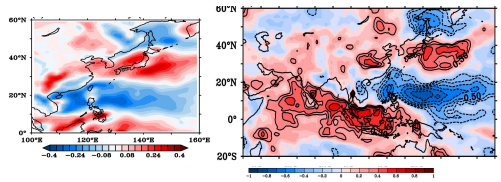
Climate Variability and Data Assimilation Research

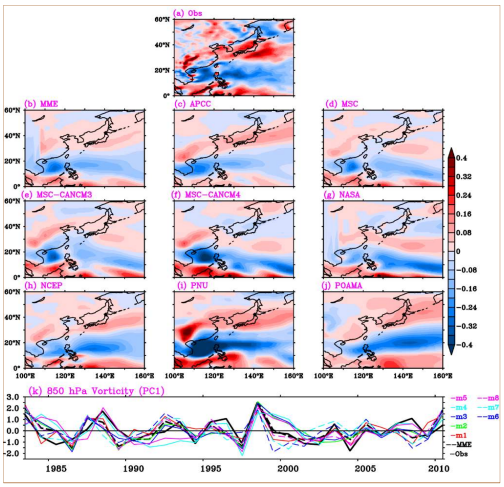
(Team: C. Gnanaseelan, Anant Parekh, Jasti S Chowdary, Prem Singh, Rashmi Kakatkar, J. S. Deepa)

Impact of variations in Western-north Pacific climate on Indian summer monsoon rainfall

Introduction: On the interannual time scale, SST anomalies associated with the El Niño-Southern Oscillation (ENSO) are the dominant forcing for the ISM variability in spite of the uncertainty in the stability of the monsoon–ENSO teleconnections (Krishna Kumar et al. 1999, 2006; Lau and Nath 2000; Turner and Annamalai 2012). The accurate prediction of boreal summer season (June, July and August; JJA) rainfall (especially India land region) over the South Asian region is one of the challenging problem for any numerical model. Assessment of the coupled models skill is very important for predicting the ISM rainfall (Gadgil and Sajani 1998; Wang et al. 2004; Annamalai et al. 2007; Kripalani et al. 2007; Kim et al. 2008; Rajeevan and Nanjundiah 2009; Lee et al. 2010; Sperber et al. 2012). Apart from ENSO, other climate modes such as Pacific decadal Oscillation (PDO) and Interdecadal Pacific Oscillation (IPO) also show significant impact on South Asian summer monsoon rainfall variability (Krishnan and Sugi 2003; Krishnamurthy and Krishnamurthy 2014; Joshi and Kucharski 2016; Joseph et al. 2013 etc.). However, studies in relation to the impact of the dominant mode of Western-north Pacific (WNP) climate variability in low level circulation namely the Pacific Japan (PJ) pattern on the South Asian summer monsoon are limited. The main focus of the present study is the assessment on predictability of PJ or WNP circulation teleconnections to South Asian summer monsoon (JJA) rainfall in APCC coupled general circulation models (CGCMs) hindcast.

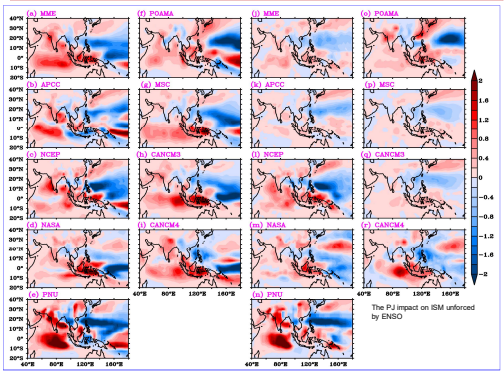


Boreal summer season (JJA): EOF1 of relative vorticity at 850 hPa (shaded; 10^5 s^{-1}) and correlation of RV-PC1 with precipitation. Srinivas et al. 2018.



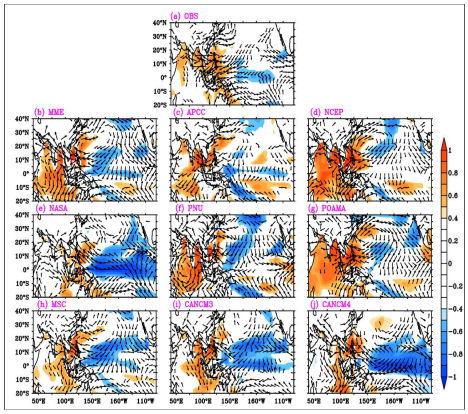
JJA season EOF1 of relative vorticity at 850 hPa (shaded, 10^5 s^{-1}) for a) ERA-Interim, b) MME and (c) – (j) are different models APCC, MSC, MSC_CANCM3, MSC_CANCM4, NASA, NCEP, PNU, POAMA and (k) time series of PC1.

- Precipitation anomalies showed significantly positive correlation over the Maritime Continent and southern parts of India. Enhanced convection in southern peninsular India is due to the response of deep convection over the Maritime continent through northwestward propagation of warm Rossby waves. Enhanced deep convection over the Maritime Continent is associated with tropical WNP anomalous anticyclone as a part of the PJ pattern.
- In conjugation with this, the east-west circulation (zonal and vertical) cell with ascending motion corroborated by low level convergence and upper level divergence over the Indian subcontinent and strong subsidence over WNP region indicates the influence of the PJ pattern on ISM rainfall.

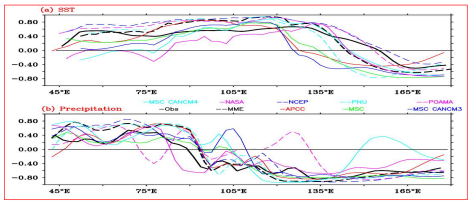


Relative vorticity PC1 regression with Precipitation for ensemble mean and inter-member variability

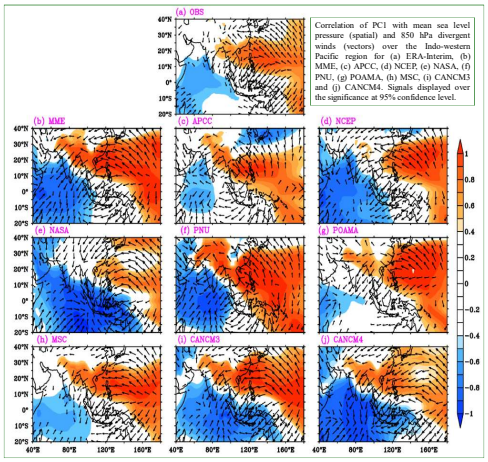
Data: The Asia-Pacific Economic Cooperation (APEC) Climate Center (APCC) has provided the retrospective forecasts (hindcasts) based on eight independent models which are initialized with one month lead for the calendar months from January to December (Lee et al. 2011; Jeong et al. 2012; Sohn et al. 2012; Min et al. 2014). The APCC upgraded its prediction line of monthly and seasonal mean forecasts to upcoming 6 months. The simple average of all independent models gives the multi model ensemble mean (MME). The common hindcast period from 1983-2010 is considered for detailed analysis. All selected coupled models are initialized from May month which yield 1-month lead seasonal forecast for boreal summer season JJA. The skill of MME basically originates from the models ability to capture the predictable modes.



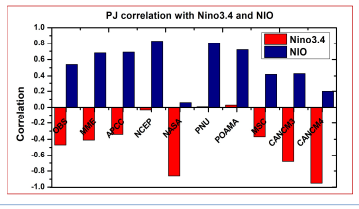
Correlation of PC1 with SST (shaded) and 850 hPa winds (vectors) for (a) ERSST/ERA-Interim, (b) MME, (c) APCC, (d) NCEP, (e) NASA, (f) PNU, (g) POAMA, (h) MSC, (i) CANCM3 and (j) CANCM4. Signals are displayed over the significance at 95% confidence level.



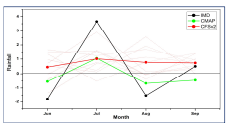
Longitudinal correlation coefficient of a SST (average of latitude 5 – 15°N; °C) for observation, MME and individual models, b same as a but for precipitation (average of latitude 10 – 20°N; mm/day).



- ✓ Low level convergence centre over the South Asian monsoon region is seen mainly over the southern tip of India and Sri Lanka and central Arabian Sea along with negative SLP anomalies in the observations, which clearly supports positive rainfall anomalies over these regions.
- ✓ Another convergence centre is also present over the Maritime Continent. Models like APCC and NCEP and MME are able to predict convergence zone and negative SLP anomalies over the southern tip of India and over Sri Lanka and central Arabian Sea closer to the observations, which is consistent with rainfall patterns as well.

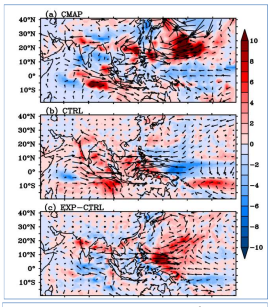


Correlation between WNP 850hPa vorticity PC1 (the PJ Pattern and Niño 3.4 (red bars) and North Indian Ocean SST anomalies (blue bars).



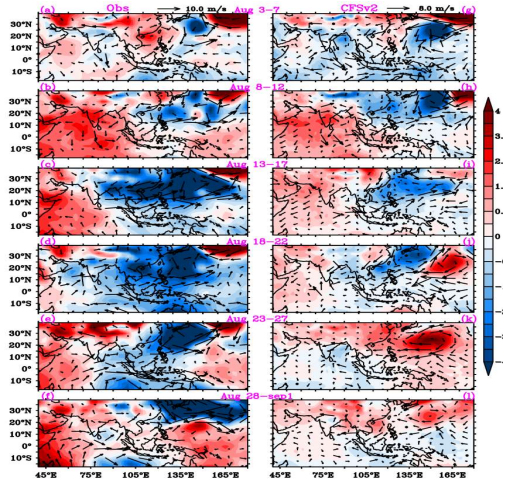
Plumes of predicted precipitation (mm day^{-1}) for summer 2016 over the Indian subcontinent based on CFSv2 (May initial conditions) individual ensembles (red dashed lines), ensemble mean (thick red line), IMD gridded rainfall (thick black line) and CMAP precipitation data (thick green line).

The CFSv2 based prediction during summer 2016, initialized in May, showed above normal monsoon in all months unlike in the observations. This suggests that the model display poor skill in representing month-to-month fluctuations in ISM rainfall during 2016.



Anomalies of precipitation (shaded; mm day^{-1}) and winds at 850 hPa level (vectors; m s^{-1}) in August: a) observed precipitation, b) CFSv2 control run (CTL), c) the difference between CFSv2 experiment (EXP) and control run (CTL).

Using coupled climate model experiments, it is shown that reduced rainfall over India during August 2016 is mainly due to enhanced convective activities over the WNP region. This supports our hypothesis that the variations in WNP convective activities/number of TCs could influence month-to-month ISM rainfall.



Five- days average (pentad) anomalies from 3rd August 2016 SLP (shaded, hPa) and 850 hPa winds (vectors, m/s) for (a)-(f) observations and (g)-(l) CFSv2 hindcast initiated from last three days of July (29th, 30th and 31st) and first two days of August (1st and 2nd). Chowdary et al. 2018.

Anomalous circulation pattern over the WNP region during August 2016 is reasonably well predicted in short-lead time upto two pentads but the model skill is gradually decreasing as lead increases.

Summary

- Discrepancy in representing the PJ pattern teleconnections to South Asia region in the models like NASA, MSC, CANCM3, CANCM4, PNU and POAMA is due to the misrepresentation of low level convergence (divergence) zones over the tropical Indian Ocean (Pacific Ocean).
- Shift in the circulation pattern is highly influenced by dominant negative SST anomalies over the equatorial Pacific during the PJ years in NASA, MSC, CANCM3 and CANCM4 models. In case of PNU and POAMA the spatial patterns of tropical Indian Ocean SST associated with the PJ pattern are partly responsible for the shift in the convection centres.
- Therefore, this study indicates that the disorganized large scale circulation patterns in some models is responsible for the misrepresentation of South Asian rainfall associated with PJ pattern teleconnections.
- Further, improvement in the predictability of western Pacific circulation would help to enhance the model skill in representing month-to-month fluctuations of ISM rainfall. The implications of these findings are particularly important for understanding the month-to-month fluctuations associated with ISM rainfall.

Srinivas, G., J. S. Chowdary, Y. Kosaka, C. Gnanaseelan, A. Parekh, and K.V. Prasad, 2018: Influence of the Pacific–Japan Pattern on Indian Summer Monsoon Rainfall. *Journal of Climate*, 31, 3943–3958, https://doi.org/10.1175/JCLI-D-17-0408.1

Chowdary J. S, G. Srinivas, Yan Du, K. Gopinath, C. Gnanaseelan, A. Parekh and P Singh 2018, Month-to-month variability of Indian summer monsoon rainfall in 2016: Role of the Indo-Pacific climatic conditions, *Climate Dynamics*, doi: 10.1007/s00382-018-4185-4, published online.

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