6A.3 CONNECTIONS BETWEEN THE AFRICAN AND INDIAN RAINFALL REGIMES

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1. INTRODUCTION

Observational studies suggest an association exists between the monsoon rains of East Africa and India during the boreal summer. Camberlin (1995; 1997) observed that summer rainfall over East Africa (Ethiopia, Sudan, and Kenya) is positively correlated with Indian rainfall. During wet (dry) African and Indian monsoon seasons, sea-level pressure over the Arabian Sea tends to be anomalously low (high) and the low-level westerly flow over central Africa and the Arabian Sea is anomalously strong (weak). While some studies provide insight into these relationships (Camberlin 1995; 1997; Rodwell and Hoskins 1996), the underlying mechanisms are still unclear.

The purpose of this paper is to understand the mechanisms that connect Indian and African rainfall by using a tropical mesoscale climate model (TMCM) developed from the PSU/NCAR mesoscale model 5 (MM5). There may be many mechanisms capable of perturbing rainfall over Africa and India (e.g., changes in global SSTAs patterns, and/or changes in land surface boundary conditions over Africa and India). Here, the focus is on a particular mechanism, namely the influence of cold Arabian Sea SSTAs on rainfall over India and Africa.

2. EXPERIMENTAL SET-UP

Two 139-day (May 15th – September 30th) simulations are utilized. One is a control integration, and the other simulation is identical to the control except cold (-2 K) SSTAs are imposed in the Arabian Sea (Fig. 1). Note that our SSTAs are robust in magnitude and shape in order to better diagnose the response of the TMCM.

Each simulation is run at 120-km grid spacing, with 24-vertical sigma levels, a model time step of 2 minutes, and fixed pressure at the top of the atmosphere at 50 mb. Physical options chosen include: Blackadar planetary boundary layer scheme, RRTM radiation, simple ice cloud physics, Kain-Fritsch cumulus scheme, and shallow cumulus convection parameterization.

Initial conditions for all the simulations, 00Z on 15 May, are climatological May conditions from the NCEP reanalysis. Lateral boundary conditions are updated every 12 hours using the NCEP climatology. Monthly means are used to represent the middle of the month, and a temporal linear interpolation is utilized to generate boundary conditions every 12 hours. Likewise, boundary conditions for SSTs and soil moisture availability are generated from observed monthly means. The first 17 days are discarded, and the rest of the output is averaged to form monthly and seasonal climatologies.

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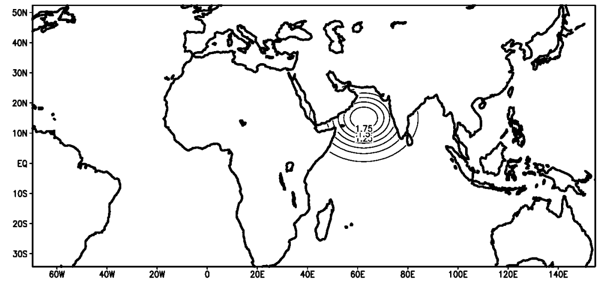

Fig. 1 Domain and position of SSTAs for TMCM simulations. Contours are every 0.25 K.

3. RESULTS

A positive correlation is found between rainfall over northern Ethiopia and India when cold Arabian Sea SSTAs are present. In agreement with the observational results of Camberlin (1995; 1997), rainfall decreases over the Indian peninsula and over northern Ethiopia, north of 10°N (Fig. 2). Further south over southern Ethiopia and Kenya, rainfall increases by over 60%. While this indicates a negative correlation in rainfall between this southern East Africa region and India, Camberlin's observational studies also suggest that two coherent regions of rainfall variability exist over East Africa during the summer, namely one north of 7°N and the other south of 7°N.

The positive correlation between Ethiopian and Indian precipitation can be understood largely in terms of the dynamical response to steady atmospheric forcing associated with anomalous heating from the cold Arabian Sea SSTAs, namely a stationary Rossby wave response to the west of the SSTA and a stationary Kelvin wave to the east near the equator.

Fig.3a shows the 870 mb winds and heights for the control, while Fig. 3b shows the 870 mb anomalous winds and geopotential heights for the cold SSTA simulation. Positive height anomalies are centered over the western Arabian Peninsula and just north of Madagascar, while negative height anomalies are positioned over the Bay of Bengal and southeast Indian Ocean. Anomalous flow between the equator and 20°N is easterly over Africa and the Arabian Sea, and westerly over the Bay of Bengal. Over northeast Africa the anomalous flow is southerly.

Consistent with Camberlin's (1997) results, lower-tropospheric heights are higher over the western Indian Ocean basin, while the zonal flow associated with the Somali jet is weaker than in the control simulation. This anomalous pattern indicates a weakening of the monsoonal trough over India, the Arabian Peninsula, and Africa. Low-level westerly flow associated with this trough decreases from central Africa to India.

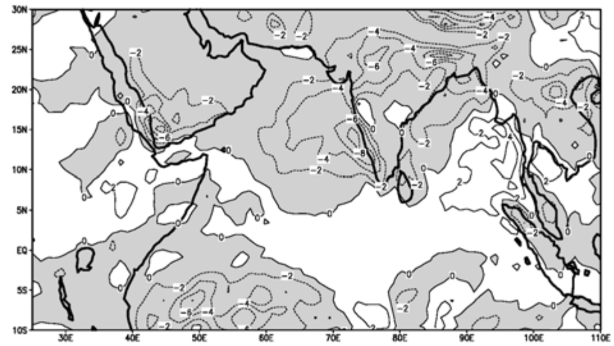

Fig. 2 June-September precipitation anomalies for the cold Arabian Sea SSTA simulations. Contours are every 2 mm day^{-1}.

Over northern Ethiopia and Sudan, the lower-tropospheric westerly flow is important for transporting moisture from West Africa and the Congo Basin (Fig. 3a). Associated with the weaker westerly flow when SSTAs are cold in the Arabian Sea, moisture convergence and hence rainfall decrease along the western slopes of the Ethiopian Highlands over northern Ethiopia and Sudan.

Further south over southern Ethiopia and Kenya low-level westerly flow from West Africa also decreases, yet rainfall increases over this region. This can be attributed to an increase in the southeasterly flow through the Lake Turkana valley (i.e., a stronger Turkana jet). Moist flow associated with the Somali jet converges with the westerly flow from the Congo Basin in this valley increasing moisture convergence and rainfall over this region when SSTAs are cold in the Arabian Sea.

Our TMCM results are not in agreement with Camberlin's findings, possibly suggesting the importance of other mechanisms for the Turkana Valley region. For example, Camberlin (1995) suggests that a negative correlation in precipitation also exists between southern Ethiopia/Kenya region and along the Guinean Coast of West Africa. This observation and our TMCM results may suggest that atmospheric forcing over West Africa or the Gulf of Guinea is more influential in perturbing rainfall over southern Ethiopia and Kenya than forcing from Arabian Sea SSTAs.

The low-level zonal westerly flow is also important for providing moisture necessary for rainfall over India. Weaker westerlies in the cold SSTA case are associated with a decrease in moisture convergence and rainfall over India. Additionally, cold SSTAs in the Arabian Sea are associated with a decrease in evaporation and low-level moisture content over this region, further contributing towards decreasing the moisture convergence and precipitation over India.

4. CONCLUSIONS

Our TMCM simulations suggest that a positive connection exists between rainfall over northern Ethiopia and India. When the atmosphere is forced by cold SSTAs in the Arabian Sea, rainfall decreases over both these regions. The mechanism responsible for this case is a dynamical response to anomalous heating associated with the SSTAs (i.e., stationary equatorial Rossby and Kelvin waves). Similar to the observations, the monsoonal trough and associated low-level westerly flow from West Africa to India weakens during dry Indian and East Africa rainfall events, resulting in a decrease of moisture convergence and rainfall over northern Ethiopia and India.

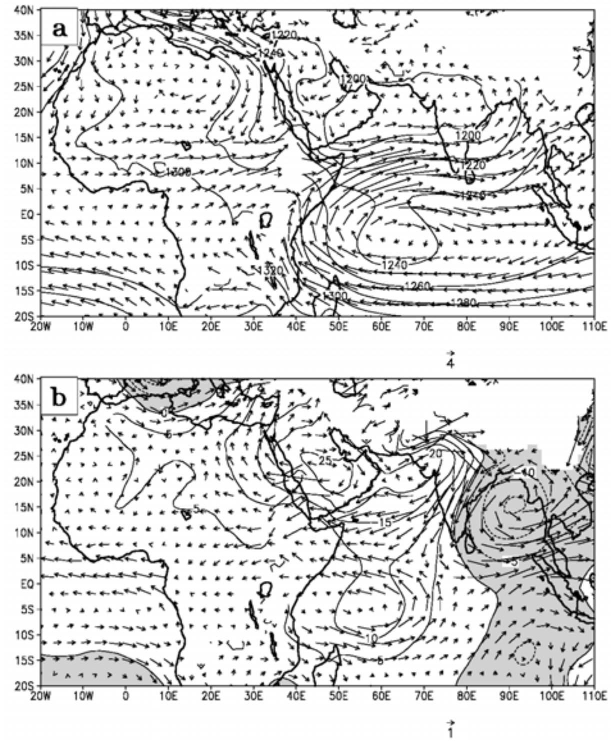

Fig. 3 June-September 870 mb (a) control height and winds, and (b) height and wind anomalies for the cold Arabian Sea SSTA simulation. Contours are in gpm, and wind vectors are in m s^{-1}.

Our TMCM results also suggest a negative relationship exists in rainfall over southern Ethiopia/ Kenya and India for this particular SSTA case. Rainfall increases in the Turkana Valley between the Ethiopian and East African Highlands. This is associated with an increase in southeasterly flow of moist air from the Indian Ocean through the Turkana Valley and a decrease in westerlies from the Congo Basin. This does not agree with previous observational studies, and may indicate the importance of a different mechanism in perturbing this region (e.g., Gulf of Guinea SSTAs).

5. ACKNOWLEDGMENTS

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6. REFERENCES

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