P1.28 SEASONAL RAINFALL VARIABILITY WITHIN THE WEST AFRICAN MONSOON SYSTEM

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1. INTRODUCTION

Marked seasonal cycle exists in both surface rainfall and large-scale environment over the tropical eastern Atlantic-West African region. Major intense rainfall events are generally observed in the Gulf of Guinea during April-June. The seasonal mean rainy belt moves to about 10^{o}N during the boreal summer, and then retreats back to the south after mid-September-October, manifesting the seasonal march of the ITCZ. Time-latitude diagrams of mean rainfall indicate that this seasonal migration is characterized surprisingly by an abrupt shift of major rainy zone during June-July (Sultan and Janicot 2000).

Careful examinations of rainfall on the weekly time scale show that the abrupt shift or "jump" of the major rain belt is actually a manifestation of the onset of intense convection and rainfall along 10^{o}N within the interior West African continent and a simultaneous, sudden termination of convection near 5^{o}N. It thus seems to suggest that two distinct physical processes are active near the latitudes of 5^{o}N and 10^{o}N, respectively, and the peak rainfall seasons favored by them are different due to different seasonal evolutions in the large-scale environment (Lebel *et al.* 2003). Here a detailed description of seasonal variations of various variables within the West African Monsoon system are provided by means of currently available, high-quality TRMM satellite observations (Adler *et al.* 2000). The study is concentrated on the variability in rainfall, sea surface temperature (SST) in the tropical eastern Atlantic, and large-scale circulation patterns, *e.g*., the African easterly jet (AEJ), tropical easterly jet (TEJ), *etc*. Based on the observational evidences, we argue that, the rainfall near the Gulf of Guinea where rainfall peaks during May-June is primarily modulated by the oceanic seasonal forcing. In contrast, rainfall and variability within the interior West Africa mostly result from the interaction between various dynamic components.

2. OCEANIC FORCING

Seasonal cycles in rainfall (Fig. 1) and various variables and their relationships in the Gulf of Guinea are examined using the weekly TRMM products. Higher (lower) SST generally corresponds to more (less) rainfall. Intense rainfall appears at two different seasons and in two different regions. A sharp reduction of rainfall south of 5^{o}N occurs at the day 190-200 period (Mid-July), resulting from the cold SST damping. Warmer SST forces convection and rainfall south of 5^{o}N within the Gulf of Guinea before day 190. However, a lag-phase (about one month) is evident between the maximum rainfall and warmest SST. It is also interesting to note that the most intense rainfall zone actually comes along with the appearance of strong SST meridional gradient, though the mean SST has to be above a certain threshold (>26^{o}C). This tends to suggest the importance of both SST thermal and dynamic forcing in organizing surface convergence, tropical convection and rainfall.

Weekly surface wind components from the QuikScat satellite in the tropical eastern Atlantic indicate evident wind direction changes from southwesterly to southeasterly around day 120. Particularly, an abrupt increase in meridional wind component occurs during the day 120-150 period, which might be instrumental to equatorial upwelling. Despite high-frequency variability in surface wind components on the weekly time scale, coherent relations between zonal and meridional winds can still be discerned. Within this region, the surface trade wind vectors always shift from southwesterly to southeasterly, or *vice versa*.

3. MEAN WIND FIELD AND RAINFALL-RELATED PERTURBATIONS

Previous studies indicate that summer rainfall variability over West Africa is closely associated with the variability in the large-scale environment, such as AEJ and TEJ. The mean zonal wind fields from the NCEP/NCAR reanalysis project show an abrupt development in the low-level westerly flow, quantified by the zonal wind at 850 *mb*, concomitant with the onset of the rain events along 10^{o}N. The AEJ moves northward and becomes stronger in spring. It becomes weaker during the day 180-200 period, possibly related to the appearance of the intense African easterly waves (AEWs) which tend to weaken AEJ. As the low-level westerly flow, a sudden development of TEJ is also seen approximately at the same time period. These concurrent transition features in various fields imply their close association.

Surface daily rainfall patterns are further decomposed into various perturbation signals, particularly within the synoptic-scale domain (here referred to wavenumber k=6-10). This effort is to explore whether any season- and/or latitude-dependent wave modes exist in rainfall variability. For k= 6-10, most of the spectral signals move to the north from April to August, following the seasonal migration of major rain events. During April-June, most propagating signals are eastward-propagating and along 2^{o}N-6^{o}N, which may be

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associated with the synoptic-scale Kelvin-type waves. During July-September, in contrast, westward-propagating signals are dominant within a frequency band of -0.1 - -0.3 cycles day^{-1}, corresponding to intense AEW activity within the major rainy belt along 10^{o}N. For k=1-5, an evident power peak is seen at f=0.02 - 0.04 cycles day^{-1}. Contrasting to their synoptic-scale counterparts, these wave signals are always propagating eastward, though they roughly follow the seasonal march of surface rainfall. These wave signals might be related to the Madden-Julian Oscillation (MJO).

4. CONCLUSIONS

Surface rainfall and seasonal variability over West Africa seem to be associated with two distinct processes. Near the Gulf of Guinea (about 5^{o}N), intense rainfall begins in April following warm SST in the tropical eastern Atlantic. Meridional SST gradients play an essential role in forcing convection and rainfall during the day 120-190 period (from May to mid-July). Low-level southerly flow accelerates, a possible direct response to convection and rainfall, which induce SST decrease through an enhanced equatorial upwelling. Besides enhancing the southerly flow, the formed cold SST zone quickly begins to suppress the convection and rainfall when the mean SST is less than about 27^{o}C, though the strong meridional SST gradients still exist till about day 250. That the major deep convective zone fails to move northward across the land may also be due to the unfavorable surface land conditions. Consequently the major surface rainfall events near the Gulf of Guinea disappear due to the formation of an oceanic cold tongue complex in the tropical eastern Atlantic. During the course of this evolution, surface rainfall is shown to be both a passive and an active member in the entire coupled system. Other large-scale factors such as AEJ and TEJ, however, have not shown any significant impact in this region.

Along 10^{o}N over the West Africa, a second rain belt begins to develop from July and remains there during the later summer season. This belt seems to be independent of the first one to the south. The onset of rainfall events within this belt is concomitant with a northward-movement of AEJ and accompanying horizontal and vertical shear zones, the appearance and strengthening of TEJ and a strong low-level westerly flow, and the appearance of intense westward-propagating synoptic-scale wave signals. Thus, rainfall and variability within the West African continent are primarily modulated by these large-scale features (*e.g*., Grist and Nicholson 2001). However, indirect dynamic effects of SST may not be neglected. Significant negative correlation between SST in the tropical eastern Atlantic and mean rainfall along 10^{o}N can be found. Additionally, intense surface meridional SST gradient during the day 190-250 period might be favorable for the surface convergence zone and rainfall along 10^{o}N.

Spectral decomposition of surface rainfall shows that most eastward-propagating (intraseasonal and synoptic-scale) wave signals are observed within the first rainfall peak zone during May-June. During July-September, however, AEWs dominate the variability in the synoptic-scale domain within the second rainfall peak zone, even though eastward-propagating intra-seasonal signals appear as well.

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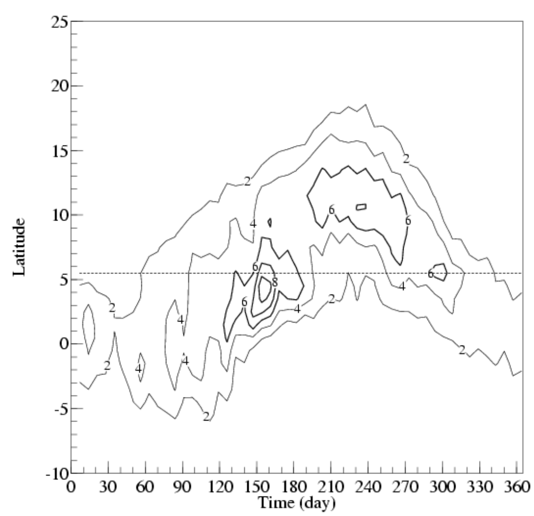

Figure 1 Seasonal cycle in weekly TRMM rainfall between 9.5^{o}W-9.5^{o}E.