HOW THE INDIAN OCEAN DIPOLE-MODULATED HADLEY CIRCULATION REDUCES THE ENSO INFLUENCE ON THE INDIAN MONSOON: AGCM SENSITIVITY STUDIES

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ABSTRACT

It has been known that the ENSO influence on the Indian summer monsoon rainfall (ISMR) has weakened in the last two decades of the 20th century. Particularly in the 1990s, despite the occurrence of frequent and protracted ENSO events, ISMR remained normal or excess. During these two decades, there was relatively frequent occurrence of the strong Indian Ocean Dipole (IOD) events. The ISMR and the Indian Ocean Dipole Mode Index (IODMI) are positively correlated. These factors have motivated us to investigate into the possible role of the IOD in weakening the monsoon ENSO relationship.

Using the observed data, we found that the IOD-ISMR relationship varied complementarily to that between ENSO-ISMR. The weakening relationship between the IOD and ENSO was accompanied by strengthening IOD-ISMR relationship (Fig.1). Thus, the frequently occurring IOD events have been the reason behind the weakening ENSO-ISMR relationship in the last two decades of the 20th century.

We used the Frontier Atmospheric General circulation Model version 1.0 (FrAM1.0) to understand how the IOD events influence the Indian summer monsoon. In the first experiment, the seasonally varying climatological sea surface temperatures (SSTs) were used as the lower boundary conditions. Two more sets of experiments were carried out by imposing both positive, and negative IOD type of sea surface temperature anomalies (SSTA) on the climatological SST respectively. The results show that the positive (negative) phase of the Indian Ocean Dipole strengthens (weakens) the meridional monsoon Hadley cell, and causes surplus (deficit) rainfall over the Indian region.

To demonstrate that a strong positive IOD event can really reduce the co-occurring ENSO influence on the Indian monsoon, we conducted several other experiments; in the third experiment, we imposed ENSO type SSTA respectively on the climatological SST to obtain the lower boundary conditions. In the final experiment, referred to as the combined experiment, both the positive IOD type and NINO type of SSTA were imposed on the climatological SST. The experiments have shown that there exists a low-level anomalous divergence center over the Western Pacific during an El Niño event that extends over to India. This anomalous divergence over the Indian region causes anomalous subsidence and weakened rainfall. When a positive IOD event simultaneously occurs with El Niño, the anomalous divergence center moves in to the eastern tropical Indian Ocean. The anomalous divergent flow, crossing the equator, converges over the Indian monsoon region, and thus cancels the ENSO induced subsidence and the related deficit of rainfall (Fig. 2).

These AGCM experiments demonstrate that the frequently occurring positive Indian Ocean Dipole events during the nineties, through modulation of the Hadley circulation, have caused low level convergence over the Bay of Bengal and Indian monsoon trough region and reduced the ENSO influence on the Indian summer monsoon.

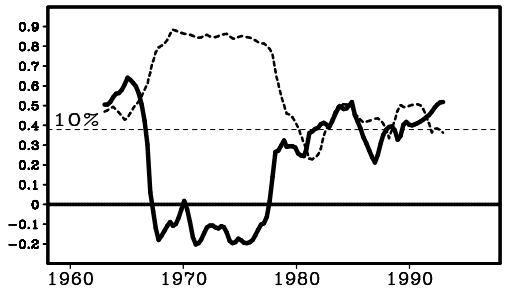

Figure 1. The 41-month sliding correlation coefficients between ISMR and IODMI (solid), and those between monthly ISMR and NINO3 SST (dashed; to be multiplied by –1) during 1958-1997. The significant correlation value at 90% confidence level is 0.38 (verified by 1,000 randomized time series, using the Monte-Carlo simulations)

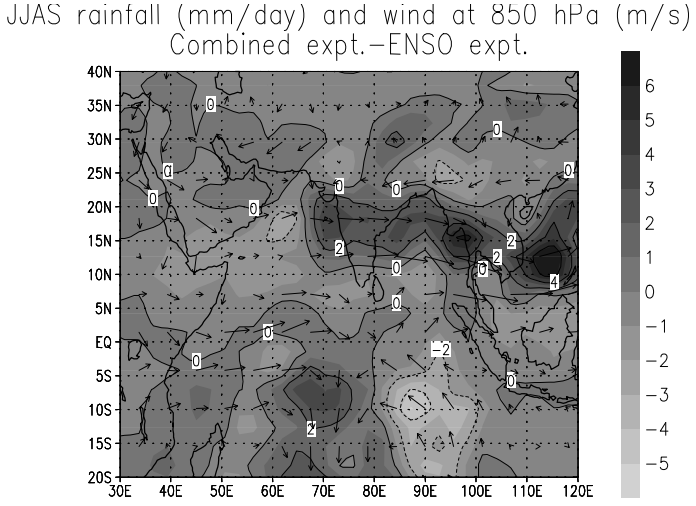

Fig.2