Role of Coupled Dynamics in Tropical Indian Ocean and Pacific Ocean on Indian Summer Monsoon Simulation and Prediction in CFSv2 Model

Gibies George, D Nagarjuna Rao, C.T. Sabeerali, S. Mahapatra, Ankur Srivastava, A. Suryachandra Rao
Program for Extended Range and Seasonal Prediction of Monsoon
Indian Institute of Tropical Meteorology

This study investigates the relative role of the Indian Ocean and Pacific Ocean coupled dynamics on the simulation and prediction of Indian summer monsoon rainfall using a set of carefully designed sensitivity experiments with CFSv2 coupled model. Some previous studies (Lau and Nath 2000) have highlighted the importance of coupled dynamics in the mean monsoon simulation; however, the present study is more focused on the importance of coupled dynamics on seasonal prediction of the monsoon. The prediction skill of the model sensitivity experiment (PSLAB), wherein the coupled dynamics in the tropical Pacific was decoupled, dropped to 0.05 from 0.5 in the control experiment.As a result of cold SST bias in the tropical Indian Ocean, the seasonal mean rainfall over the Indian landmass is underestimated in the CFSv2 control (CTL) run. Simulated weak monsoon results in simulating westerly wind core associated with AISMR located along the equator while in observation there is clear cross equatorial flow. This is because the tropospheric temperature gradient in CFSv2 CTL run is not strong enough to drive the cross equatorial flow. Once we reduce the cold SST bias in the northern tropical Indian Ocean (by artificially suppressing Indian Ocean coupled dynamics), the magnitude of rainfall over the Indian landmass is enhanced. The regressed wind correctly simulates the cross equatorial flow in absence of Indian Ocean coupled dynamics. However, the prediction skill of AISMR has slightly reduced (from 0.5 to 0.3) in the absence of Indian Ocean coupled dynamics.

Sensitivity experiments have clearly highlighted that the prediction skill of All India Summer Monsoon Rainfall (AISMR) in CFSv2 is basically coming from the ENSO-monsoon relationship in the model and it is reasonably captured. Further, it is noticed that the cold SST bias in the tropical Indian Ocean is to be minimized to improve the magnitude of the AISMR simulation, whereas the correct representation of Indian Ocean coupled dynamics is essential to improve the AISMR prediction skill. Therefore, this study highlights the need to improve the Indian Ocean coupled dynamics in CFSv2 for the further improvement of simulation and prediction skill of AISMR.

(Unit: Peta Watt)		**Q net**	**Lateral Heat Trans.**	**Net Heat**	**Mean SST (ºC)**
Arabian Sea	**Observation**	0.35	-0.42	0.07	28.01
	CFSv2 CTL run	0.19	-0.67	-0.47	27.26
Bay of Bengal	**Observation**	0.15	-0.83	-0.68	28.80
	CFSv2 CTL run	0.04	-0.55	-0.51	28.56
Southern Tropical Indian Ocean	**Observation**	-0.51	1.86	1.34	25.36
	CFSv2 CTL Run	-1.49	1.19	-0.30	24.74

Table 1: Heat Budget for Tropical Indian Ocean (top 500m) averaged for June through September (JJAS).

In comparison to observation, model CTL run remove more (equal or slightly less) heat from the

Arabian Sea (Bay of Bengal) and hence cold (neutral) SST bias is observed in the Arabian Sea (Bay of Bengal). This clearly highlighted that coupled dynamics are not properly simulated and therefore results in strong cold bias.

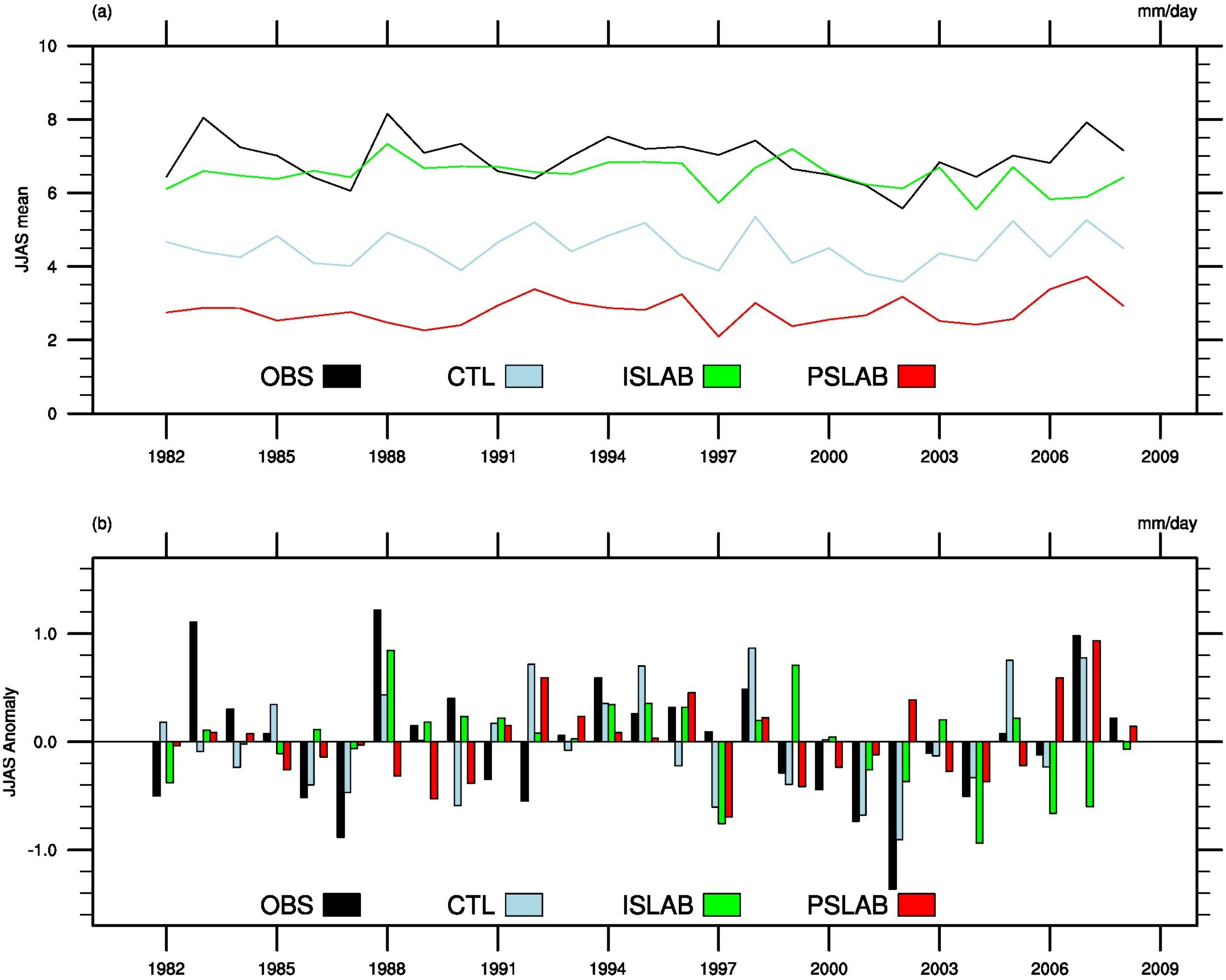

Fig 1:(a) Interannual variations of Indian summer monsoon rainfall for different CFSv2 run and observation, (b) same as (a) but the anomaly values are plotted.

The CFSv2 CTL is better in predicting the extreme rainfall events and hence, has anomalous correlation coefficient of 0.5 for AISMR. In spite of the reduced prediction skill (0.3), the ISLAB run is still able to predict the correct sign of the anomaly (even if magnitude varies) in most of the flood years (anomaly > 0.2mm/day; e.g. 1983, 1988, 1990, 1994, 1995, 1996, 1998). The associated Walker circulation anomaly (composite Walker circulations corresponding to flood years) in observations (figure not shown) show enhanced convection in the Indian region and enhanced subsidence over the Pacific Ocean. This La Nina like response in the observed Walker circulation is well represented in the ISLAB run (Figure not shown). Most of the strong monsoon years forced by La Nina condition are simulated better in ISLAB run compared to the CTL run. This indicate that with a slab in the Indian Ocean, the teleconnection of Pacific are better captured compared to the CTL run. ISLAB run predicted correct phase of AISMR anomaly in half of the drought years (anomaly < -0.2mm/day; 1982, 1987, 2001, 2002, 2004).

On the other hand, the drop in the AISMR prediction skill in ISLAB run is mainly due to its failure inpredicting the phase of the AISMR anomaly in half of the drought years (1986, 1991, 1992, 1999, 2000). Among these 1986 and 1999 (negative IOD years) are correctly predicted in CTL run, while 1991, 1992 and 2000 are common failure for all the runs. There are three flood years (1984, 2007, and 2008) which ISLAB run failed to predict the correct phase (Out of three flood years 2007 and 2008 are positive dipole years). The AISMR phase of 2007 is successfully predicted in the CTL run. Both CTL and ISLAB runs predicted the right phase of the flood year 1994, but none of them captured exact magnitude of the AISMR anomaly. The anomalous correlation coefficient has dropped to 0.3 in ISLAB run which indicate that accurate Indian Ocean dynamics and coupled dynamics are essential for the seasonal prediction of AISMR. Hence, the improvement of Indian Ocean coupled dynamics in the CFSv2 is very important for reducing the Indian Ocean SST bias and thereby improving the prediction of extreme rainfall events. On the other hand, in PSLAB run the interannual variability is poorly captured, resulting in anomalous correlation coefficient of 0.05, suggesting that the ENSO-monsoon teleconnection is very important for the seasonal prediction of AISMR in the model.

The present study highlights the role of coupled dynamics in reducing the model biases and improving prediction skill of AISMR. In addition to coupled dynamics, Saha et al. (2012) have suggested that reduction of snow cover over Eurasia will reduce the dry bias over the Indian landmass. Recently, Goswami et al. (2014) have shown that convective stratiform rainfall ratio is not adequately captured in the CFSv2 and hence, it is required to improve convective parameterization schemes in the model. Pokhrel et al. (2012) reported that there is enhanced evapouration in the model results in the cold SST bias. This study only highlights the importance of coupled dynamics in simulation and prediction of AISMR, without underestimating the importance of other parameters.

References

Goswami B.B., Deshpande M.S., Mukhopadhyay P., Saha Subodh K., Rao Suryachandra A., Murtugudde R., Goswami B.N. (2014) Simulation of monsoon intra seasonal variability in NCEP CFSv2 and its role on systematic bias. Clim Dyn 1-21. doi:10.1007/s00382-014-2089-5

Lau N-C and Nath MJ (2000) Impact of ENSO on the variability of the Asian–Australian monsoons as simulated in GCM experiments. *J. Clim* **13:**4287–4309.

Pokhrel S, Rahaman H, Parekh A, Saha SK, Dhakate A, Chaudhari HS, Gairola RM (2012)Evaporation-precipitation variability over Indian Ocean and its assessment in NCEP ClimateForecast System (CFSv2). Clim Dyn 39:2585-2608

Saha S, Moorthi S, Wu X, Wang J, Nadiga S et al (2013) The NCEP Climate Forecast System Version 2. J Clim 27:2185–2208. doi:10.1175/JCLI-D-12-00823.1

Saha SK, Pokhrel S, Chaudhari HS (2012) Influence of Eurasian snow on Indian summer monsoon in NCEP CFSv2 freerun. Clim Dyn 41(7-8):1801–1815. doi:10.1007/s00382-012-1617-4