Automated identification of South Asian monsoon low pressure systems: Historical variations across reanalyses

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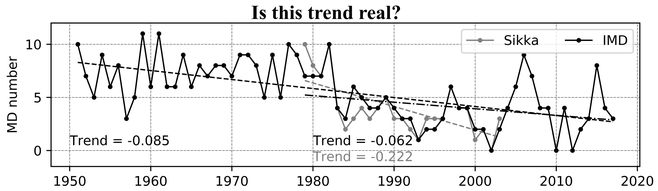
Introduction & Objective

- Monsoon Low Pressure Systems (LPS) are cyclonic vortices that produce a large fraction of South Asia's rainfall
- Intense LPS are called Monsoon Depressions (MDs).
- The India Meteorological Department (IMD) record shows a large downward trend in the number of MDs, but their tracking methods have changed over time and do not include weaker LPS (Lows).



Goal: devise a fast, objective, optimal tracking algorithm that can identify monsoon LPS in ensembles of high-resolution data

Tracking tools & criteria

- We use **TempestExtremes**, an automated Lagrangian pointwise feature tracker (Ullrich and Zarzycki, 2016).
- **Training:**
  - Identify LPS tracks in 4 reanalyses (ERA-Interim, JRA55, CFSR, MERRA2) for 1990-2003, selecting tracking criteria to match overall statistics of an existing hand-analyzed LPS dataset (Sikka, 2006)

Candidate variables
Mean sea level pressure
Geopotential at 850hPa
Streamfunction at 850hPa
Relative vorticity at 850hPa

  - Consider 4 geophysical variables x 8 intensity thresholds x 2 radii thresholds x 8 relative humidity thresholds
  - Additionally, 8 relative humidity thresholds (at 850 hPa) are considered to differentiate heat lows from moist LPS.
- We use the Critical Success Index (CSI), the ratio of the number tracks that match between the test dataset and reference datasets to the number of unique tracks in both datasets

$$CSI(dataset, reference) = \frac{Matches}{Matches + NonMatches}$$

- A single tracking algorithm is selected using a **combined CSI** that weights agreement across reanalyses with agreement with the reference dataset

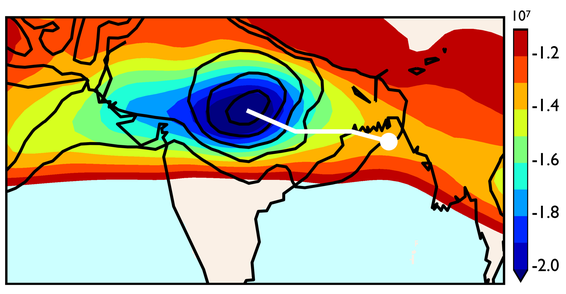
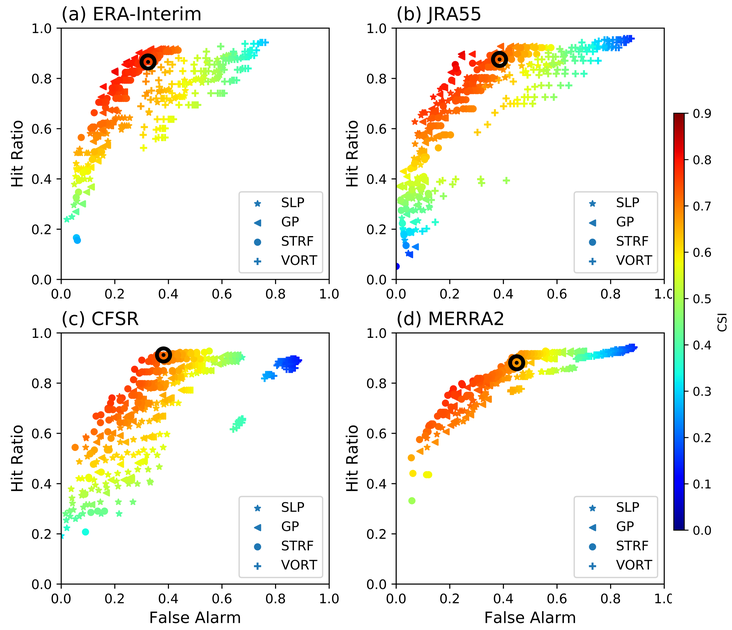


Figure 1: A sample LPS track, overlaid on 850 hPa stream-function (colors) and mean sea level pressure (contours). White dot denotes genesis location.

Selecting an optimal tracking algorithm



- The CSI metric (colors) rewards "hits" while penalizing "false alarms"
- The optimal metric tracks 850 hPa streamfunction minima and requires RH > 85%. It correctly matches about 90% of LPS in the reference dataset
- Interannual correlation coefficients of track counts between reanalyses vary from about 0.5 - 0.7 (not shown)

Figure 2: CSI metric (colors) as a function of hit ratio and false alarm ratio for each of 512 algorithms applied to 4 reanalyses, referenced to the hand-analyzed (Sikka) dataset. Black circle marks the optimal algorithm chosen based on the combined CSI.

Data & algorithm availability

- Tracks from 5 reanalyses are available on request (will post online after paper acceptance): ERA5, ERA-Interim, CFSR, MERRA2 (all 1979-2018), and JRA55 (1958-2018)
- Tracking algorithm and TempestExtremes software are available and can be used to extract LPS from any model, including CMIP models.
- We have also extracted tracks from the Indian Monsoon Mission model, CFS-IITM.

Interannual modes of variability

- The number of LPS is higher during strong monsoon years and during La Niña, but there is no significant change in counts in Indian Ocean Dipole events.

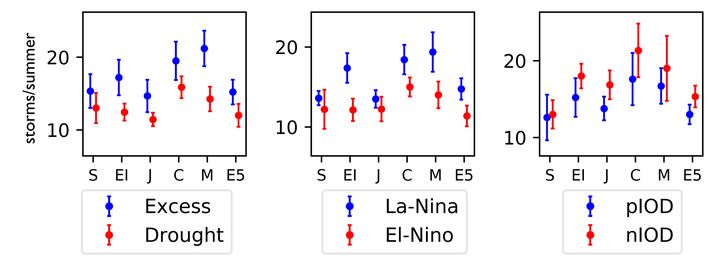


Figure 3: LPS counts in excess vs. drought South Asian summers (left), El Niño vs. La Niña (middle), and positive vs. negative Indian Ocean Dipole events. Vertical bars show 95% confidence interval. Axes abbreviations are S: Sikka (hand-analyzed reference dataset), EI: ERA-Interim, J: JRA55, C: CFSR, M: MERRA2, E5: ERA5.

Can we find a historical trend in any of the reanalyses?

No detectable long-term trend

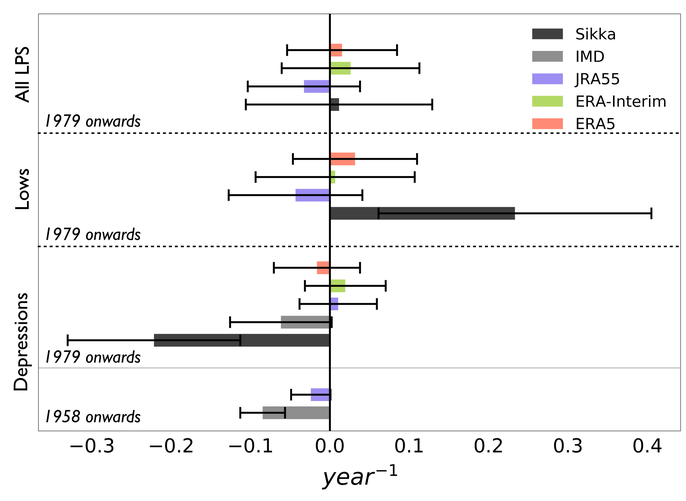


Figure 4. Trend in LPS, Lows, and Depressions in all datasets. Error bars represent the 95% confidence interval for these trends. Sikka dataset ended in 2003.

- No trend in Depression counts exists in any of the 5 reanalyses between 1979-2018.
- In JRA55, a weak downward trend in Depression counts exists over the longer period 1958-2018, but its error bar is large enough to include zero.

Are we seeing a poleward shift in genesis?

- Prior studies (Sandeep et al. 2018) found a poleward shift in the genesis distribution in GCM simulations of the next century.
- Something that looks like a poleward shift appears over the past 40 years, but the change in the mean latitude of genesis is not statistically detectable.

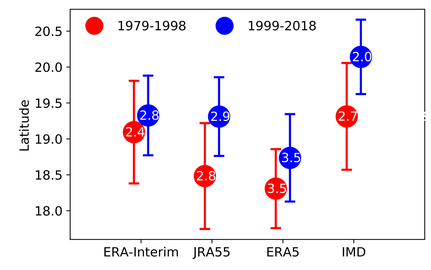


Figure 6. Mean latitudinal position of Depression genesis in the two epochs. Error bars show the 95% confidence interval. Values in circles are mean seasonal counts.

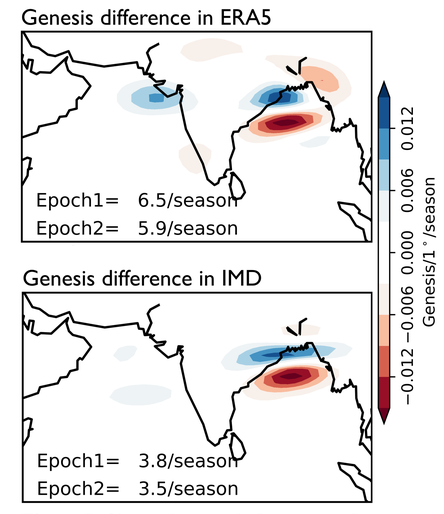


Figure 5: Change in genesis frequency of Depressions between epoch 1 (1979–1998) and epoch 2 (1999–2018).