

Observed Intensification of Moist Heat Stress over the Indian Region

Lekshmi S

MoES Research Fellow

Climate Applications and User Interface (CAUI) Group

India Meteorological Department, Pune

PhD Student

Savitribai Phule Pune University, Pune



Contents

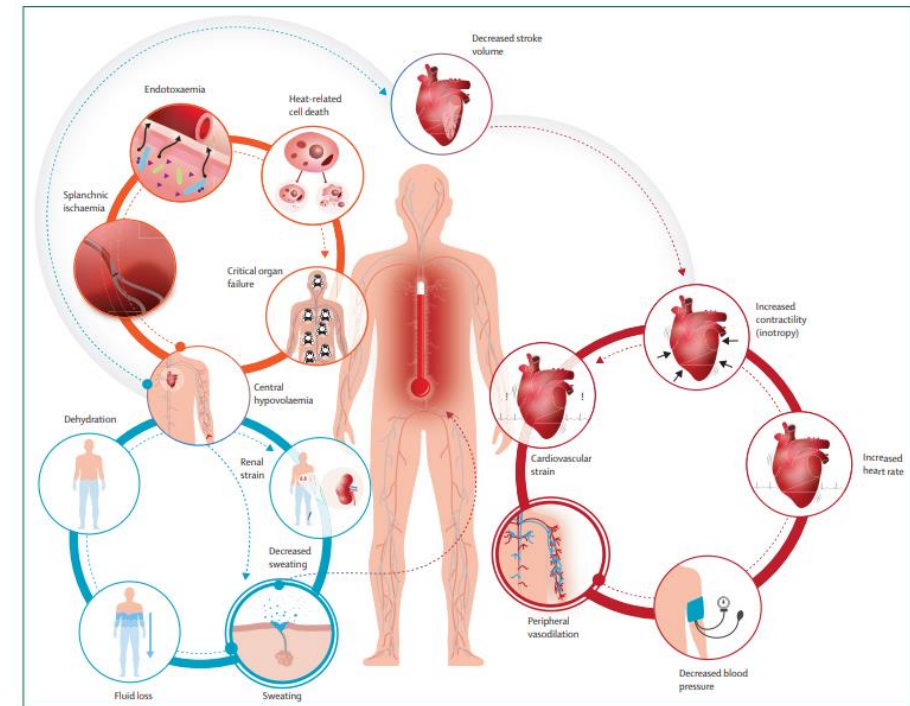
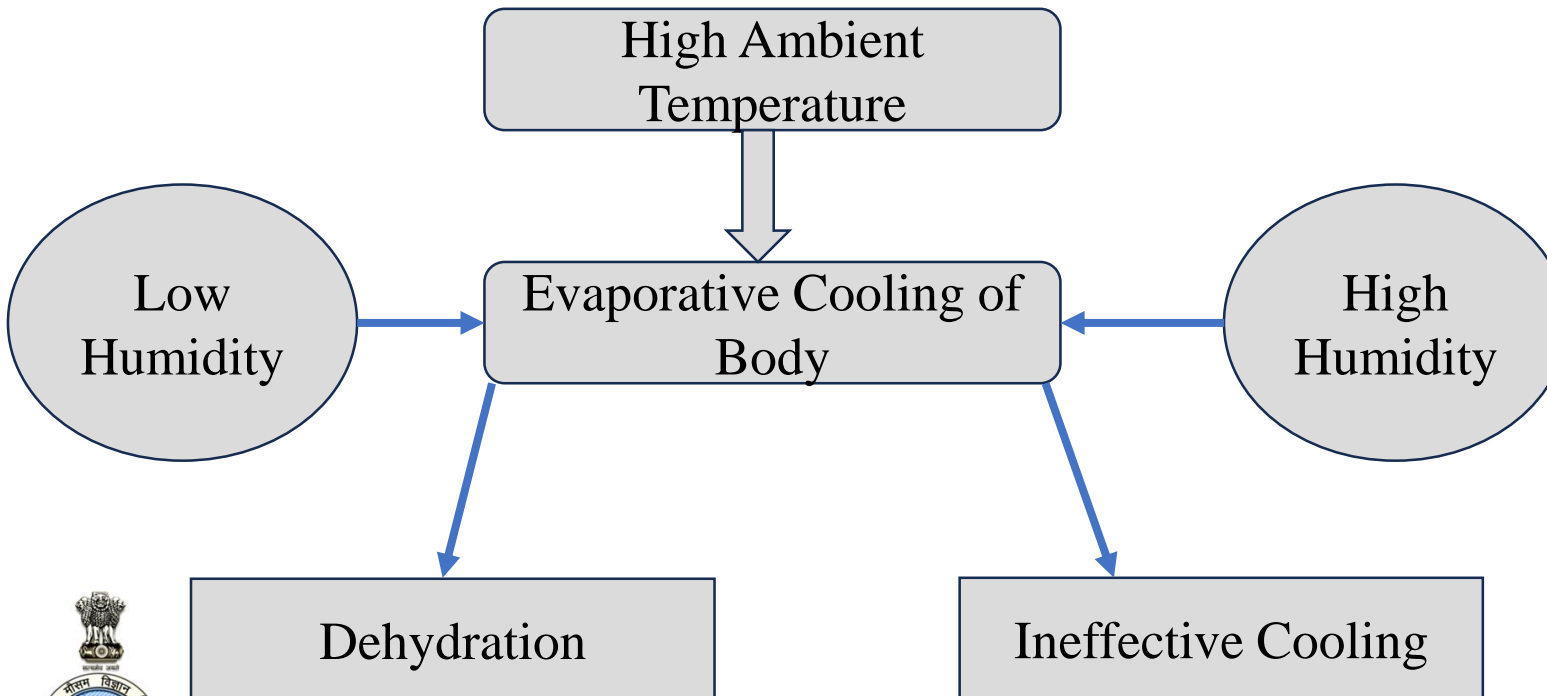
1. Dry and Moist Heat Stress
2. Role of Moisture in Driving Human Heat Stress
3. Summer Temperature ISO & Extremes over the Indian Region
4. Associating Temperature ISO Modes to Heat Stress
5. Mode 2 and Regional Moist Heat Stress
6. Mode 2 Intensification over Indian Region
7. Operational Application
8. Conclusion



Dry and Moist Heat Stress

- Heatwaves are the meteorological conditions of extreme temperature over any region which can cause severe impacts
- Heat Stress: Heat stress is the net heat load to which someone is exposed and heat strain is a body's response to heat stress.
- Heat stress can be categorized as two: Dry and Moist Heat stress

Figure: Physiological Pathway of Human Heat Strain



Role of Moisture in Driving Human Heat Stress

- Moisture has been understood as a major element of heat stress ([Haldane 1905](#), [Brunt 1943](#)).
- Heat stress is maximized during simultaneous high extremes of both temperature and humidity.
- The primary method of removing excess heat is through evaporation, which controls ~75% of heat loss ([Koppe et al. 2004](#)).
- However, if the local moisture conditions in the environment reduce the effectiveness of evaporation.

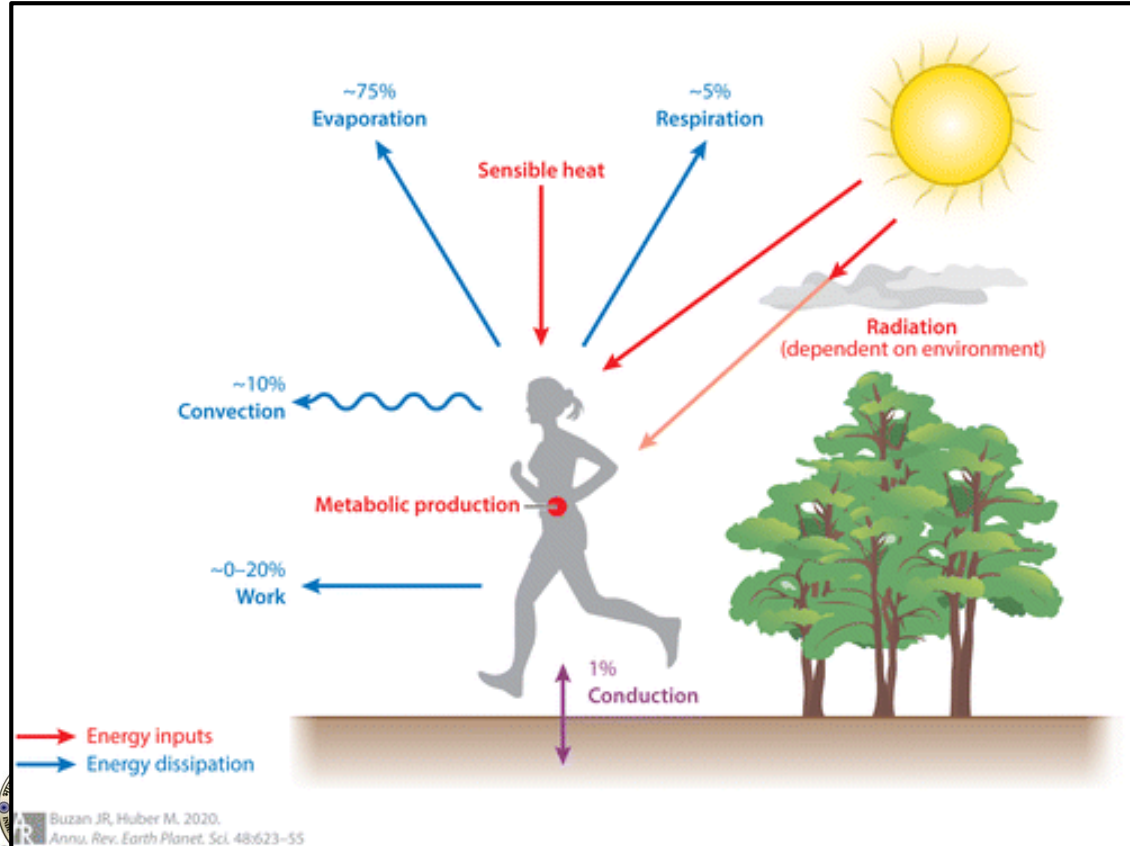


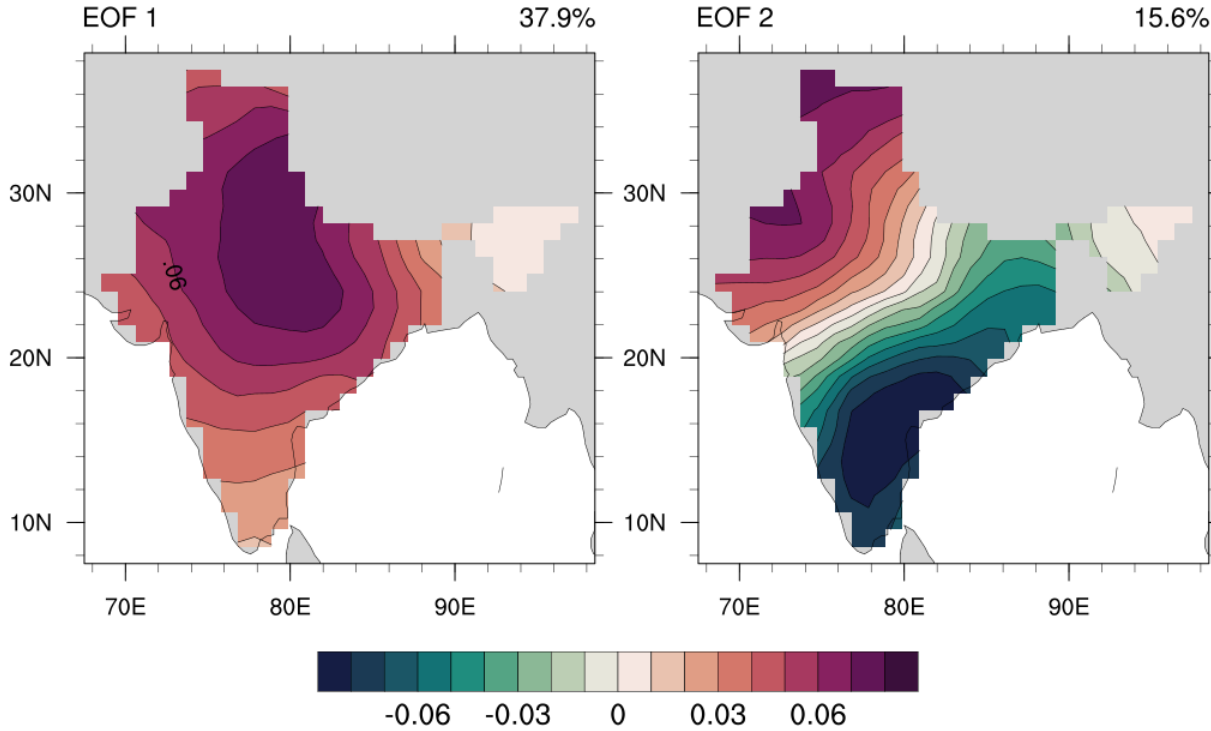
Figure: Energy balance in the human body. The red arrows represent the flux of energy into humans. The blue arrows are energy dissipation mechanisms.

Recent years have witnessed heat-related deaths even in conditions with ambient temperatures less than the threshold criteria of the operationally monitored heatwaves over the Indian region as well.

[\(https://indianexpress.com/article/explained/explained-climate/heatstroke-deaths-kharghar-mumbai-why-humidity-explained-8560541/\)](https://indianexpress.com/article/explained/explained-climate/heatstroke-deaths-kharghar-mumbai-why-humidity-explained-8560541/).

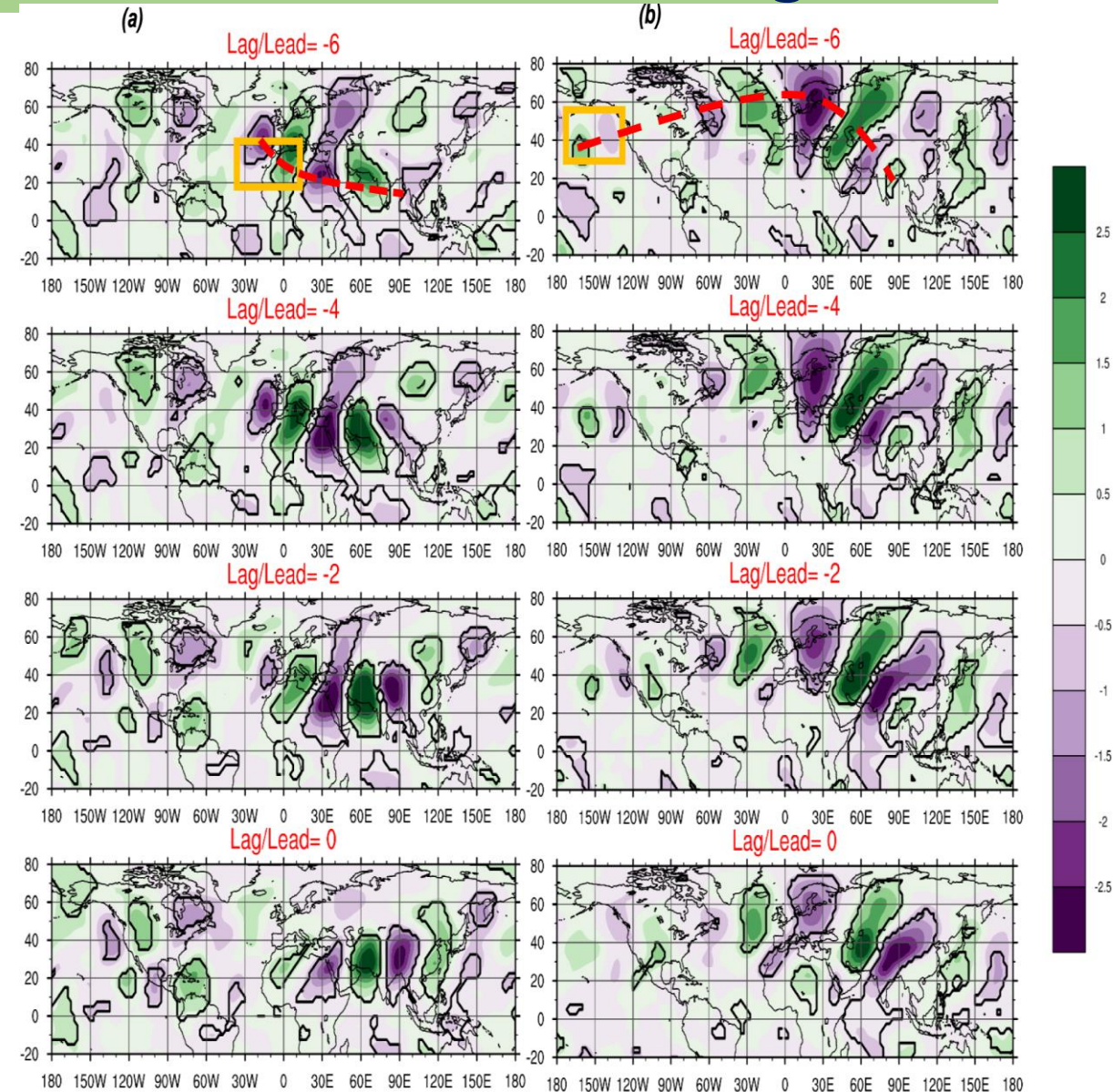


Summer Temperature ISO & Extremes over the Indian Region

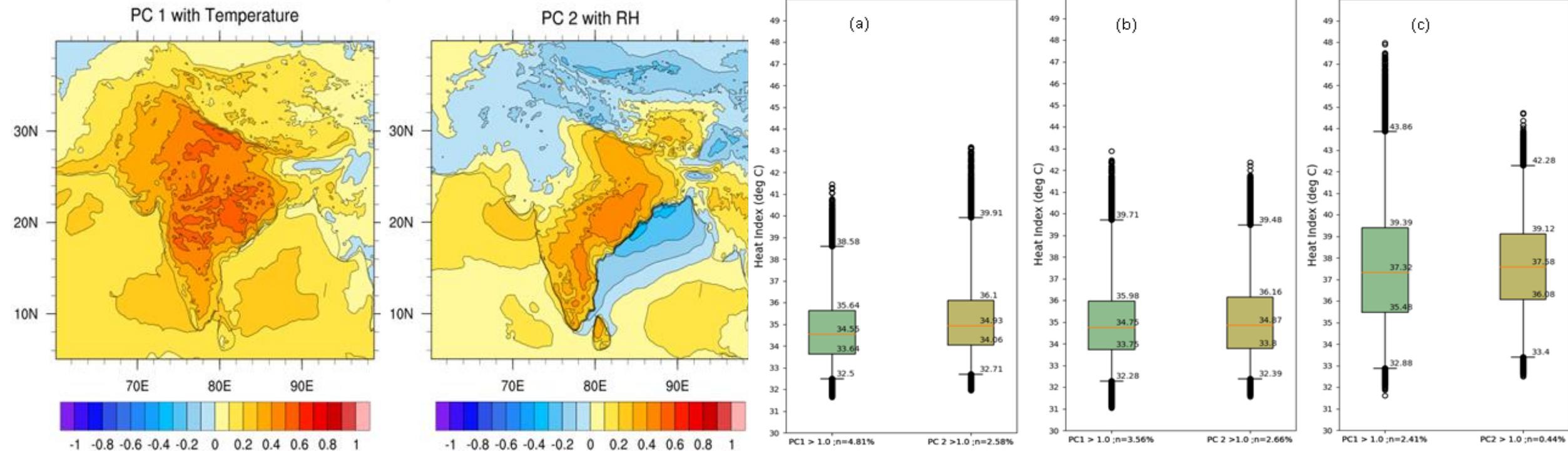


Spatial pattern of the **two dominant modes of summer temperature variability** based on EOF analysis.

Mid-latitudinal Rossby waves drive the temperature oscillations over the Indian region
Intensification of circulation patterns during extreme events was found



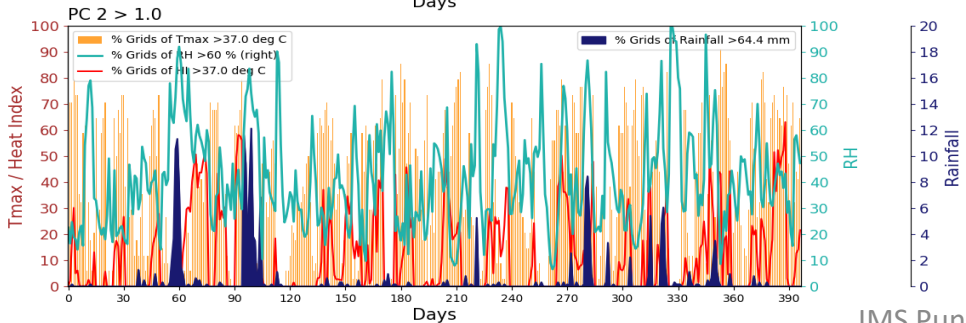
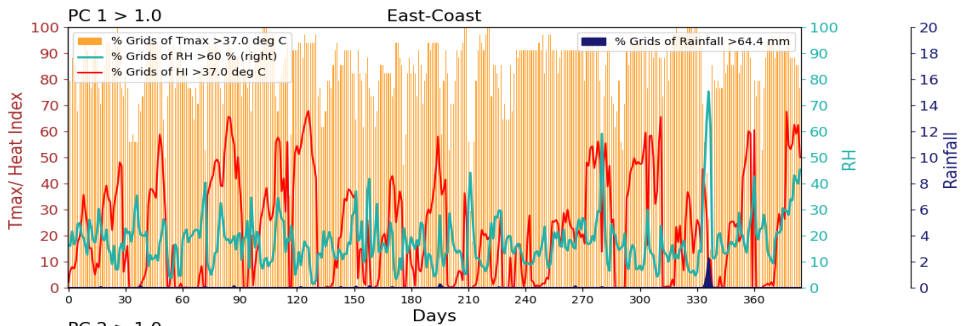
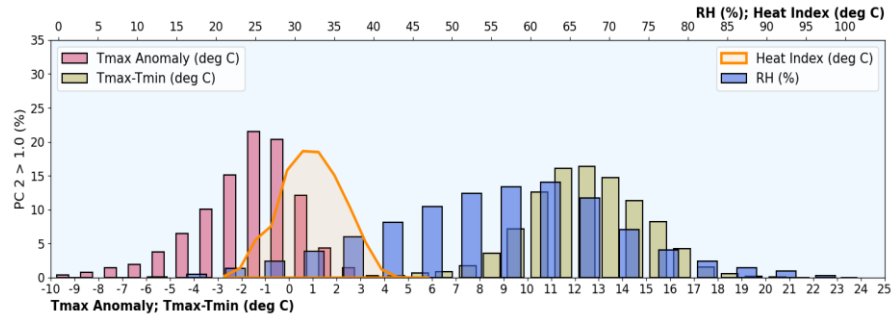
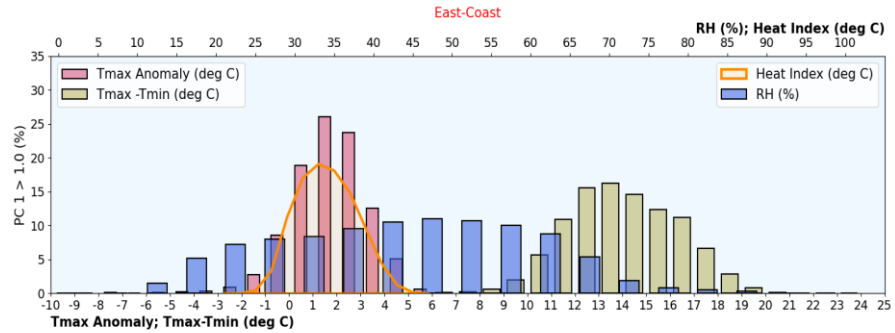
Associating Temperature ISO Modes to Heat Stress



- The correlation of PC 1 and PC 2 with temperature and RH shows that,
 - PC 1 points towards the formation of dry heat stress conditions
 - PC 2 points towards occurrence of moist heat stress conditions.
- Rise in Heat Index indicates increased heat stress conditions when PC 1 > 1.0 and PC 2 > 1.0.

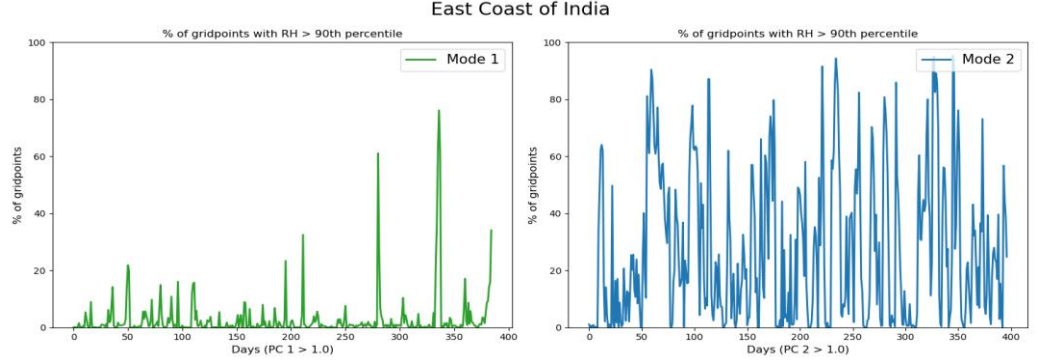
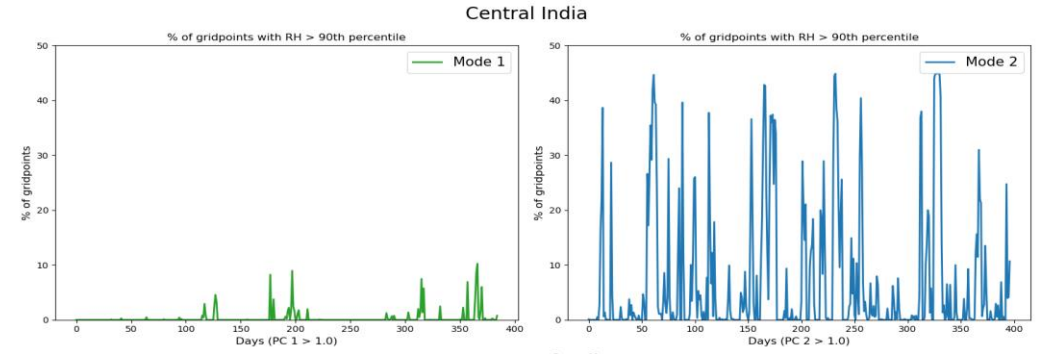
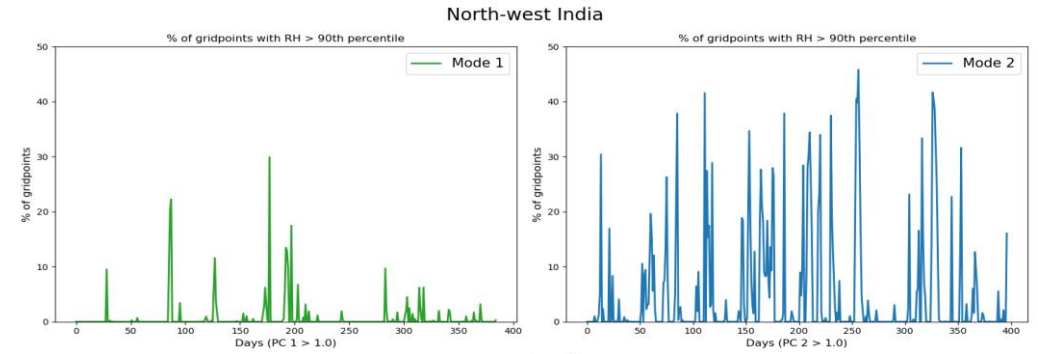


Mode 2 and Regional Moist Heat Stress



Both the modes are showing similar discomfort conditions (based on Heat Index). But in Mode 1, temperature is the dominating factor and in Mode 2 it is RH.

Percentage Distribution of Heat Index, RH, T_{max} Anomaly, T_{max}-T_{min}

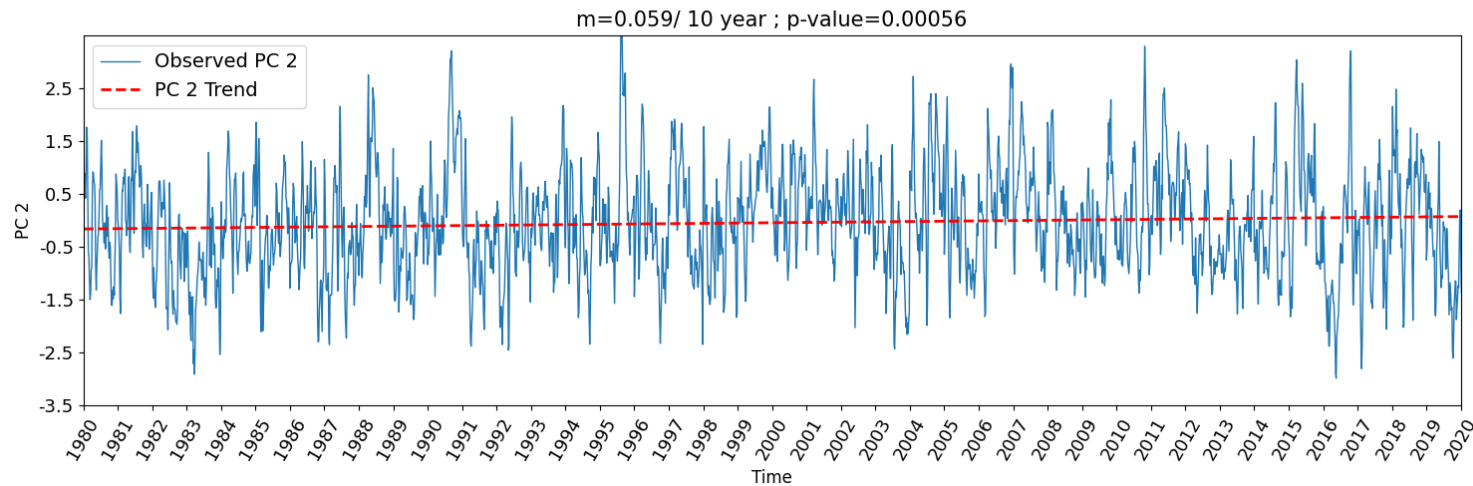
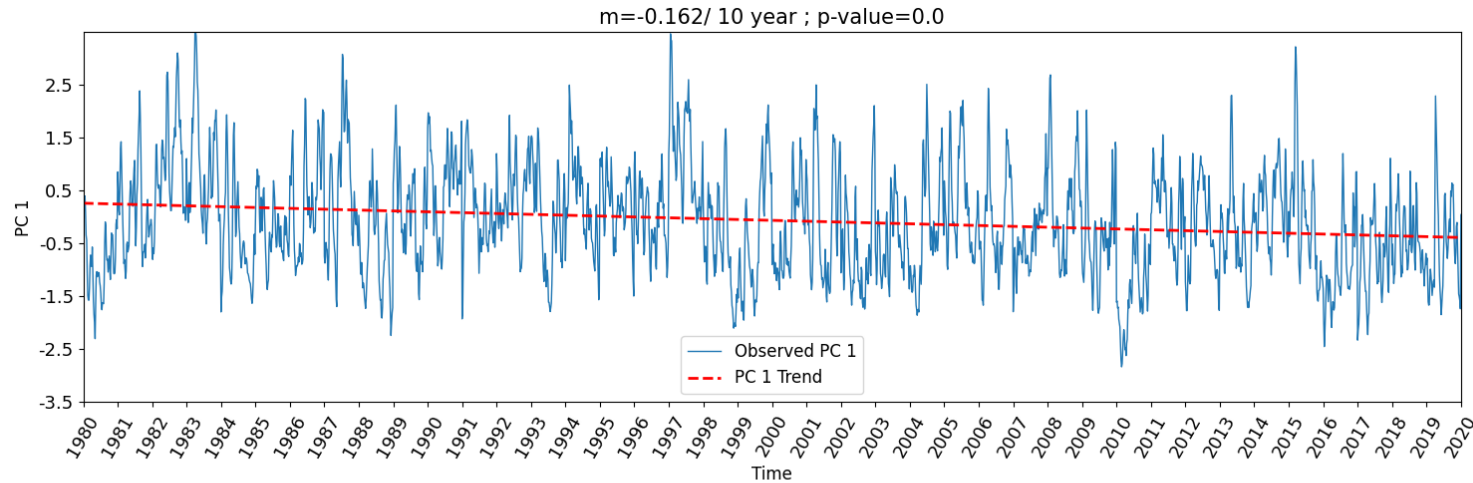


Percentage of grid points with RH > 90th percentile value



Mode 2 Intensification over the Indian Region

Why Understanding Mode 2 is important?



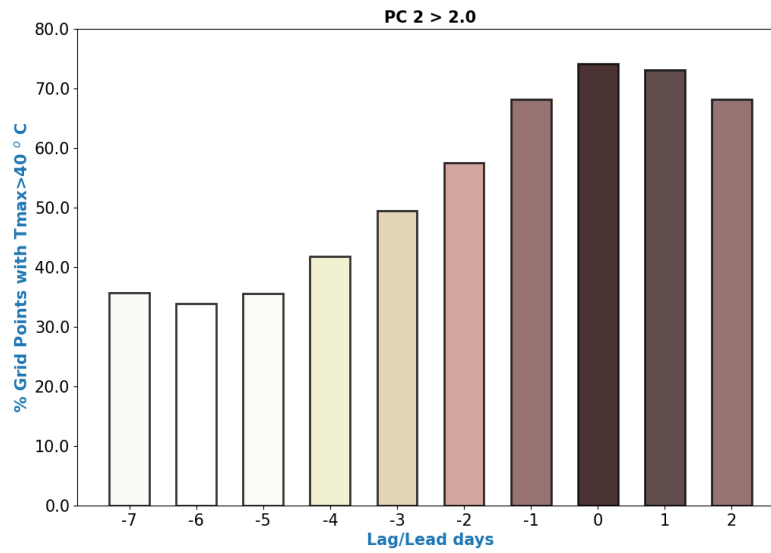
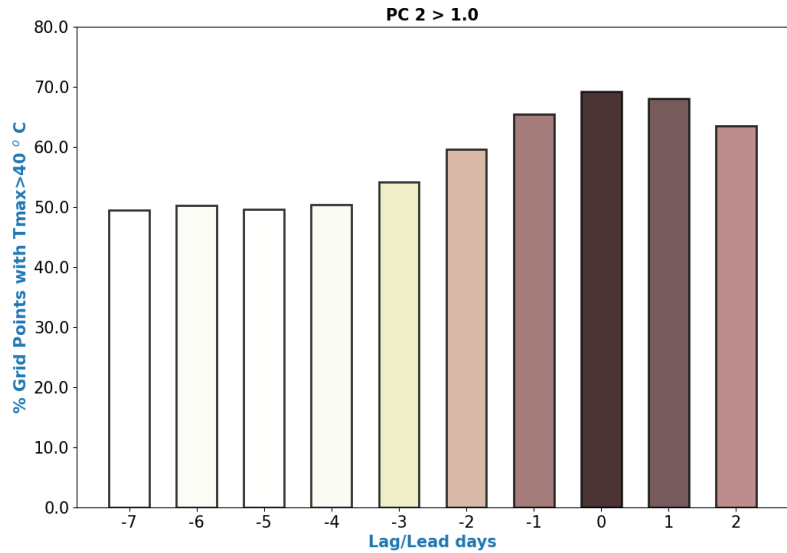
Long-term significant increasing trend in PC 2



Rise in Moist Heat Stress over Indian region

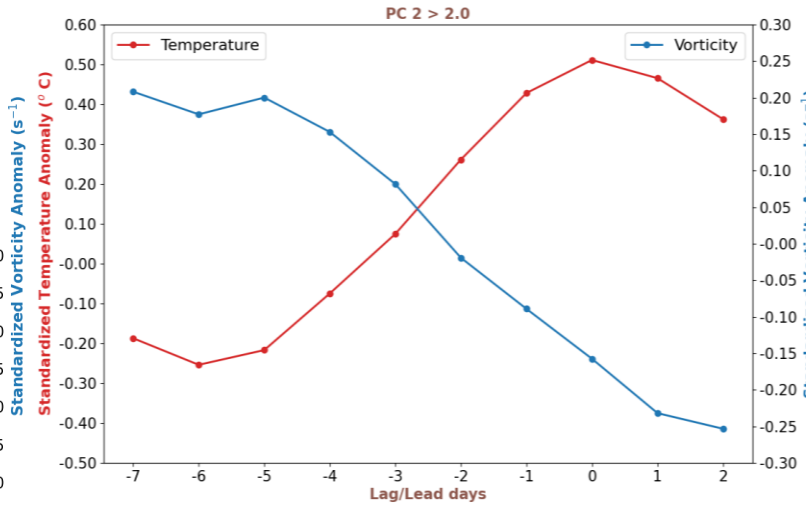
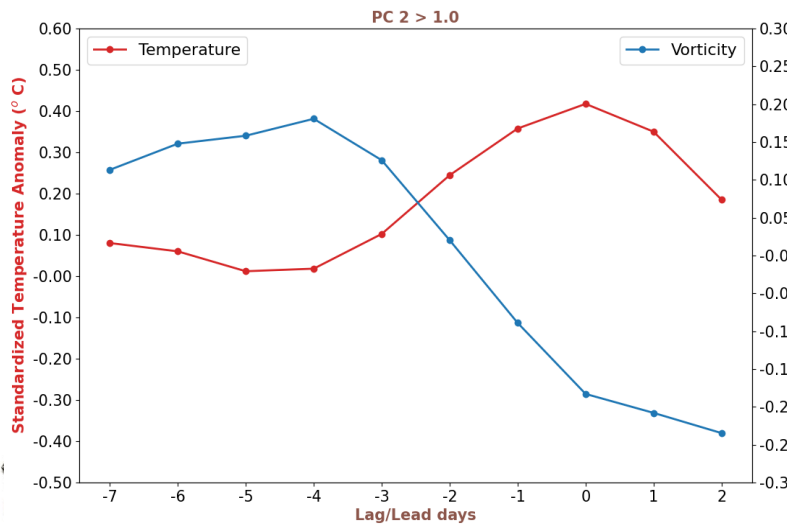


Mode 2 Intensification over the Indian Region



Percentage of grid point with $T_{max} > 40$ deg C for those days when $PC\ 2 > 1.0$ and $PC\ 2 > 2.0$

Intensification can be considered as a function of **amplitude** and **persistence**.

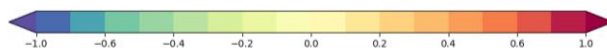
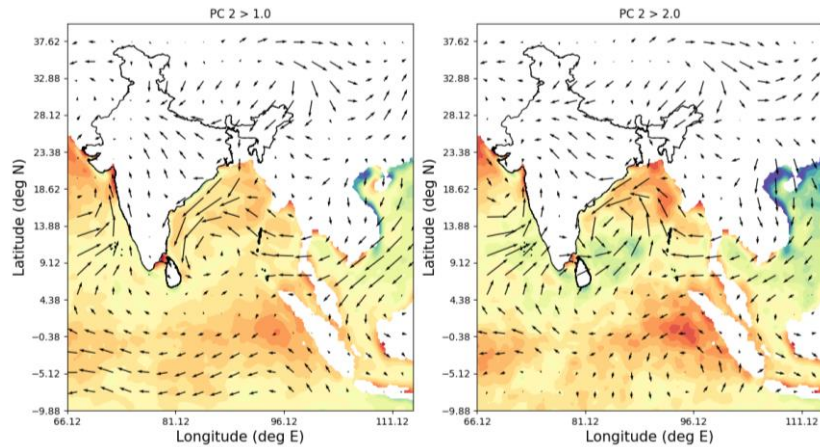
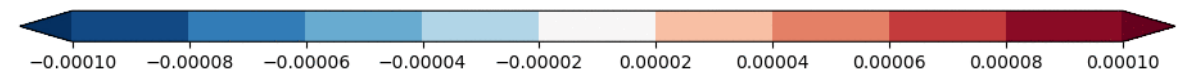
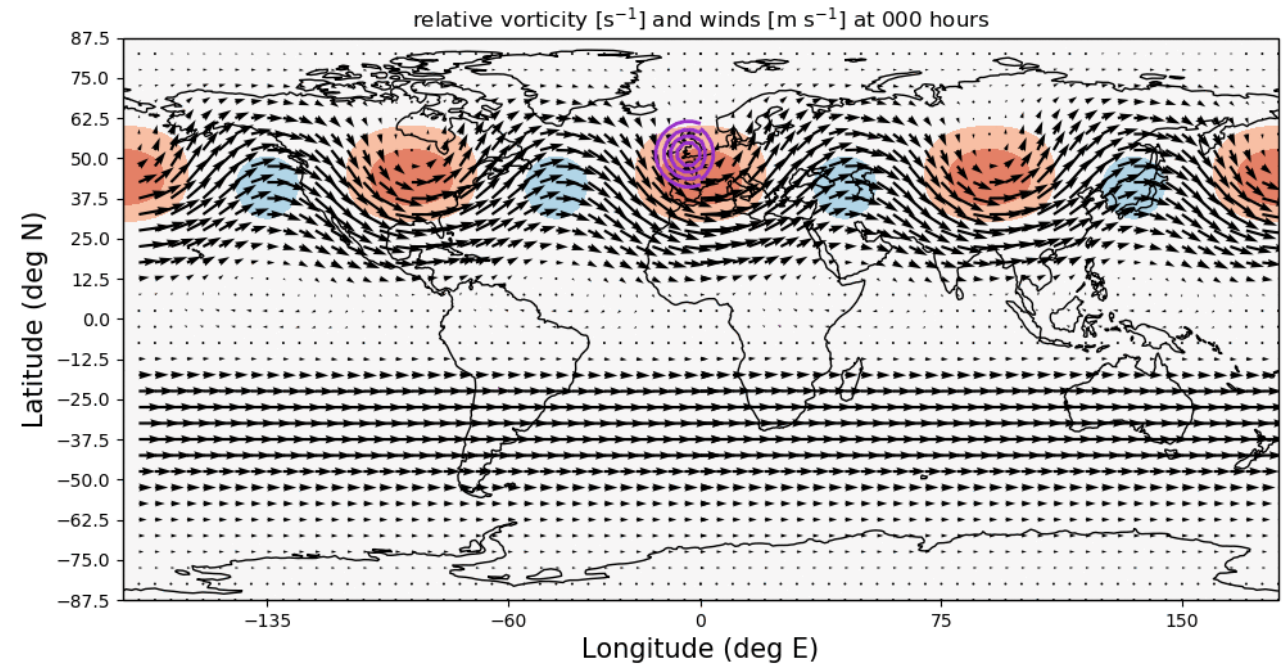
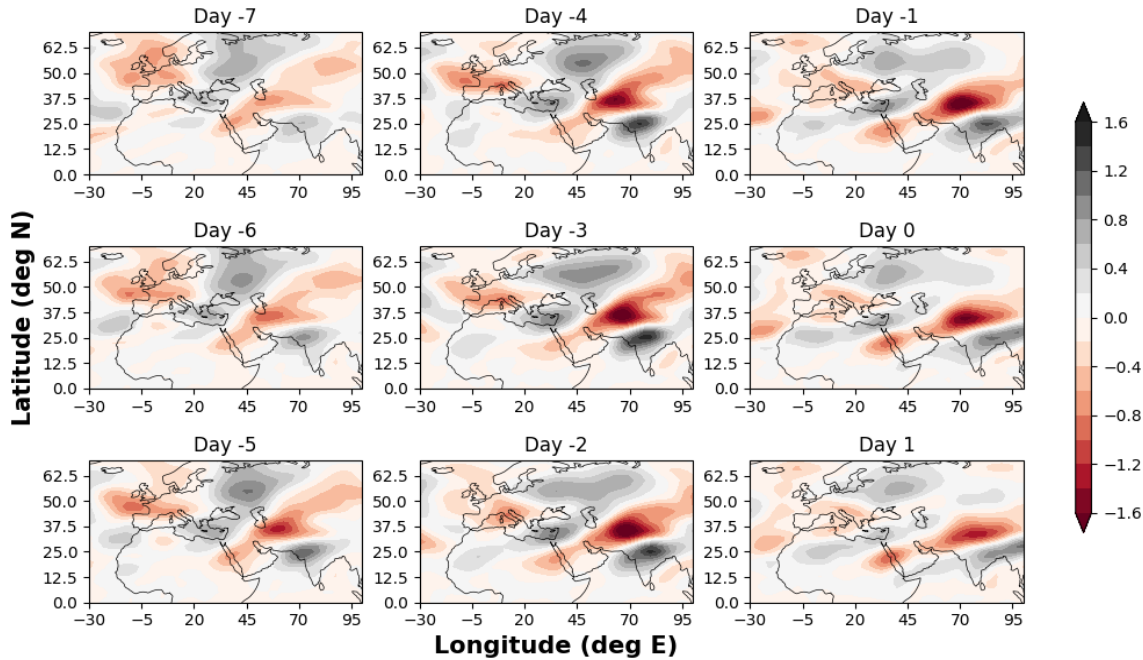


Gradual rise in the amplitude of vorticity and temperature and persistence of temperature is noted.

Composite of standardized temperature and vorticity anomaly for those days when $PC\ 2 > 1.0$ and $PC\ 2 > 2.0$



Mode 2 Intensification over the Indian Region

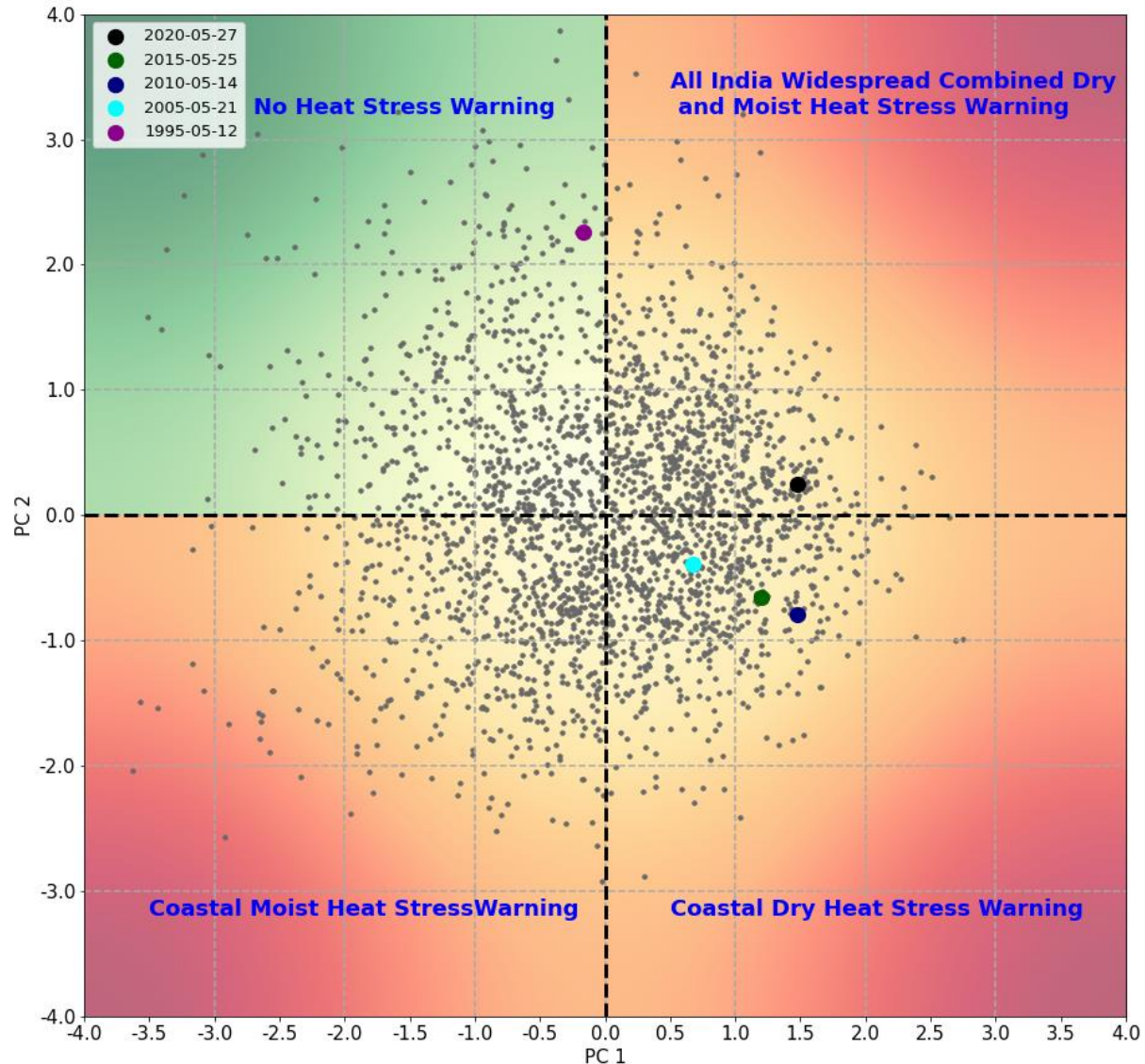


Intensification of the anticyclonic vorticity over the Indian region is possible due to many factors, such as, sea surface temperature, soil moisture conditions etc.

This has to be looked into based on modelling experiments.



Operational Application



A (PC 1, PC 2) phase space diagram which can give information about any event such as its:

- 1. Spatial extent** (Coastal or All India),
- 2. Amplitude** (Strength of an event with respect to others)
- 3. Impact** (whether it is dry or moist event)



Conclusions

- Dry and Moist Heat Stress have **different physiological impacts** in a human body.
- Over **75% of the heat loss** from a body takes place through evaporation.
- **Summer Temperature ISO** modes provides insight to the dynamical mechanism of dry and moist heat stress occurring over the Indian region.
- **Mode 2**, which drives regional moist heat stress shows a **long-term increasing trend** over the Indian region.
- **Intensification** of the circulation, as a combined effect of amplitude and persistence, is leading to intensification in temperature conditions, with the mode 2 supplying additional moisture.
- Many **local factors** can drive the intensification, which requires further modelling studies.
- Phase plot of PC 1 v/s PC 2 can **distinguish the dry and moist heat discomfort conditions** and monitor their strength and possible spatial extent.



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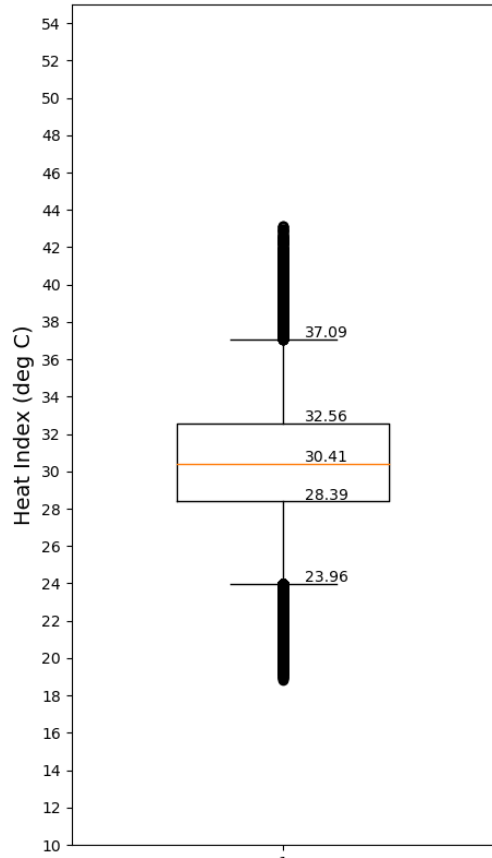
Acknowledgements

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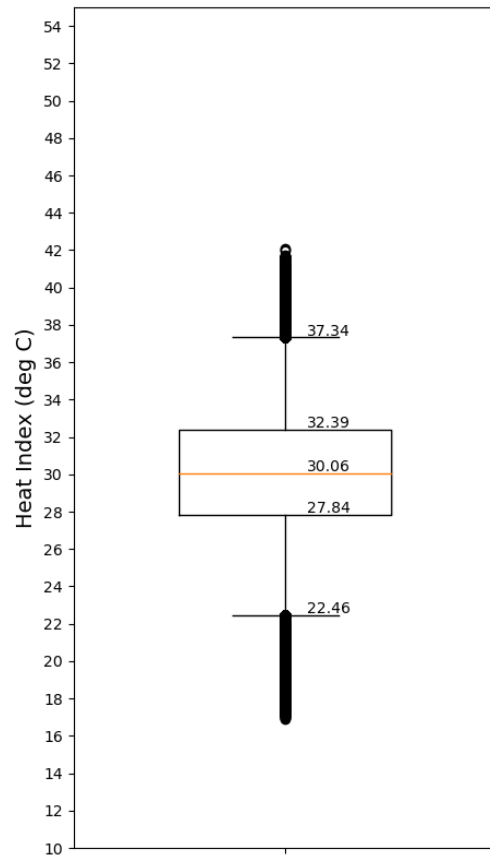
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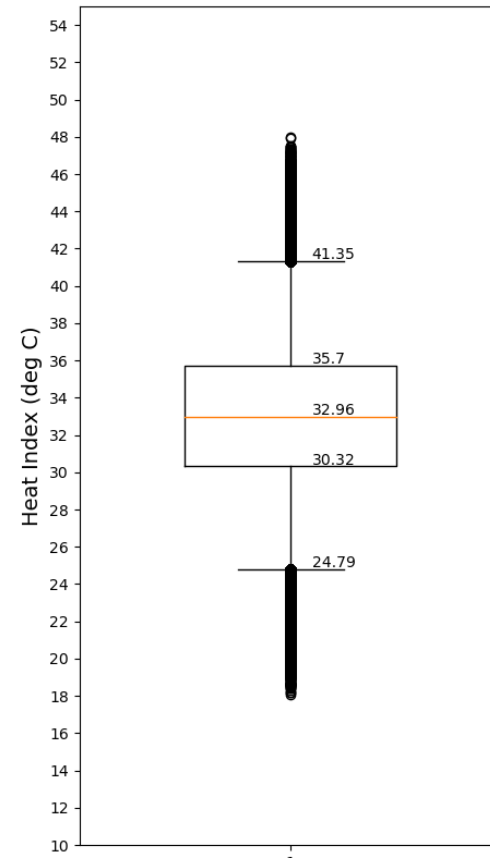
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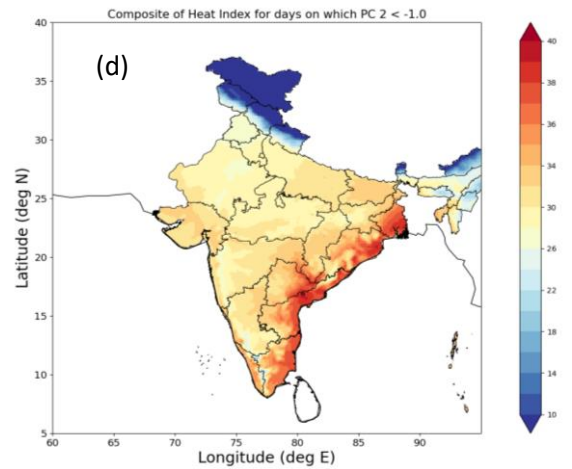
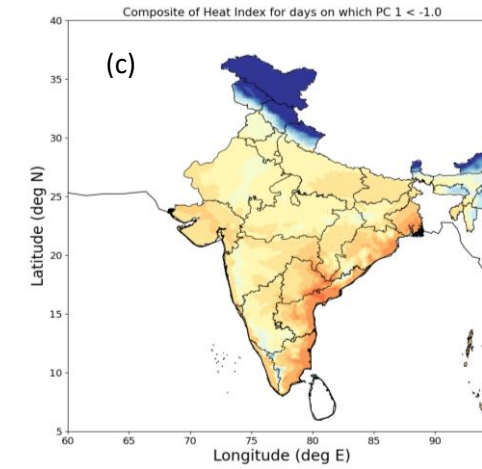
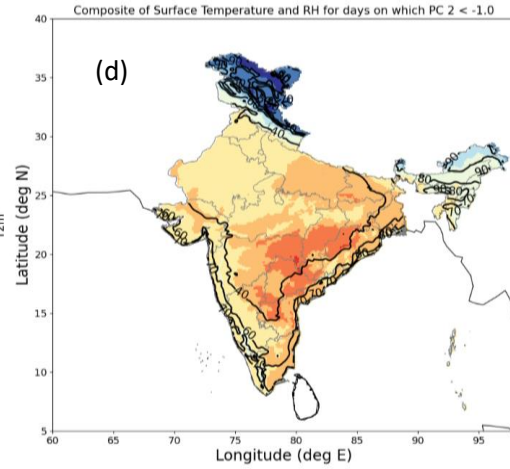
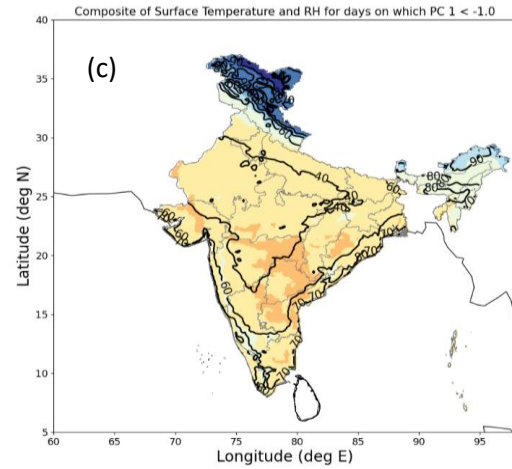
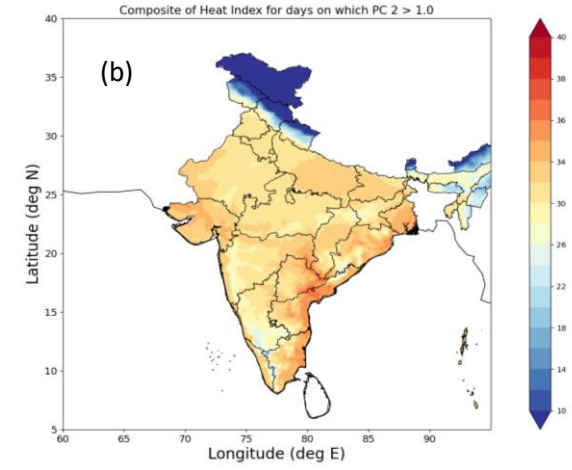
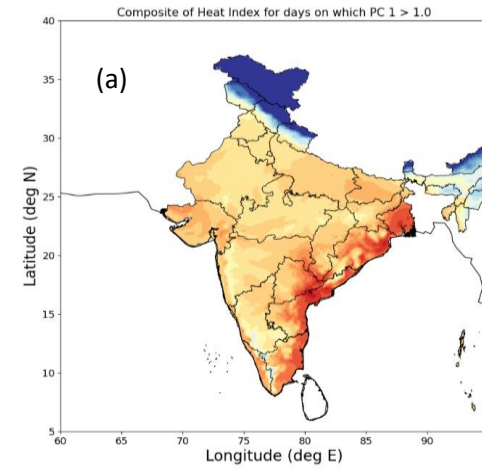
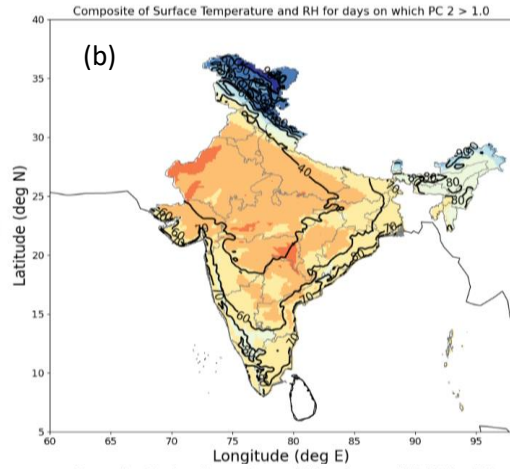
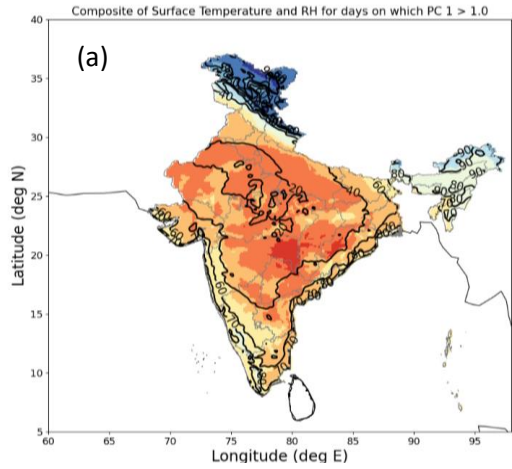
(b) Northwest India

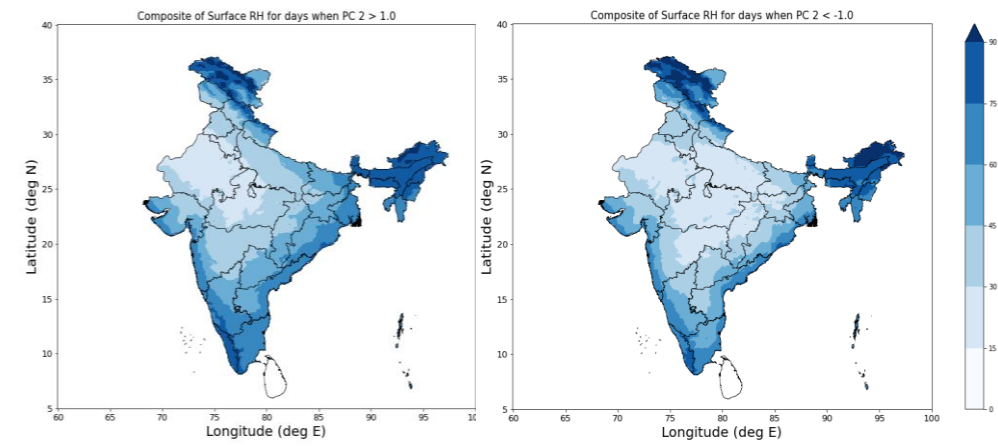
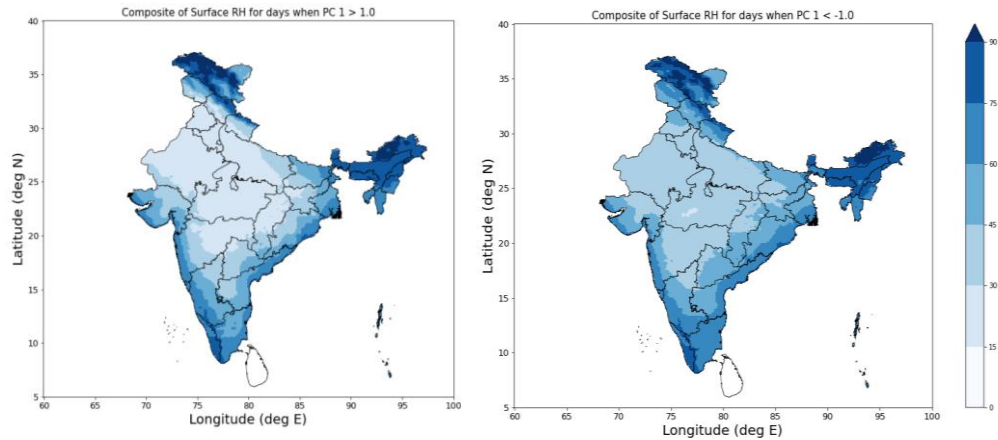


(c) East Coast



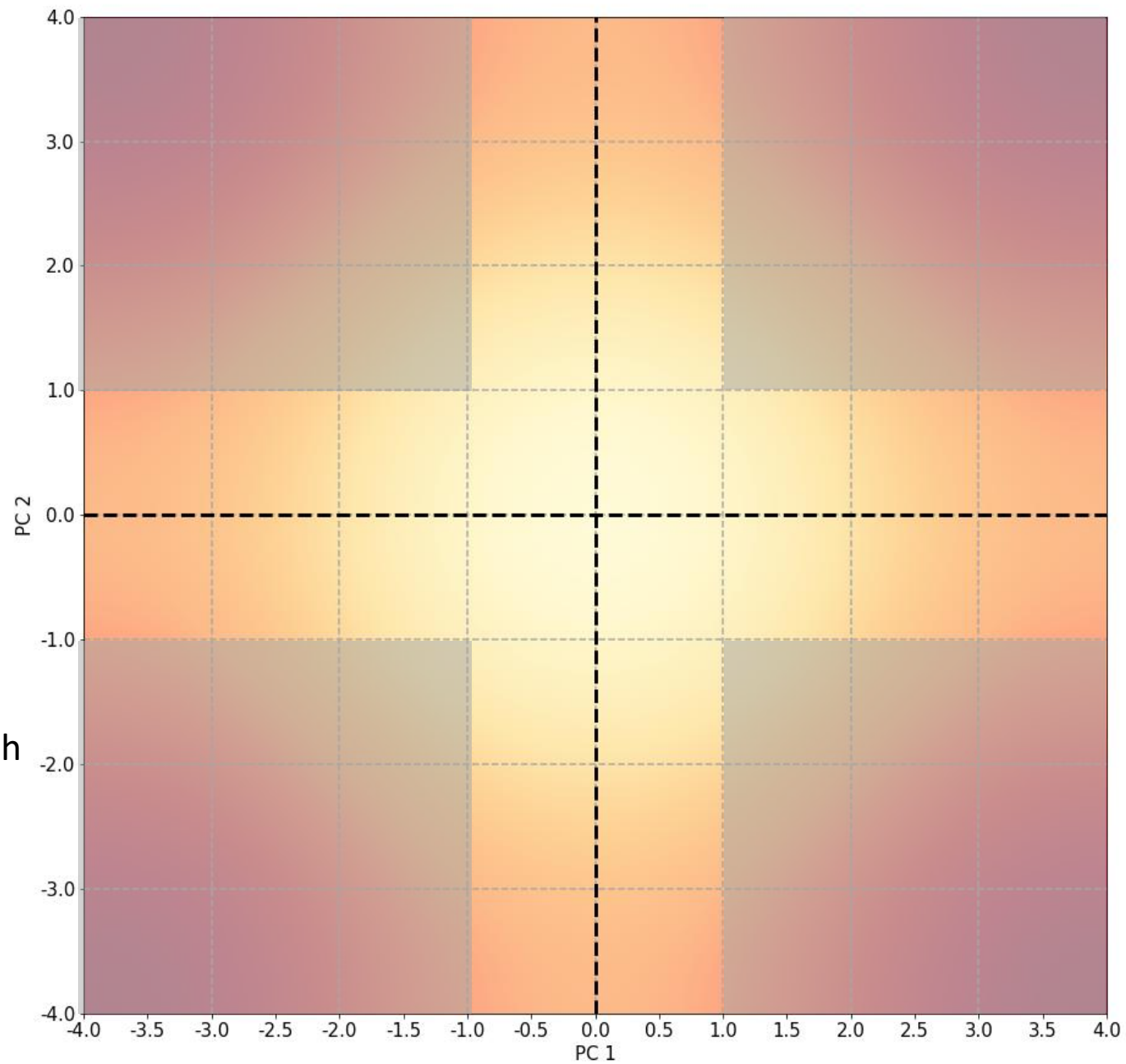
Regional Impacts: Dry and Moist Heat Stress





Low Temperature
High Humidity

High Temperature
High Humidity



Low Temperature (High
in Coast)
Low Humidity

High Temperature
Low Humidity