Overestimation of the ENSO-ISMR Relationship in Coupled General Circulation Models

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1. Introduction

The Indian Summer Monsoon (ISM) contributes majority of the rainfall over the Indian subcontinent. The variability of Indian Summer Monsoon Rainfall (ISMR) occurs across various time scales, including interannual, decadal, sub-seasonal, and daily. The predictability of ISMR on a seasonal scale is linked to the slowly varying Sea Surface Temperature (SST). SST anomalies in the Pacific Ocean influence ISMR through the El Niño/Southern Oscillation (ENSO). The ENSO-ISMR teleconnection is also influenced by the different phases of the Indian Ocean Dipole (IOD). Additionally, the phases of the monsoon ISO and monsoon trough can amplify synoptic variability over central India. Therefore, understanding complex ENSO- ISMR relationship due to presence of processes like IOD, synoptic system that affect ISMR variability is difficult. The strong interaction between the different phenomenon at different timescale make the predictability of the ISMR a challenging problem. This motivated us to understand the ENSO-ISMR variability and its interaction on different timescale in the coupled model.

2. Results

Monsoon Mission CFS (MMCFS, T382) and North American Multi-Model Ensemble (NMME) are used in this study to understand the ENSO-ISMR relationship. Observational data from 1982 to 2017 reveal that the ENSO-ISMR correlation is strong in June, July, and September but weak in August. This weak correlation during August is due to formation of low-pressure systems (LPS) in the Bay of Bengal (BoB). The formation of LPS results in the enhanced rainfall over the central India region. Thus, presence of LPS during August reduced the large-scale influence of the ENSO over the ISMR. However, the Coupled models often fail to capture the complex relationship of ENSO influencing ISMR. Observations show a weak correlation between Niño 3.4 and ISMR during August, while models such as MMCFS and CanCM4 exhibit a significantly stronger correlation, indicating that the models are not capturing the observed variability. These systems are not adequately represented in the models, causing them to overestimate the large-scale ENSO-driven circulation patterns and, consequently, the ENSO-ISMR relationship. During August, MMCFS and NMME models (GFDL-FLORB and CCSM4) underestimate the synoptic variance (Fig 1h, 1m, 1r). GFDL-FLORB shows a higher synoptic variance as compared to other models and simulate weaker ENSO-ISMR relationship for August as seen in the observations. Thus, predictability of the ISMR is limited by the underestimation of synoptic variability in the models.

However, MMCFS simulates a weak meridional gradient of potential vorticity and dry bias at the low level represents the unfavourable condition for the growth of LPS (Fig 2). Weak cyclonic circulation is simulated over the head BoB. To improve the predictability of ISMR we need to improve synoptic and sub-seasonal variance in present-day climate models. This study highlights the limitations of current coupled models in predicting the ENSO-ISMR relationship accurately. The overestimation of this correlation is primarily due to the models inability to capture synoptic variability, particularly the formation and impact of LPS during August. As a result, the models fail to represent the observed weakening of the ENSO-ISMR relationship during this month. Improving the representation of synoptic processes in coupled models, especially the dynamics of LPS, is crucial for enhancing the accuracy of ISMR predictions.

References

Das, R.S., Rao, S.A., Pillai, P.A. *et al.* Why coupled general circulation models overestimate the ENSO and Indian Summer Monsoon Rainfall (ISMR) relationship? *Clim Dyn* **59**, 2995–3011 (2022). https://doi.org/10.1007/s00382-022-06253-w.

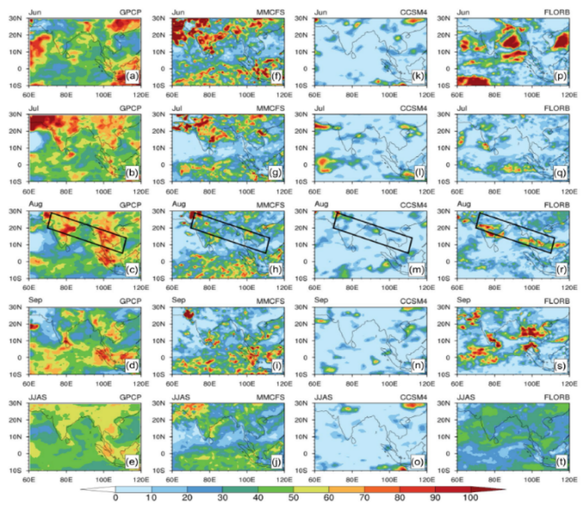

Figure 1: Ratio of synoptic scale (2–10 days band pass filter) variance to total variance in GPCP for June (**a**), July (**b**), August (**c**), September (**d**), and JJAS (**e**). **f**–**j** is similar to (**a**–**e**) but for MMCFS, **k**–**o** is similar as (**a**–**e**) but for CCSM4 and (p–t) is similar as (**a**–**e**) but for GFDL-FLORB (values are given in percentage).

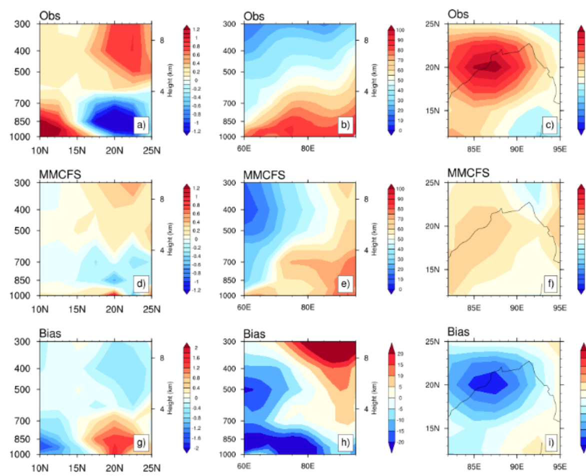

Figure 2: August mean meridional gradient in potential vorticity ($\times10^{-7}$ K m^2 kg^{-1} s^{-1}) on isobaric levels at 85°E (a), relative humidity (%) averaged over 15°N-25°N (b), and relative vorticity ($\times10^{-5}$ s^{-1}) at 850 hPa (c) for NCEP reanalysis 2. Similarly, MMCFS is plotted and Bias between the MMCFS and Obs is plotted.