

THREE-DIMENSIONAL STRUCTURE OF AFRICAN EASTERLY WAVES BASED ON 1B.5

EMPIRICAL ORTHOGONAL FUNCTIONS

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1. INTRODUCTION

The long history of research on African easterly waves (AEWs) has mostly focused on their mean structure and the associated dynamics (e.g., Reed et al., 1977; Kiladis et al., 2006; Thorncroft and Hoskins 1994). While these studies provide us a useful framework to understand the dominant dynamics of AEWs, substantial variability of the waves in terms of their structure and intensity prevail (Bain et al. 2011). For example, the variability in the monsoon and the African easterly jet (AEJ) are likely to have significant impacts on the structure and amplitude of the AEWs. In this talk, we revisit the three-dimensional structure of AEWs with an Empirical Orthogonal Function (EOF) approach and investigate the variability of AEW characteristics. While the EOF approach has been adopted to evaluate the representation of AEWs in climate models (e.g., Ruti and Dell'Aquila 2010), it has not been exploited to shed new insights on wave structure and variability.

2. METHOD

In this study, dynamical fields from the European Centre for Medium-Range Weather Forecasts ERA-Interim reanalysis from 1984 to 2013 are used (Dee et al. 2011). The brightness temperature from Cloud Archive User Services for the same period is employed as a proxy for convection (Hodges et al. 2000). The EOF analysis is conducted with two variables that are routinely used to track AEWs, 700 h Pa meridional wind and satellite brightness temperature. Before applying the EOF analysis, meridional wind is filtered to retain power in the 2-6-day band using a Lancos filter, while the tropical-depression (TD) filter is applied to the brightness temperature. The structure of the AEWs is extracted by projecting the wind fields and brightness temperature onto the principle components associated with the EOF patterns. This approach isolates the most dominant wave structure and through lagged regression analysis we can explore the associated evolution of the

AEWs. The EOFs explored in this study are found to be physical and robust as determined by a series of domain sensitivity tests (not shown).

3. RESULTS

3.1 EOF patterns based on the two variables

Figure 1 shows the leading pairs of EOFs based on 2-6-day filtered meridional wind and TD-filtered brightness temperature. The principle components of each pair of EOFs are highly correlated at lags (correlation coefficient > 0.9) and the EOF patterns represent a westward propagating wave structure. Over West Africa, the meridional wind EOF patterns have a wavelength of about 3,500 km while the brightness temperature EOF pattern has a slightly shorter wavelength of about 3,000 km.

3.2 Evolution of AEW based on 2-6-day-filtered meridional wind

Consistent with literature, the lagged regression map (Fig. 2.) reveals a meridionally broad circulation spanning from 15° S to north of 30° N. In addition, as shown by Kiladis et al. (2006), a distinct evolution of convection within the jet-level wave is observed at 10°N: convection occurs in northerly flow over East Africa, shifts into the trough around the Greenwich Meridian and into southerlies behind the trough as the wave moves over the Atlantic.

Close inspection reveals a “checkerboard” pattern in convection that has not been clearly seen in previous studies. On day -2, the convection associated with the trough around 5°W is mostly confined south of 15° N. By Day 0, the convection remains active within the southern portion of the wave while a separate peak in convection is observed north of 15° N lagging the trough. The map of the low-level moisture field (Fig. 4a) suggests the enhanced convection to the north is linked to the increased moisture advection associated with the baroclinic northern vortex (NV) around 18°N and the Greenwich Meridian. This favorable environment provided by the NV seems consistent with the observed secondary peak of squall line generation in the low level maximum southerlies in the Sahel (Fink and Reiner 2003).

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3.3 Evolution of AEW based on TD-filtered brightness temperature

The circulation and convection associated with the brightness temperature EOF are presented in Fig. 3. While a similar shift of convection relative to the wave is observed, the convection is mostly confined to the southern portion of the wave. In addition, despite the fact that the zonal wavelength is only slightly smaller than that of the meridional wind EOF, the circulation associated with it is significantly weaker and more meridionally confined. As indicated by the weak and open circulation around 20°N, the low-level dynamical field reveals more of a structure of the downward reflection of a Rossby wave at the jet level (Fig. 4b), as opposed to the clear NV circulation captured by the meridional wind EOF (Fig. 4a). These results suggest that a strongly convectively-coupled AEW could be associated with a short wavelength and meridionally-confined circulation and does not necessarily include a prominent low-level NV (Berry et al 2007).

4. DISCUSSIONS

The significant differences in the patterns and evolution of convection and circulation between the two pairs of EOFs demonstrate the capacity of EOF approach to isolate different characteristics of AEWs and highlight the distinctive behaviors of AEWs. In fact, the nature and causes of the different AEW behaviors can be attributed to part of a larger question of intraseasonal variability of AEW activity. We hypothesize that the large-scale environment plays a significant role in the intraseasonal variability of AEW activity and that the wave activity variations are accompanied by changes in AEW behavior. In other words, the two distinctive AEW structures documented by the EOF approach are hypothesized to be linked to the large-scale environment. An enhanced AEJ, for example, may imply enhanced mixed barotropic-baroclinic growth and a more dynamically-driven wave while a moist environment is likely to spin up a more convectively-coupled wave that grows more via diabatic heating. How these two different routes of energetics lead to the change in amplitude and structure of waves could improve our understanding of the intraseasonal variability of AEW activity.

Our current work has shown the capacity of an EOF approach to highlight the AEW behaviors and we

will pursue this method to shed light on the nature and causes of AEW variability.

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5. REFERENCE

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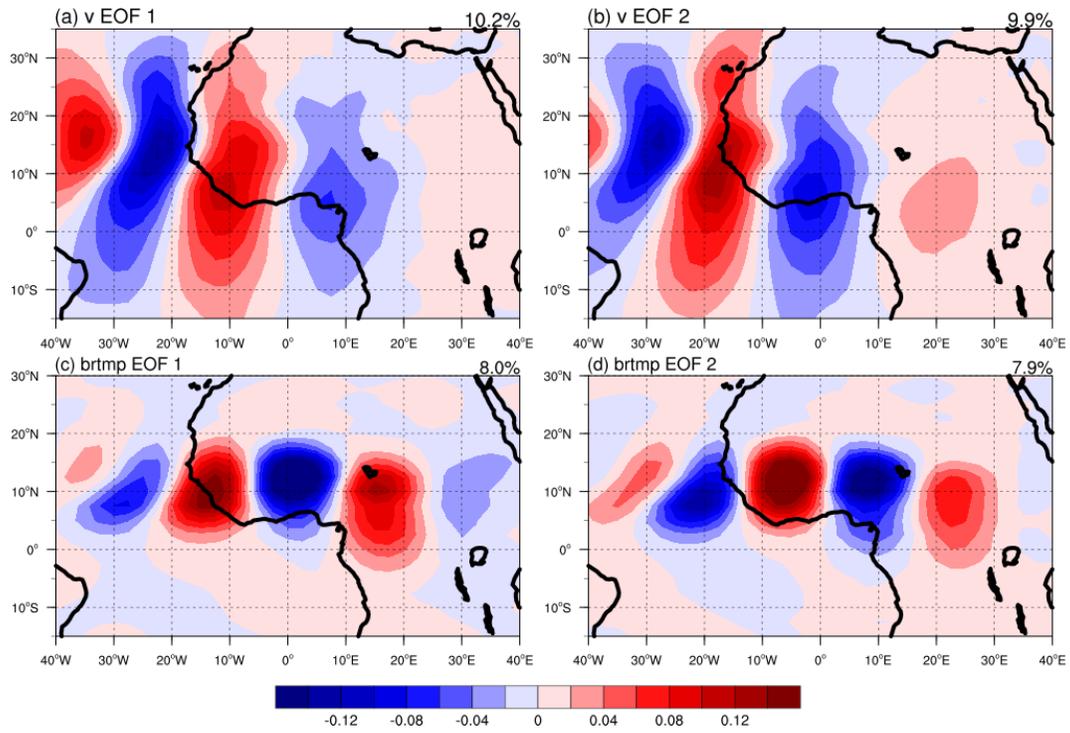


Fig. 1 The leading pair of EOF patterns based on (a) and (b) 2-6-day-filtered meridional wind and (c) and (d) TD-filtered brightness temperature. The variance explained by each EOF is shown in the upper right corner of each plot.

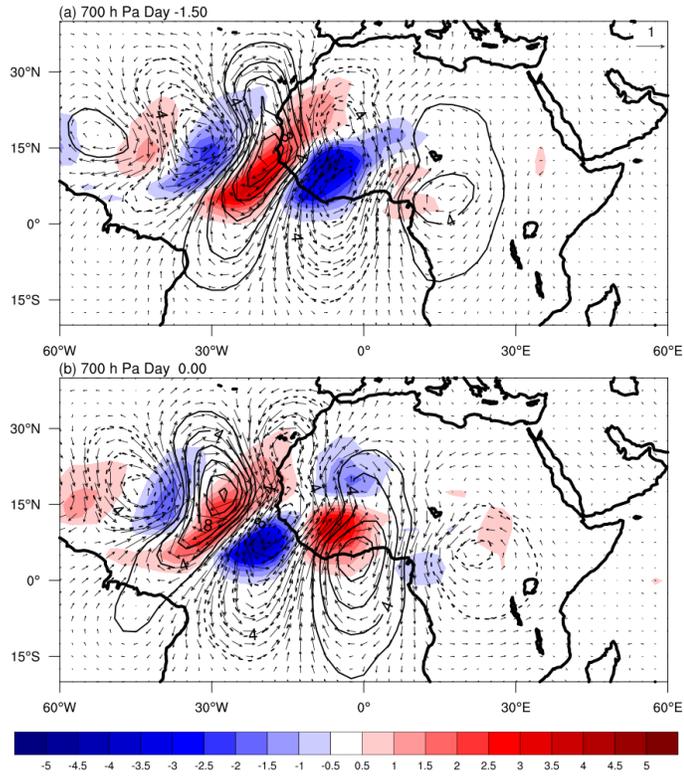


Fig. 2 The anomalous 700 h Pa circulation, brightness temperature (shadings) associated with the EOF based on 2-6-day filtered meridional wind on (a) Day -1.5 and (b) Day 0. The contours are streamfunction ($10^5 \text{ m}^2 \text{ s}^{-2}$). The unit of brightness temperature is in K. The scale of the wind vectors (m s^{-1}) is shown on the upper right corner.

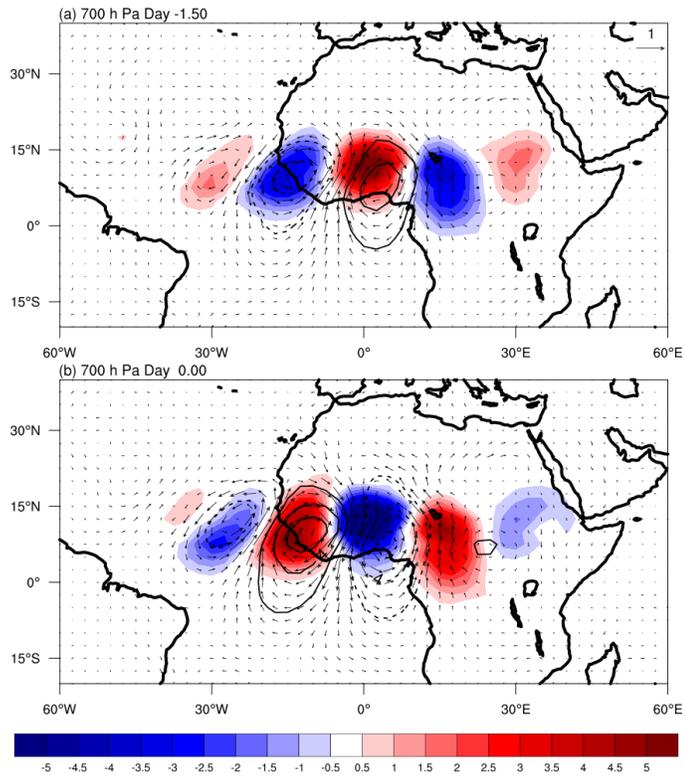


Fig. 3 As Fig. 2 but for EOF based on TD-filtered brightness temperature.

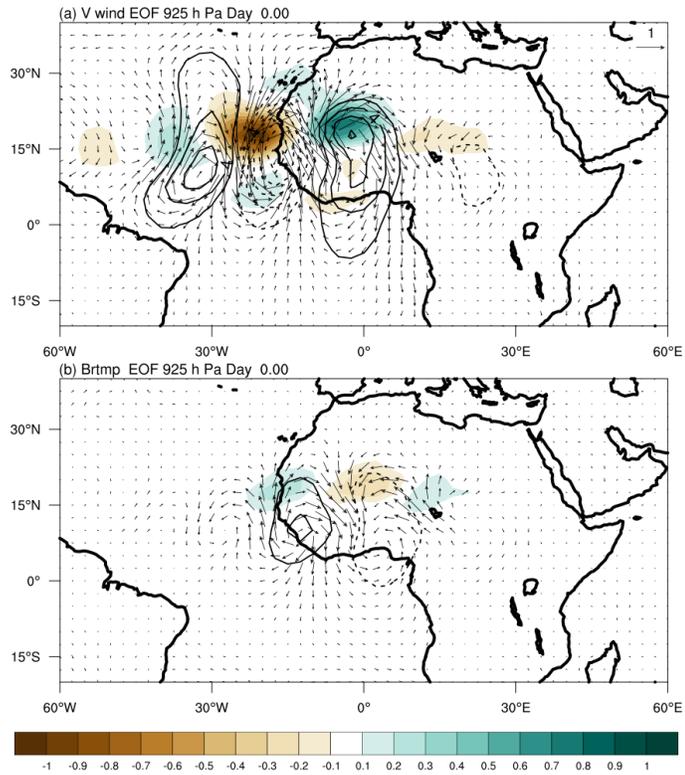


Fig. 4 The anomalous 925 h Pa circulation, specific humidity (shadings) associated with the EOF based on (a) 2-6-day filtered meridional wind and (b) TD-filtered brightness temperature on Day 0. The contours are streamfunction ($10^5 \text{ m}^2 \text{ s}^{-2}$). The unit of specific humidity is g kg^{-1} . The scale of the wind vectors (m s^{-1}) is shown on the upper right corner.