The role of convectively-coupled Kelvin waves on tropical cyclogenesis over the tropical Atlantic

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1. Introduction

Convectively-coupled atmospheric Kelvin waves (CCKWs) over the tropical Atlantic and Africa have been considered in only a limited number of studies. CCKWs are eastward propagating tropical convective disturbances with the dispersion characteristics of equatorially trapped shallow water Kelvin modes (Takayabu 1994; Wheeler and Kiladis 1999, henceforth WK99). Variations in cloudiness associated with CCWKs peak along the latitude of the climatological inter-tropical convergence zone (ITCZ), which generally is located between 5-15°N over the Atlantic Basin, varying seasonally over Africa (Roundy and Frank 2004; Kiladis et al. 2009). Mekonnen et al. (2008) demonstrated that African topographic features (e.g., the Guinea, Fouta Djallon, and Ethiopia Highlands) strongly react to the passage of the convectively active phase of a CCKW by dramatically increasing in rainfall during the time of passage. Further, CCKWs have been shown to modify the background state (e.g., Mounier et al. 2008), as well as intensify westward moving African easterly waves (AEWs) travelling through its convectively active phase (e.g., Ventrice 2010). Therefore it is natural to wonder the role of CCKWs on tropical cyclogenesis over the main development region (MDR; 5-20°N, 20-65°W) during the West African monsoon (WAM) season.

2. The role of CCKWs on convection over the tropical Atlantic and Africa

Figure 1 highlights the influence of CCKWs on the total OLR and the 850 hPa wind field. Fields of total OLR, Kelvin filtered OLR anomalies, and 850 hPa wind anomalies are averaged over each lag based off a CCKW index. The CCKW index is derived by selecting all days where negative Kelvin-filtered OLR anomalies were less than -1.5 standard deviations in magnitude during the 1989-2009 JJAS seasons over a grid point (9°N, 15°W). Lags are used on this time series in order to highlight the evolution and propagation characteristics. For clarification, "Day 0" is when the minimum Kelvin filtered OLR anomaly moves over the selected base point.

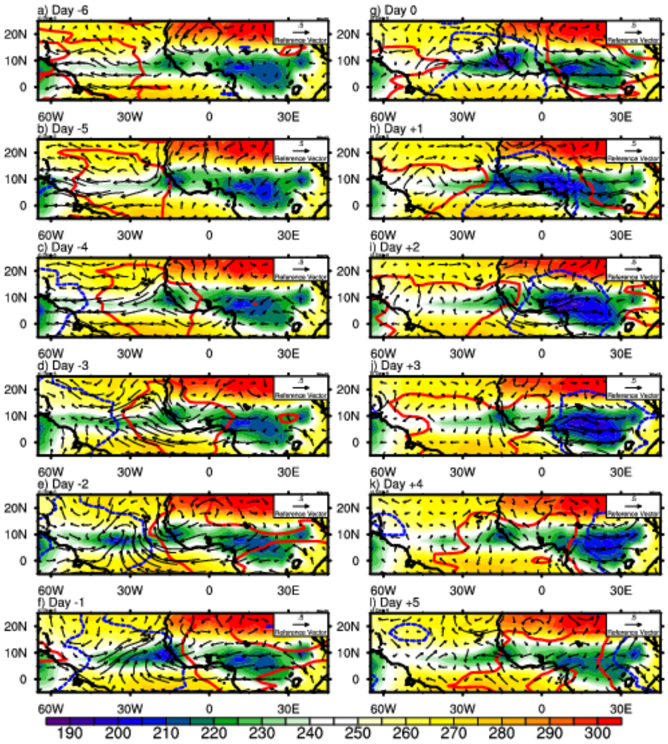

FIG. 1. Unfiltered NOAA daily averaged interpolated total OLR (shaded), Kelvin filtered OLR anomalies (contoured), and 850 hPa wind anomalies (vectors) averaged over the Northern Hemisphere summer months (JAS) from 1989-2009 for each CCKW day lag. Positive (red) and negative (blue) CCKW filtered OLR anomalies are statistically different than zero at the 95% level. Shade interval is 5 Wm^{-2}; reference wind vector is 0.5 ms^{-1}.

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This figure highlights the eastward progression of low OLR values within the composited convectively active phase of the CCKW over the tropical Atlantic and Africa. The convectively suppressed phase (red contour) of the composited CCKW moves eastward ahead of the convectively active phase (blue-dashed contour), and is observed to weaken local convection over the Atlantic ITCZ and tropical African region.

The convectively active phase of the CCKW progresses eastward and acts to locally enhance convection. A second convectively suppressed phase of the CCKW follows the convectively active phase, again acting to reduce local convection. This "suppressed-active-suppressed" convective pattern associated with the CCKW travels eastward together with an average phase speed of 15 ms^{-1}. This phase speed is consistent with the observed phase speeds of CCKWs over the Indian Ocean, which average between 12-15 m s^{-1} (e.g., Dunkerton and Crum 1995; Roundy 2008), and suggests CCKWs over tropical West Africa posses similar magnitudes to those observed over the Indian Ocean.

3. The influence of CCKWs on tropical cyclogenesis over the MDR

Figure 2 shows a time-longitude plot using the CCKW index of unfiltered OLR anomalies (shaded) and the locations of tropical cyclogenesis events occurring equatorward of 25°N. A reduction of tropical cyclogenesis events is observed within the leading convectively suppressed phase of the CCKW, with an enhancement of tropical cyclogenesis events after the passage of the convectively active phase. Tropical cyclogenesis does commonly occur within the convectively active phase of the CCKW, like the case study of Tropical Storm Debby in 2006 (larger yellow crossed circle; see Ventrice et al. 2011). However, tropical cyclogenesis is observed to be more frequent one-to-two days after the passage of the convectively active phase. This result arises from a modification of the large-scale environmental conditions over the tropical Atlantic by the CCKW.

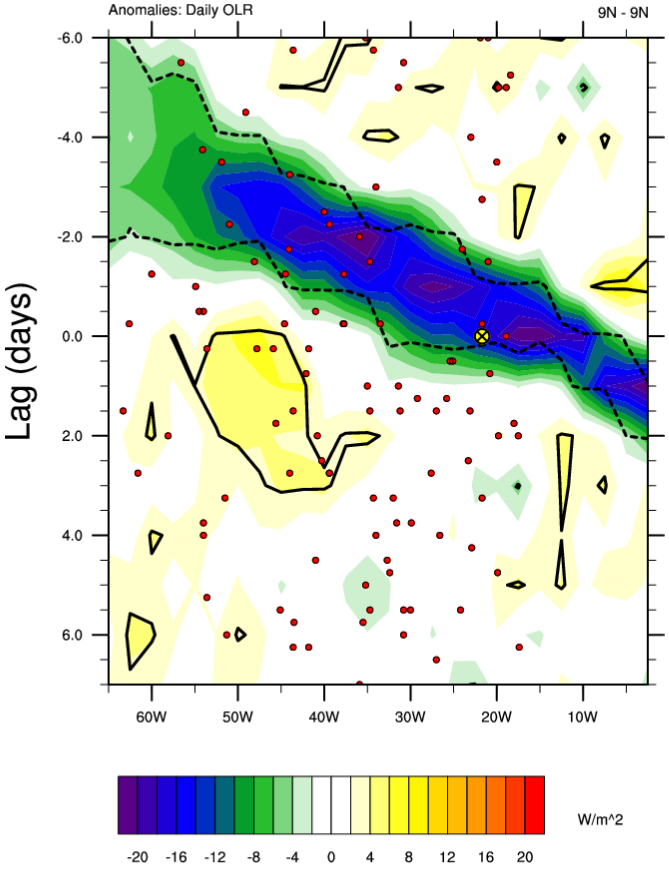

FIG. 2. Time verse longitude section plot of composited unfiltered OLR anomalies averaged along 9°N during June-September 1974-2009. Composite unfiltered OLR anomalies are shaded. Positive OLR anomalies statistically different than zero at the 95% level are within the solid contour. Negative OLR anomalies statistically different than zero at the 95% level are within dashed contour. Tropical cyclogenesis within the MDR (5-25°N, 65-15°W) for any given lag is denoted by a red circle. The genesis of Tropical Storm Debby is highlighted by the large yellow crossed circle. Shade interval is 2 Wm^{-2}.

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