4B.5 Waves interactions during the 1984 African monsoon onset

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1. INTRODUCTION

Intra-seasonal variability of the West and Central African monsoon is analyzed through a case study of the onset of the 1984 monsoon. The dominant waves and modes for this selected case are convectively coupled Kelvin waves and a 15-day periodicity mode we call the Guinean Quasi-Biweekly Mode of convection (GQBM).

The convectively coupled Kelvin waves originate from the Pacific sector, interact with deep convection of the ITCZ (Inter-Tropical Convergence Zone) over the Atlantic and West and Central Africa, then weaken over East Africa and the Indian ocean. The convective and dynamical patterns identified over the Atlantic and Africa show some resemblance to the theoretical equatorially trapped Kelvin wave solution on an equatorial beta-plane. Most of the flow is in the zonal direction as predicted by theory and there is a tendency for the dynamical fields to be symmetric about the equator, even though the ITCZ is concentrated north of the equator at the full development of the African monsoon. The full description of the dominant mode of convectively coupled Kelvin waves during the West African monsoon is presented in Mounier et al. (2006a).

The 15-day periodicity intra-seasonal mode of convection in the African monsoon during northern summer identified as the GQBM is mostly characterized by a quasi-stationary zonal dipole of convection whose dimension is larger than the West African monsoon domain, with two poles centered respectively along the Guinean coast and between 30°W-60°W in the equatorial Atlantic (Mounier et al., 2006b). This mode has been defined from a Spatial Empirical Orthogonal Function analysis (SEOF) performed on the 10-25-day band-pass filtered June-September OLR values over the domain 10°S-30°N/30°W-30°E for the period 1979-2000. Fig. a (contours) displays the 10-25-day filtered OLR composite map of strong minus weak convective intra-seasonal events, where strong (resp. weak) events are selected when the respective Principal Component (PC) time series values have maximum (resp. minimum) greater (resp. lower) than the PC standard deviation. This pattern represents an enhancement, up to 25 $W.m^{-2}$, of the mean convection over the African ITCZ (in summer the ITCZ is centered along 10°N). To validate this result based on OLR as a proxy for convection, wet minus dry composites of unfiltered rainfall fields based on the OLR PC time series have been computed over the period June-September from 1979 to 1990, the common period between the NOAA-OLR and the IRD-rainfall datasets (Fig.a; shaded). This composite highlights the link between this mode and a modulation of rainfall including the whole ITCZ with high differences in precipitation amounts, but without any significant changes in the latitudinal location of the ITCZ.

On a larger scale, the GQBM dipole pattern appears to be controlled by an equatorial atmospheric dynamics through a Kelvin wave type pattern propagating eastward between the two poles and also by land surface processes over Africa, inducing combined fluctuations in surface temperatures, surface pressures and low-level zonal winds off the coast. When convection is the suppressed over West and Central Africa, the lower cloud cover induces higher net shortwave flux at the surface which increases surface temperatures and lowers surface pressures. This induces an east-west pressure gradient both at the latitude of the ITCZ (10°N) and of the Saharan heat low (20°N) leading to an increase of the westerly moisture advection inland. The arrival from the Atlantic of the positive pressure pole front amplifies the low-levels westerly wind component and the moisture advection inland leading to high convective activity over West and Central Africa. Then opposite phase of the dipole develops. The full description of this GQBM is presented in Mounier et al. (2006b).

2. DATA

These analyses are based on the use of different resolution convection proxy. First, 2.5° resolution datasets are used: the daily Interpolated OLR dataset from the Climate Diagnostics Centre have been used as they are a reference for tropical studies where deep convection and rainfall can be estimated through low OLR values, a daily interpolated in-situ rainfall dataset from the IRD (Institut de Recherches pour le Développement) over the domain 3-20°N/18°N-25°E for the period 1979-1990.

Higher resolution data (a regular 0.5° latitude-longitude grid at 3-hourly intervals) have been exploited: the Cloud Archive User Service (CLAUS), an archive of global window brightness temperature for the period 1983-1993. This archive is based on the International Satellite Cloud Climatology Project (ISCCP) level B3 data (Rossow et al. 1997).

Finally, a database identifying cloud clusters from the full-resolution (30 mn, 5 x 5 km^2) Meteosat infrared channel (10.5-12.5 µm) has been used. The mesoscale convective systems (MCS) identification was carried out through tracking algorithm based on an area overlap method (Mathon and Laurent 2001, Mathon et al. 2002). MCS systems have been defined as convective clouds larger than 5000 km^2 at the 233K brightness temperature threshold commonly used for identifying deep convection (Duvel 1989) and accumulated convective precipitation in the Tropics (Arkin 1979). MCS lasting more than 12 hours have been retained. This dataset is available for the monsoon period (June to September) between 1983 and 1999 over the domain 0°-20°N/ 60°W-40°E.

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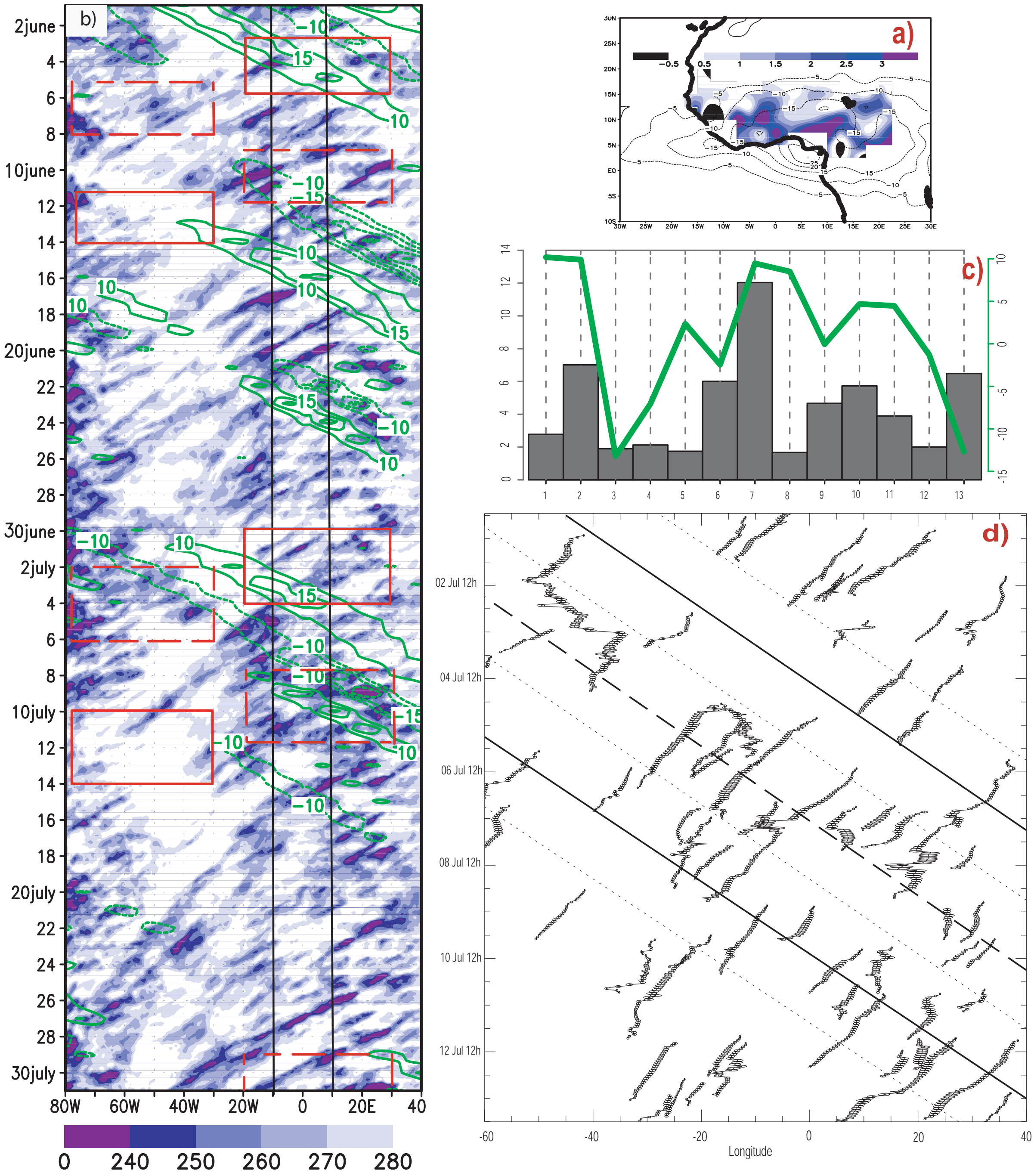

Figure. (**a**) Composite fields of strong minus weak convective events for JJAS 1979-2000 based on the PC time series (see details in the text); contours: OLR differences (W.m^{-2}); shaded: same as contours but for unfiltered rainfall (mm.d^{-1}) computed on the period 1979-1990; *The case study of the 1984 African monsoon season*. (**b**) Longitude-time diagram from 1st June to 31st July 1984 of three-hourly CLAUS brightness temperature (°K; blue shading) and of daily Kelvin-filtered OLR (green contours; W.m^{-2}), both averaged over the latitudes 5°N-12.5°N. The longitude area 10°W-10°E is delineated. The red squared contours are based on the PC1 peaks and depict the space-time areas of the GQBM dipole (solid/dashed contours for positive/negative OLR anomalies). (**c**) Time sequence of precipitation from IRD data set computed between 01July1984 and 13July1984 over the area 2.5°W-2.5°E/7.5°N-12.5°N. Grey bars represent rainfall (mm.d^{-1}) and the line the Kelvin-filtered OLR values (W.m^{-2}) over the same area. (**d**) Longitude-time diagram of individual MCS tracking from 01July1984 to 13July1984 over the latitudes 5°N-12.5°N. Individual MCS trajectory is displayed for MCS lasting more than 12 hours by ellipses whose size represents the spatial extension of the MCS coverage at the 233K threshold. Heavy solid (dashed) line represents the trajectory of the dry (wet) phase of the Kelvin wave, and thin dotted lines display the area of these dry/wet phases.

Because of the varying availability of Meteosat data, the extracted areas are not identical, the overlapping area being 5°N-20°N and 20°W-20°E. No data were available east of 20°E over the period 1989-1991, south of 5°N and west of 29°W for the year 1992, and west of 25°W over the period 1993-1997.

3. THE 1984 WEST AFRICAN MONSOON ONSET

The impact of the GQBM combined with a Kelvin wave train is illustrated in this abstract during the monsoon onset in 1984 as it effects convection (Fig. b, c), rainfall (Fig. c) and the life cycle and track of individual westward propagating convective systems (Fig. d). The year 1984 has been a very particular year for the African summer monsoon season since it was the driest year ever known during the last century due to highly abnormal warm sea surface temperatures in the Guinea Gulf leading to an abnormal southward location of the ITCZ (Lamb et al. 1986). For instance the ITCZ gravity center was located about 9°N in the last part of July instead of 11°N for the multi-year mean (Le Barbé et al. 2002) and the isoline 5 mm.d^{-1} did reach 12°N instead of 14°N for the mean (Sultan and Janicot 2003). This fact may be favorable to higher interactions between the ITCZ and both equatorial Kelvin waves and GQBM since the ITCZ is then nearer to the equator. Sultan and Janicot (2003) defined for that year the monsoon onset date on July 3rd based on IRD rainfall indexes at 5°N and 10°N. This date corresponds to the beginning of the transition phase characterized by a general significant weakening of the convection over West Africa and leading to the definite installation of the rainfall regime on the northernmost latitudes, characterizing also the abrupt displacement of the ITCZ from the Guinean Coast to the Sahelian latitudes.

Fig.b presents the longitude-time diagram of the three-hourly CLAUS brightness temperature field and of the daily Kelvin band filtered OLR (see Wheeler & Kiladis (1999) for more detail on the filtering technique). The CLAUS data enables to follow westward tracks of MCS from East Africa to the west as far as the Mexico Gulf. The Kelvin wave activity has been delineated when the related filtered OLR signal is higher than 10 W.m^{-2} in absolute value. Several wave trains are detected crossing from West to East Africa in particular. It is very interesting to notice the modulation of the activity of MCS by the passage of such a Kelvin wave train, the negative (positive) OLR phase of the wave enhancing (weakening) convection in the MCS. Furthermore, as for the modulation of the MCS by the Kelvin waves, we can notice that the GQBM negative/positive phases (red squared contours) are associated with the enhancement/weakening of the convective intensity of the embedded MCS. In particular, the PC1 presents a minimum the 3rd of July during the onset in agreement with the significant decrease of convection associated with this type of event. Moreover, the highest modulation of PC1 occurs on 10th July. The impact of the GQBM on the MCS activity at this time is drastic. An envelope of highly enhanced convection is located over West Africa and is associated with the absence of any significant convective activity over the central and western Atlantic during the following days partly due to the development of the opposite pole of the GQBM dipole.

The impact of the Kelvin wave crossing over West Africa on local rainfall is highlighted on Fig.c through the time sequence of precipitation from IRD data set computed over the area 2.5°W-2.5°E/7.5°N-12.5°N (bars). The Kelvin wave crossing this area is depicted by the Kelvin-filtered OLR values computed over the same area (green line). The impact of the Kelvin wave appears clearly through weak precipitation occurrence when its dry phase is present on July 3rd (the onset date), then the abrupt rainfall increase on 6th and 7th of July at the maximum of its wet phase, followed by weaker rainfall amounts once the wet phase goes further east.

Finally, Fig.d highlights the impact of this Kelvin wave on the MCS life cycle by displaying the corresponding longitude-time diagram of individual MCS tracking over the latitudes 5°N-12.5°N. Each individual MCS track is displayed by ellipses whose size represents the spatial extension of the MCS coverage at the 233K threshold. During the first dry phase of the Kelvin wave, there are very few and very weak convective systems. On the other hand, the wet phase occurrence is associated with more and highly developed convective systems. Rather surprisingly we also observe that some of these systems have not a regular westward trajectory but show some backward (eastward) displacements that may be due to the dynamical forcing of the eastward propagating Kelvin wave. Lastly, when the following dry Kelvin wave occurs, we observe less and weaker convective systems than during the wet Kelvin wave phase.

4. CONCLUSION

The particular event of the 1984 West African monsoon onset highlights complex but coherent interactions between equatorial Kelvin waves and intra-seasonal GQBM mode. This interactions effects convection, rainfall but also the life cycle and track of individual westward propagating MCS.

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