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Dynamical Aspects of Indian Ocean Dipole and East African Rainfall Anomaly Linkages

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Abstract

Space-time characteristics of a series of dynamical parameters were investigated using fields from NCEP/NCAR reanalysis and ECHAM4.5 general circulation model to asses the physical reality of the observed teleconnections between the phases of the IOD and regional rainfall anomalies.

Results indicated dominant strong easterly (westerly) wind anomalies over northern and central Indian Ocean during extreme positive (negative) IOD events. The easterly (westerly) wind anomalies have been associated with enhanced (reduced) advection of moisture into the eastern parts of the sub region from Indian Ocean. Climatic conditions that have been shown to be associated with the IOD phases over the region through conventional statistical methods were well captured by the ECHAM4.5 GCM products.

1. INTRODUCTION

Recent observational studies have shown the influence of IOD on East African seasonal rainfall. In our earlier paper (Owiti and Ogallo,2007, this issue) we used statistical approaches to show that there is a significant linkage between the east African rainfall variability and the Indian Ocean Dipole. In this paper we assess the physical linkages using dynamical products from NCEP/NCAR reanalysis and ECHAM GCM.

The skill of ECHAM4.5 over the east African sub region has been address by IRI/ICPAC Dynamical Modeling Collaboration (2002), Mutemi (2003) and Indeje (2000). Examples from some of these studies are shown in figures 1a and 1b. The results indicated that ECHAM4.5 was the best model especially between July – December months. The skill of the model was found to be higher during ENSO when large SST values are found over many parts of the equatorial tropics. In general, ECHAM4.5 had the best prediction skill (*figure 1a*). IRI and ICPAC produce ECHAM4.5 products every month for the region. These products have been used in this study.

The Observed and simulated interannual variability is shown in figure 1b. It is evident that the model Rainfall anomalies for the OND season closely marched the observations.

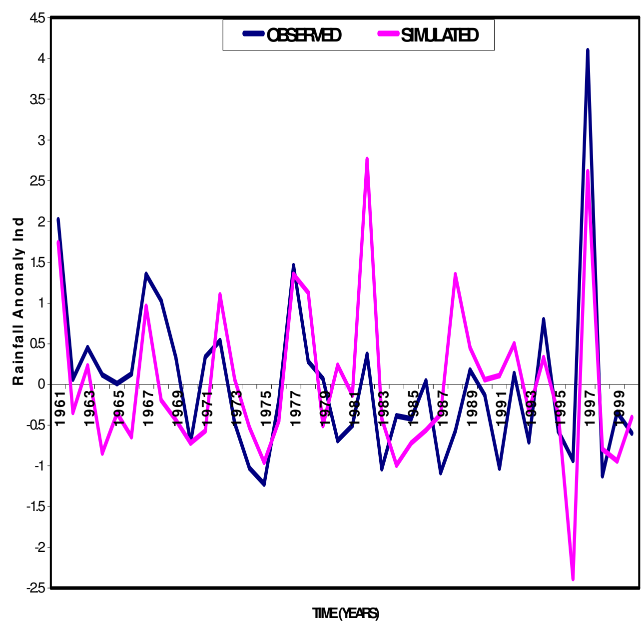

Figure 1a: *Simulation of the rainfall annual cycle over Eastern Africa using different GCMs, (IRI/ICPAC Dynamical Modeling Collaboration, 2002).*

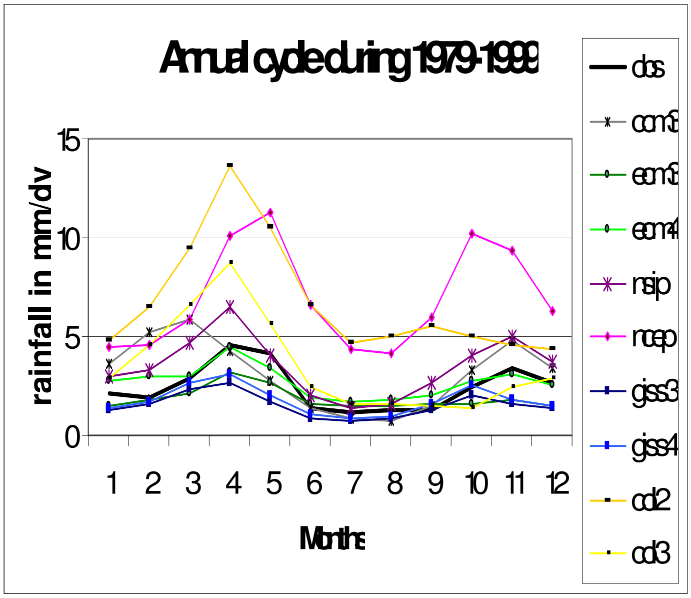

Figure 1b: The ECHAM model simulation of interannual variability of rainfall over East Africa (350E – 38⁰E, 2⁰S – 2⁰N) during the OND rainfall season (October – December).

2. DATA AND METHODOLOGY

In order to asses the physical linkages of the observed teleconnections between the phases of the IOD and regional rainfall anomalies, space-time characteristics of a series of dynamical parameters were investigated using products from NCEP re-analysis and ECHAM4.5 general circulation model (Roeckner et al. 1992). This involved examination of the ECHAM4.5 simulated Rainfall anomalies and the major circulation patterns that could be associated with the East African rainfall- IOD linkages.

3. RESULTS AND DISCUSSION

Figure 2 shows observed composite of gridded rainfall data and the corresponding ECHAM simulated rainfall anomalies over the region for the composites of positive and negative dipole events.

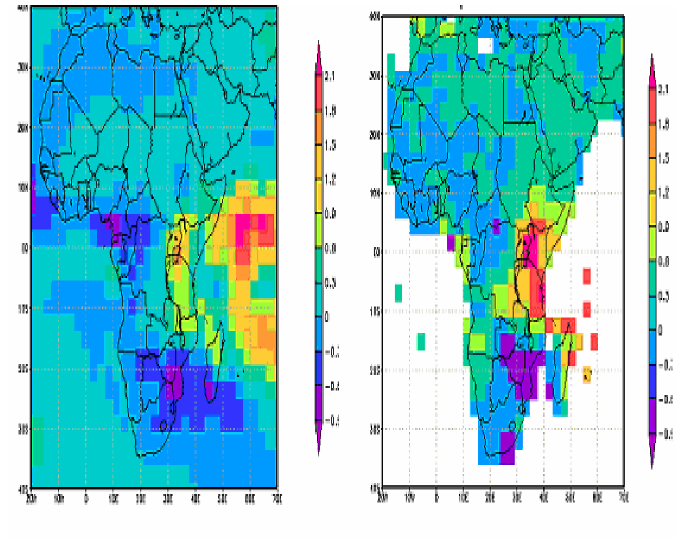

Figure2a: *The comparison of observed and ECHAM simulated rainfall anomalies for October to December season over Africa for composites of Positive Phases of dipole events:*

(i) Left panel: Simulated composite rain indices from ECHAM model.

(ii) Right panel: Observed rain indices from gridded global data

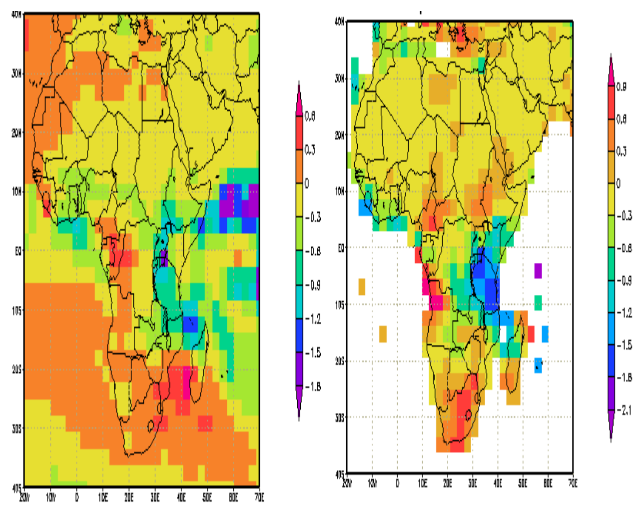

Figure 2b: *The comparison of observed and ECHAM simulated rainfall anomalies for October to December season over Africa for composites of Negative Phases of dipole events:*

(i) Left panel: Simulated composite rain indices from ECHAM model.

(ii) Right panel: Observed composite rain indices from gridded global data

Results from these numerical products show the ability of ECHAM model to simulate rainfall features over the East African region associated with IOD events. The model is able to simulate some aspects of the differences that have been observed in October to December rainfall season during some specific dipole cases. Comparison of the simulated rainfall during the opposite phases of the IOD shows that the model, in general, captured the contrasts in rainfall conditions associated with the positive and negative dipole phases well. However, the results further indicated that the skill of the model in simulating seasonal rainfall varies over space and time. The most striking feature of the comparison between the observed and simulated rainfall is that the model reproduced the above/below normal conditions over most parts of the region for the positive/ negative IOD composite. This is quite consistent with the results from statistical analyses. Past studies, (Black et al., 2003; Webster et al., 1999; Kijazi, 2003) have also noted dominance of heavy rainfall over East Africa during the positive phases of the dipole events.

Composite pictures of SST and surface wind anomalies are shown in figures 3(*a-d*) for the positive and negative IOD phases. To make these plots, we composited some significant event years; 1961, 1967, 1972, 1982, 1994 and 1997 for positive IOD; while 1960, 1975, 1984, 1992 and 1996 for negative IOD phase.

From figures 3, it is evident that during the June-August (JJA) season, the maximum positive SST anomaly is located away from the western coast of the Indian Ocean (east African coast). During September-November (SON) season, when the IOD peaks, the contrasting warm (cool) SST anomaly pattern in the western (eastern) Indian Ocean intensifies. The maximum positive SST anomaly is located near the Somali coast (it is shifted westward as compared to the previous season when it is located slightly away from the coast).

It is quite evident from the figure 4 that during positive (negative) IOD events, strong easterly (westerly) wind anomalies prevail over many parts of central and eastern parts of the equatorial Indian Ocean.

There are however very significant variations in the spatial patterns of the circulation pattern in some years. The figures show clear differences in the circulation patterns over the equatorial western Indian Ocean regions in some IOD years.

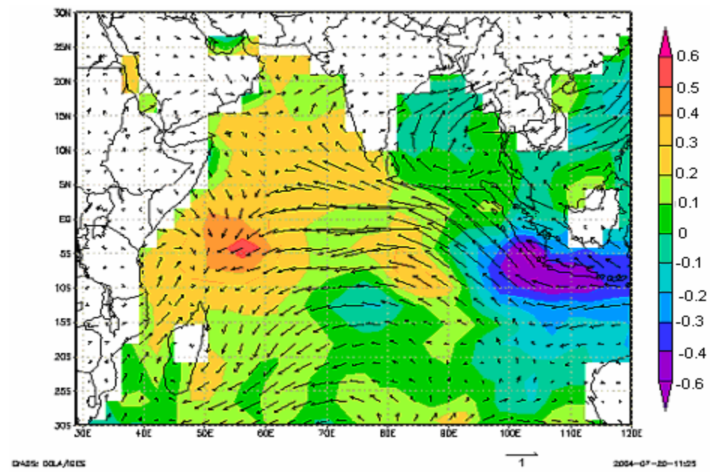

Figure 3a: *Composite of surface circulation patterns (anomalies) over the Indian Ocean during the positive IOD event years for the JJA season.*

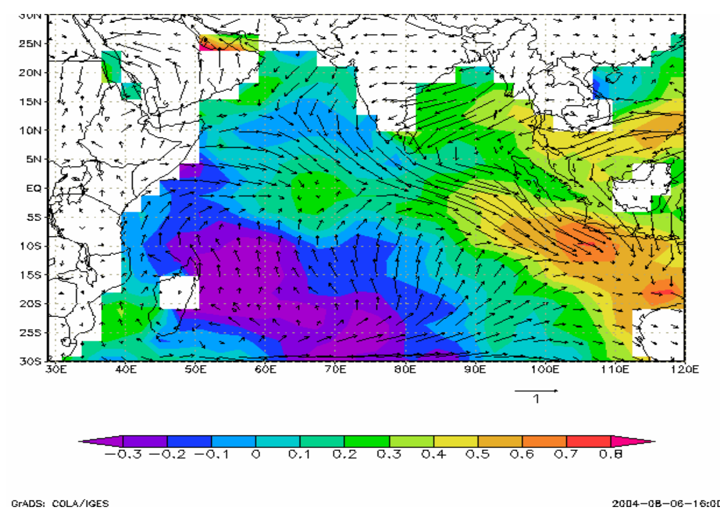

Figure 3b: *Composite of surface circulation patterns (anomalies) over the Indian Ocean during the positive IOD event years for the JJA season.*

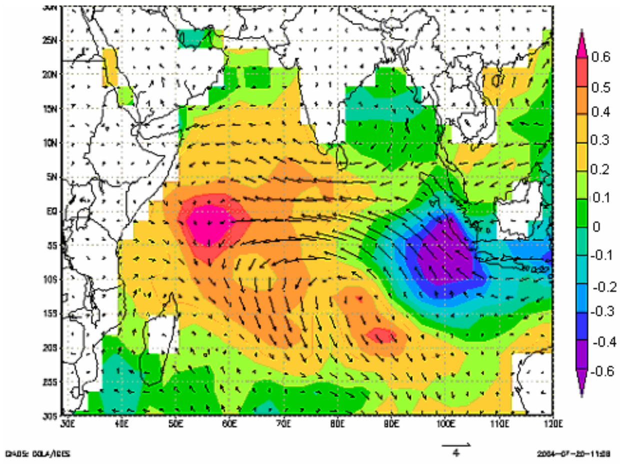

Figure 3c*: Composite of surface circulation patterns (anomalies) over the Indian Ocean during the positive IOD event years for the SON season.*

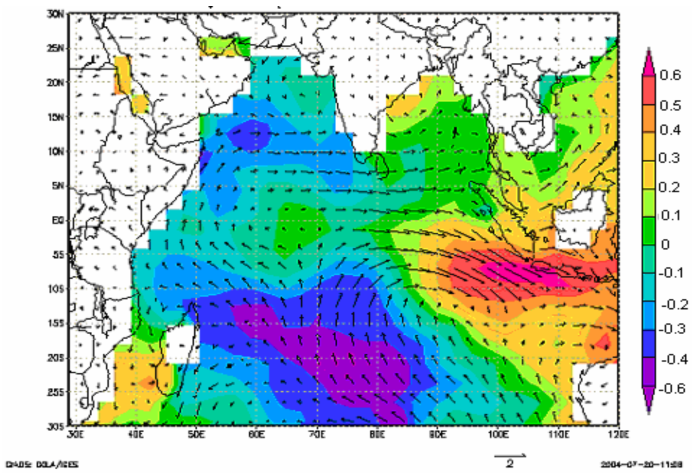

Figure 3d: *Composite of surface wind circulation (anomalies) over the Indian Ocean during the negative IOD event years for the SON season*

The observed wind and SST anomalies during the positive/negative IOD events support the enhanced/suppressed transport of moisture into the East African region.

Previous studies have linked easterly (westerly) wind anomalies with enhanced (reduced) advection of moisture into the eastern parts of the sub region from Indian Ocean.

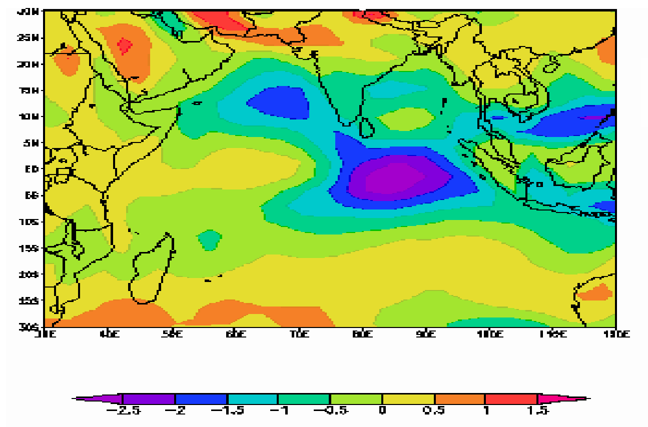

Figure 4a: *Composite for SON zonal wind anomalies (m/s) - Positive IOD.*

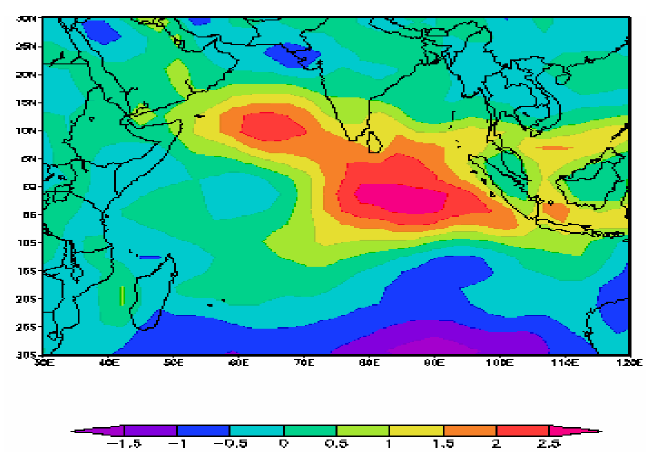

Figure 4b: *Composites of SON zonal wind anomalies (m/s) -Negative IOD.*

Ininda (1994), Beltrado and Camberlin, (1995), Mukabana and Pielke, (1996) Camberlin and Wairoto, (1997), Indeje, (2000), Kijazi, (2003); among many recent studies have observed that the rainfall over East Africa is enhanced (reduced) when there is anomalous low-level easterly (westerly) flow over the equatorial Indian Ocean.

4. CONCLUSION

It may thus be concluded from this study that the linkages that were observed from our earlier statistical analyses had some physical reality. Some of the linkages however seemed to be quite complex and need further analyses. These include variations in the spatial and peak circulation patterns during the positive and negative IOD events. Although the ENSO and non-ENSO years could account for some of the differences, some of the differences were hard to explain from the analyses that were carried out in this study. Addressing of such differences would require complex simulation experiments to explain. This should be the key focus of the future research.

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