Intraseasonal variability of air sea interaction over the Indian Ocean and its influence on regional and intraseasonal variability of the Indian monsoon

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Abstract

Intraseasonal variability of air sea interaction over the Indian Ocean and its influence on the regional and intraseasonal variability of Indian monsoon is evaluated in this study. This study shows the necessity for taking into account the spatial variability of Indian monsoon and does a regional study, instead of analyzing All Indian Rainfall (AIR) alone. Precipitation over the Western Ghats (WG) in the southwest coast of India and the Ganges-Mahanadi Basin (GB) in the northeast India are studied here as they are found to be the regions of maximum precipitation with marked variability. Arabian Sea and Bay of Bengal lying on the either sides of the Indian subcontinent are analyzed and compared for its association with these regions of maximum precipitation variability.

Sea surface temperature (SST), surface winds, surface latent heat flux (SLHF) and outgoing longwave radiation (OLR) over the north Indian Ocean and precipitation over the Indian subcontinent are analyzed to characterize the intraseasonal variability during the period 1998-2002. Intraseasonal variability of monsoon over WG is found to have maximum correlations with intraseasonal variability of air sea interaction over Arabian Sea. Meanwhile, correlation is weak between GB monsoon intraseasonal variability and Bay of Bengal intraseasonal variability. Composite evolution of the active/break phases over WG and GB are studied with respect to air sea interaction over the Arabian Sea and Bay of Bengal. Significant and contrasting roles played out by these surrounding oceans over the different regions are analyzed. The study reveals that air sea interaction over Arabian Sea influences both the WG and GB regions while Bay of Bengal has a weak influence over the GB region. Arabian Sea acts as an active moisture contributor during a WG active phase and then the precipitation band moves northeastward and combines with the convection bands from Bay of Bengal, enhancing the GB active phase.

1. Introduction

The intraseasonal variability of monsoon is delineated by active periods of heavy rainfall interrupted by drier periods of deficient rainfall. The dry and wet spells of the active and break conditions represent intraseasonal variations of the monsoon with time scales longer than synoptic variability but shorter than a season.

Lying on both sides of the continent, Arabian Sea and Bay of Bengal are found to influence this monsoon intraseasonal variability significantly. Studies have shown that the moisture for the southwest monsoon, transported over to the continent, is collected by evaporation from the Arabian Sea and Bay of Bengal [Findlater, 1969; Saha, 1970] and also transported from the southern hemisphere [Cadet and Greco, 1987a; 1987b].

The few studies which have analyzed the relationship between monsoon and the surrounding ocean basins in intraseasonal timescales, take the All India Rainfall (AIR) for studying monsoon variability whereas in our study we take into account the spatial variability of Indian monsoon and does a regional study. This is because studies show that monsoon over the Indian subcontinent varies regionally.

2. Data and analysis methods

Availability of data from satellites like Tropical Rainfall Measuring Mission (TRMM) during recent years helps us to look into variabilities on all time scales from few days to interannual. The precipitation used is obtained from the Climate Prediction Center Merged Analysis of Precipitation (CMAP), SST from the TRMM Microwave Imager (TMI), surface flux and winds from the European Center for Medium range Weather Forecasting (ECMWF) and OLR from the National Oceanic and Atmospheric Administration (NOAA).

As SST data is available daily, rest of the data are interpolated to daily for compatibility. All available data between June 1 and Sept 30 (summer monsoon) for the years 1998 to 2002 are band pass filtered to retain periods between 10-60 days using a boxcar filter. The processed data is used to further analyze the variabilities in intraseasonal timescales.

We define the WG active phase as when the normalized Western Ghats intraseasonal precipitation anomaly exceeds 4.0 mm/day and break phase as when the minimum of intraseasonal precipitation anomaly exceeds -4.0 mm/day. SST, surface latent heat flux, surface winds and OLR are composited based on identification of active-break phases in precipitation over the Western Ghats region. These composites are prepared at lags and leads for several days. We also define the GB active phase as when the Ganges-Mahanadi Basins intraseasonal precipitation anomaly exceeds 4.0 mm/day and break phase as when the minimum of intraseasonal precipitation anomaly exceeds -4.0 mm/day. Compositing and analysis, similar to that of WG active phase mentioned above, is carried out for all parameters with respect to the GB active and break phases.

3. Intraseasonal variability of air sea interaction over the Arabian Sea and Bay of Bengal and its influence on the WG and GB intraseasonal monsoon variability

The intraseasonally filtered precipitation for the summer monsoon is used to map the standard deviation of intraseasonal variability for the years 1998-2002 (Figure 1). The standard deviation map marks out two regions with high standard deviation or variability, the Western Ghats in the south west region and the Ganges-Mahanadi Basins in the north east. We use these two regions and analyze the Indian Ocean influence on monsoon regionally.

Intraseasonal variability of monsoon over WG is found to have maximum correlations (r=0.6) with intraseasonal variability of air sea interaction over Arabian Sea. Meanwhile, correlation is weak (r=0.2) between GB monsoon intraseasonal variability and Bay of Bengal intraseasonal variability. Composite evolution of the active/break phases over WG and GB are studied with respect to air sea interaction over the Arabian

Sea and Bay of Bengal. SST 1 week prior to WG active phase enhances the convective activity over WG region, resulting in a WG active phase (Figure 2). GB active phase is found to occur 10 days after a WG active phase. 10 days before a GB active phase, the precipitation bands are located along the western coast and the Bay of Bengal (Figure 3). The precipitation bands over the WG region are found to move northeastward. Meanwhile the precipitation bands over the Bay of Bengal move north westward towards the GB region. 5 days before the active phase, both the precipitation bands combine to form the GB active phase. This implies that the Arabian Sea is an active moisture contributor for the active phase over the GB region. It also explains the question on why a high precipitation maximum over Bay of Bengal during WG active phase is not reflected on the GB region. The sequence of the events can be simplified as follows. Arabian Sea acts as an active moisture contributor during a WG active phase. The precipitation bands then move northeastward over the Indian subcontinent and combines with the precipitation bands from Bay of Bengal, enhancing the GB active phase.

4. Conclusion

Intraseasonal precipitation over WG and GB regions are found to be simultaneously uncorrelated to each other with both displaying different precipitation variabilities. Central and northern Arabian Sea is observed to have pronounced intraseasonal variance in SST prior to a WG active phase. The composite evolution of the air sea interaction over Arabian Sea and Bay of Bengal show that SST influences on precipitation over these oceans are dissimilar, with the precipitation over the Bay of Bengal lagging SST by 3/4th of the cycle while for Arabian Sea the lag is 1/4th of the cycle. Weak mean southwesterly winds 10 days prior to a WG active phase lead to warm SST over the Arabian Sea, destabilizing the lower atmospheric column and facilitating moisture uplift thus leading to a convergent zone over the Arabian Sea. This leads to an abrupt shift of the intraseasonal northeasterlies to southwesterlies, leading to a WG active phase. GB precipitation follows WG precipitation by 10 days though the SST variability over Bay of Bengal is weak prior to a GB active phase. This is attributed to the influence of Arabian Sea as the precipitation bands leading to the active phase over WG continue northeastward, merging with the precipitation bands from Bay of Bengal, enhancing a GB active phase.

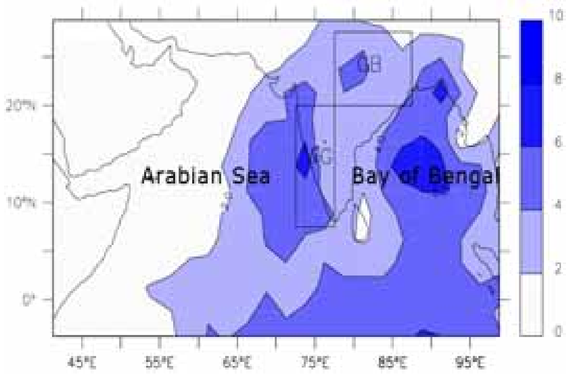

Figure 1. Standard deviation of intraseasonal variability of precipitation (mm/day) for June- Sept (1998-2002)

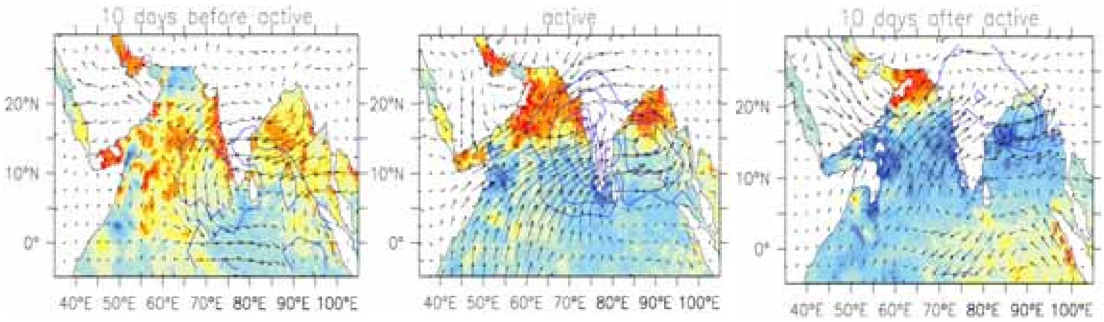

Figure 2. Composites of SST, winds & precipitation for WG active phase in Jun-Sep, 1998-2002 are filtered to retain periods between 10-60 days. SST in colored contours, surface winds as vectors and precipitation superimposed as contour lines. Active phase defined as when filtered precipitation is above 4mm/day.

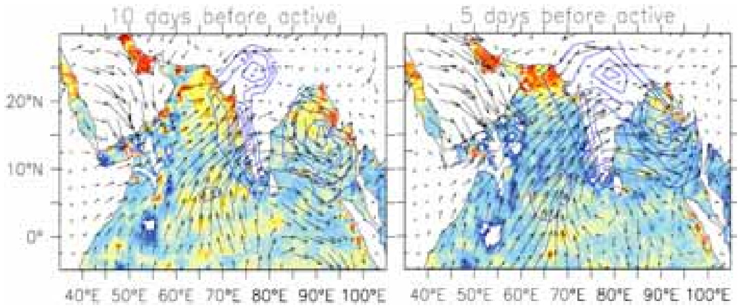

Figure 3. Composites of SST, winds & precipitation for GB active phase in Jun-Sep, 1998-2002 are filtered to retain periods between 10-60 days. SST in colored contours, surface winds as vectors and precipitation superimposed as contour lines. Active phase defined as when filtered precipitation is above 4mm/day.