Compound Hot-Dry Events in Urban India:

Variability & Drivers

Picture Credit: Matei, K.B (June, 2021)

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Climate Risks

Interconnected Natural-&-Built Environment System would Trigger Cascade Hazard

Heat waves

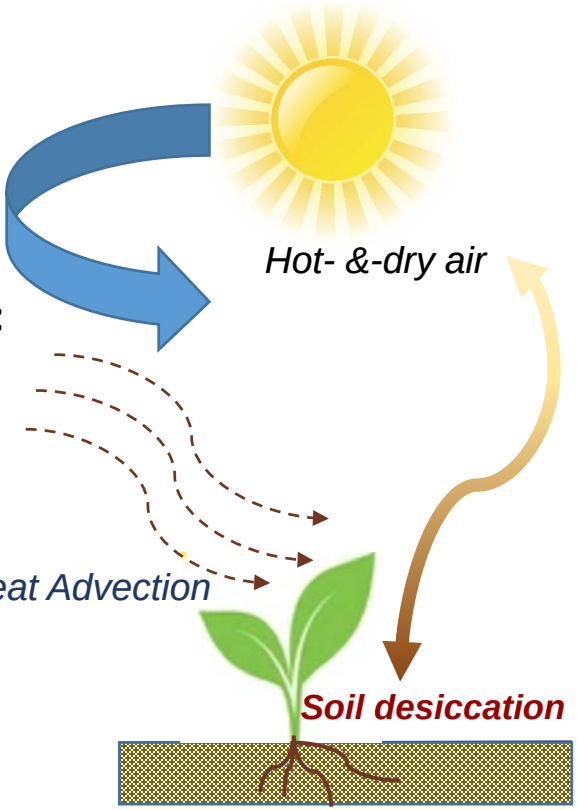
Drying Water bodies

Increased Agricultural Water Demand

Severe Heat, water stress: Threat to Power sector

Compound heat-moisture (limited water availability) couplings stresses crops

Lesk et al. (2021)



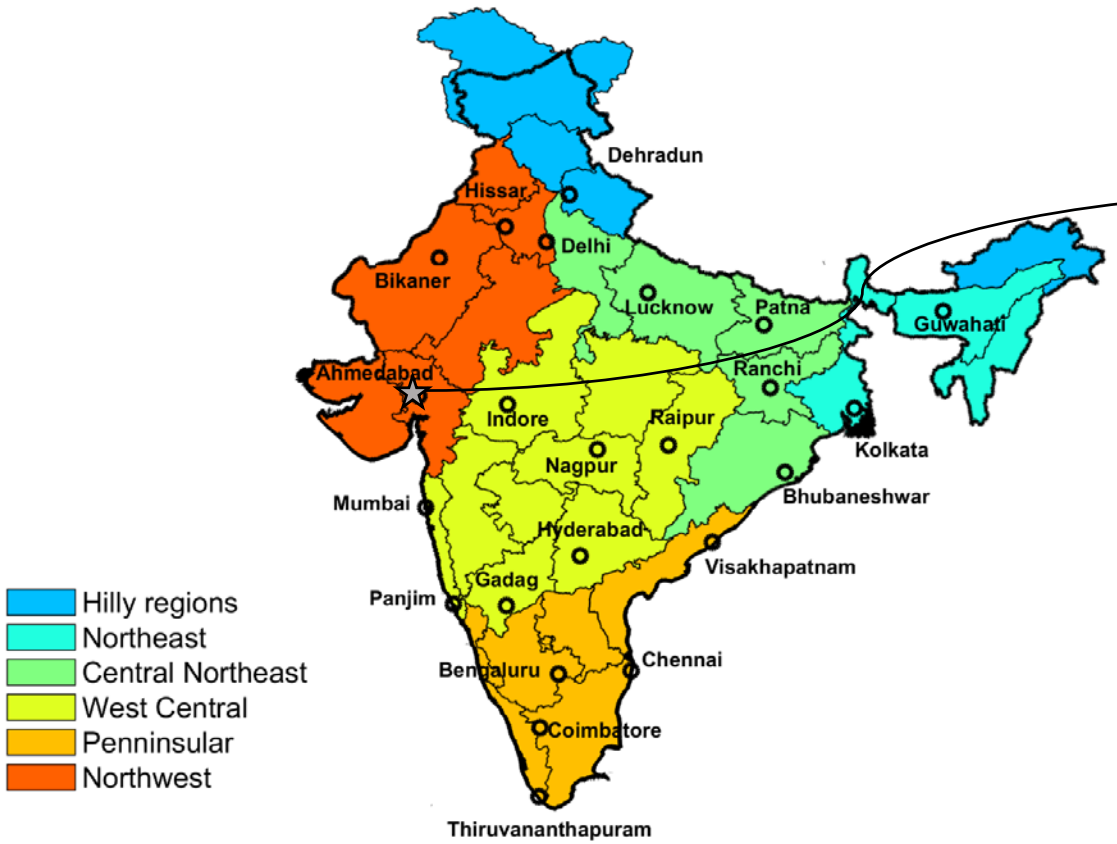
after Schumacher et al. (2019)

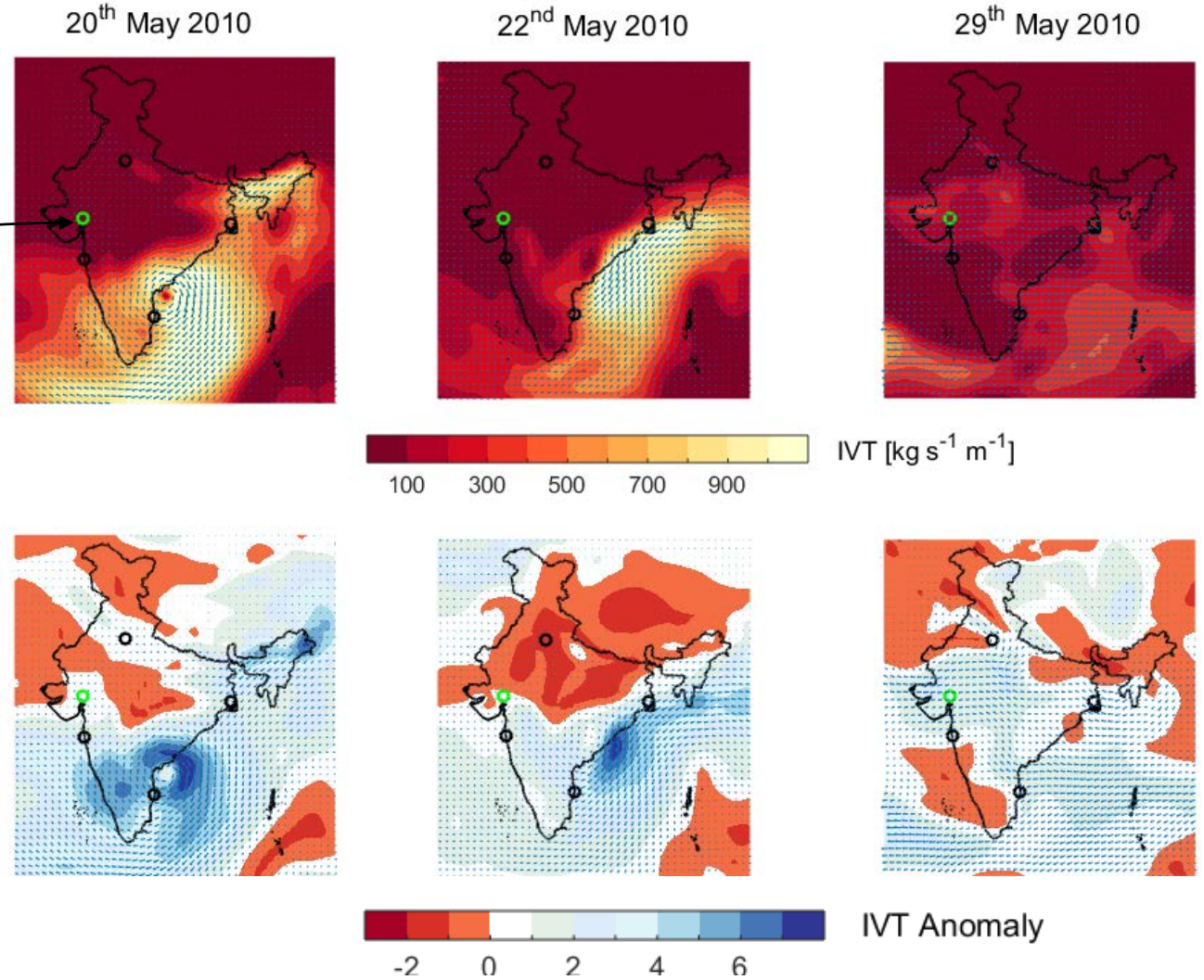
Rationale & Research Gaps

- Very few studies have identified climate 'hotspots' areas of India considering hot-dry states.
  - In tropics, during warm season, often precipitation show negative relation with surface temperature.
    - Decrease in moisture availability at higher temperature & soil-atmospheric feedback (Schumacher et al. 2019; Miralles et al. 2019).
- Besides temperature, surface wind speeds control the evaporative demand → *Drought mechanism*
  - In South Asia, atmospheric pattern during heatwaves linked to large-scale blocking in mid-latitudes that persist several consecutive days to weeks (Dubey et al 2021).

Concurrence of heat stress, below average rainfall (i.e., dry-spell), low-wind speed in same geographical area within limited time window can have significant impact.

Heatwave Vulnerability in Indian Urban Corridor

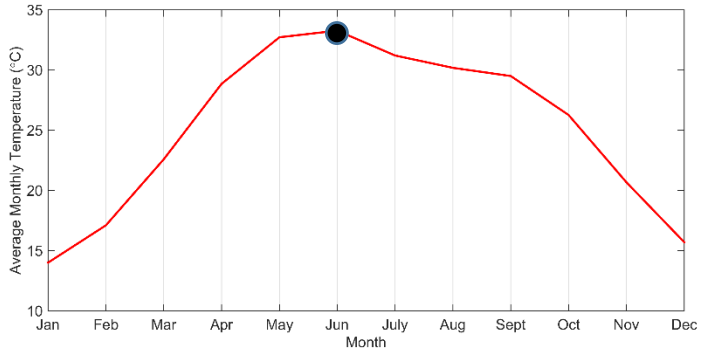




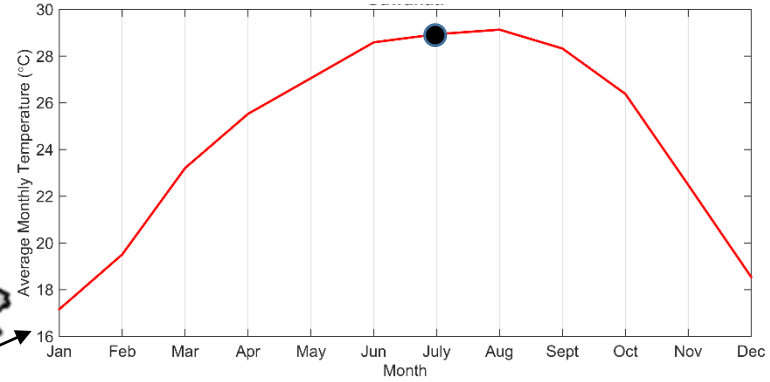
Seasonality of Heatwave-Rich Phases

Identification of Four Distinct Climate Regimes Based on Heatwave Timing

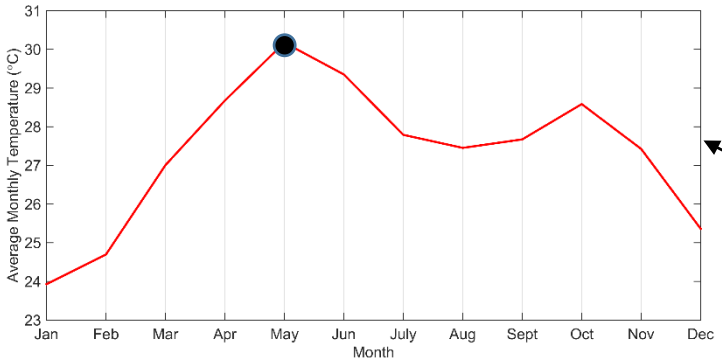
Delhi

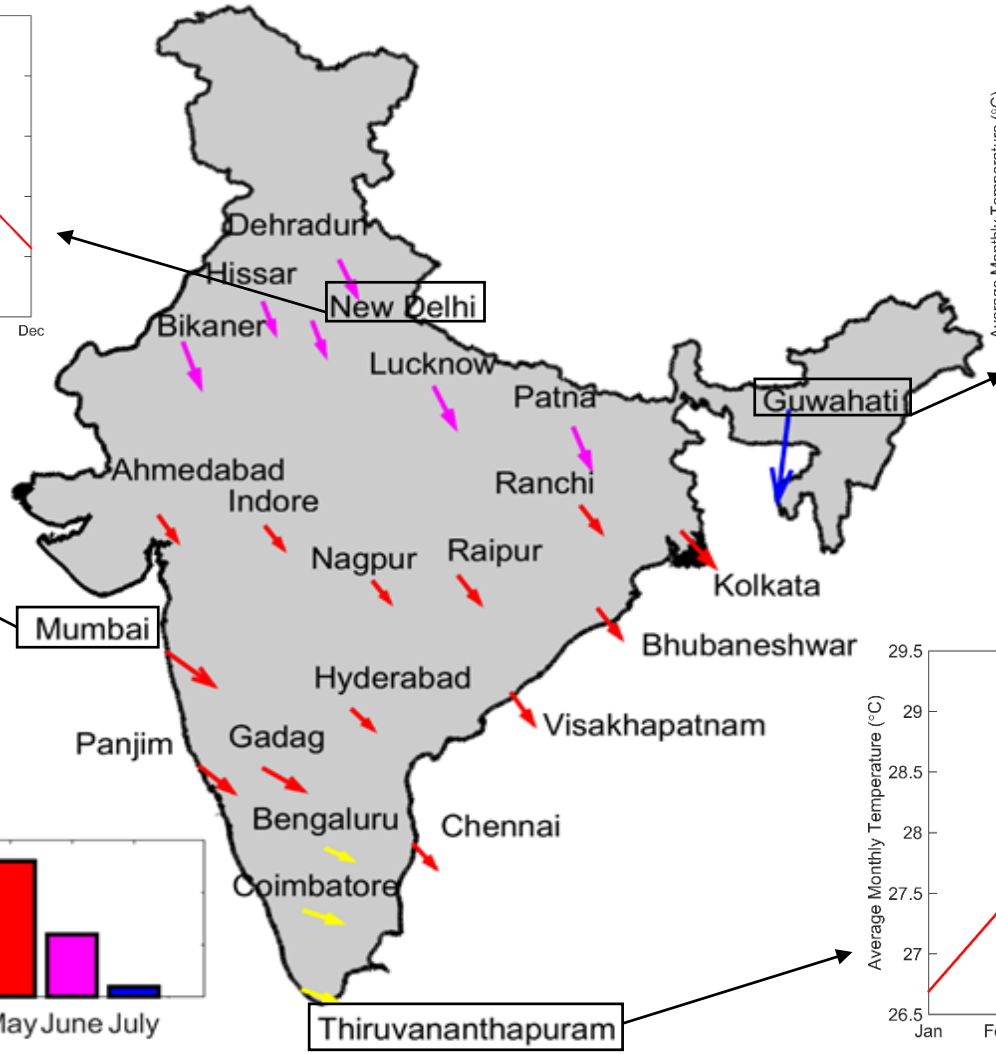


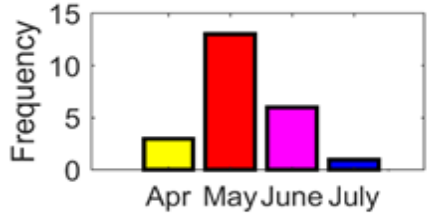
Guwahati



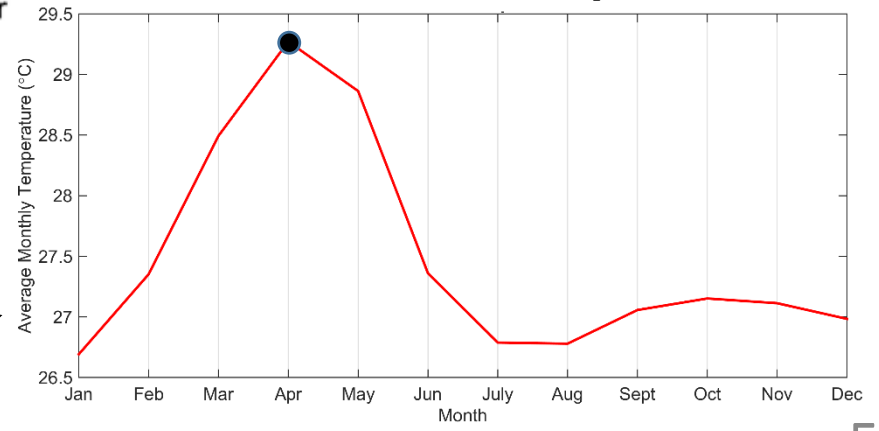
Mumbai



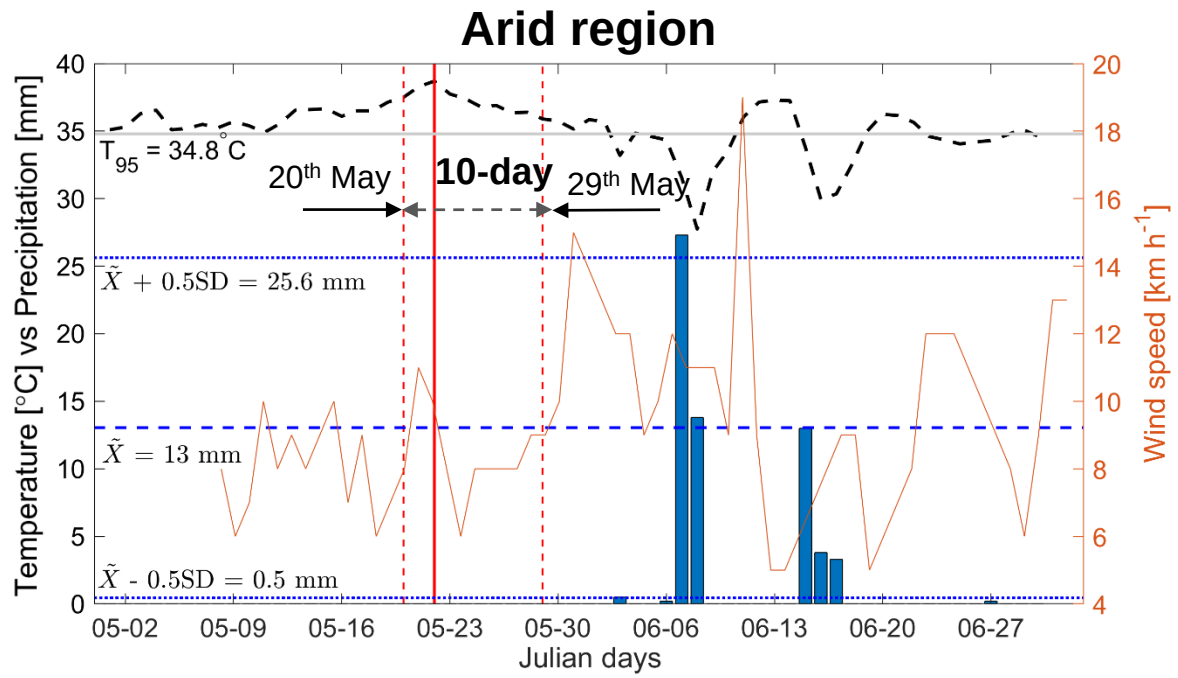


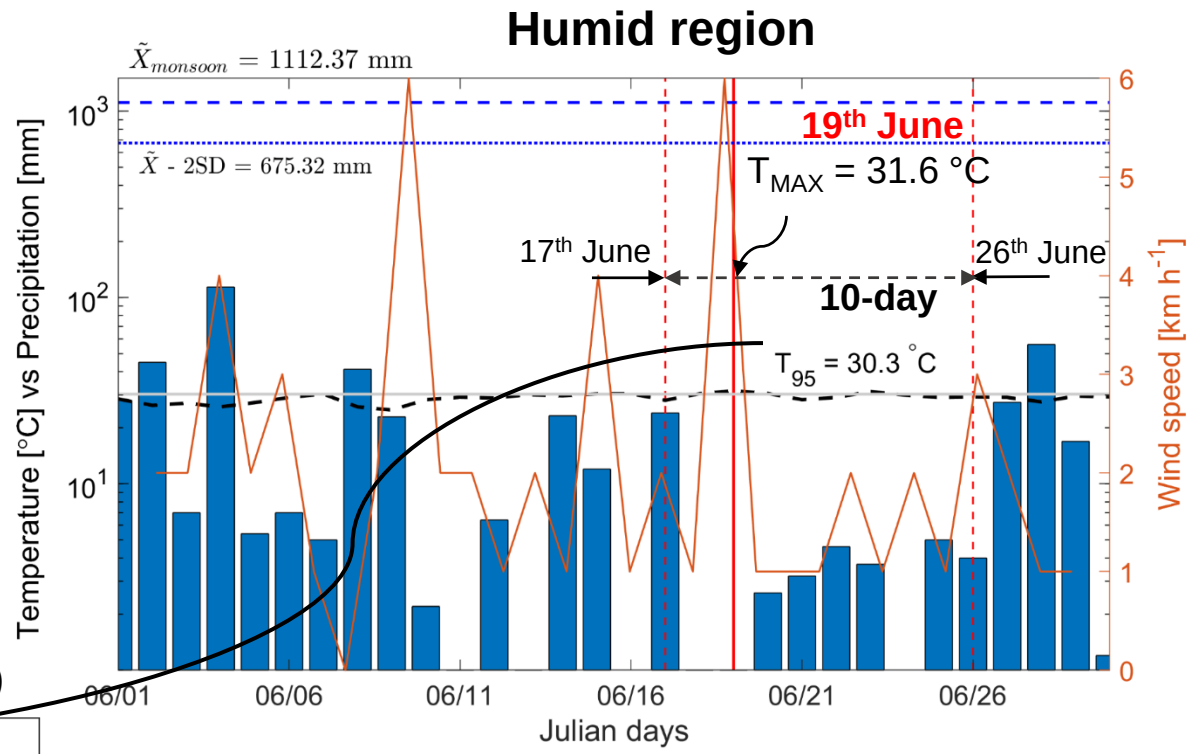


Thiruvananthapuram



Characterization of Hot-Dry Episodes

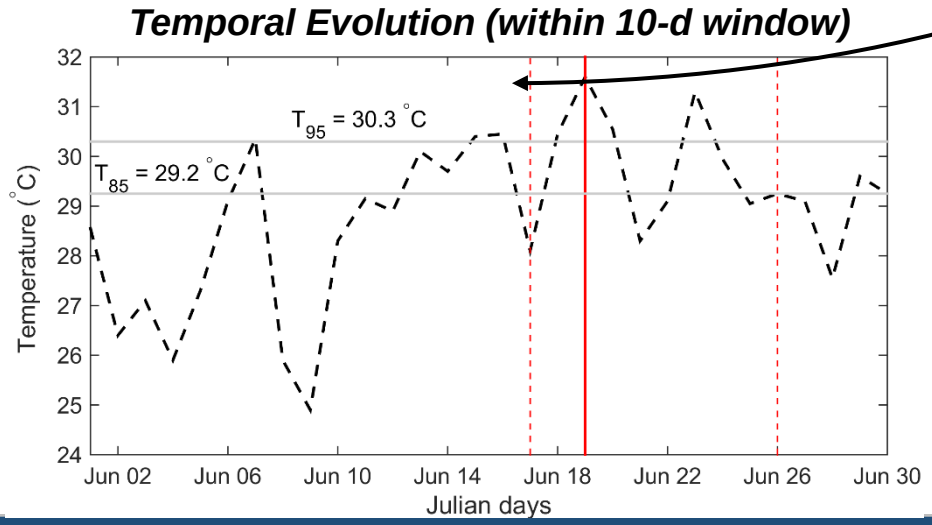




Temperature (°C)

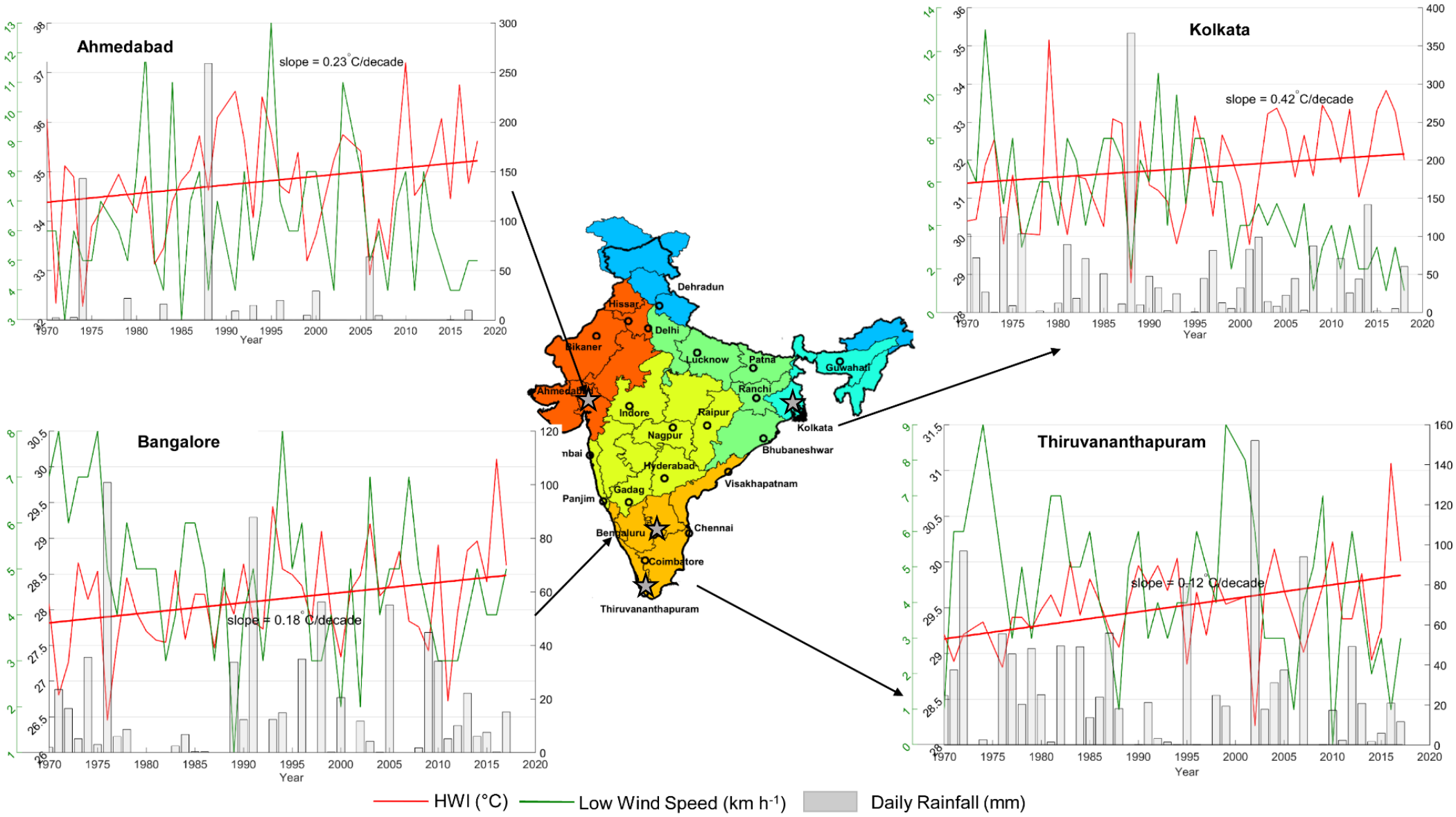
Wind Speed (km/h^{-1})

Daily Rainfall (mm)



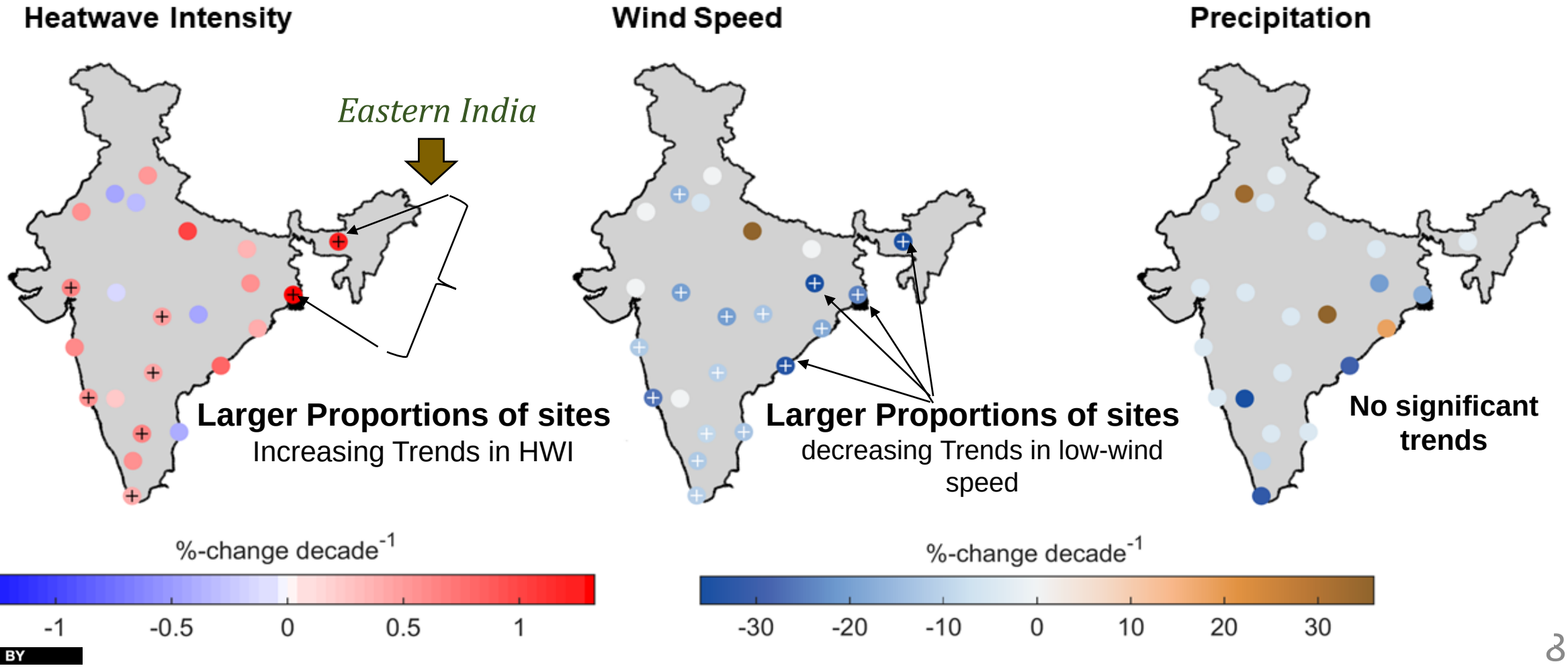
- Heatwaves in northwest & central India are linked to abnormal blocking over North Atlantic (Dubey et al. 2021).
- In humid areas, the high temperature is compounded by low-precipitation during monsoon break period, notable in eastern & north-east India (Ivanovich et al. 2021).

Trends in Heatwave Intensity, Low-wind Speed & (Deficit) Precipitation



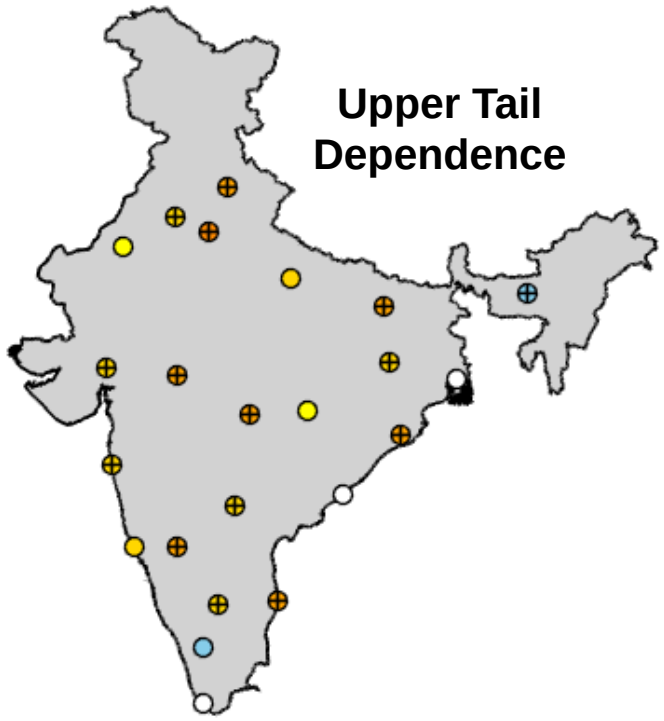
Does Apparent Nonstationarity Among Drivers Affect Multi-hazard Frequency?

Trends in Individual Drivers

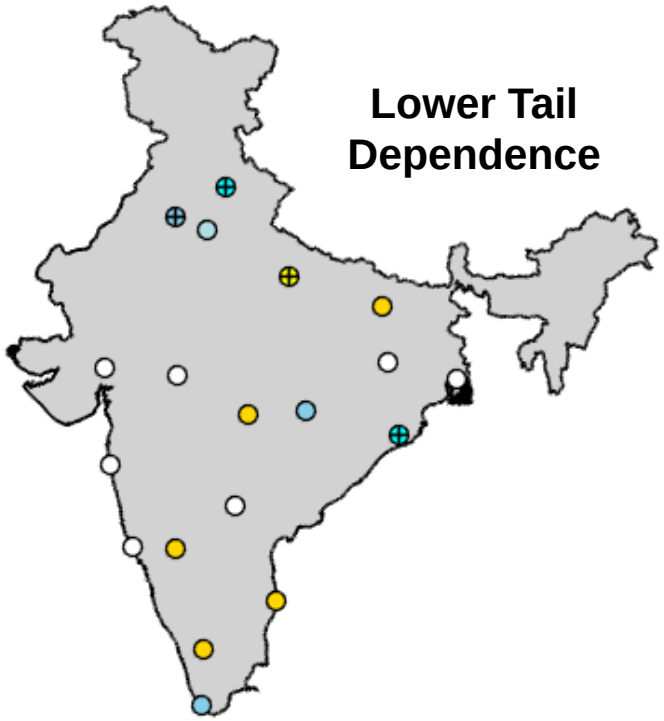


Trends in Upper-Tail Dependence of Concurrent Drivers

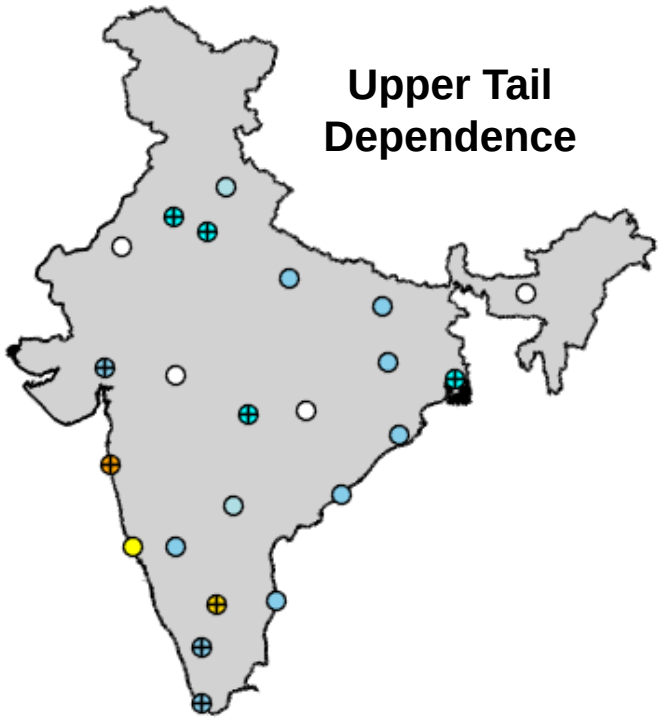
HWI - low Wind speed: λ_U

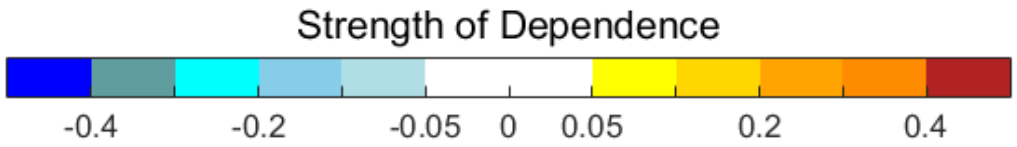


Precipitation - Low Wind Speed: λ_L

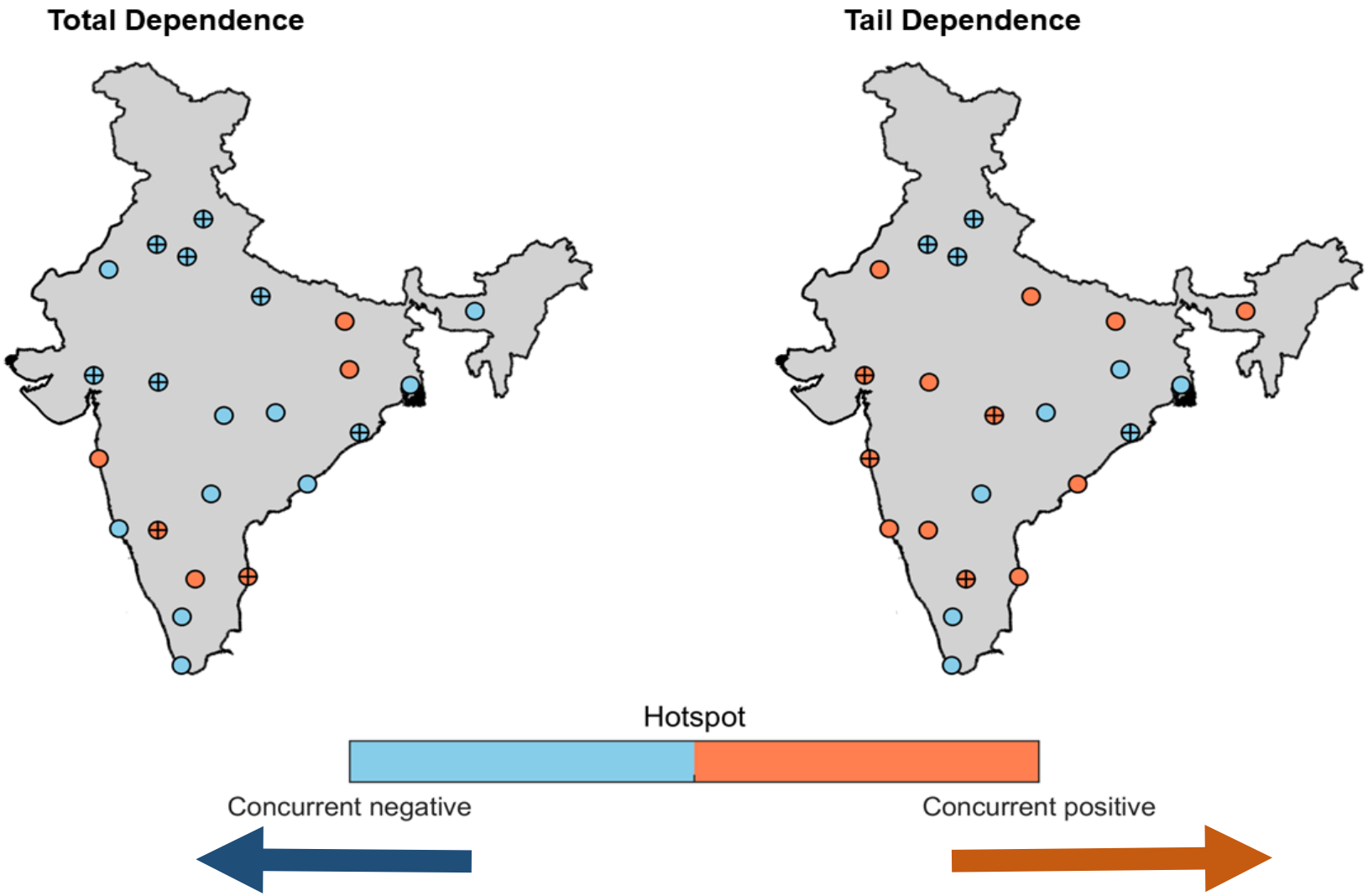


Precipitation - HWI: λ_U





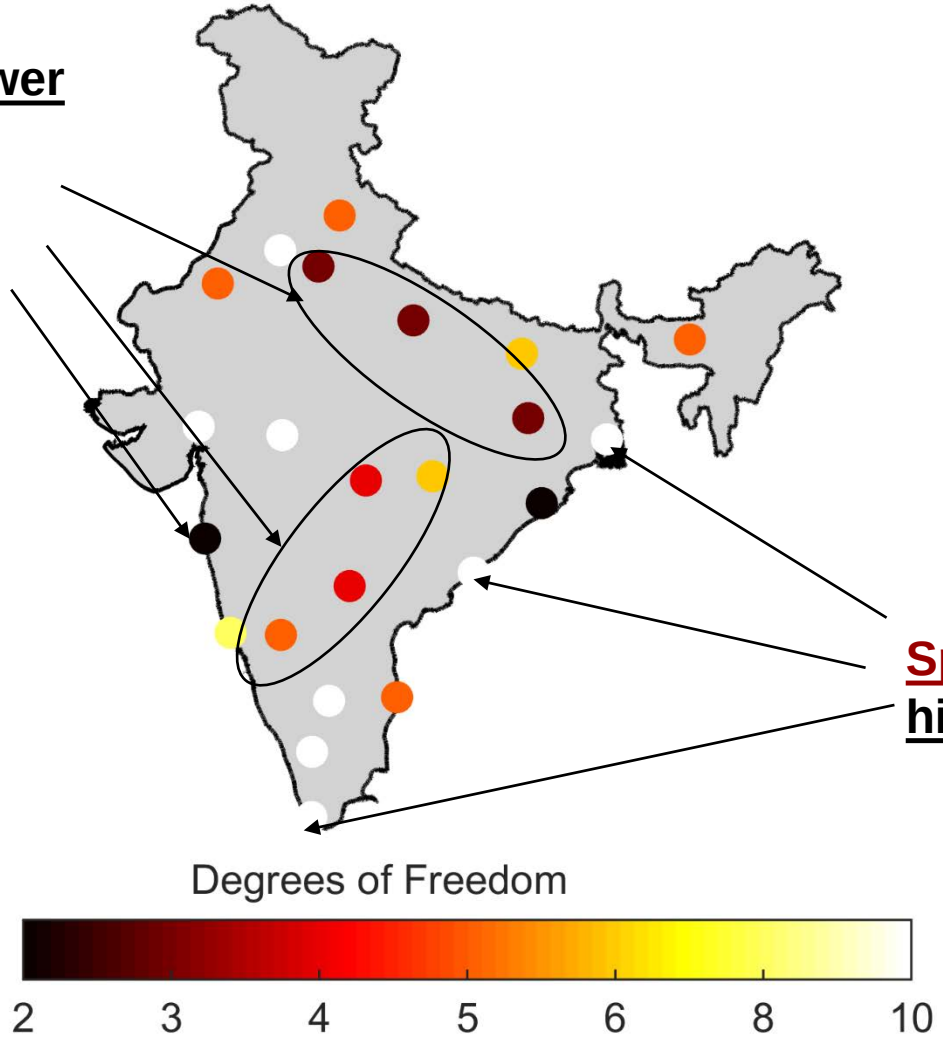
Extremes at Tail Tend to Cluster Together Favoring Large Exceedances



Spatial Clustering of Degrees of Freedom Parameter

Spatial Clustering of lower degrees of freedom

Fatter tail for interior cities except Mumbai, BBSR



Spatial Clustering of higher degrees of freedom

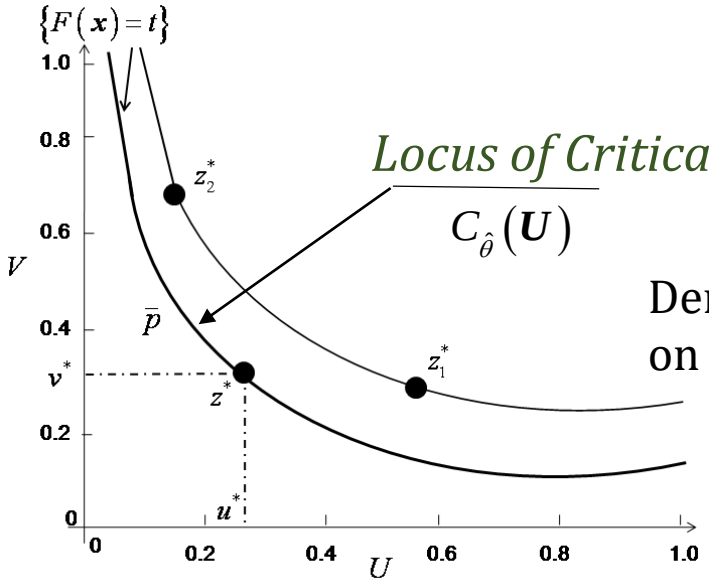
Lighter tail at coastal cities

Compound Dry-Spell Hazard Potential Index [*CDPI*]

Univariate heatwave freq., T = 50-yr RP

$$CDPI = \frac{T_{HWI}}{T_{Compd}} = \frac{T_{HWI}}{\left(\frac{1}{1-K_C(\bar{p}_t)}\right)} \qquad CDPI \in [0,\infty), CDPI > 0$$

Compound heatwave-dry spell freq., for T = 50-yr RP quantiles for each driver



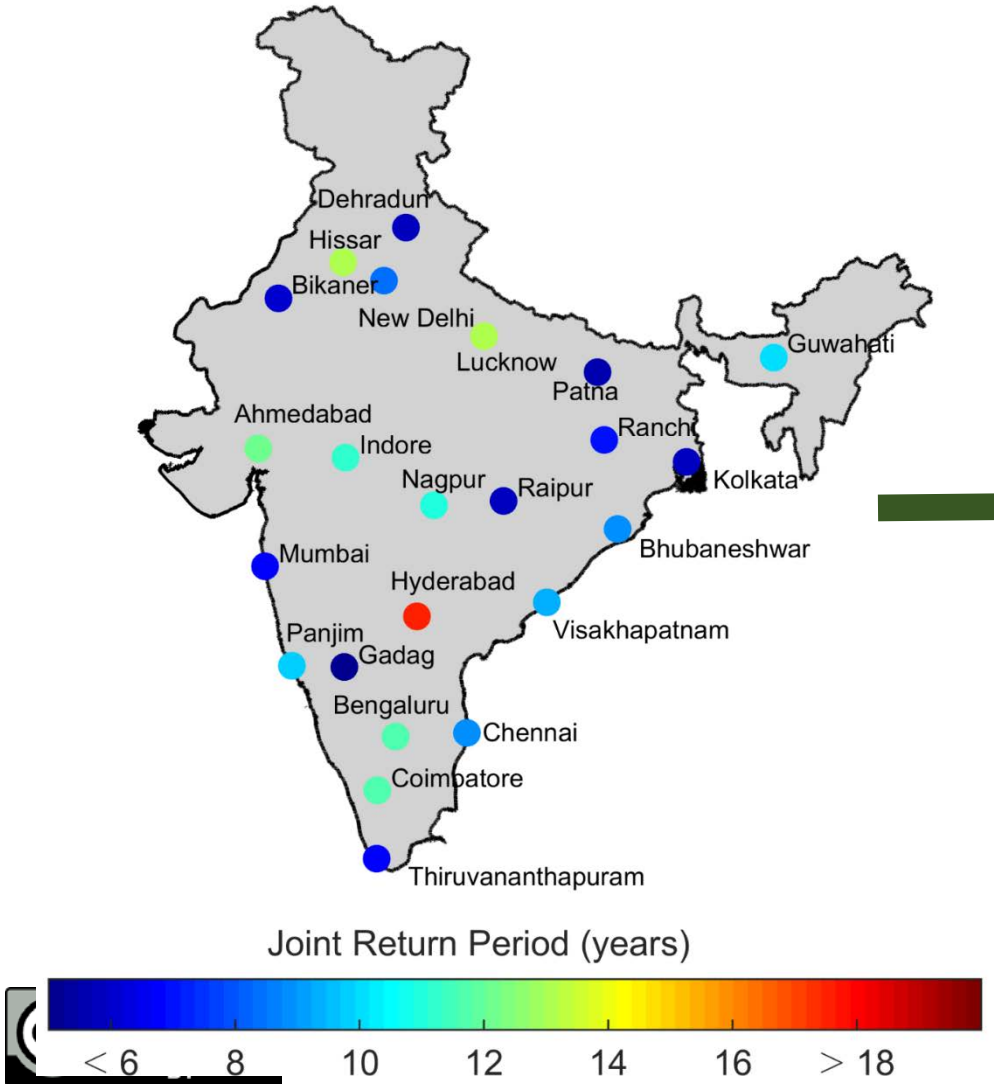
Locus of Critical Probability

$C_{\hat{\theta}}(\boldsymbol{U})$

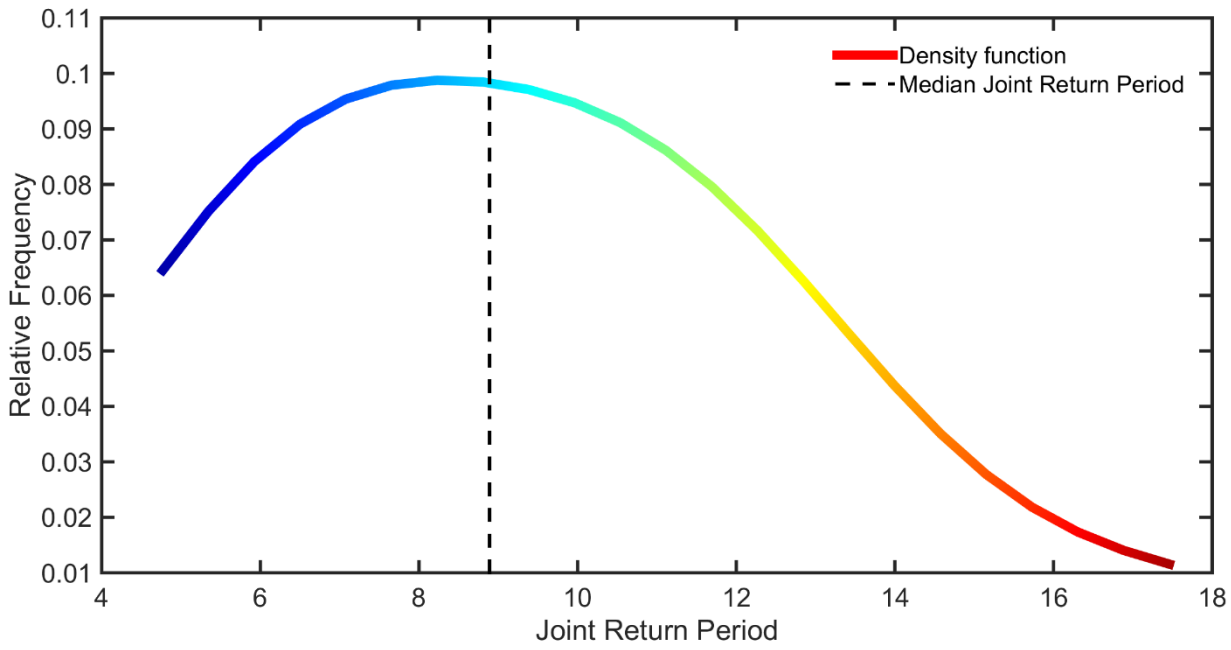
Derived based on 100 00 MC

- CDPI = 1, perfect agreement b/n at-site frequency of heatwaves and compound hot-dry spell.
- CDPI > 1, Amplification
- CDPI < 1, depletion

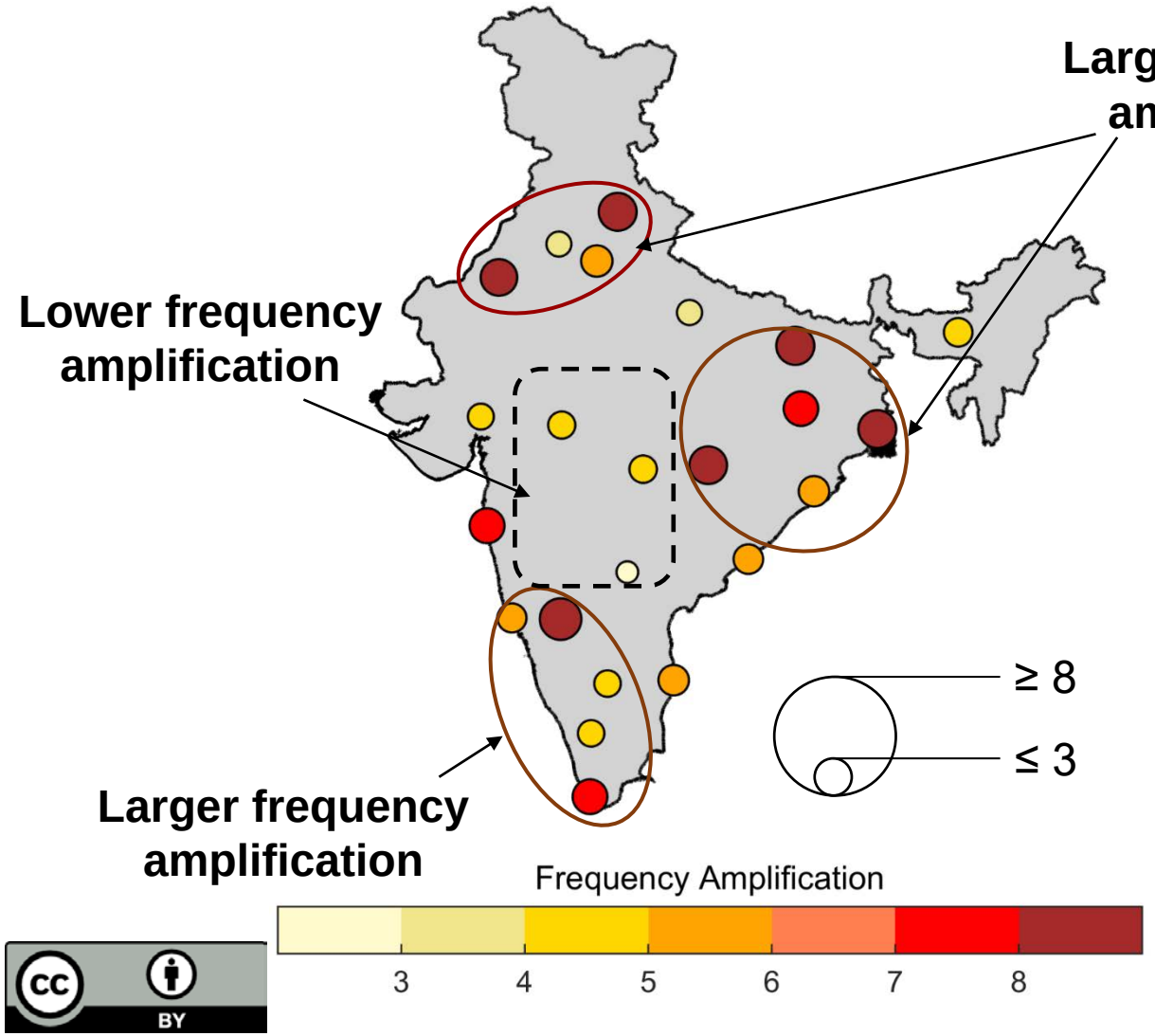
To what Extent Inter-related Climate Hazards Contribute to Amplifications in Compound Hot-Dry Event Frequency?



50-year Event tend to become more frequent



How Severe would be Compound Hazard-potential relative to Univariate Hazard, solely accounting Temperature Extreme?



Key Insights

- Compound hazard potential tends to amplify in a nonstationary climate.
- A median 6-fold amplifications are observed – none of cities show depletion.
- Cities across eastern & southern coasts show larger frequency amplification, i.e., concurrence of high temperature-low wind speed-&-deficit precipitation is pronounced here.

Resources

Springer

Climate Dynamics

Observational, Theoretical and Computational Research on the Climate System

To know more about the work

- For details, please visit: Ganguli, P. (2022). Amplified risk of compound heat stress-dry spells in urban India. Climate Dynamics, DOI: 10.1007/s00382-022-06324-y.

- EGU22-2647: Pradhan, S., Ganguli, P. (2022). Multivariate approach reveals a higher likelihood of compound warm-wet spells in urban India. In session, CL3.2.6 – Climate extremes, biosphere & society: Impacts, cascades, feedbacks and resilience.

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Variability & Drivers

Thanks!

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Picture Credit: Matei, K.B (June, 2021)

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