most vulnerable communities bearing the brunt of these changes.

The aim of this study is to analyse climate change in India with respect to climate classification and to investigate the underlying factors driving these changes.

Köppen-Geiger classifications, the present-day map (1980–2016) (Beck et al. 2018)



Datasets and Methods

- Observed gridded rainfall with 0.25ºx0.25º resolution over the past seven decades (1951-2020) from India Meteorological Department (Pai et al 2014).
- IMD gridded observed Maximum and Minimum temperatures (original resolution is 1ºx1º resolution) but re-gridded to 0.25 resolution (Srivastava et al 2009).
- Monthly 1ºx1º SST dataset used the Ocean Centennial in Situ Observation-Based Estimates of the Variability of SST and Marine Meteorological Variables27 (COBE 2 SST).
- The Köppen-Geiger climate classification as described in Peel et al., 2007 which was also used by Kriticos et al., 2012.

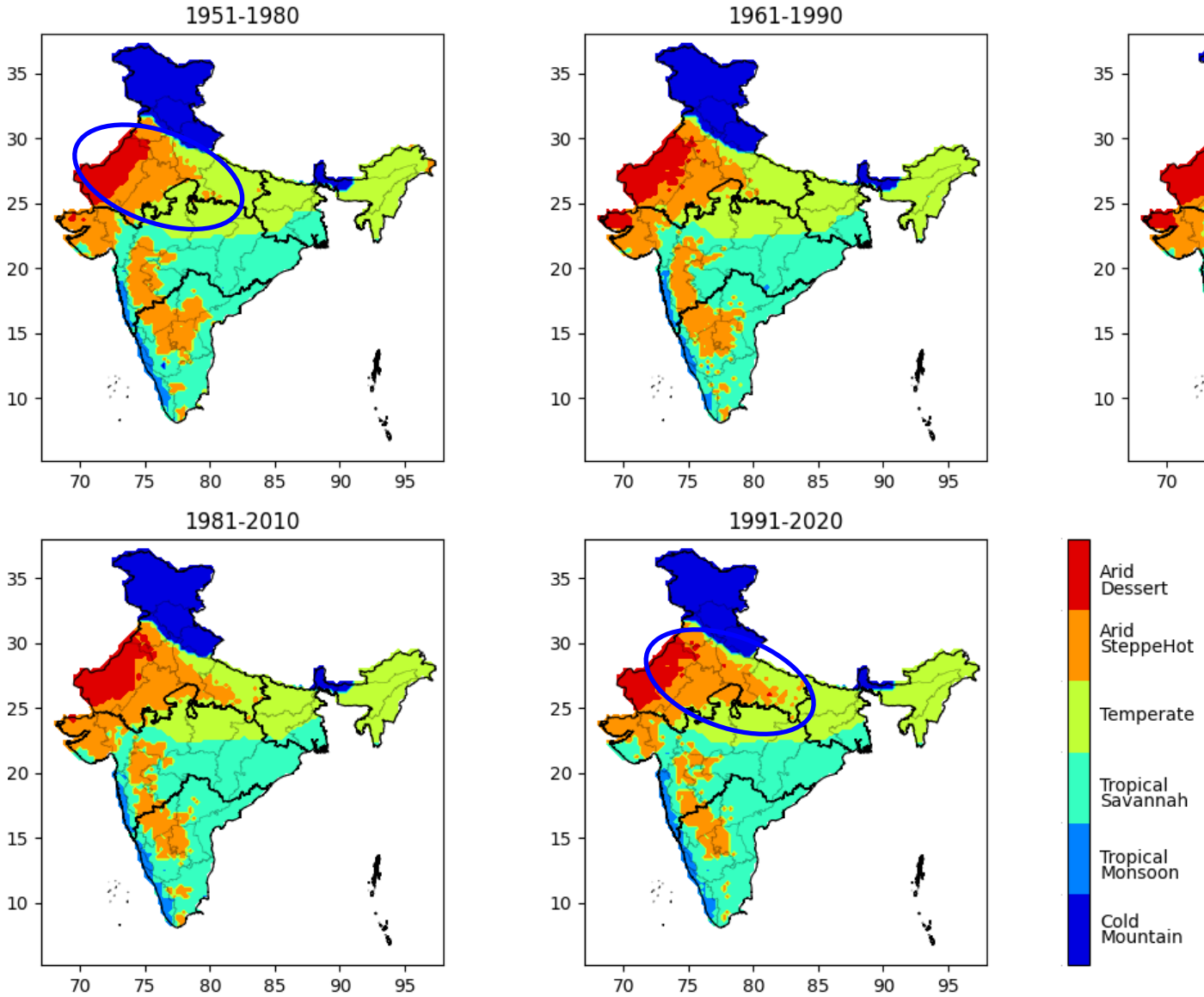
Climate Class	Description	Criterion
Tropical (A)		Not Arid & $T_{cold} \geq 18$
	Monsoon (m)	Not $P_{dry} \geq 60$ & $P_{dry} \geq 100 - MAP/25$
	Savannah (w)	Not $P_{dry} \geq 60$ & $P_{dry} < 100 - MAP/25$
Arid (B)		$MAP < 10 \times P_{threshold}$
	Desert hot (Wh)	$MAP < 5 \times P_{threshold}$, $MAT \geq 18$
	Steppe hot (Sh)	$MAP \geq 5 \times P_{threshold}$, $MAT \geq 18$
	Dessert Cold (Wk)	$MAP < 5 \times P_{threshold}$, $MAT < 18$
Temperate (C)		Not Arid & $T_{hot} > 10$ & $0 < T_{cold} < 18$
	Dry Winter (w)	$P_{wdry} < P_{swet}/10$,
	Hot Summer (a)	$T_{hot} \geq 22$
Cold (D)		$T_{hot} > 10$ & $T_{cold} \leq 0$
	Dry summer (s)	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	Warm summer (b)	Not $T_{hot} \geq 22$ & $T_{mon10} \geq 4$
Both Cold climate regions (BWk and Dsb) are considered as Cold Mountain here		

Köppen-Geiger climate classification for subdivisions of India

- **IMD gridded rainfall, minimum and maximum temperatures for historical period from 1951-2020 of moving climatological mean 30-years updated every decade.**
- **India spans six major climate zones as the Köppen-Geiger climate classification i.e., Arid Desert, Arid Steppe Hot, Tropical Monsoon, Tropical Savannah, Temperate and Cold Mountain.**

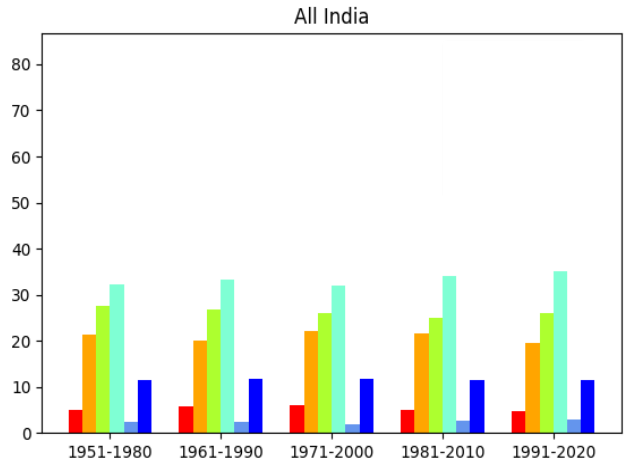
MAP=Mean Annual Precipitation. MAT = Mean Annual Temperature

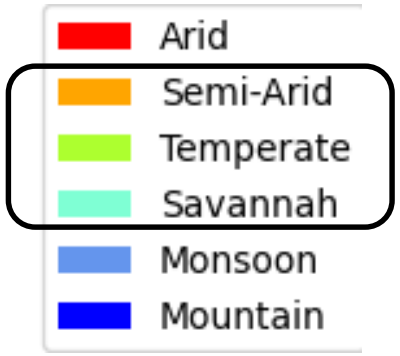
$$P_{threshold} = 2 \times MAT \; if \; atleast \; 70\% \; Annual \; Precip \; in \; winter$$
$$2 \times MAT + 28 \; if \; atleast \; 70\% \; Annual \; Precip \; in \; Summer$$
$$2 \times MAT + 14 \; otherwise$$

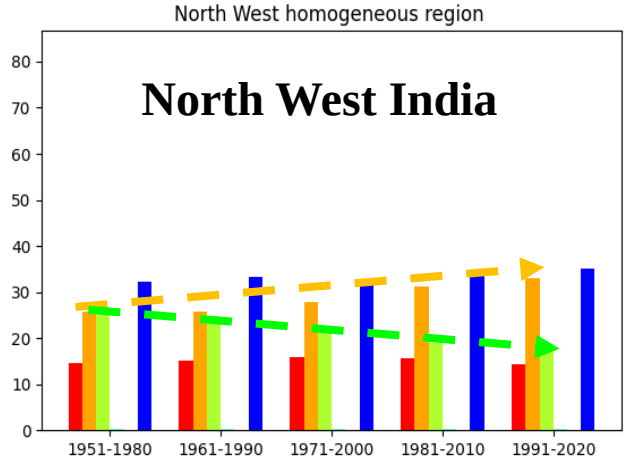


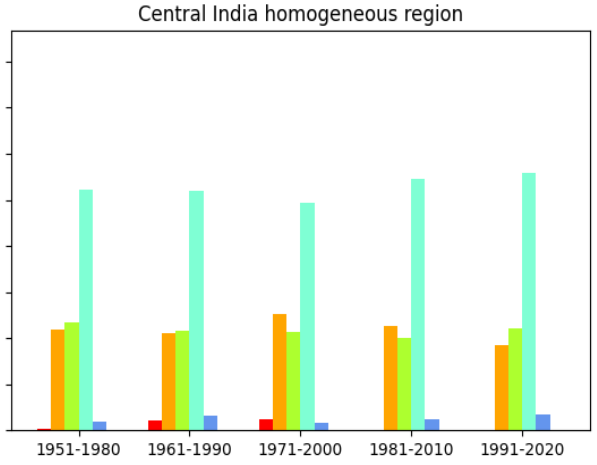
- **India spans six major climate zones**
  1) **Arid Desert,**
  2) **Arid Steppe Hot,**
  3) **Tropical Monsoon,**
  4) **Tropical Savannah,**
  5) **Subtropical Temperate**
  6) **Cold Mountain.**
- **Five Climatological Epochs moving with per decades are**
  - **Epoch1 = 1951-1980,**
  - **Epoch2 = 1961-1990,**
  - **Epoch3 = 1971-2000,**
  - **Epoch4 = 1981-2010,**
  - **Epoch5 = 1991-2020**

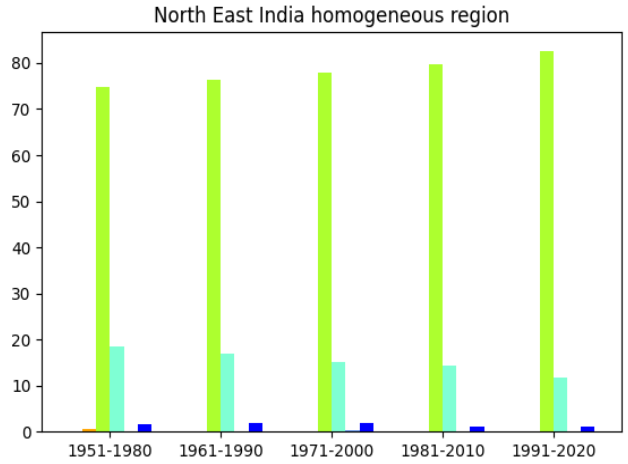
Bar diagram of six climate zones in percentage (%) area over India

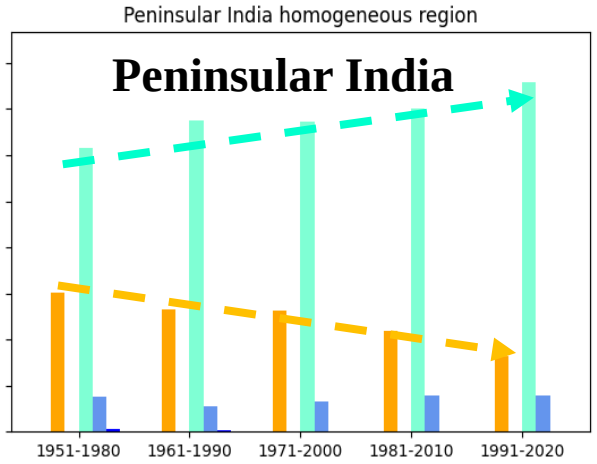












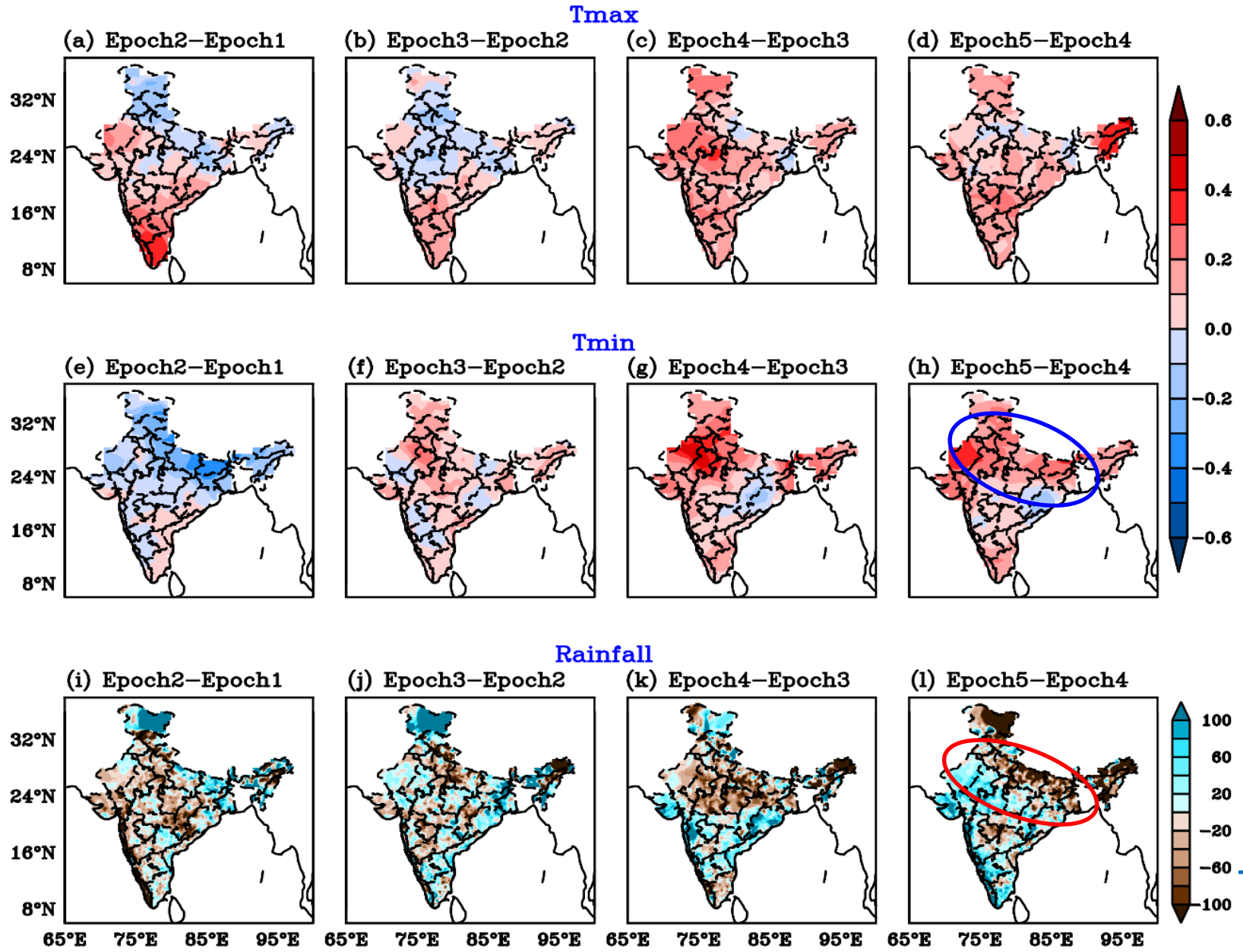
Climate zones in percentage (%) area over Northern India

	1951-1980	1961-1990	1971-2000	1981-2010	1991-2020
Arid Desert	13.8	14.4	15.19	14.75	13.77
Arid SteppeHot	24.2	25.6	27.6	31.2	33.1
Subtropical Temperate	25.8	24.8	21.8	19.0	18.7

Climate zones in percentage (%) area over Peninsular India

	1951-1980	1961-1990	1971-2000	1981-2010	1991-2020
Arid SteppeHot	30.3	26.6	26.2	21.9	16.4
Monsoon	4.4	4.4	3.7	5.0	5.6
Savannah	61.6	67.6	67.3	70.1	75.7

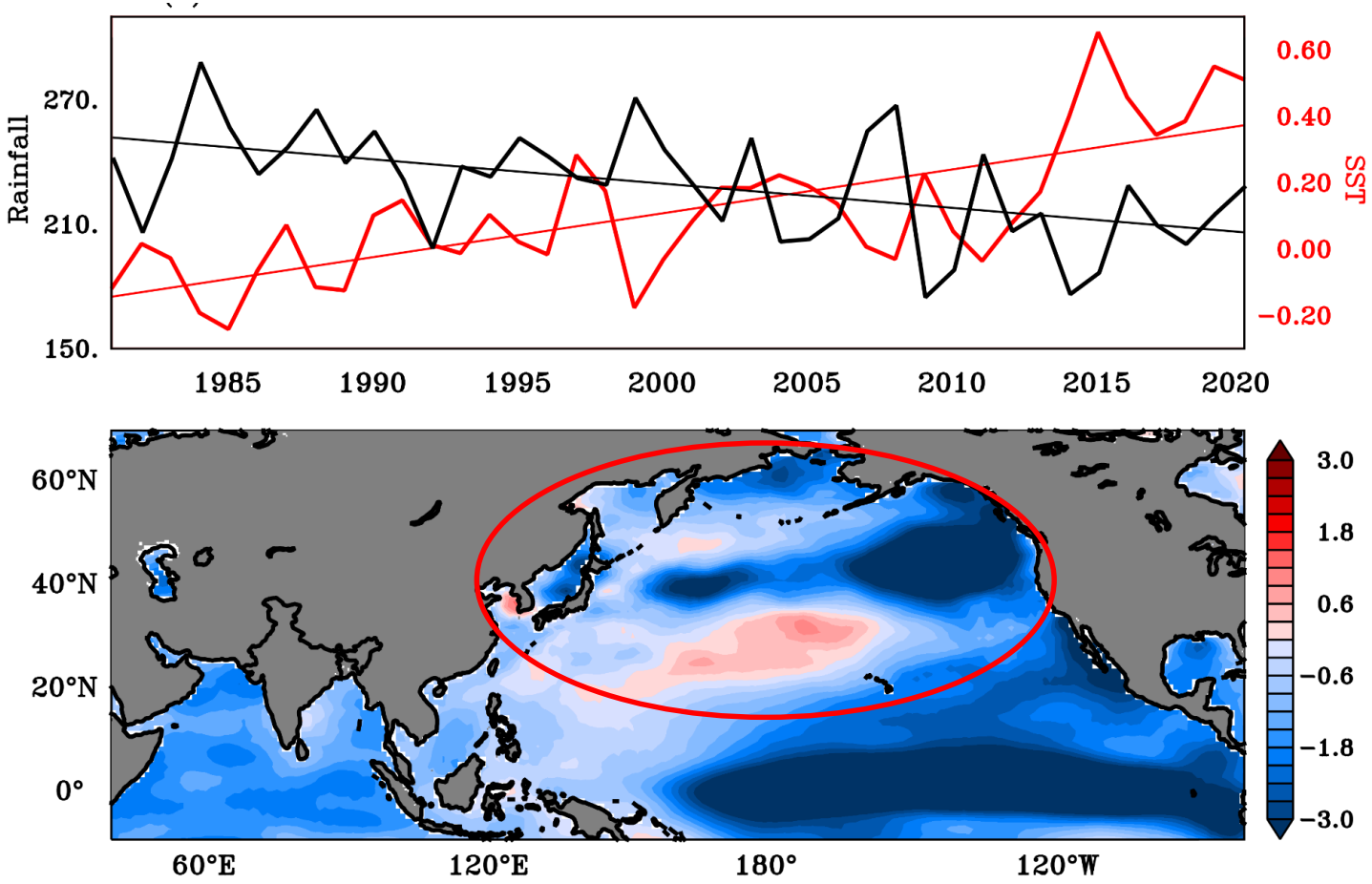
Maximum and Minimum Temperature and Rainfall difference for each climatological epoch from its previous epoch

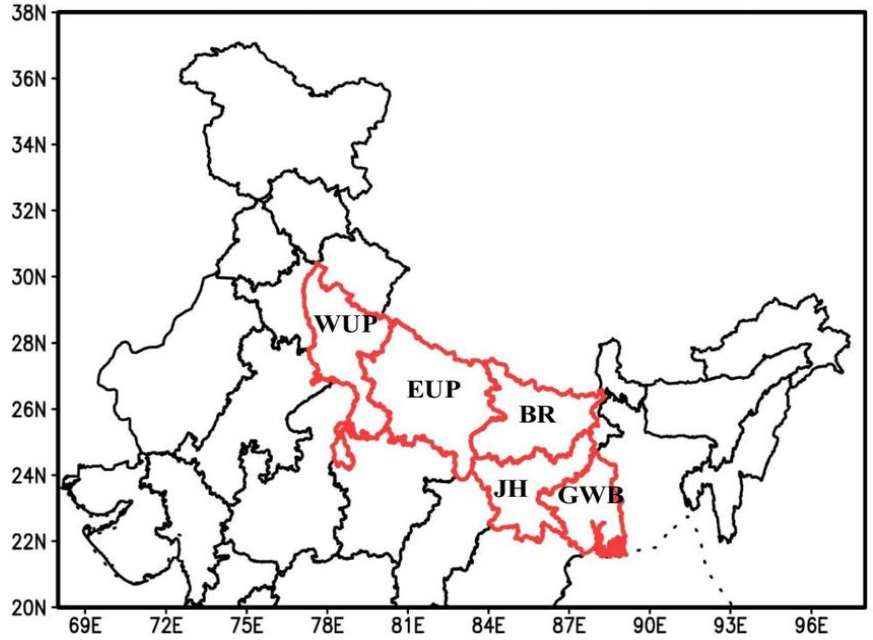


- To understand the epochal modulation of temperature and rainfall than its previous one climatological difference for each epoch from its previous epoch calculated.
- The gradual increase in maximum and minimum temperature from epoch1 to epoch5 in contrast the rainfall shows the reduction in northern India but intensified for the southern India.

Years of Service to the Nation

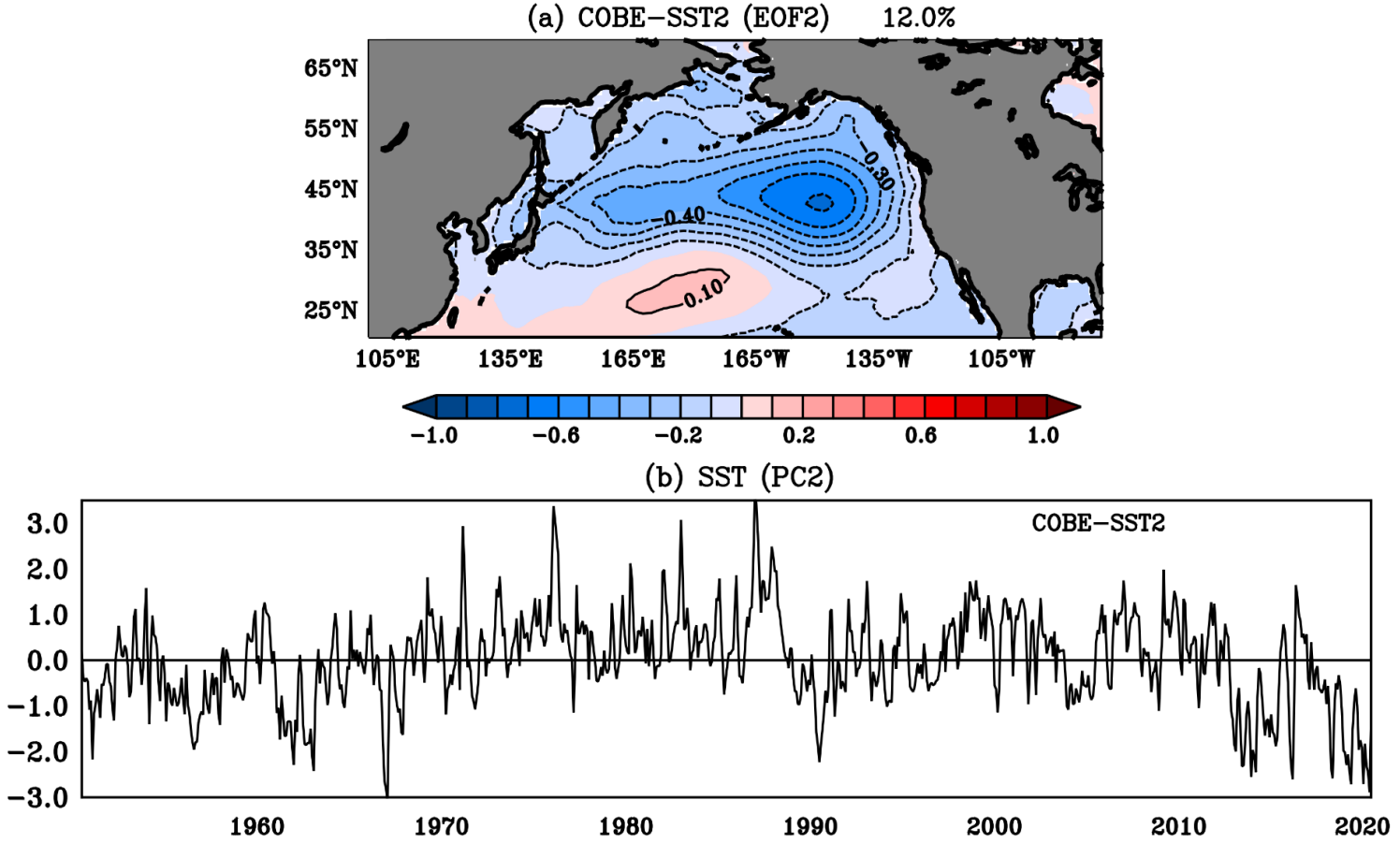
Teleconnection with the Indo-Pacific Ocean





The yearly rainfall time series (in black) for Northern India Agro-Climatic Zone (West Utter Pradesh, East Utter Pradesh, Bihar, Jharkhand and Gangetic West Bengal subdivisions) and The yearly SST anomaly time series (in red) for North Pacific for recent two climate epochs 1981-2020.

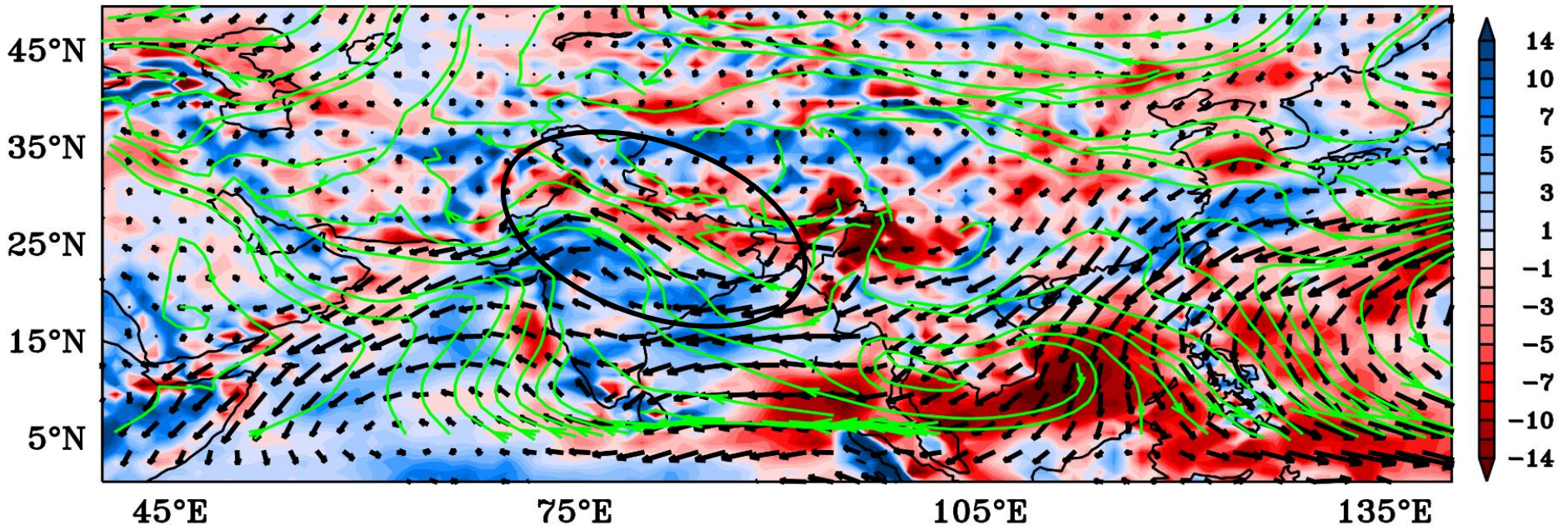
Teleconnection with the North Pacific Ocean



Previous study suggests that knowing the phase of different oceanic variability of Indo-Pacific Ocean may lead to better long-term prediction of the seasonal monsoon rainfall (Krishnamurthy et al 2014, Chowdary et al 2023).

This indicated the SST anomaly pattern as negative phase of Victoria mode (VM) which is the second mode of north pacific EOF analysis (12%, PC2).

Regression of Moisture transport on Victoria Mode (PC2)



regressed vertically integrated (1000–300-hPa) moisture flux (shaded; mm/day) and vertically integrated moisture transport (vectors; kg/m/s) anomalies and the streamlines (in green contour) on second mode of North Pacific (PC2) SST anomaly.

It is important to note that weak dipole type convergence and divergence moisture transport pattern over India regressed on PC2.

In addition, the regressed streamline analysis on PC2 (green contour line) show an anomalous anti-cyclonic pattern over Gangetic West Bengal and neighbourhood.

Conclusion

- The area of the Indian homogeneous region depicts a shift to the drier climate zone in North West India and North East India from Temperate to Arid steppe hot and Tropical savannah to Temperate climate respectively.
- The change at North India (West Uttar Pradesh, East Uttar Pradesh, Bihar, Jharkhand and Gangetic West Bengal subdivisions) is nearly 7% of the total area of India due to an increasing trend in temperature and a decreasing trend in rainfall which controlled by the negative phase of Victoria Mode (VM) decrease in moisture transport and divergence over Northern India Indo-Gangetic Plane.
- This climate zone shift could adversely impact the agriculture in the Northern India Agro-Climatic Zone in the future. Overall, this study enhances the knowledge about climate zone change and therefore the IMD forecasting system

THANK YOU