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Fidelity of the CMCC SPS model in simulating the dominant mode of tropical variability in boreal winter

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Objective and Background:

The capability of the fully coupled CMCC seasonal prediction system/model in simulating the dominant modes of variability at sub-seasonal to seasonal (S2S) time scales of the tropical atmosphere, with particular emphasis on the Madden-Julian oscillation (MJO) and the El Niño-Southern Oscillation (ENSO), is investigated.

As we know, the MJO is the dominant mode of intraseasonal variability (ISV; 30- to 90-day) in the tropical atmosphere and a major source of global predictability at the sub-seasonal time scale *(Madden and Julian 1971, 1972, 2005; Waliser 2009).*

Unlike a standing pattern like the ENSO, the MJO is an eastward propagation at a speed of about 5 $m\,s^{-1}$ of the large-scale disturbances along the equator from the western Indian Ocean to the western Pacific *(Waliser 2009).*

It affects the timing and evolution of the ENSO and the active and break episodes of the Asian-Australian monsoon, and the genesis and track of tropical cyclones are also affected by MJO *(Waliser 2009).*

Despite significant advances in state-of-the-art coupled models in recent decades, realistic simulation of the space-time and propagation characteristics of the MJO remains difficult.

Madden, R. A., & Julian, P. R. (1971). Detection of a 40–50 day oscillation in the zonal wind in the tropical Pacific. Journal of Atmospheric Sciences, 28(5), 702-708.
Madden, R. A., & Julian, P. R. (1972). Description of global-scale circulation cells in the tropics with a 40-50 day period. Journal of Atmospheric Sciences, 29(6), 1109-1123.
Madden, R. A., & Julian, P. R. (2005). Historical perspective. Intraseasonal Variability of the Atmosphere-Ocean Climate System, W. K. M. Lau and D. E. Waliser, Eds., Springer, 1-18.
Waliser, D., et al. (2009). MJO simulation diagnostics. Journal of Climate, 22(11), 3006-3030.

Methodology:

The multi-channel singular spectrum analysis (MSSA; *Ghil et al 2002; Plaut and Vautard 1994*) method is used to isolate the dominant modes associated with the tropical boreal winter daily OLR anomalies. [NOAA OLR has been used for model validation purposes]

By applying MSSA, we acquire eigenmodes with lagged maps of space-time EOFs (ST-EOFs) and space-time principal components (ST-PCs).

The part of the original time series corresponding to the each eigenmode can be reconstructed by combining the ST-PC and its respective ST-EOF in a least square sense, and is referred as the reconstructed component (RC).

The RCs can be considered as filtered time series and have the same spatial and temporal dimensions as the original field.

Basically, the MSSA over the daily data produces two types of modes:

(1) intra-seasonally oscillatory modes (2) non-oscillatory or persistent modes

The non-oscillatory modes are ‘persistent’ within the seasonal time period such that they remain with same sign anomalies during the season.

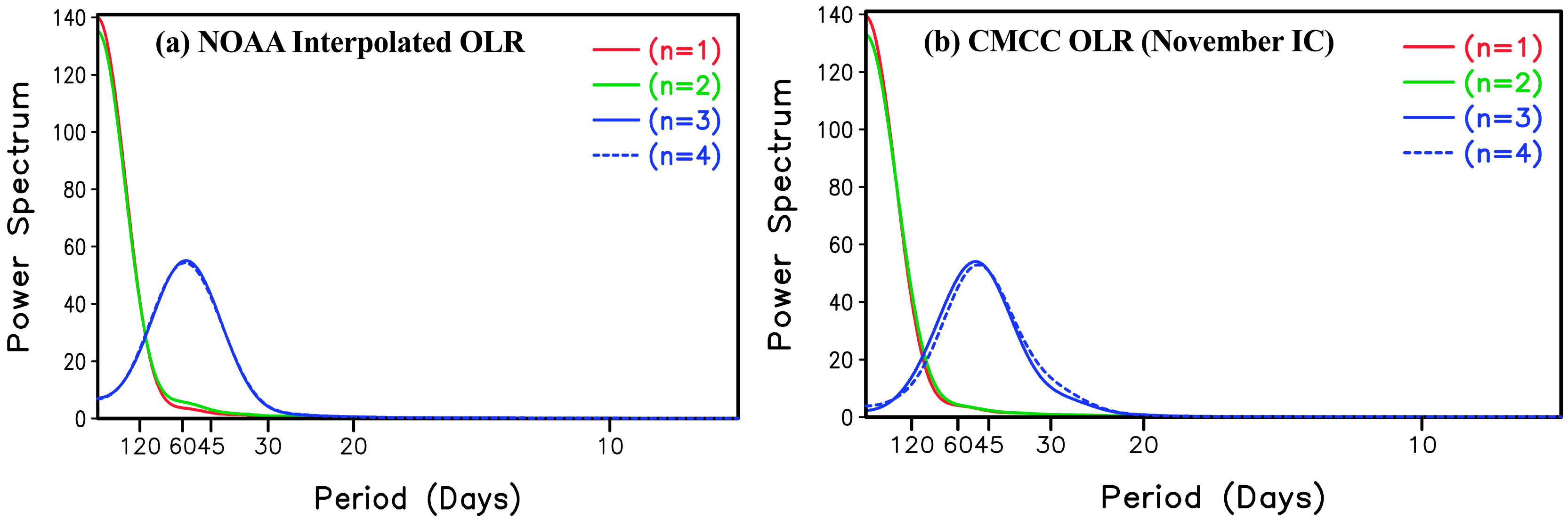
Ghil, M., Allen, M. R., Dettinger, M. D., Ide, K., Kondrashov, D., Mann, M. E., ... & Yiou, P. (2002). Advanced spectral methods for climatic time series. Reviews of geophysics, 40(1), 3-1-3-41.
Plaut, G., & Vautard, R. (1994). Spells of low-frequency oscillations and weather regimes in the Northern Hemisphere. Journal of the atmospheric sciences, 51(2), 210-236.

Results:

MSSA with a lag window of 91 days is applied on the daily unfiltered OLR anomalies of the boreal winter season (November to April) over the tropical region (0°-360°E, 30°S-30°N) for the period 1993-2016 .

The hindcast datasets of 40 ensemble members for 185 days lead time starting from 1st November initial conditions have been used.

Power spectra of ST-PC of the first four eigenmodes



Two consecutive eigenmodes with nearly equal eigenvalues is a criterion for identifying the oscillatory modes. The RC of an oscillatory mode is a sum of the RCs of the individual eigenmode of the pair and it is represented as RC(i)+RC(j)=RC(i, j). Those eigenmodes are identified as non-oscillatory modes whose power spectra are red. *(Plaut and Vautard, 1994; Moron et al. 1998; Krishnamurthy & Shukla 2007)*

Modes 3 and 4 show the oscillatory mode with broad spectra centered around 55-day and the first two modes emerge as non-oscillatory modes (i.e., 1 and 2).

We observed non-oscillatory modes in all 40 ensemble models of model simulations including the ensemble mean.

However, we have observed an oscillatory mode in only 10 out of 40 ensemble members with some variations in the broad spectra (for example, the power spectra of the first ensemble member is shown in figure) .

Plaut, G., & Vautard, R. (1994). Spells of low-frequency oscillations and weather regimes in the Northern Hemisphere. Journal of the atmospheric sciences, 51(2), 210-236.

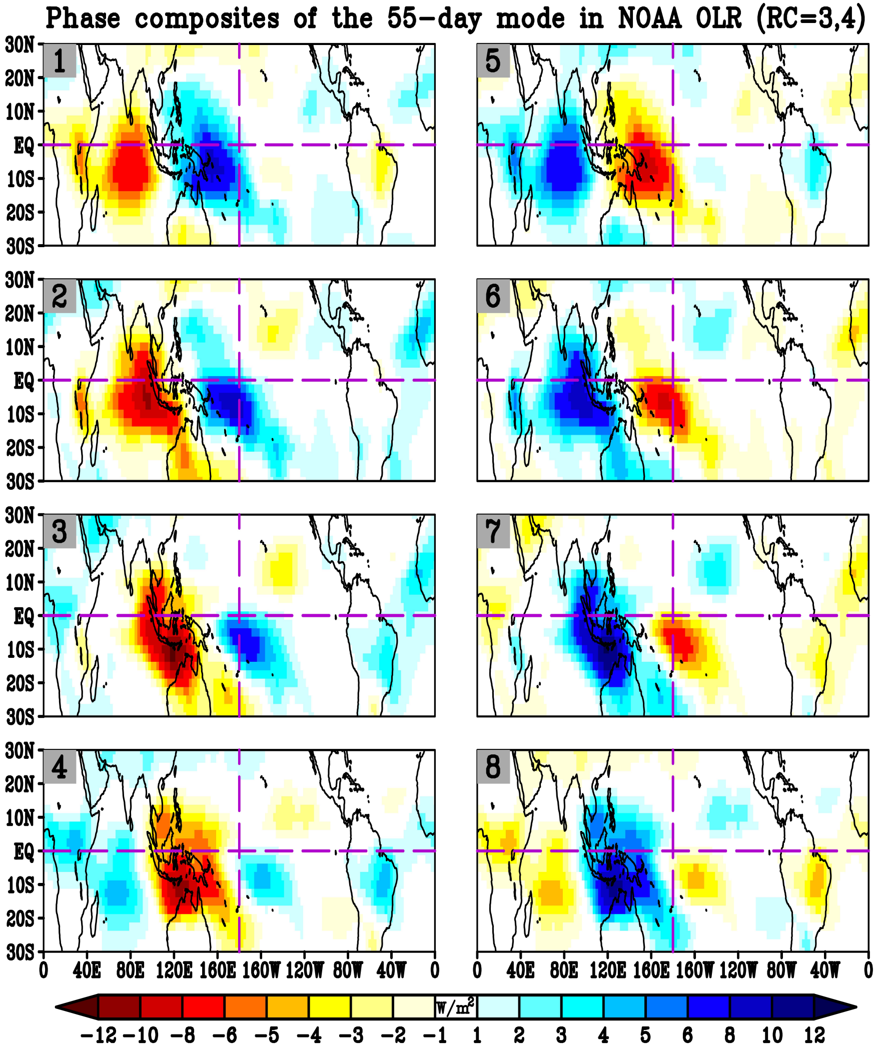
Moron, V., Vautard, R., & Ghil, M. (1998). Trends, interdecadal and interannual oscillations in global sea-surface temperatures. Climate Dynamics, 14(7), 545-569.

Krishnamurthy, V., & Shukla, J. (2007). Intraseasonal and seasonally persisting patterns of Indian monsoon rainfall. Journal of climate, 20(1), 3-20.

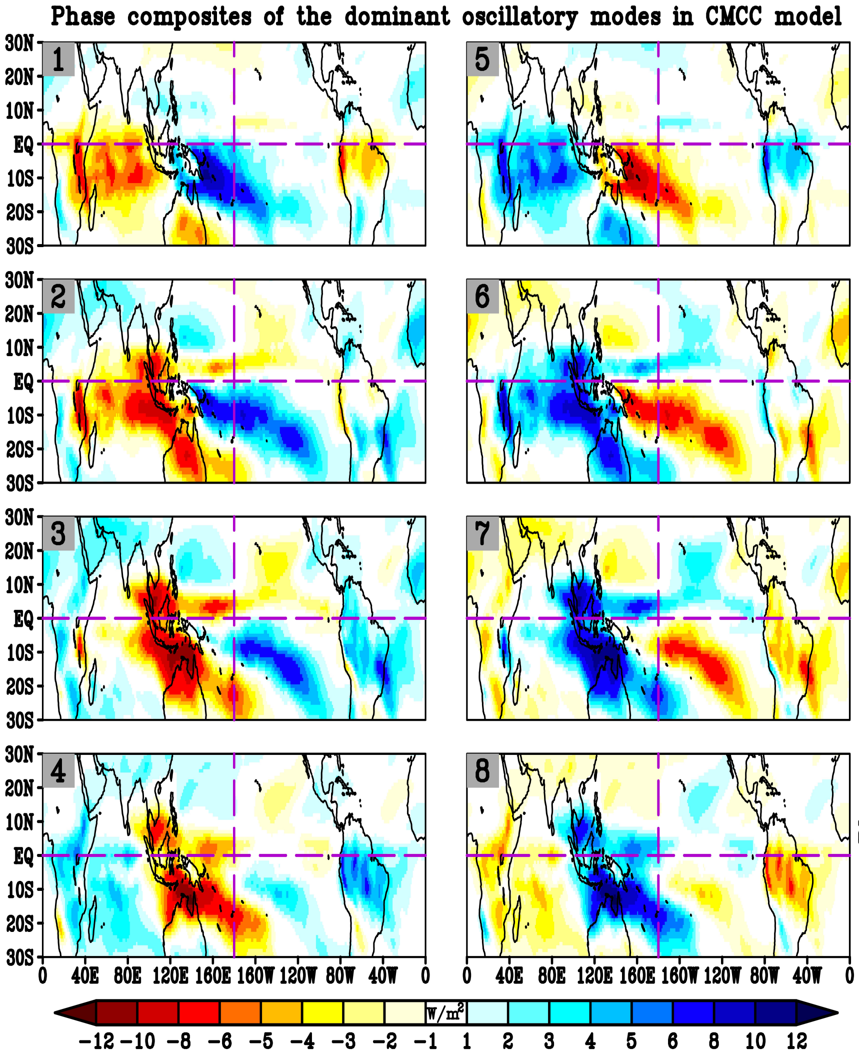
The space-time structure of oscillatory mode is depicted using phase composites which is obtained by averaging the RC in eight equal intervals, and the eastward propagation is obtained by averaging the phase composites over latitudinal belt of (15°S-10°N)

It can be seen from the figure that the MJO convection, initiated from Africa and the western Indian ocean (P1), propagates eastward from the Indian Ocean across the Maritime Continent to the western Pacific and finally disappears near the central Pacific (P2-P8), and this sequence clearly demonstrates the eastward propagation of OLR anomalies.

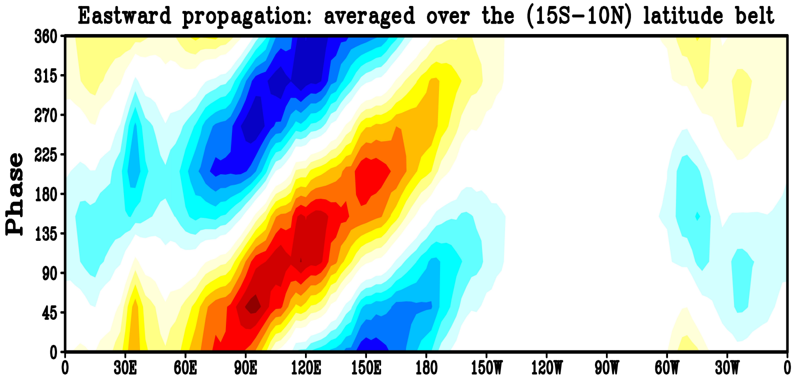
NOAA OLR observation

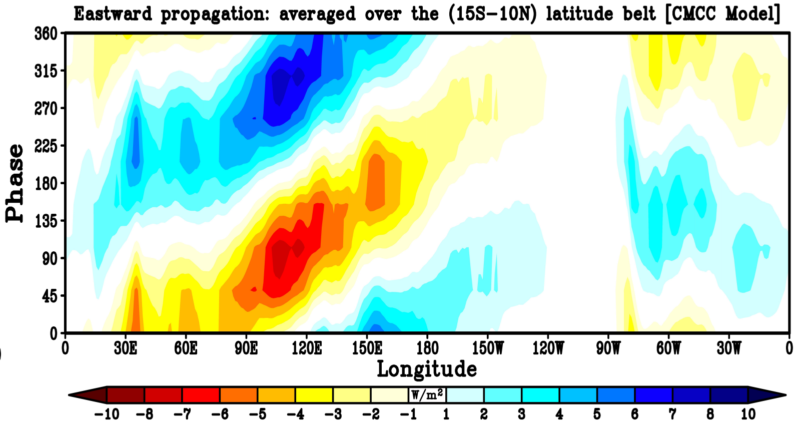


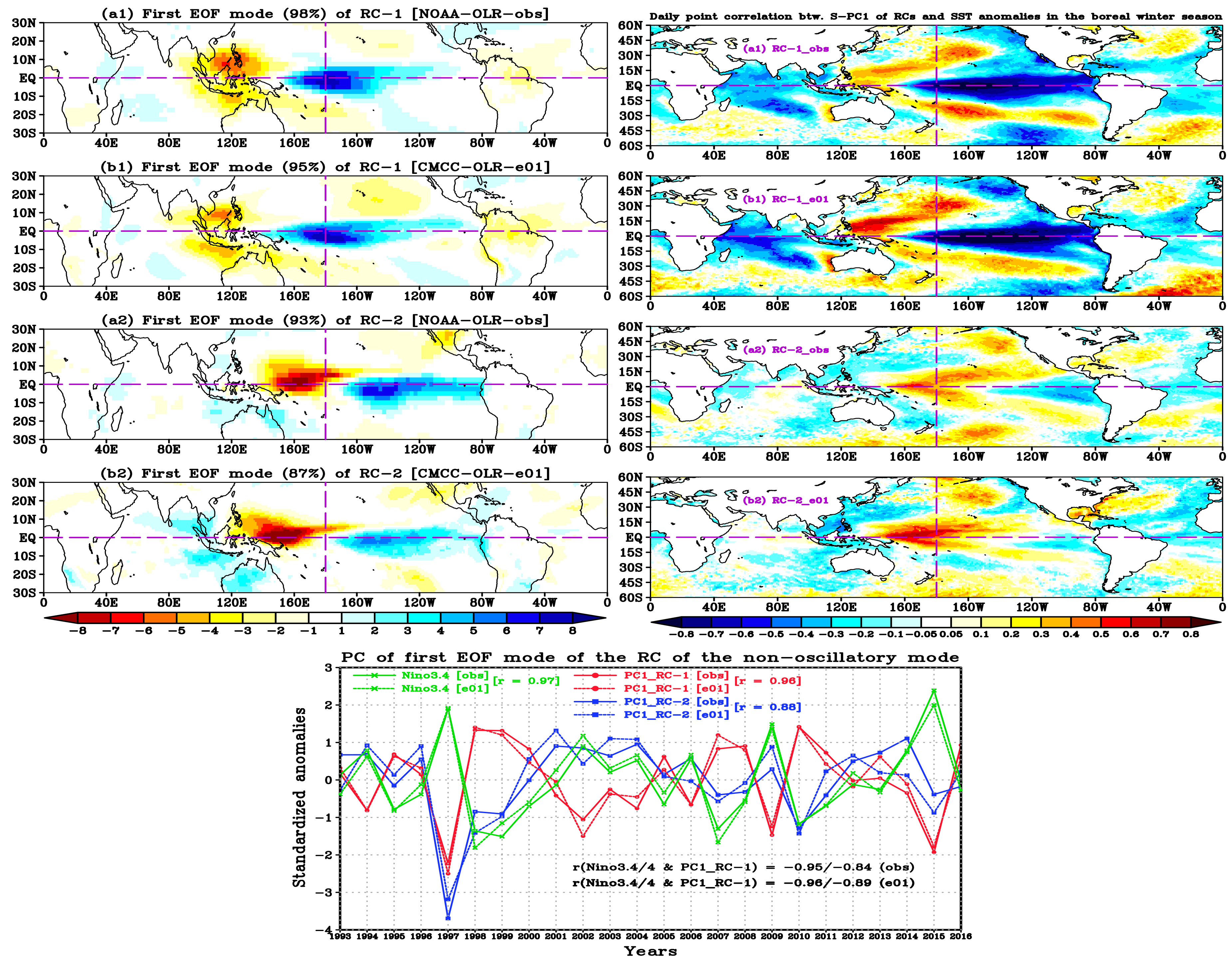
Composites of 10 ensemble members



We observed almost identical sequences with positive OLR anomalies (i.e., suppressed convection) during phase 5 to phase 4.







The spatial patterns of the non-oscillatory modes are obtained by performing EOF analysis on the daily OLR anomalies of the RCs of the non-oscillatory modes (i.e., 1 & 2). *Here we showed results for the first member and similar results we observed for the other members.*

The first EOF mode of RC-1 is associated with enhanced convection in the western pacific and suppressed convection over the central pacific regions (vice-versa) and is highly correlated with ENSO/Niño variability.

It is interesting to observe the co-variability/conjunction of the Indian Ocean, particularly the southern IO and the Niño.

The first EOF mode of RC-2 shows a pattern of OLR anomalies close to RC-1 with an eastward shift and is correlated with the east-central Pacific ocean.

Conclusions

- It has been found that each ensemble member of the simulation produced the observed ENSO variability with high skill, although we observed considerable eastward-propagation MJO signals in only 10 out of the 40 ensemble members of the model.

- Furthermore, we observed the dominant ENSO signal in the ensemble mean of the simulation, but we did not see the MJO mode.

- Overall, this study highlights the skill of the CMCC seasonal prediction system in stimulating tropical variability at S2S time scales and also reveals insights into the benefit of performing analyses on each ensemble member rather than an ensemble mean.

Thank you for your attention!