Predictability of sub-seasonal low level circulation and rainfall associated with Indian summer monsoon in a coupled model

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Introduction

- **Lower tropospheric circulation associated with summer monsoon has strong impact on rainfall over the Indian Subcontinent (Joseph and Raman 1966; Findlater 1969).**

- **The large thermal gradients between the Asian landmass and surrounding oceans and Coriolis force causes for formation of strong the Low Level Jet (LLJ at 850 hPa level) over the Arabian Sea (Hoskins and Rodwell 1995; Boos and Emanuel, 2009).**

- **Strong cross equatorial (LLJ) flow from the Southern Indian Ocean to Arabian Sea and Bay of Bengal is very important component of summer monsoon season (ISM) system (Krishnamurti et al. 1976).**

- **The LLJ play important role in transporting moisture from southern Indian Ocean- Arabian Sea to Indian subcontinent (Pushpanjali et al. 2014).**

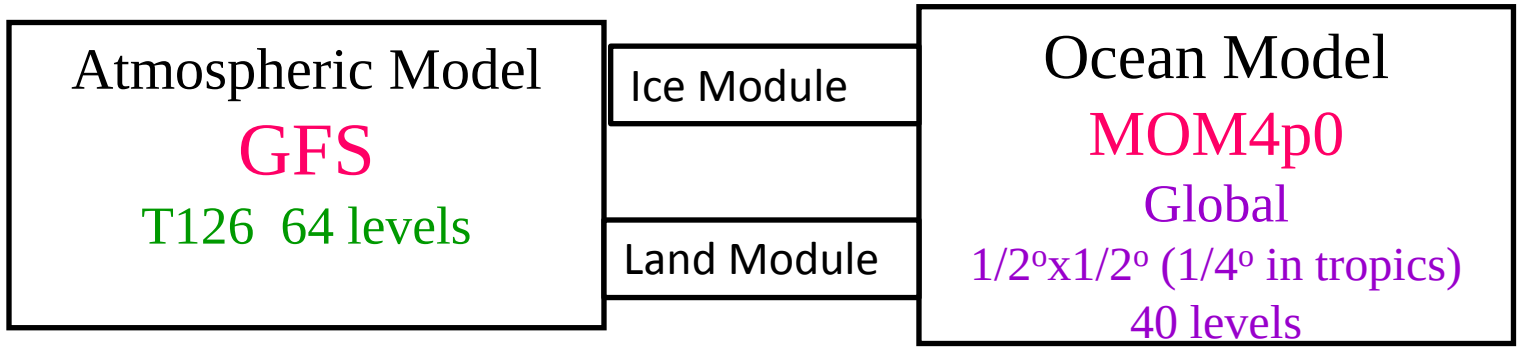
- **For decades a number of studies on interannual and intra-seasonal variability of monsoon low level circulation are carried out** (e.g., Joseph and Raman 1966; Findlater 1969; Joseph and Sijikumar 2004; Joseph et al. 2013; Krishnamurthy and Kinter 2003; Webster et al. 1998; Kripalani and Kulkarni 1999; Wang et al. 2001; Chowdary et al., 2006; Boschat et al. 2011; B. Pushpanjali et al. 2014).

- **This all suggests the importance of understanding and predicting variability of LLJ and its relation with rainfall.**

- **Previous studies have not examined sub-seasonal prediction skill of LLJ in coupled models.**
- **This study focused on sub-seasonal prediction skill (monthly) of ISM circulation along with seasonal mean in a coupled model.**

Model used in the present study is National Centers for Environmental Prediction (NCEP) Climate Forecast System version2 (CFSv2) (Saha et al 2014).

Hindcast for the period of 1982-2009 (ensemble mean; 13) is used.



- **ECMWF Reanalysis Dataset(ERA Interim) Monthly Mean Data for winds (850 hPa), mean sea level pressure (1° X 1°)**

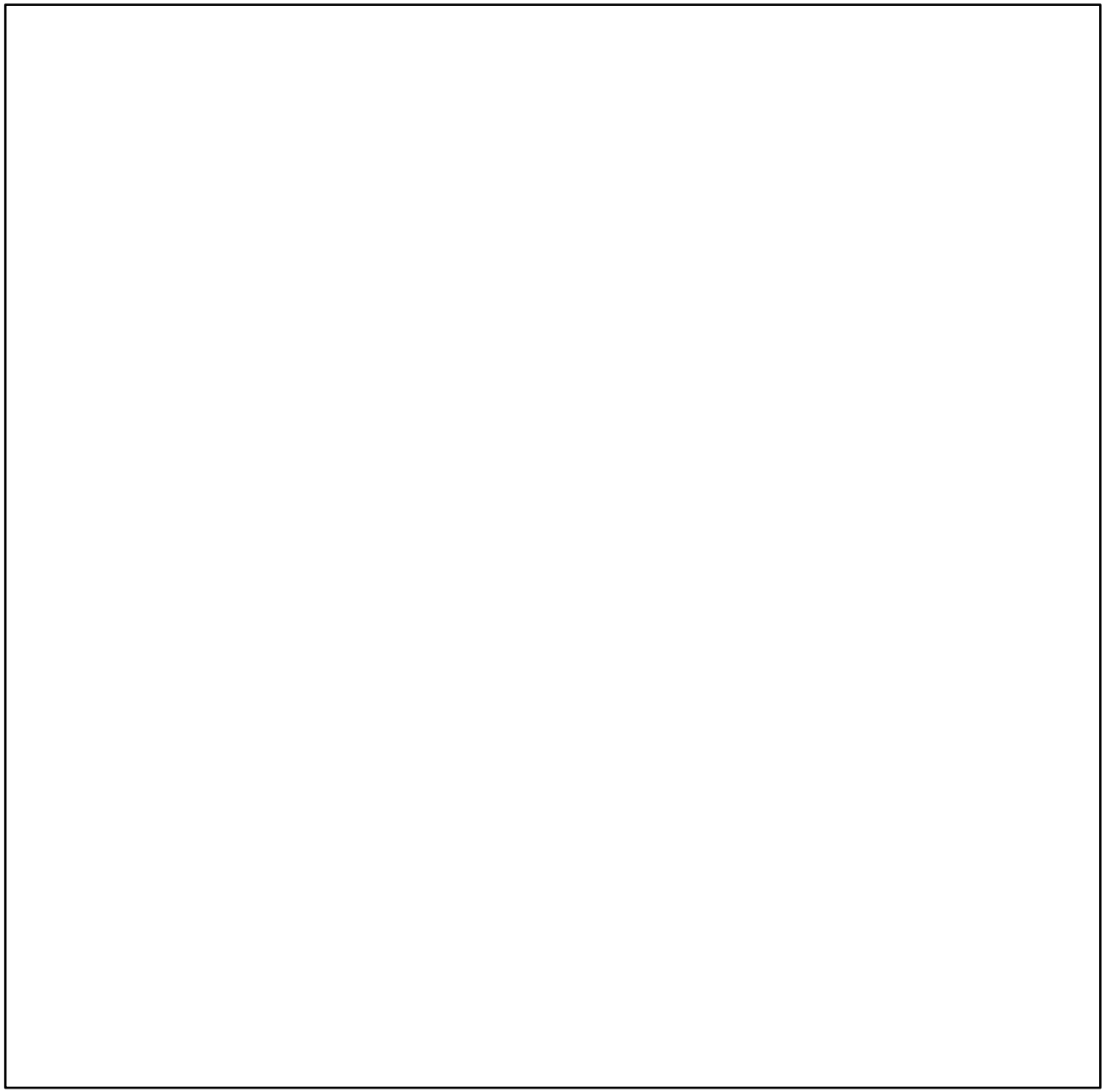
  (Dee et al., 2000)
- **CPC merged analysis of precipitation (CMAP) data for rainfall (2.5° X 2.5°)**

  (CMAP– Xie and Arkin, 1996).
- **NOAA Optimum Interpolation Data for SST (1° X 1°)**

  (Reynolds et al., 2002).
- **Data is de-trended in order to remove any secular warming trend.**

Observation

Model (May IC)



Observed and CFSv2 (May IC) 850hPa wind and precipitation climatology for (a) JJAS, (b) June, (c) July, (d) August, and (e) September.

- **The Southwesterlies associated with LLJ is extended to central India by July & persisted in August in both observation & model.**

- **Over all the model is able to represent monsoon circulation well in all summer months (May ICs).**

JJAS

June

July

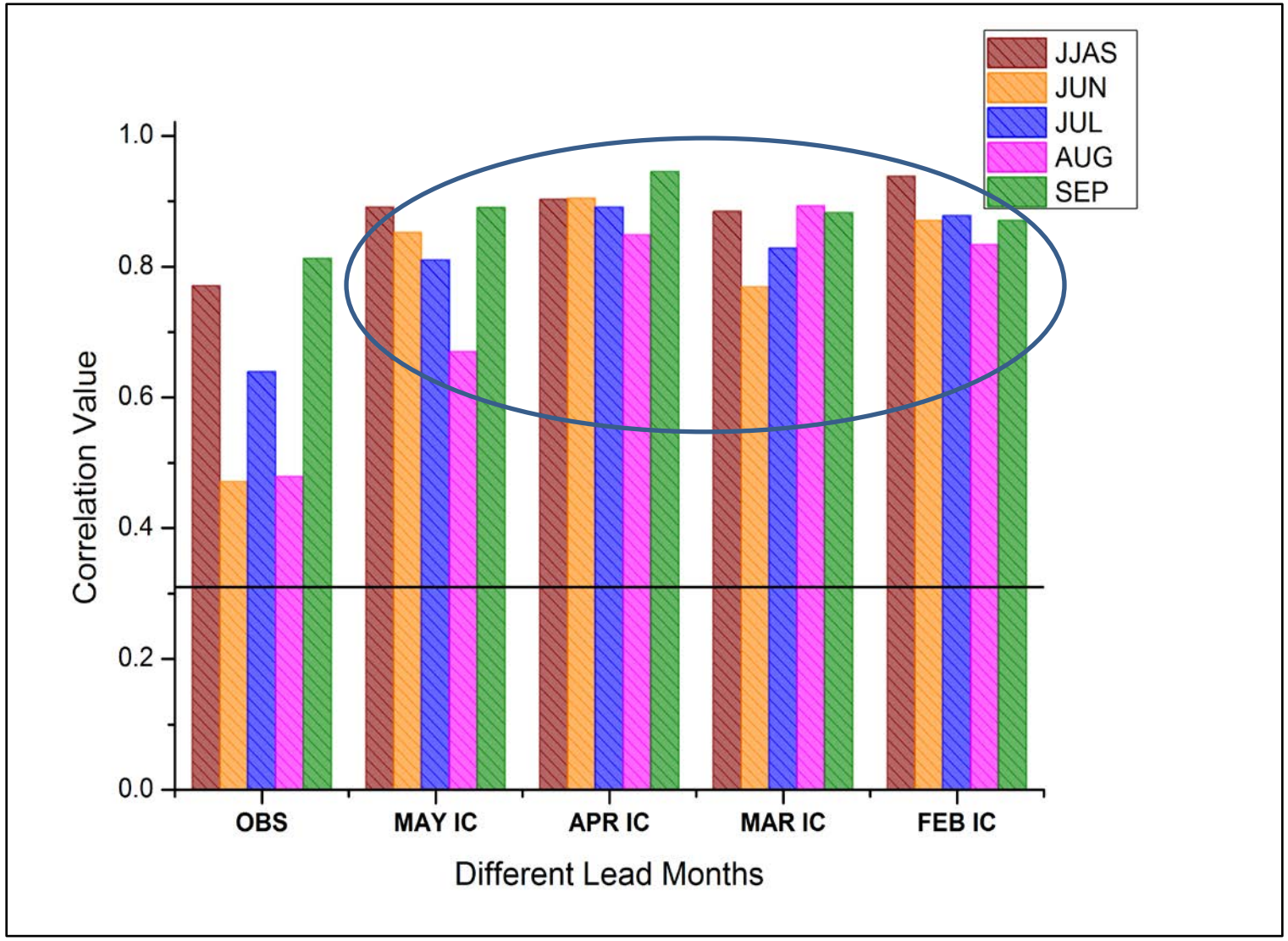
Aug

Sep

Time series of ISM low level circulation index (IMC) for CFSv2 (May IC) and observations during all summer months.

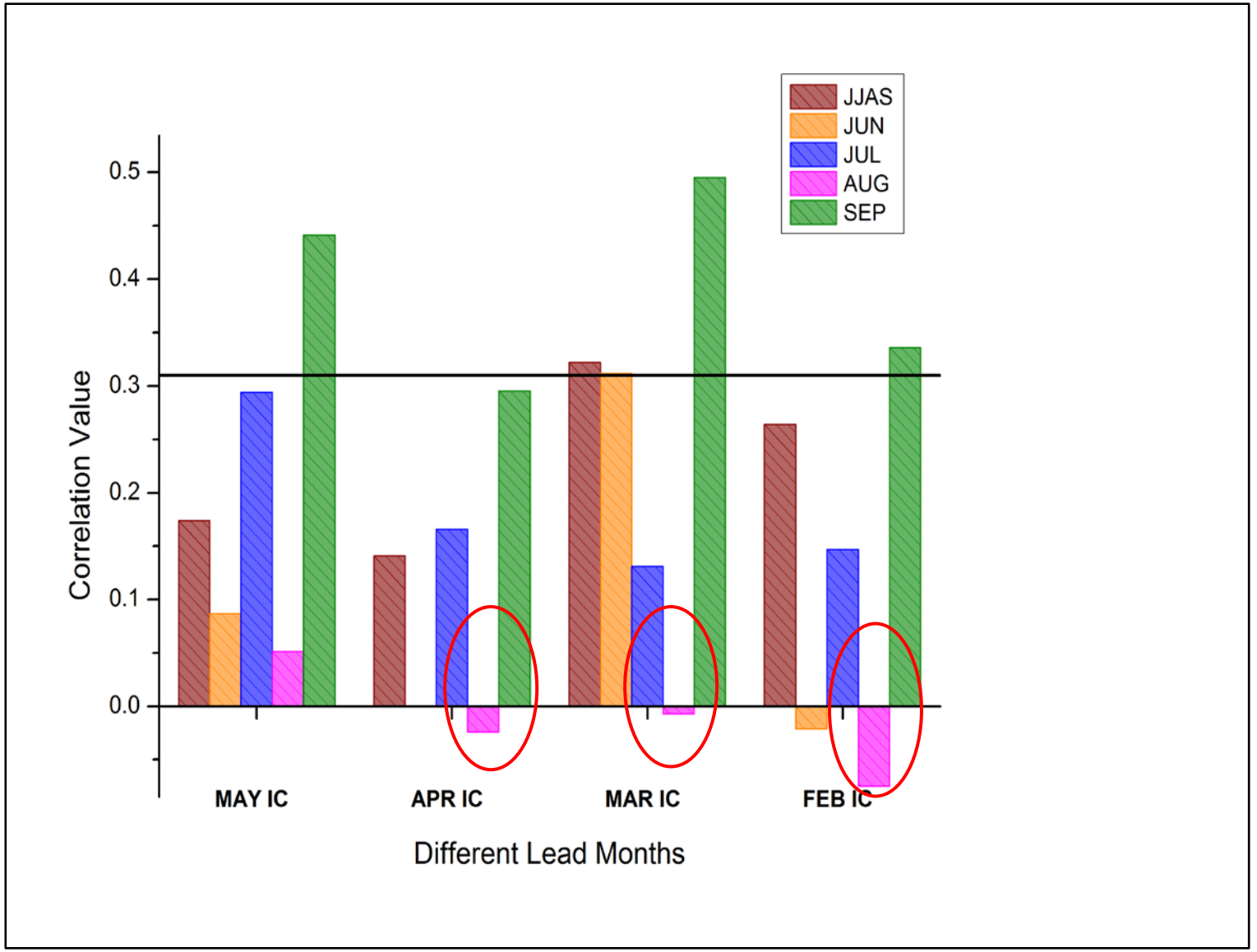
- **This dynamic index defined as [850 hPa (5°N-15°N, 40°E-80°E minus 20°N-30°N, 70°E-90°E)]. [Wang et al.(2001)].**
- **Standard deviation of IMC index suggests the clear existence of interannual variability in low level winds.**
- **This motivated to us examine the relation between rainfall over India land region and LLJ variations.**

Correlation between IMC index and Monsoon core rainfall index for observation and model 1 to 4 month lead.



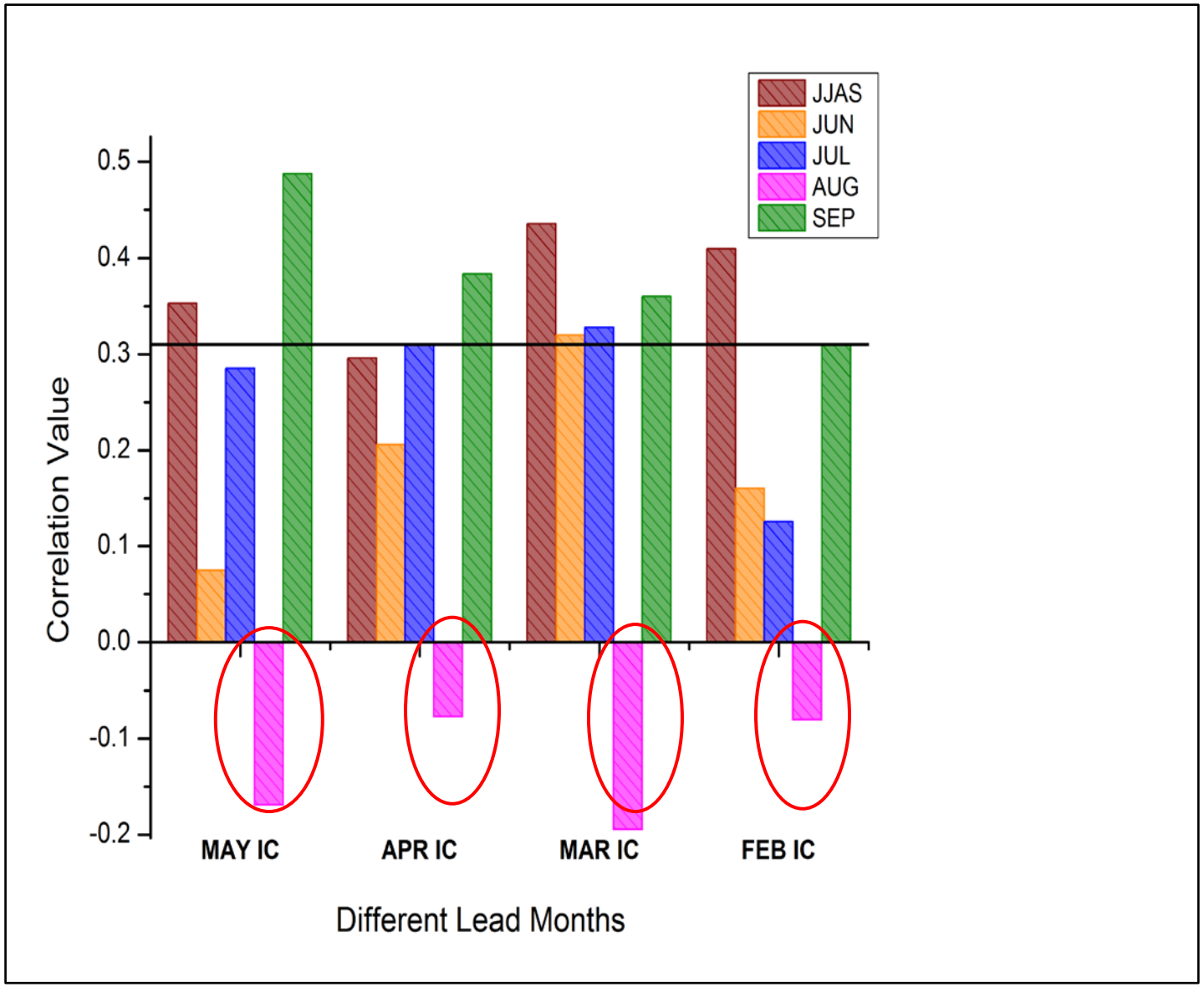
- **Monsoon core rainfall index (18°N-28°N to 65°E-88°E). [Rajeevan et al.(2010).**
- **Correlation is highly significant for Model May to Feb ICs.**
- **Result showed that there is strong relation between circulation and rainfall over India in the interannual time scale in both observations and model at different lead months.**

Model skills at different lead months in predicting central India or monsoon core rainfall.



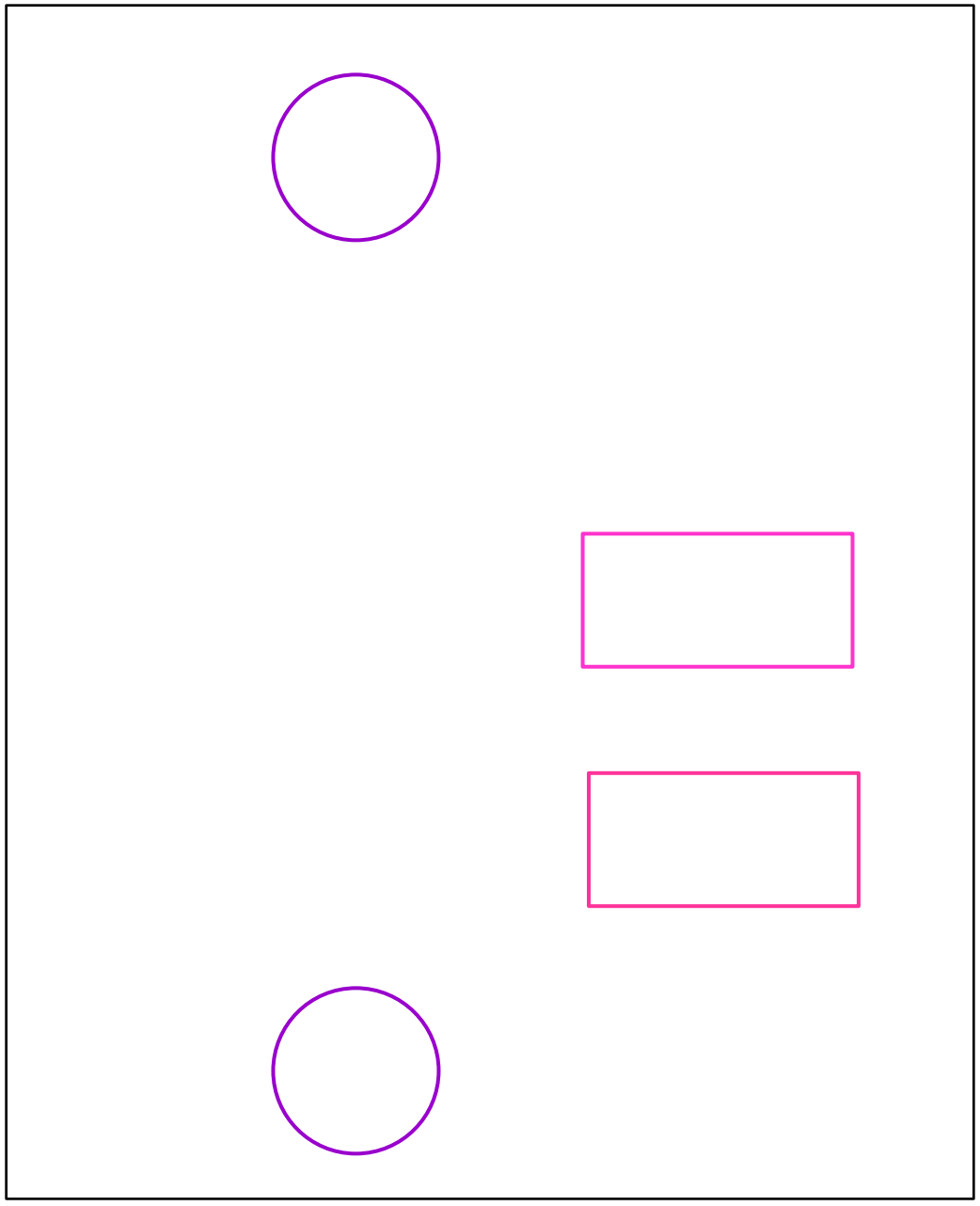
- Model display some significant (0.31) skill only at (March ICs) for JJAS & June.
- Model has weak skill in predicting August rainfall .
- September rainfall skill of the model is higher.
- Over all, models show very poor skill in predicting rainfall most of summer months (except September) for shorter or longer lead months.

Model skills at different lead months in predicting IMC index



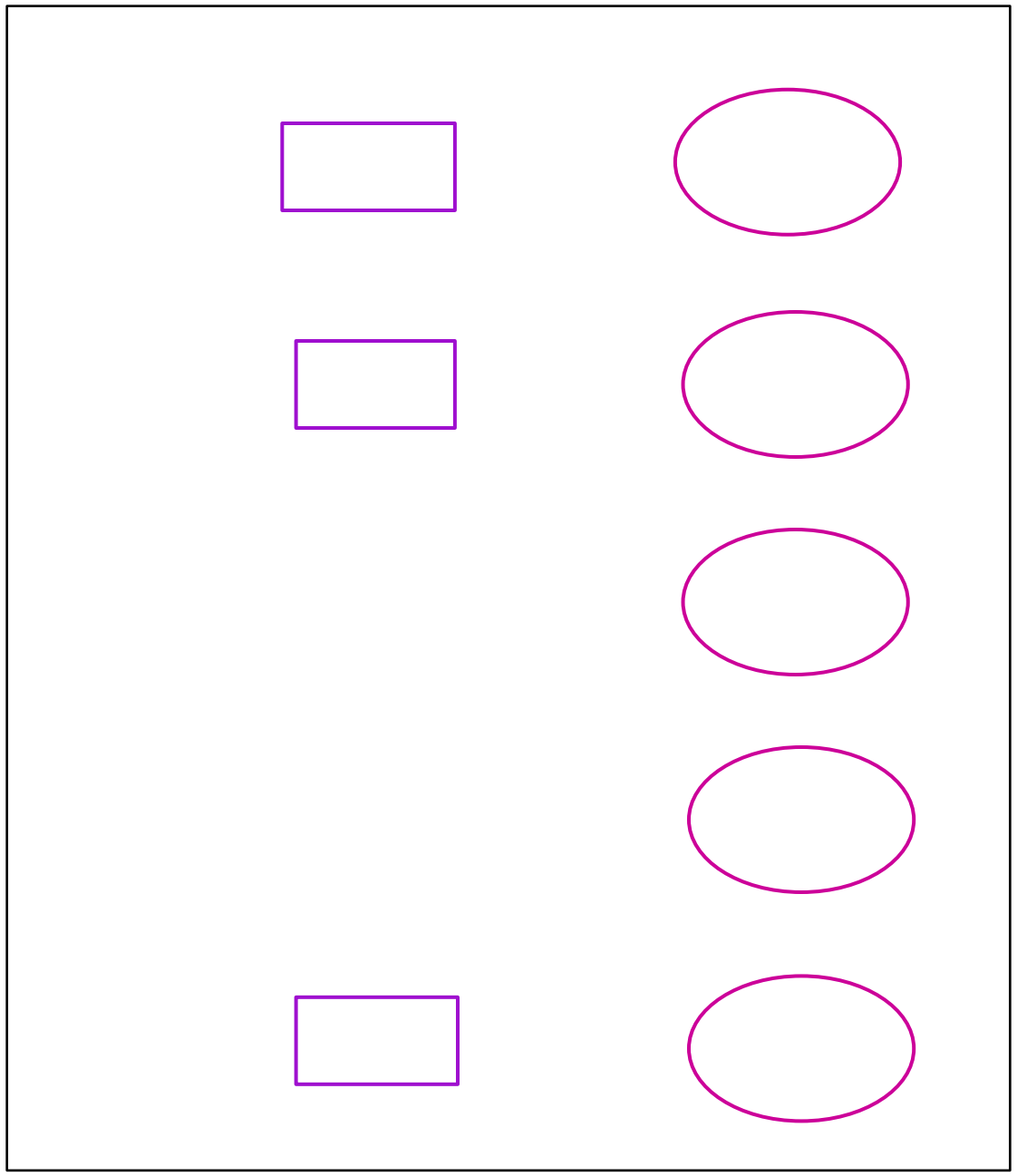
- **Model showed better prediction skill for JJAS & September at all lead months.**
- **Model skill during August is very poor or negative at all lead months.**
- **This analysis show that model skill in predicting LLJ variability is better than rainfall prediction over India (except August).**
- **Thus it is important examine why Model skill is low from June to August.**

Observation Model May ICs



Observed and CFSv2 (May IC) correlation of IMC index with SST and regressed 850hPa wind anomalies over the Indo-Pacific Ocean.

- From observation seasonal mean and September SSTs & wind over the central eastern Pacific are highly correlated with IMC index.
- CFSv2 showed strong correlation with SSTs & winds over the central and eastern Pacific in all summer months and seasonal mean.
- This analysis shows that the model ISM circulation changes in the interannual time scale is over depend on the ENSO.
- Thus strong relation between ISM circulation and ENSO in the model is mainly responsible for weak skill in predicating circulation.
- This indicates unrealistic ENSO- monsoon teleconnections in the model especially during July and August.

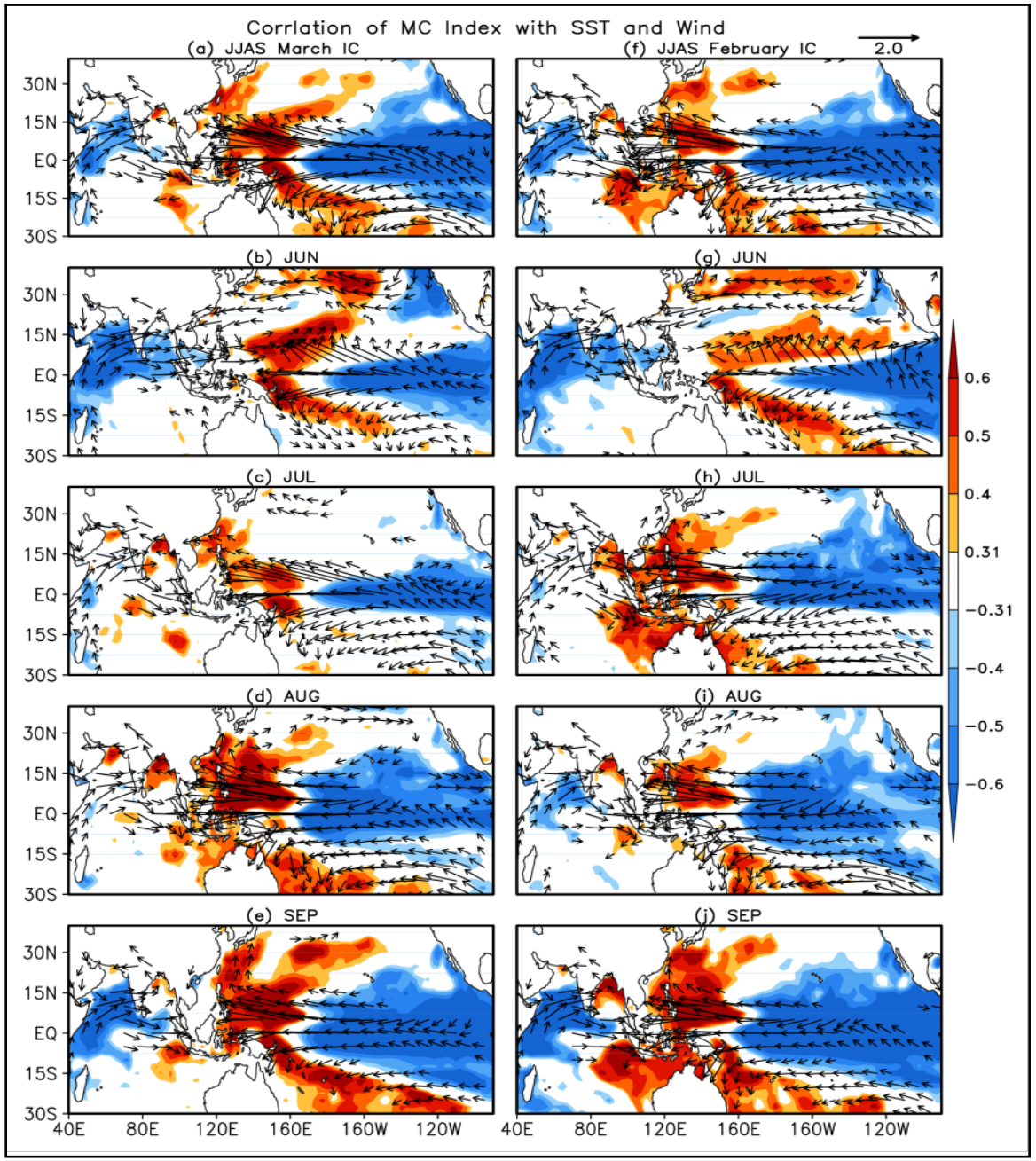


Observed and CFSv2 (May IC) correlation of IMC index with Rainfall and SLP over the Indo-Pacific Ocean.

- **In observation central & eastern Pacific displayed highly correlation during seasonal mean, June & September and weak correlation for July & August.**
- **The monsoon circulation is influenced by remote forcing mainly in June & September.**
- **In the observation very week correlation over the central & eastern Pacific SLP with IMC index.**
- **In CFSv2 central & eastern Pacific rainfall and SLP are highly correlated with IMC index.**
- **In model ISM circulation is over dependent on ENSO throughout the season.**

March IC

February IC

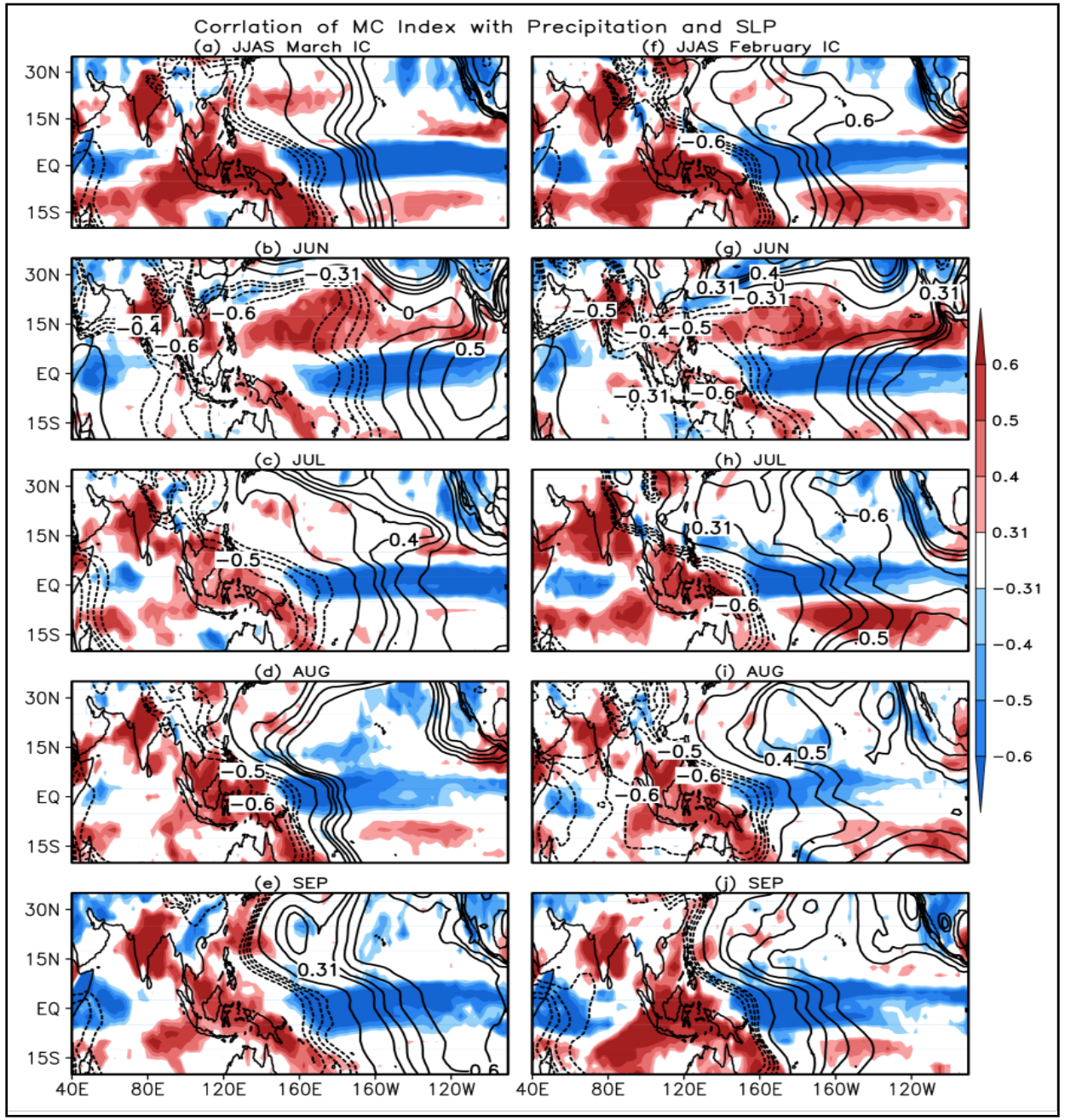


Correlation of IMC index with SST and regressed 850hPa wind anomalies for March IC and February IC model prediction.

- **It is similar to May IC IMC index is highly correlated with central and eastern equatorial Pacific SST anomalies in summer months and for seasonal mean.**
- **Strong easterly winds anomalies over the ENSO region are apparent in model long lead months when regressed with IMC index.**

March IC

February IC



Correlation of IMC index with Precipitation and SLP for 3 & 4-month lead model prediction.

- **Precipitation and SLP anomalies are significant negative and positive correlation is noted respectively in the east of date line around the equator.**

Summary

- Strong relationship between low level wind circulation and rainfall during ISM period is noted model.
- The model is able to represent the spatial distribution of LLJ circulation and rainfall over the ISM region for seasonal mean and individual months.
- Analysis of model clearly suggests that variation in monsoon LLJ is over dependent on ENSO.
- This unrealistic dependency of monsoon circulation of ENSO may lead to low prediction skill in ISM circulation and rainfall in the model.
- Even at long lead months, strong correlation between Monsoon Circulation and central Pacific SST is high.
- This is clearly suggesting that LLJ variability is strongly associated with ENSO in the model than in the observations.


Thank You