Role of internal processes in maintaining boreal summer intraseasonal variability

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1 Introduction

The space-time evolution characteristics of the boreal summer intraseasonal (30-50 day) variability (BSISV) over the Asian summer monsoon region are more complex than its boreal winter counterpart, the Madden-Julian oscillation (MJO), since it also exhibits northward and northwestward propagating components near India and over the west Pacific, respectively. Here, the hypothesis that internal processes, namely the interaction between moist physics and equatorial waves plays an important role in BSISV characteristics, in particular the poleward propagation over India is tested from a suite of model simulations. Specifically, the relative role of local air-sea interaction versus internal processes in moistening the boundary layer ahead of convection is examined.

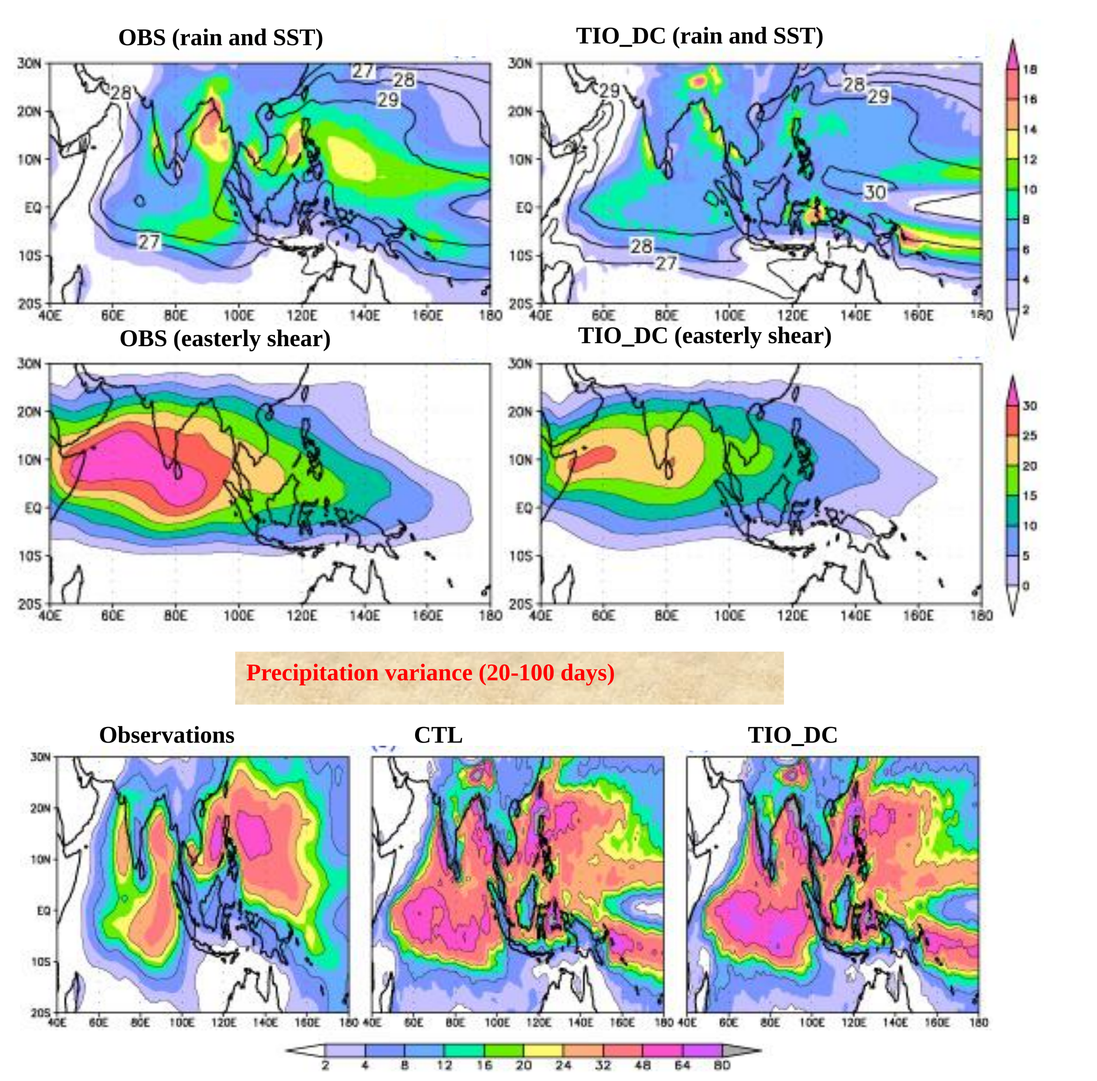

Figure 1: SINTEX coupled model precipitation (shaded) and SST (contour) climatology from tropical Indian Ocean decoupled (TIO_DC) runs. Results from observations are also shown. The basic state easterly shear is shown in the middle panel. Bottom panel corresponds to variance at intraseasonal time scales from observations, CTL and TIO_DC runs.

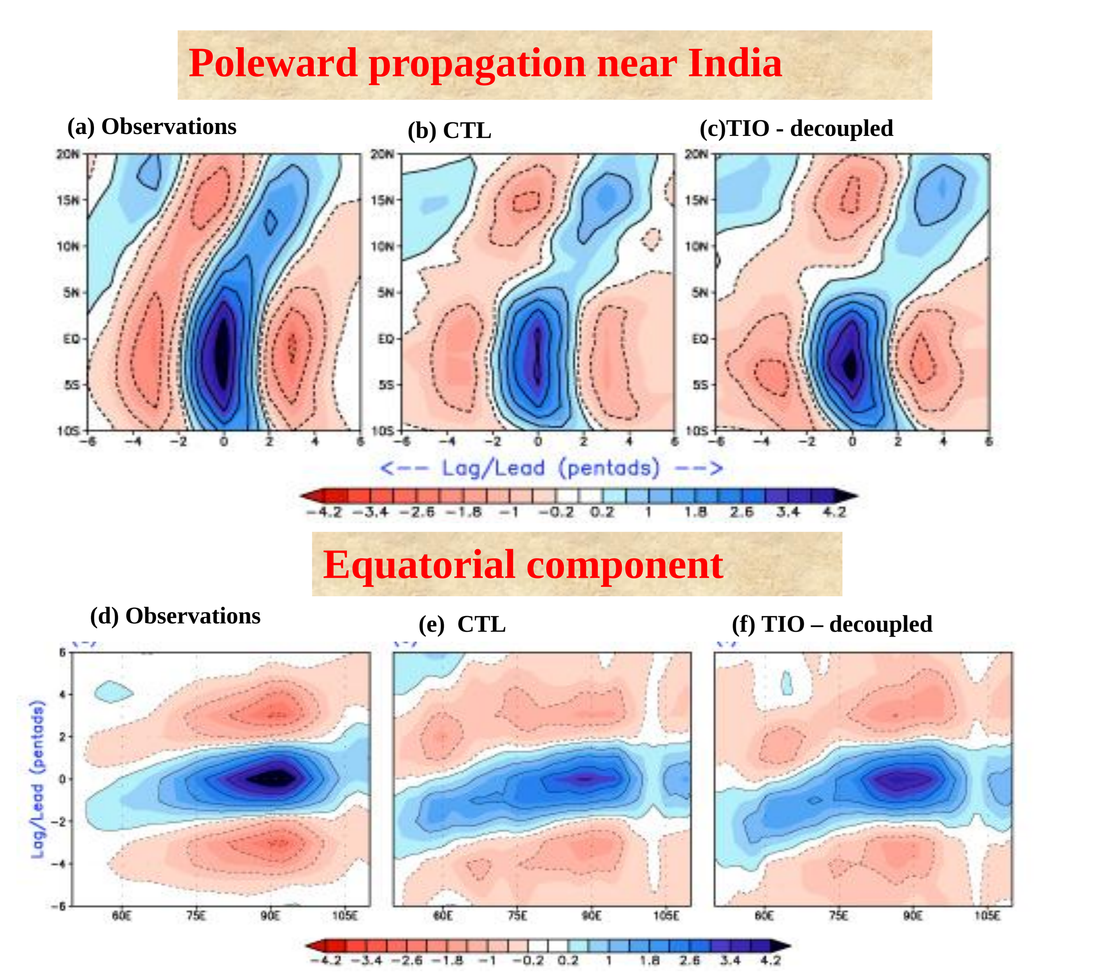

Figure 2: Lead-lag regression between equatorial Indian Ocean precipitation index versus precipitation anomalies: (top panel) latitude-time plot corresponds to poleward propagation of precipitation anomalies averaged over 80°-90°E; (bottom panel) longitude-time plot illustrating the equatorial propagation of precipitation anomalies averaged over 10°S-5°N

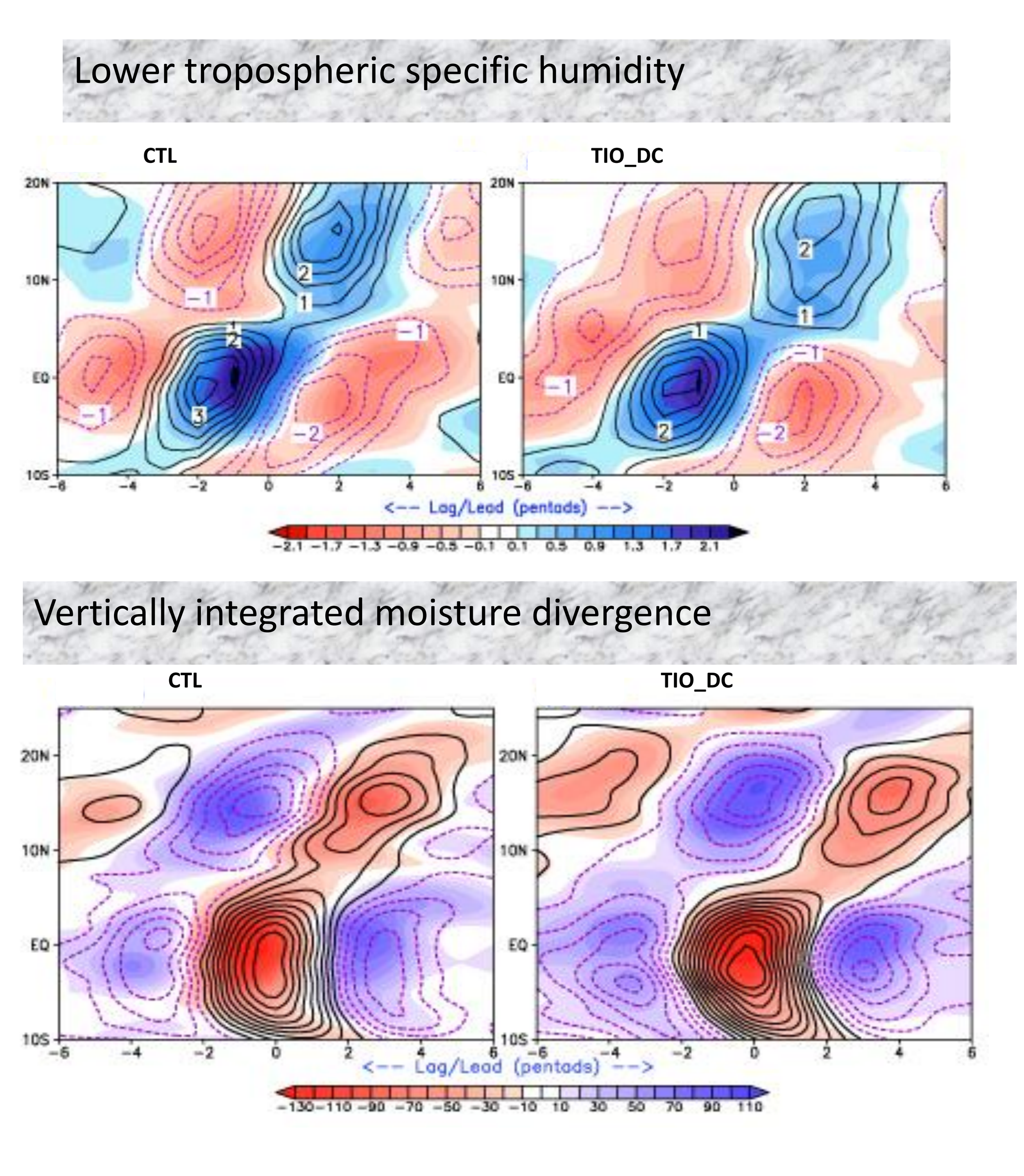

Figure 3: (top panel) Lead-lag regression between equatorial Indian Ocean precipitation index versus precipitation anomalies (shaded) averaged over 80°-90°E and lower tropospheric specific humidity (contours); (bottom panel) same as the top panel but vertically integrated moisture divergence are shown as contours, and precipitation in shaded (both in units of W/m²).

2 Diagnostics

In SINTEX model integrations, the sensitivity experiments are designed in such a manner to allow full coupling in specific ocean basins but forced by temporally varying monthly climatological sea surface temperature (SST) adopted from the fully coupled model control runs (CTL_RUN). In the sensitivity experiment, air-sea interaction only over the tropical Indian Ocean is not allowed (TIO_DC). Our diagnostics show that the basic state in precipitation, the zonal and meridional extent in easterly vertical shear and the magnitude of simulated intraseasonal variability in precipitation (**Fig. 1**) as well as the BSISO properties remain unchanged due to either inclusion or exclusion of local air-sea interaction. In particular, both the equatorial component (**Fig. 2, bottom**), and poleward propagation near India (**Fig. 2, top**) are evident in both simulations, and agree quite well with observations. Sperber and Annamalai (2008) noted that ECHAM family of coupled models outperforms other coupled models in capturing the BSISV. More detailed discussion on SINTEX results is available in Ajayamohan et al. (2010).

Next, the GFDL coupled model (CM2.1) simulations and integrations performed with its atmospheric component (AM2.1) but forced with monthly varying climatological SST are diagnosed to assess the role of air-sea interaction. Unlike in SINTEX, in the GFDL models (CM2.1 versus AM2.1) there are notable differences in the basic state in precipitation, zonal and meridional extent of easterly vertical shear and spatial distribution of precipitation variance at intraseasonal time scales (**Fig. 6**). An examination of BSISV (**Fig. 7**) shows that both the coupled (CM2.1) and uncoupled (AM2.1) simulations capture the equatorial and poleward components over the Indian sector. Some notable differences include eastward extension of the equatorial component into the western Pacific in AM2.1 (**Fig. 8, top left**), more coherent poleward migration over Bay of Bengal in CM2.1 (**Fig. 8, bottom left**) but over the Arabian Sea in AM2.1 (**Fig. 8, top right**). In the basic state, the lack of local precipitation maximum over the equatorial Indian Ocean in AM2.1 (Fig. 6) is consistent with results obtained from other uncoupled simulations (Waliser et al. 2003).

Nevertheless, both in SINTEX and GFDL simulations, equatorial and poleward components of BSISV exist whether local air-sea interaction is permitted or not. This allows us to examine processes other than local air-sea interaction in sustaining BSISV.

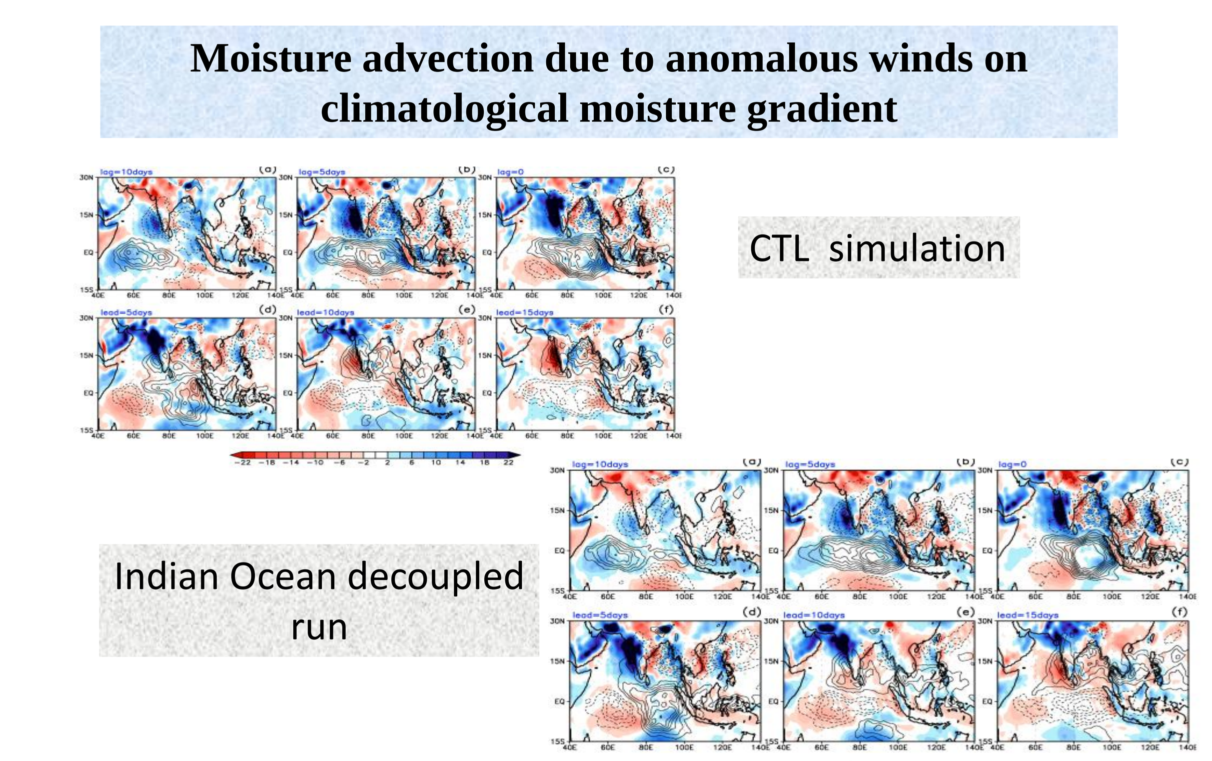

Figure 4: (top panel) Space-time evolution of lead-lag regression between equatorial Indian Ocean precipitation index versus precipitation anomalies (contours) and moisture advection due to anomalous winds on climatological moisture gradient (shaded) from SINTEX CTL run; (bottom panel) same as the top panel but from TIO_DC runs. All units in W/m²

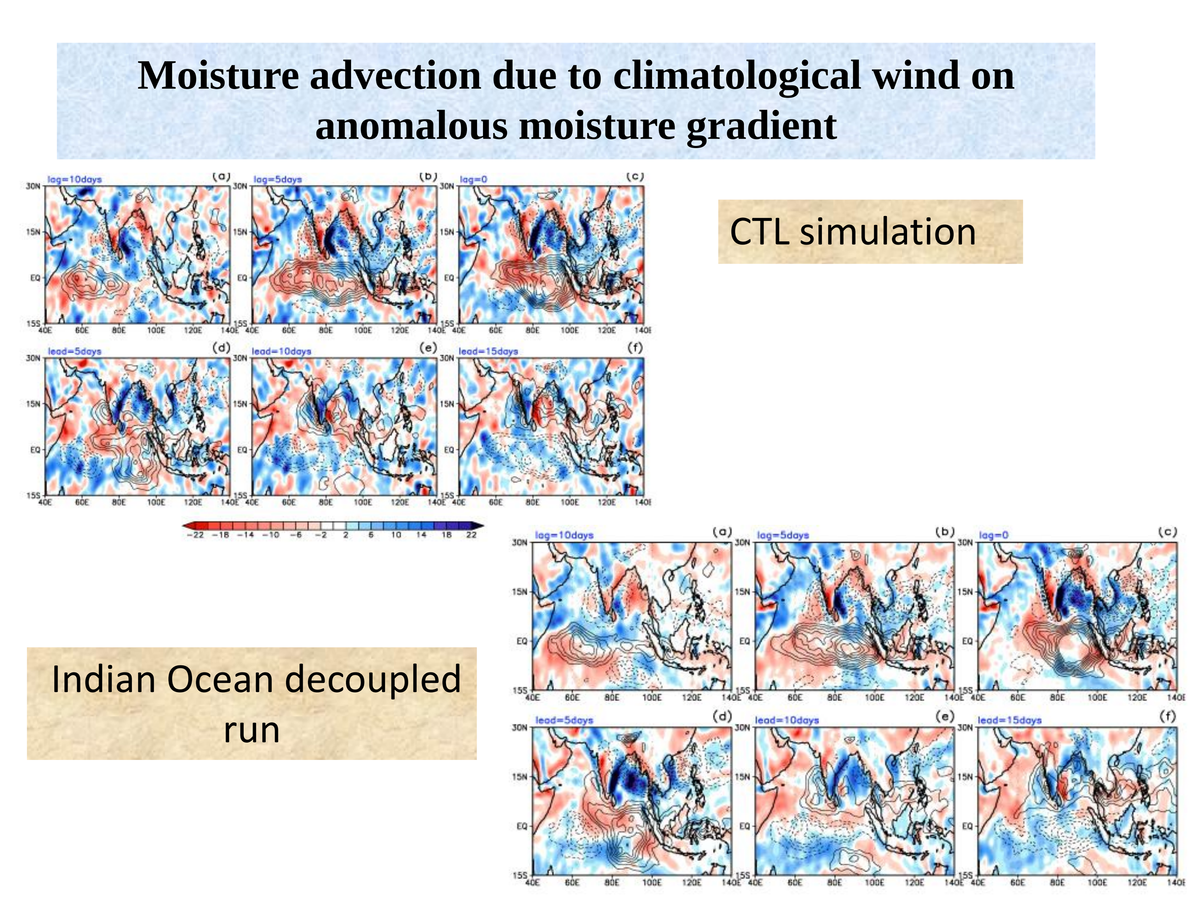

Figure 5: Same as Figure 4 but for moisture advection due to climatological wind on anomalous moisture gradient.

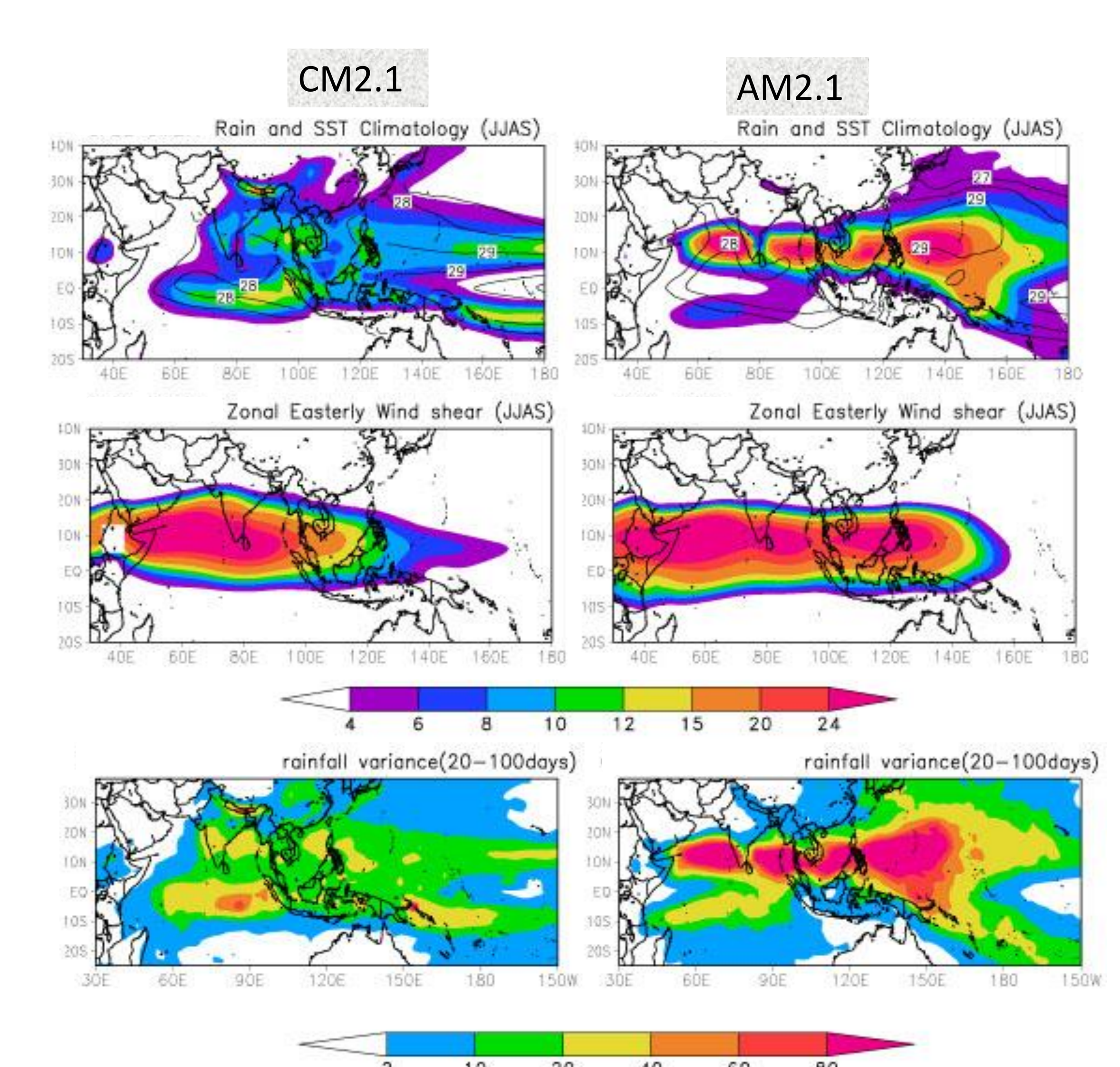

Figure 6: Same as Fig. 1 but for GFDL model simulations

3 Internal processes

Recent satellite observations indicate that boundary layer moisture leads the poleward propagating convection over the Indian sector (Tian et al. 2006). The lead-lag regression map between precipitation averaged over the equatorial Indian Ocean and lower tropospheric moisture (surface to 600 hPa) does suggest that moisture leads precipitation over Bay of Bengal (**Fig. 3, top panel**) in both CTL and TIO_DC runs of SINTEX. This motivated us to examine the moisture and moist static energy budgets (Annamalai 2010) to isolate the processes responsible for moisture leading the convection. Only the dominant budget terms are presented here.

For SINTEX simulations, the lead-lag regression between equatorial Indian Ocean precipitation index versus all leading budget terms are estimated. The vertically integrated moisture divergence anomalies (contours in **Fig. 3 bottom panel**) are superimposed with precipitation anomalies (shaded in **Fig. 3**). Note that positive values in moisture divergence correspond to net moisture convergence into the column. Similar results for GFDL integrations are shown in **Fig. 9**. Like noted earlier in observational and modeling studies (e.g., Wang 2005), in both model integrations anomalous moisture convergence does not lead precipitation anomalies over India.

In contrast, vertically integrated anomalous moisture advection (**Figs. 4, 5, and Fig. 9 bottom panel**) leads the precipitation anomalies in both models. A further examination suggests that both the anomalous wind acting on climatological moisture gradient (**Fig. 4**) and climatological wind acting on anomalous moisture gradient (**Fig. 5**) contribute to the total moisture advection.

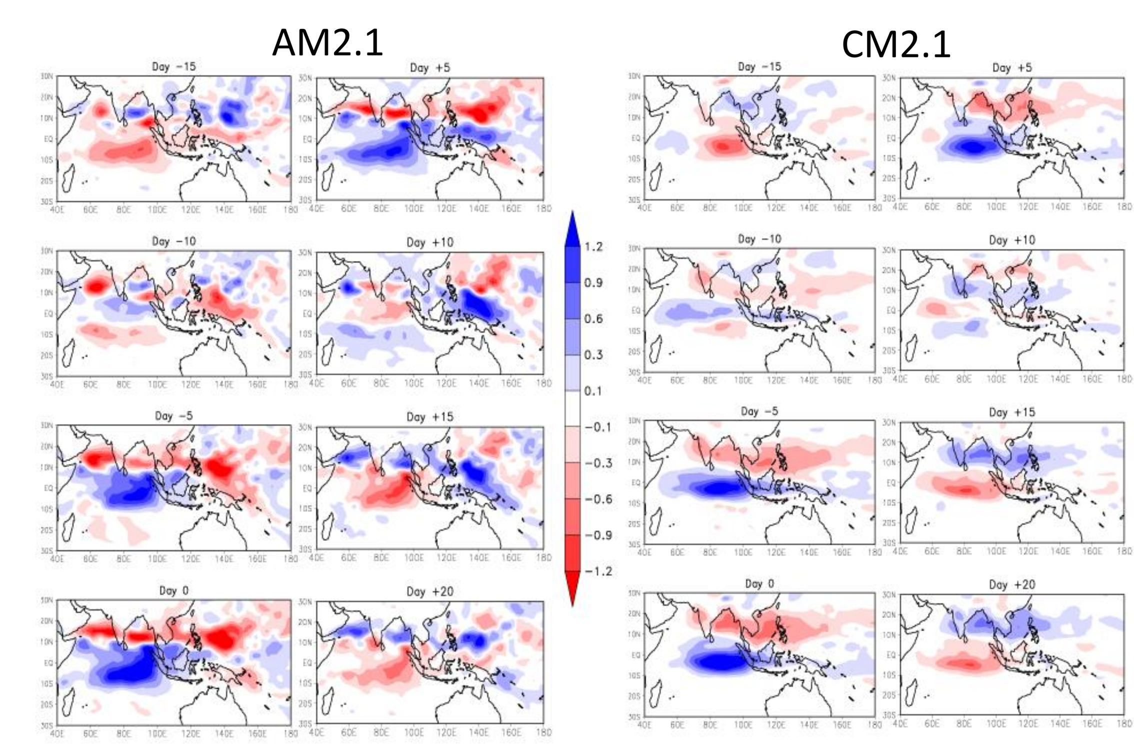

Figure 7: (left panel) Space-time evolution of lead-lag regression between equatorial Indian Ocean precipitation index versus precipitation anomalies from AM2.1 integrations; (right panel) same as the left panel but from CM2.1 integrations.

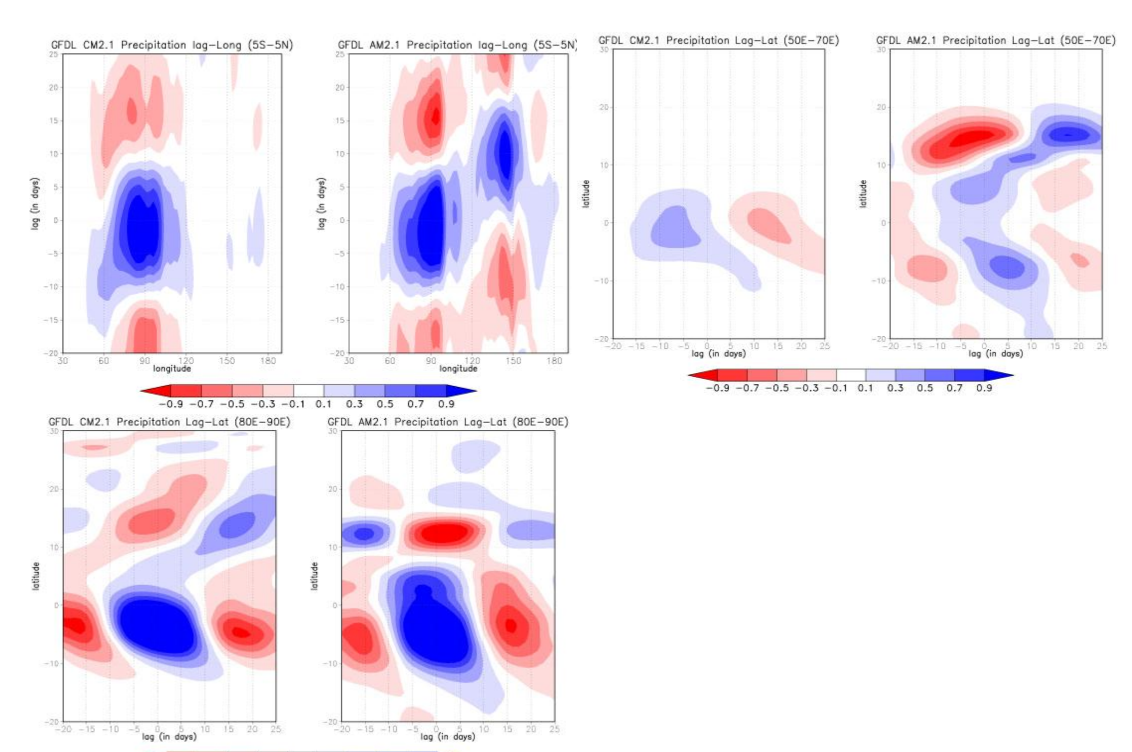

Figure 8: Lead-lag regression between equatorial Indian Ocean precipitation index versus precipitation anomalies: (top left panels) illustration of the equatorial component; (top right panels) illustration of poleward component over the Arabian Sea; (bottom left panels) illustration of poleward component over the Bay of Bengal.

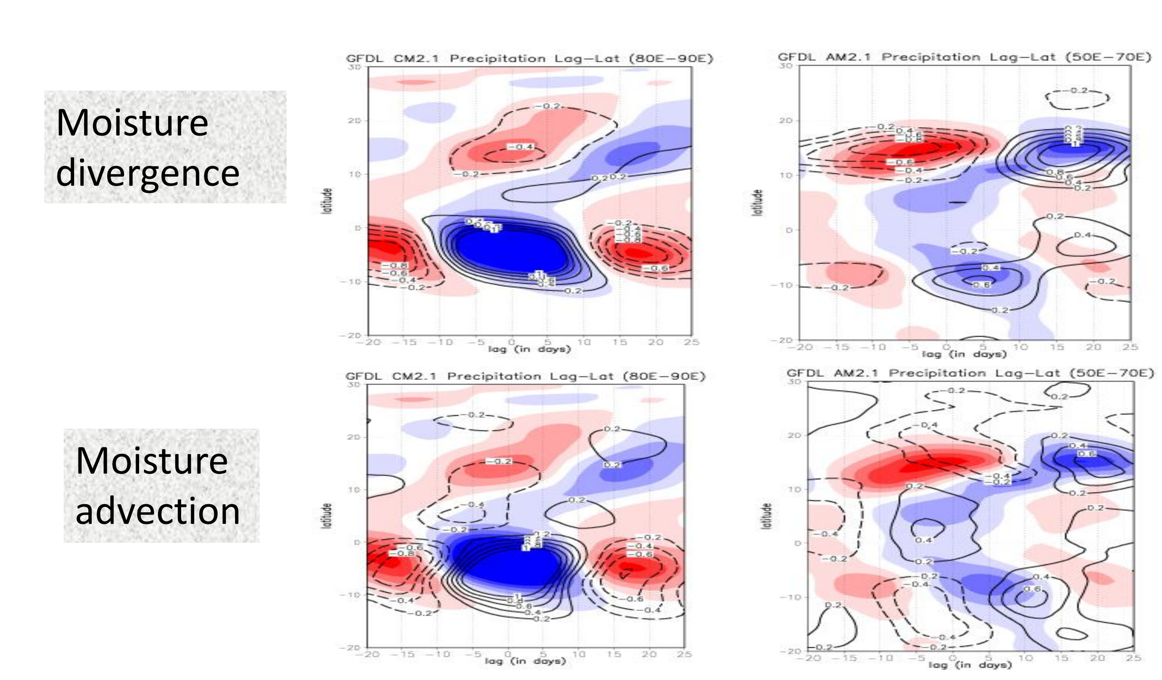

Figure 9: (top panel) Same as bottom panel of Figure 3 but for GFDL integrations; (bottom panel) same as top panel but for moisture advection (contours) and precipitation (shaded).

4 Summary

The results presented here confirm earlier suggestion that a realistic basic state, in particular the zonal and meridional extent of the vertical easterly shear (Wang 2005), and a proper representation of the equatorial component with sufficient intensity to force equatorial Rossby waves (Sperber and Annamalai 2008) are basic ingredients that models need to possess for a reasonable representation of the BSISV. In the present study, the identification of the role of basic state moisture and winds in the BSISV further emphasize the need for realistic simulation of the basic elements.

5 References

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