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# Rising heavy monsoon rains over western India guided by two emerging circulation patterns

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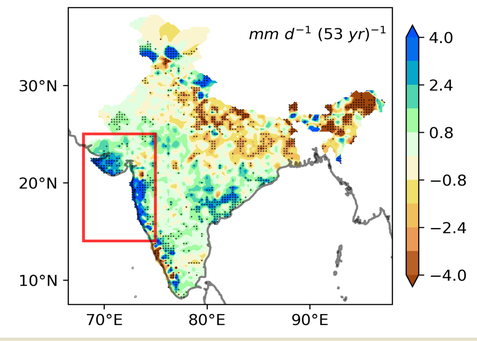
JJAS mean rainfall trend




(IMD $0.25^0 \times 0.25^0$ rainfall data)

## Motivation

- Significantly high **wetting trend** over **western India** (red box) in monsoon season (JJAS)
- **Rising frequency of heavy rainfall days** (at least 10% grids in western India receive rainfall ≥95$^{th}$ percentile (local climatology)

## Clustering methodology

**Self-organizing Maps (SOM)**

– An unsupervised artificial neural network

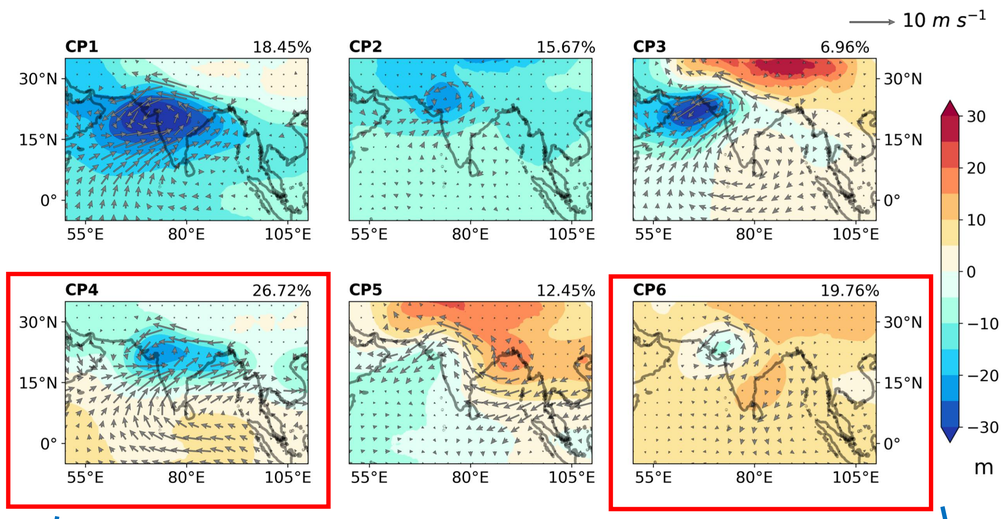
– Maps multidimensional data onto lower-dimensional (usually, 2D) clusters

Algorithm:

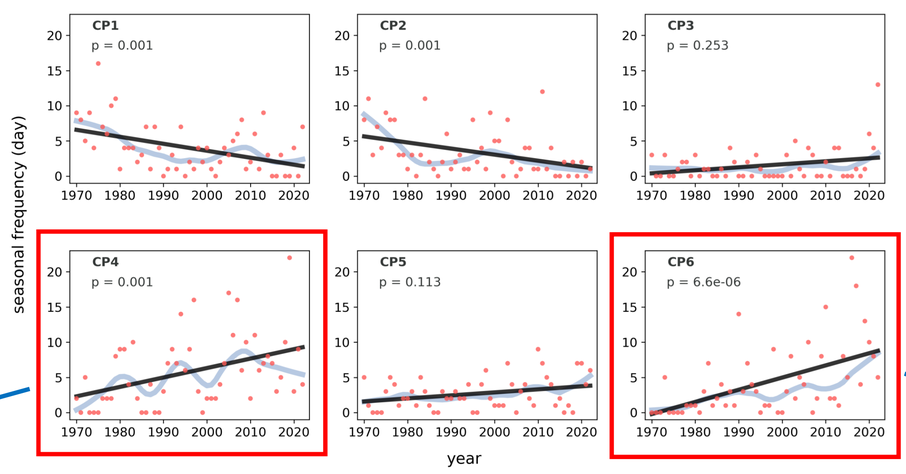
- The Euclidean distances ($d_n$) between each input vector ($x_n$) and randomly initialized weight vectors ($w_i$) for each output node (neuron) are calculated: $d_n^2 = \Sigma_n(x_n - w_{in})^2$
- The winning node is identified as the node with minimal Euclidean distance, both the winning and neighborhood nodes are updated by the input vector scaled by a decaying learning rate $L_t$: $w_{t+1} = w_t + L_t(x_t - w_t)$
- Above are repeated for N iterations and finally, each input vector is assigned to a specific node based on the minimum Euclidean distance.

SOM-clustered CPs on heavy rainfall days (ERA5 data)

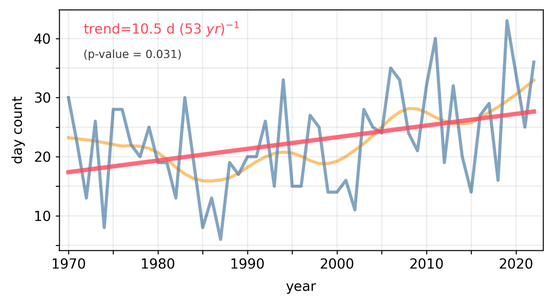
Anomalous 600 hPa GPH and 925 hPa wind clusters




Interannual frequency




JJAS heavy rainfall day count in western India

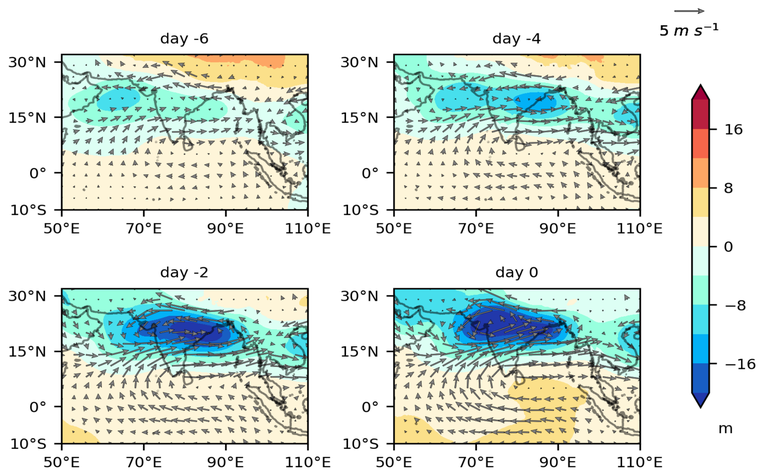



## Circulation Patterns (CPs)

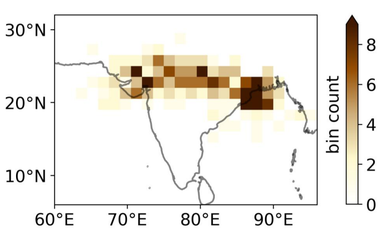
- 1149 heavy rainfall days (1970-2022)
- **CP4 and CP6 — two most prevalent circulation patterns**
- **Statistically significant and monotonic increasing trend in CP4 and CP6.** (Time-varying LOWESS fit indicates monotonicity)
- Trivial trends in CP3 and CP5
- Declining trends in CP1 and CP2 but not monotonic

## CP4

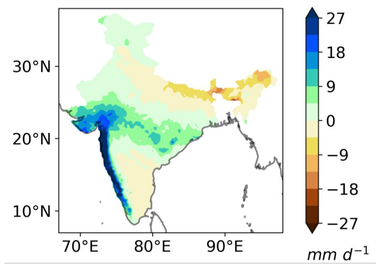
Anomalies of 700 hPa GPH and 850 hPa wind




LPS track distribution




Rainfall anomaly




## Mechanism of the Emerging CPs

***CP4 :***

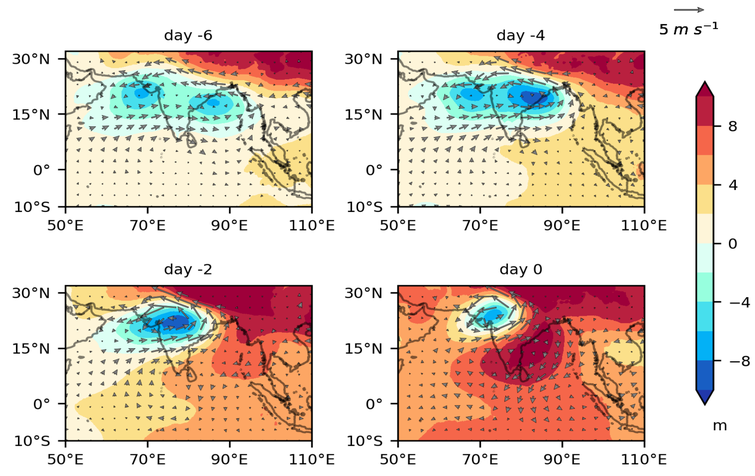
- A cyclonic vortex drifts westward from Bay of Bengal (day -4). It merges with a pre-existing vortex over western India on day 0 — **an extensive cyclonic circulation forms over India**.
- Low-level monsoon westerlies strengthen over southern peninsula.
- LPS activity along the whole east-west stretch of central monsoon zone
- **Heavy rainfall across entire west coast and Gujarat, moderate rainfall across central India.**

***CP6 :***

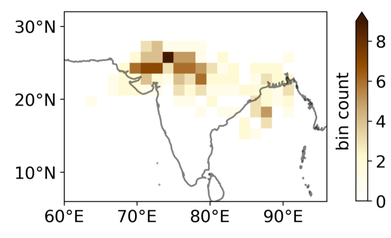
- A cyclonic vortex drifts westward from Bay of Bengal (day -6) and reaches western India on day 0 — **a localized cyclonic circulation forms over western India**.
- LPS activity near western India
- **Heavy rainfall over northern west coast and Gujarat.**

## CP6

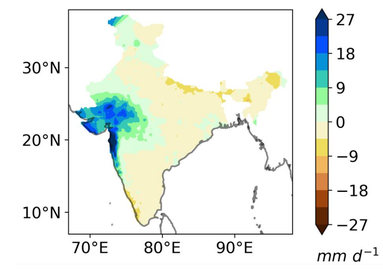
Anomalies of 700 hPa GPH and 850 hPa wind




LPS track distribution




Rainfall anomaly

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## Remarks

- ✓ **The rising trends in the two clusters, CP4 and CP6, bears signature of long-term hydroclimatic change.**
- ✓ **Both large-scale (CP4) as well as local-scale (CP6) processes are involved in the persistent rise in heavy monsoon rains over western India (under prep.)**
- ✓ By connecting large-scale weather patterns with grid-scale extremes, SOM provides insights into multi-scale interactions driving monsoon heavy precipitation.