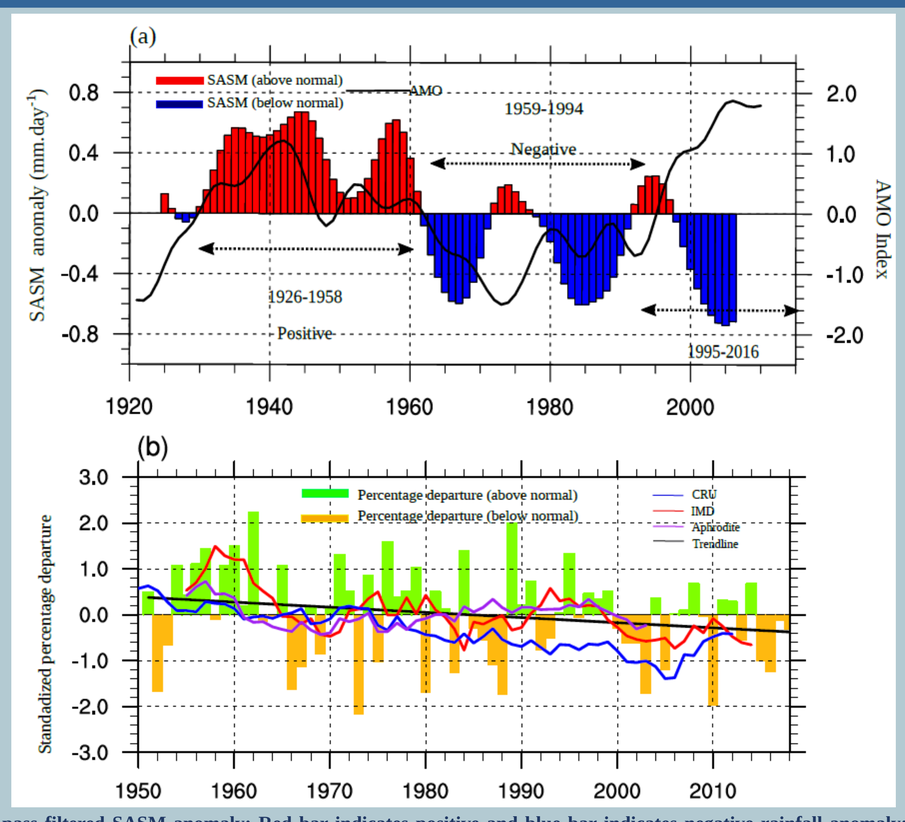
On the weakening association between South Asian Monsoon and Atlantic Multidecadal Oscillation

Sandeep N, Swapna P, R Krishnan, R Farneti, F Kucharski, Ayantika D C, Manmeet S

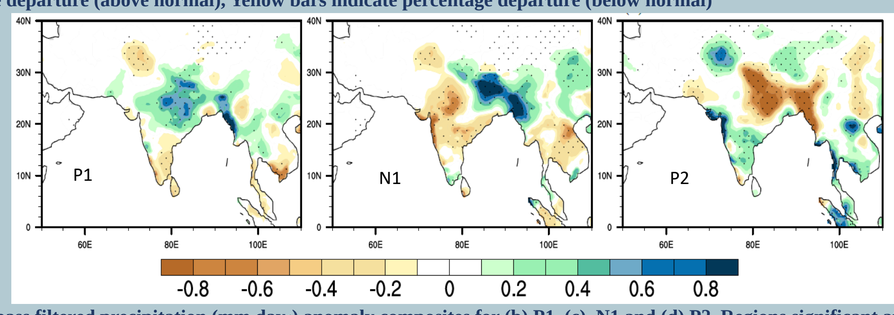
Abstract

- Long-term multi-decadal scale variability of South Asian Summer Monsoon (SASM) is known to be associated with the Atlantic Multidecadal Oscillation (AMO) with positive phase associated with above-normal rainfall and vice-versa over SASM region.
- Analysis of the 120-year historical record suggests that the relationship between the AMO and the SASM has weakened in recent decades.
- Two possible reasons emerge from the analyses of observational datasets and model experiments.
- Enhanced Indian Ocean warming and weakened North Atlantic Subtropical High (NASH) are the prime factors weakening AMO-SASM association in the recent decades.
- Indian Ocean warming co-occurred during the recent AMO warm phase weakens the meridional temperature gradient, weakening the regional Hadley cell, large-scale monsoon circulation and precipitation.
- The suppressed convection triggers a Rossby wave which manifests as a cyclonic circulation over west central Asia weakening the Tibetan anticyclone. In addition, weakening of NASH weakens the Circum-Global Teleconnection (CGT) connecting AMO to the SASM, leading to weakening of AMO-SASM association.
- Projected warming of the Indian Ocean and Atlantic demands better understanding of the AMO-SASM teleconnection and their projected changes for assessing future changes in SASM in a warming world.

Observation Evidences

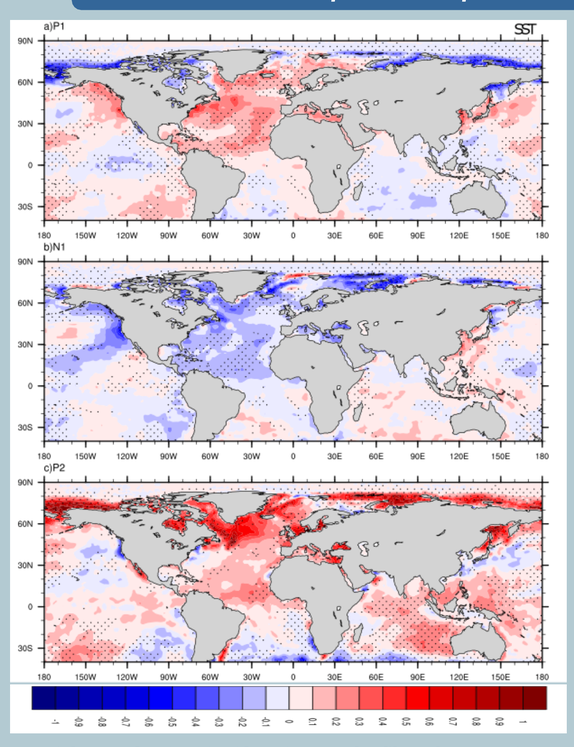


Time-series of low-pass filtered SASM anomaly; Red bar indicates positive and blue bar indicates negative rainfall anomaly; AMO Index is overlaid (black). b Time-series of precipitation averaged over core monsoon zone from different datasets. The bars indicate percentage departure. Green bar indicate percentage departure (above normal), Yellow bars indicate percentage departure (below normal)

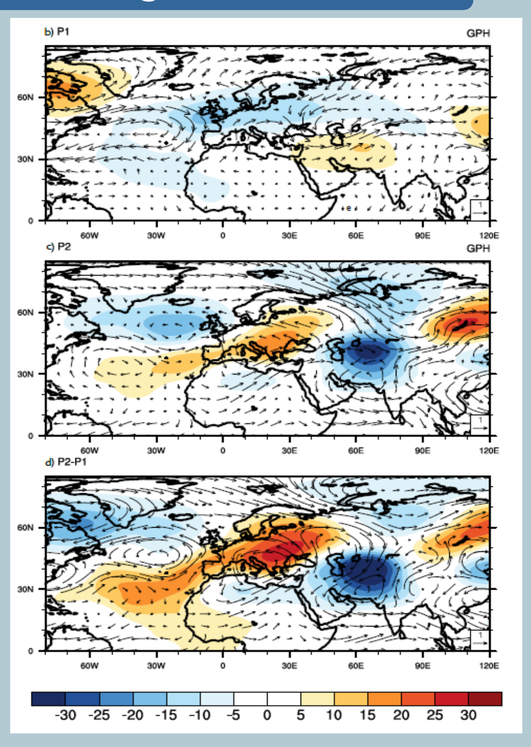


Boreal summer low pass filtered precipitation (mm.day-1) anomaly composites for (b).P1, (c). N1 and (d).P2. Regions significant at 95% confidence level are stippled.

Possible factors for the weakening association



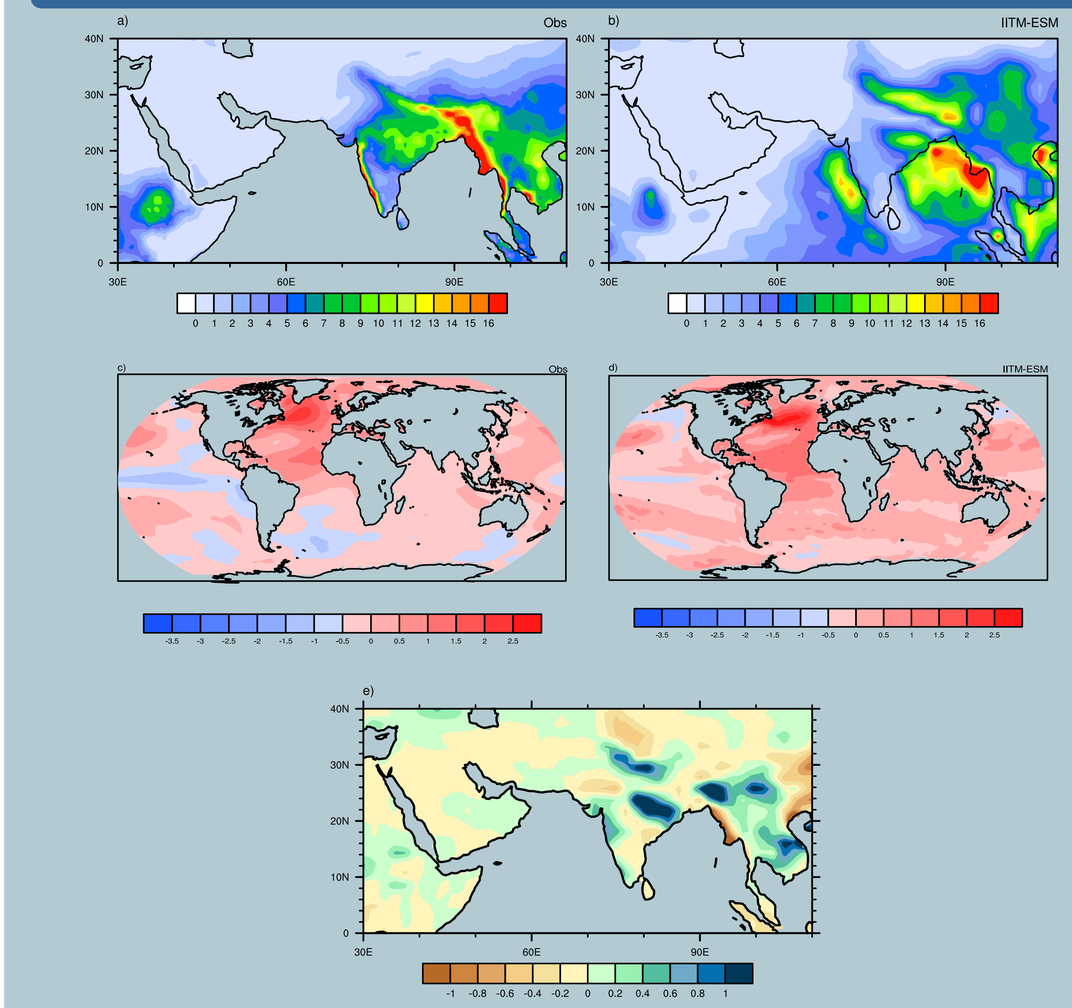
Spatial map of JJAS SST (deg C) anomaly (filtered) composite for a). P1 (1926-58), b). N1 (1959-1994) and c). P2 (1995-2017). Anomaly significant at 95% confidence level are stippled.



Spatial map of JJAS 200hPa geopotential height anomaly (m, filtered, shaded), 200hPa wind vectors(overlaid, m/s) composite for b). P1 (1926-58), c). P2 (1995-2017) and d). P2-P1.

- Enhanced Indian Ocean warming and weakened North Atlantic Subtropical High (NASH) are the prime factors weakening AMO-SASM association in the recent decades.
- **Indian Ocean warming co-occurred during the recent AMO warm phase weakens the meridional temperature gradient, weakening the regional Hadley cell, large-scale monsoon circulation and precipitation.**

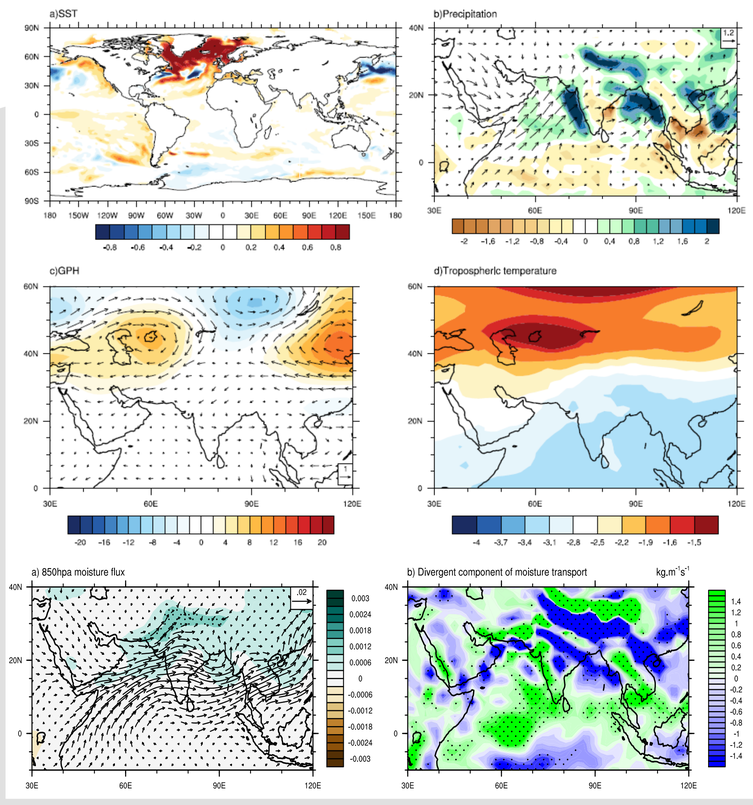
Association between AMO and South Asian Monsoon in IITM-ESM



Spatial map of JJAS mean Precipitation (mm.day-1) from a). Observations and b).GMMIP. Spatial representation of the AMO in c). Observations and d). IITM-ESM. These patterns are based regressing monthly SST anomalies (denoted SSTA*) at each grid box onto the timeseries of the AMO SSTA* Index (defined as SSTA* averaged over the North Atlantic 0-60N, 80W-0W). e). Spatial representation of AMO -SASM correlation in IITM-ESM.

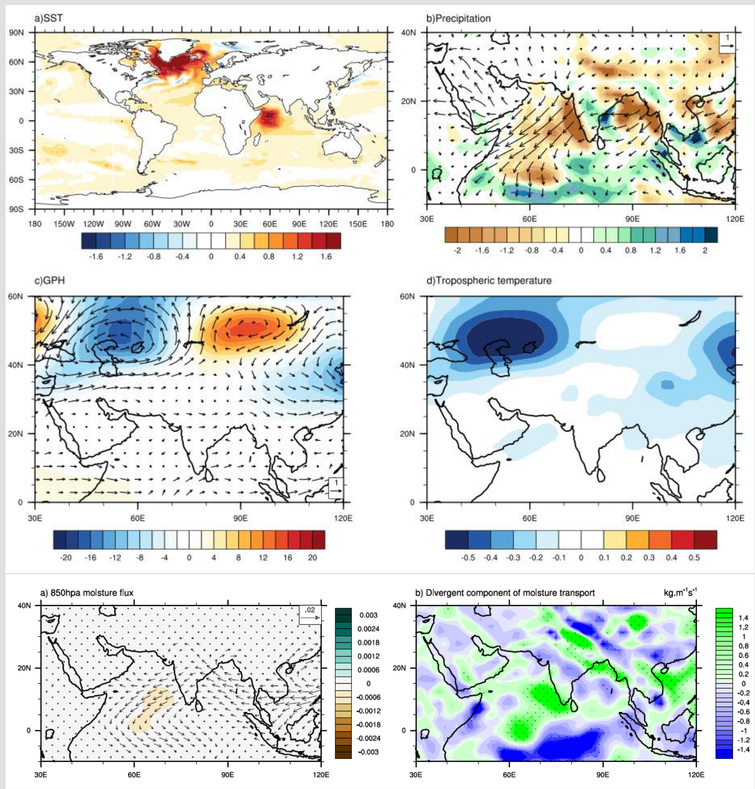
Results from Pacemaker experiments performed using IITM-ESM

Experimental protocol adapted from Kosaka and Xie (2013)



- To examine the role of remote Atlantic forcing i.e., AMO on SASM, a sensitivity experiment (AMO_{exp}) is performed using IITM-ESM by adding SST anomalies in the North Atlantic Ocean over the domain 80°W–0°E, 0°–60°N, keeping rest to climatology from the piControl run.
- A mid-latitude Rossby wave train traversing from Atlantic across South Asia region via CGT, increasing the meridional temperature contrast.

Indian Ocean Warming



- To investigate the role of local forcing i.e., Indian Ocean warming on AMO-SASM association, we performed sensitivity experiment by inducing anomalous SST warming in the Indian Ocean along with north Atlantic warming $(AMO + IOWARM)_{exp}$ keeping rest to climatology from the piControl run.
- We notice a weakening of JJAS precipitation over the SASM region in the $(AMO + IOWARM)_{exp}$ relative to piControl. Similar to the recent P2 phase, we can see a weakening of meridional temperature contrast and CGT response as shown by the200hpa geopotential height and precipitation from AMO + IOWARM relative to piControl.

Highlights

- We explore the possible reasons for the weakening association between AMO and SASM in recent decades using both observations and IITM-ESM model simulations.
- The novel aspect of our study is with a suite of experiments we demonstrate that the Indian Ocean warming, and the weakened NASH are the important factors for the weakening association between AMO and SASM.

Reference

- **Sandeep, N., Swapna, P., Krishnan, R. *et al.* On the weakening association between South Asian Monsoon and Atlantic Multidecadal Oscillation. *Clim Dyn* 59, 2531–2547 (2022). https://doi.org/10.1007/s00382-022-06224-1**