9B.4 THE AFRICAN EASTERLY JET-WAVE SYSTEM

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1 INTRODUCTION

African Easterly Waves (AEWs) are important synoptic weather disturbances during the West African monsoon between May and October. Yet details of their evolution, structure, and their interactions with the African Easterly Jet (AEJ) and the moist and dry convection are not well understood. The aim of this paper is to address these issues by examining the relationship between the jet, the waves and the dry convection, using an idealised model. The approach taken follows Thorncroft and Blackburn (1999), (TB99), where an AEJ was forced by dry convection in association with prescribed surface temperature gradients. Their work is extended by a consideration of the AEWs that grow on this jet and the role the dry convection plays in developing them. The inclusion of only dry convection is highly relevant to the low level wave structure observed to the north of the AEJ, early in the monsoon season. The model used is an intermediate GCM (IGCM) developed at Reading University. It is integrated over 15 sigma levels and has a triangular truncation at wavenumber 95, giving a resolvable length scale of approximately 67 km. Dry physics is included with surface fluxes of heat and momentum, parametrised according to the bulk surface formulation (TB99), acting over the lowest three levels. In the control integration, the drag coefficient (Cd) is chosen to be representative of land (Cd=0.004) and the heat transfer coefficient (Ch) is set equal to it. Dry convection is parametrised by a simple, hard adjustment to a dry adiabat. Further details may be found in TB99. Following the Saharan heat low run of TB99, the basic state jet was forced by dry convection using a prescribed meridional surface temperature profile. This gave a typical 16K temperature difference between 3N and 23N and the very, reduced gradient polewards of this, avoided the formation of an unrealistic, mid-tropospheric westerly jet at 33N through interactions across the Sahara. In the zonally symmetric set-up, an easterly jet was established at 14N as shown in Figure 1. It reached a maximum of 16.2ms^{-1} by day 17, at a height of 675mb, similar to observations at 650mb.

2 LINEAR INSTABILITY ANALYSIS

This analysis identified the nature of the most unstable modes which grew on the jet and compared them to previous studies since the jet here had been forced by the dynamics of the heat low, rather than prescribed, and was thus, arguably, closer to observations. The key, new results are that (1) baroclinic and not barotropic energetics, dominated; (2) significant low-level amplitudes, north of the jet were obtained as in observations; (3) growth rates were three times higher and peaked later at wavenumber 20. Calculations based on Eady's baroclinic theory have shown that these differences can be attributed to variations in the vertical shear and static stability profiles, and energy conversions. The observed wavelength region remains unexplained by the peak in the growth rate curve. Alternative explanations may lie in the limited longitudinal extent of the jet, orography, the scale of the initial perturbation itself or the inclusion of moisture.

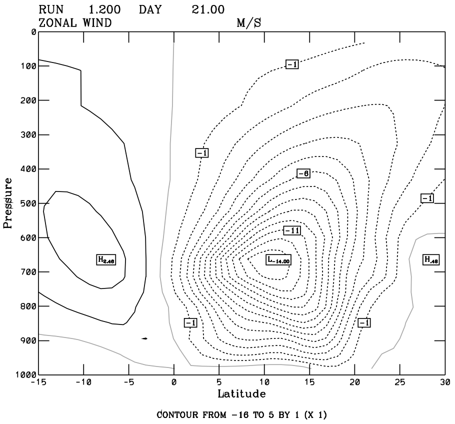

Figure 1: *Latitude-height section of the zonal mean, zonal wind on day 21 in the zonally symmetric run.*

3 LIFE-CYCLE STUDY

The non-linear behaviour of the AEWs (wave number 13) growing on the convectively forced jet was examined in this section. The more realistic framework was aimed primarily at increasing our understanding of the relationship that exists between the AEWs, the AEJ and the dry convection. The waves were initialised by randomly perturbing the surface pressure coefficients at day 0. The time series for the jet with wavenumber 13 growing on it is shown in Figure 2 with the basic jet for comparison. Extraction of energy from the mean flow by the waves, reduced the maximum zonal wind speed to 14.5ms^{-1}. As the waves grew baroclinically, they reduced the temperature gradient through changing the vertical shear and therefore the amplitude of the jet. As discussed by TB99, the observed jet must be a balance then between a jet weakening as the waves extract energy and then strengthening in association with convection. The merid-

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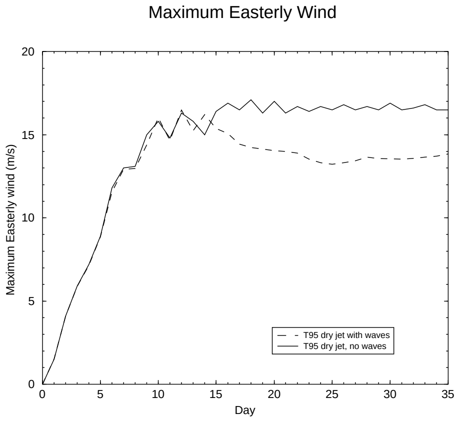

Figure 2: *Time series for the African Easterly Jet with and without, wavenumber 13 growing on it.*

ional cross-section of the wave EKE (Figure 3), exhibits significant low-level structure and is consistent with baroclinic growth as confirmed by the energetics. These instabilities arise from the interaction of the low-level meridional temperature gradient of the Saharan heat low, with the negative meridional potential vorticity (PV) gradients in the jet core.

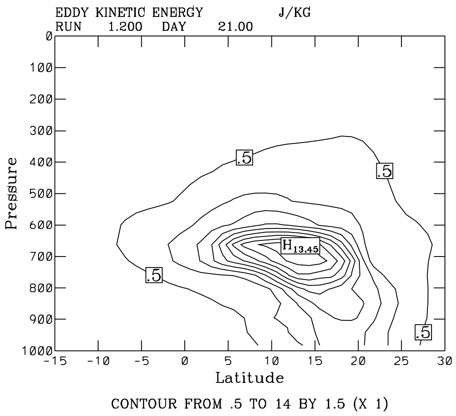

Figure 3: *Zonal-mean, eddy kinetic energy (J/kg) in the 3D heat low run.*

4 SENSITIVITY TO TRANSFER COEFFICIENTS

TB99 found that the time for the AEJ to reach a steady state changed according to the value of the transfer coefficients selected. The development rate of the jet decreased as the momentum and particularly, the heat fluxes increased. In contrast, the instability analysis here showed that increasing the surface fluxes, damped the low level wave structure and reduced the growth-rates of the unstable modes. The life-cycle analysis of growth-rates, structures and jet time series for different transfer coefficients revealed an inter-dependence of the jet and the waves on the evolution of each other, governed by two time-scales: the rate at which the jet was replenished (the replenishment rate) as the waves extracted energy from it and the rate at which the waves evolved. This has significant implications for modelling and interpreting observations since a more unstable jet could exist but have weaker waves growing on it.

5 CAPE ANALYSIS

Further analysis of this idealised, dry set-up by introducing water vapour in a passive context, gives indications to where and why convection is most likely to occur; the role it plays in developing the AEWs; and how the 'dry' waves could impact on the 'moist' waves. The advection of the tracer by the AEWs has provided a means of calculating CAPE at all grid points from the subsequent, 3D temperature and moisture fields. Preliminary results show that (1) there are large, geographical differences in the convective activity; and (2) both CIN (see Figure 4) and CAPE exhibit significant wave variations, which are affected by mid-level, dry intrusions and the moisture availability at low-levels.

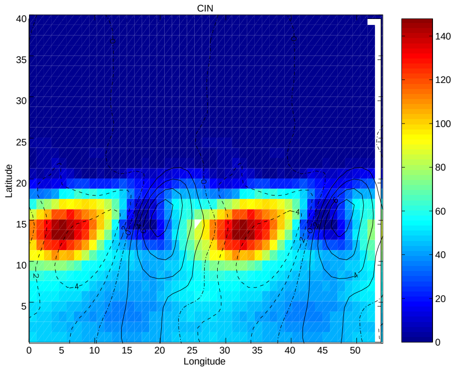

Figure 4: *Longitude-latitude plot of CIN for a passive moisture tracer in the dry simulation, overlain with meridional wind at jet level. Contour interval 2m/s.*

6 CONCLUSIONS

African Easterly waves have been grown on an Easterly jet forced in an IGCM with simple parameterizations. A linear instability analysis and lifecycle study have shown that the waves are characterised by low-level structures polewards of the jet and baroclinic energetics. The relationship of the waves, the jet and the dry convection is sensitive to the land-surface properties which has implications for how the boundary layers are incorporated into GCMs for an African climate to be well-represented. In addition, an analysis of CAPE, supports the existence of a coherent relationship between the wave structure and the convection. Results bear most relevance to the early, pre-monsoon period in north west Africa and to dry periods within the full monsoon season.

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