DOES AN INSTABILITY OF THE AFRICAN EASTERLY JET GENERATE
AFRICAN EASTERLY WAVES?

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1. INTRODUCTION

Some previous investigations suggested that the instability of a jet stream may generate wave disturbances (e.g., Fjortoff 1950, Charney and Stern 1962, Eliassen 1983). Further more Burpee (1972) suggested that African easterly waves are directly related to the African easterly jet. Although many of these studies indicated that the instability of a jet current is the probable mechanism behind the generation of wave activity, a relationship between African easterly waves and the jet has not yet been conclusively demonstrated. In order to explore whether the jet instability is the cause of African easterly waves, we modified a mesoscale model (MM5) for summer seasonal simulations over Africa and the tropical Atlantic. Two numerical experiments are performed to study the relationship between the African easterly jet and wave disturbances. Our study indicates that African easterly waves are not necessarily related to the African easterly jet, suggesting that other factors, such as surface heating or the concentration of the ITCZ, may also contribute to the generation of African easterly waves.

2. MODEL SET UP

The simulations are carried out using the MM5 mesoscale model version 3.4. The domain of simulations extends from 15˚S to 50˚N and 125˚W to 70˚E with horizontal resolution 120 km. The vertical dimension extends from 1000 mb to 50 mb with 23 half sigma levels. Two synoptic mode simulations with time step 3 minutes are initialized at 00Z on May 15th 1988 and run through Oct. 15th 1988 (154 days). The boundary conditions for soil moisture availability in the model are set in two ways, one with realistic moisture availability conditions and the other with modified moisture availability conditions, to produce two West African background climatologies, one with and one without the African easterly jet. The modified soil moisture availability can be achieved by manipulating surface boundary conditions in MM5 to eliminate the African easterly jet (Cook 1999). Lateral boundary conditions are updated every 12 hours with NCEP/NCAR reanalysis data.

The physics schemes used in the modeling are the non-convective precipitation scheme for moisture,

the Grell cumulus convection scheme, the Blackadar planetary boundary layer scheme, and the CCM2 radiation scheme.

3. RESULTS

The simulation with realistic soil moisture conditions accurately captures the African easterly jet and wave disturbances over northern Africa and the tropical Atlantic. Fig. 1a shows the MM5's mean zonal velocity and isentropes for July 1988 from the synoptic mode simulation with realistic soil moisture availability conditions. The location of the African easterly jet and the structure of isentropes are in good agreements with the NCEP/NCAR Reanalysis for July 1988 as shown in Fig.1b. The large deflection of isentropes toward
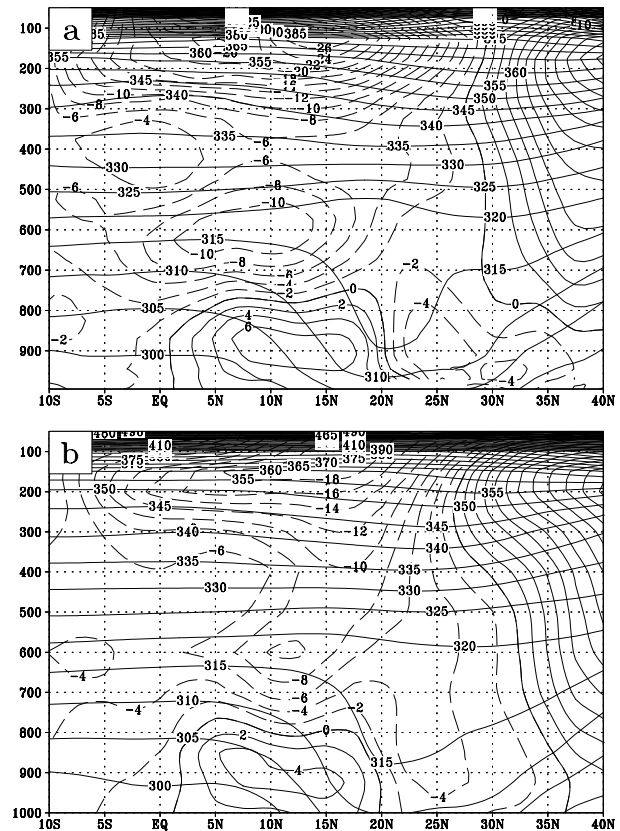

Fig.1 Mean zonal velocity and isentropes (July 1988) averaged from 10˚W and 20˚E for the (a) MM5 simulation with realistic soil moisture boundary conditions (b) NCEP/NCAR Reanalysis. Zonal velocity is in ms^{-1}, and isentropes are in K. Dashed lines denote easterly flow

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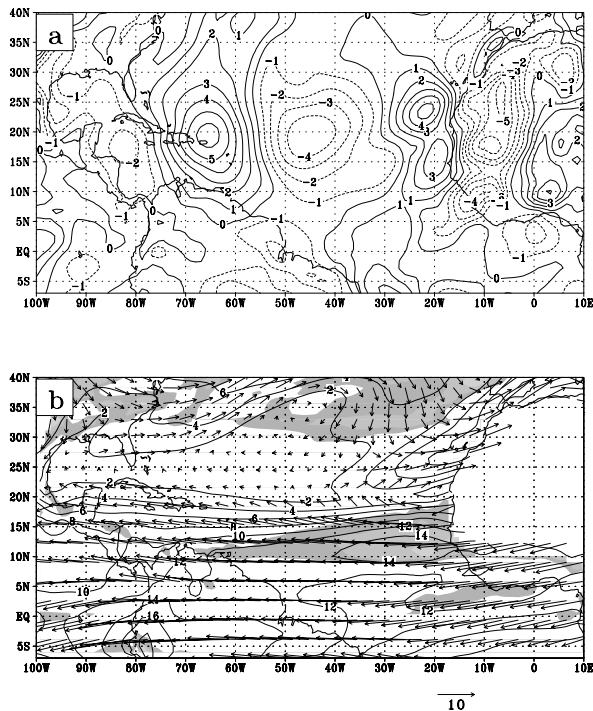
Fig.2 (a) MM5 filtered meridional wind velocity (ms⁻¹) for 12Z July 16, 1988. (b) MM5 Jun 15th –August 30th mean wind velocity (ms⁻¹) and isotachs on the 315 K isentrope. Shading denotes regions with a negative potential vorticity gradient

ground in the lower troposphere indicates baroclinicity is increasing to the north from 5˚N.

The pattern of wave disturbances with wavelengths between 3000 km and 4000 km is observable from the filtered meridional velocity field (T=3~5 days) shown in Fig.2a. The wave disturbances with positive and negative meridional velocity propagate across the Atlantic and originate over two regions. One is between 5˚N and 15˚N over Africa, and the other is between 15˚N and 30˚N. This finding is consistent with the results of Reed et al (1988). In Fig.2b, the coincidence between the velocity maximum on the 315 K isentrope and regions of negative potential vorticity gradient (shaded regions) suggests that both the Charney-Stern and the Fjortoff instability criteria are satisfied. This indicates that a barotropically and baroclinically unstable region is located between 10˚N to 15˚N over West Africa and the tropical Atlantic. A comparison with Fig. 1a shows that at 725 hPa both barotropic and baroclinic conversions from the easterly jet affect the generation of wave disturbances between 10˚N and 15˚N. It also suggests that baroclinic conversions might dominate for wave disturbances further north between 15˚N and 30˚N.

In order to determine whether wave disturbances can still be generated even without the African easterly jet, a simulation with modified soil moisture availability is also performed to eliminate the jet stream as a possible cause. Results from the simulation without the easterly jet indicate that wave activity over northern Africa and the tropical Atlantic still occurs, but with smaller wavelength (2000 km~3000 km) and slower phase speed (4~7 m/s). This suggests that diabetic heating over northern Africa may also be an important source for the generation of African wave disturbances.

4. SUMMARY

Two contrasting MM5 simulations are performed to study the mechanisms for the generation of African easterly waves. Our results suggests that both barotropic and baroclinic conversions may contribute to the generation of wave disturbances between 10˚N and 15˚N, where the African easterly jet is located. The generation of African easterly waves to the north of the easterly jet or even without the easterly jet suggests that the instability of a jet stream may not be the only cause for the generation of wave disturbances. Other factors, such as surface heating over the Sahara and the release of latent heat, may also play an important role on the generation of African easterly waves.

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