3C.1 PREDICTION OF AFRICAN EASTERLY WAVES BY THE FSU SUPERENSEMBLE

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1. INTRODUCTION

For over three decades the westward propagating wave disturbances of the lower and middle troposphere over North Africa in summer, known as African easterly waves (AEWs), have been studied by a variety of techniques, including synoptic case studies, composite techniques, spectral techniques, and through output from numerical weather prediction (NWP) models.

There has been considerable debate on how wave amplitude and structure vary in the vertical. Many studies have reported two regions of wave activity in the lower troposphere below 700 hPa. One region is located near 20 N, coincident with the surface position of the monsoon trough over North Africa, and the other region is located in the equatorial rain belt to the south, around 10 N. The current study will focus on the lower tropospheric manifestation of the waves by utilizing The Florida State University (FSU) Superensemble (SE) forecasts of 850 hPa winds and precipitation during June-October 2001.

2. FSU SUPERENSEMBLE METHODOLOGY

The FSU SE technique, as applied to numerical weather prediction, has been described by Krishnamurti *et al.* (2000a,b), and the skill of the technique has been extensively evaluated by Ross and Krishnamurti (2003). In essence the technique utilizes multiple linear regression to derive statistical coefficients from a comparison of member model forecasts to a benchmark analysis during a training period of 120 days. This procedure removes the bias of each individual model and allows for an optimal linear combination of the individual model forecasts, which takes into account the relative skill of each model. The result is a forecast that is generally superior in forecast skill compared to the individual model forecasts and to the ensemble mean (EM) forecast.

3. STATISTICAL RESULTS

Root mean square error (RMSE) results for the 850 hPa vector wind forecasts of the SE, ensemble member models, and the EM in the AEW region (35 W – 15 E and 5 S – 30 N) for June-October 2001 are shown in Fig. 1. The benchmark analysis is ECMWF analysis with FSU physical initialization. This measure of total error shows that the SE has smaller error compared to all ensemble member models through the day 6 forecast. When compared to the EM, the SE has lower error through the day 4 forecast, with equal skill shown for the day 5 forecast.

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RMSE results for precipitation are shown in Fig. 2 for the late summer period, August 15 – October 15 of 2001, when the AEWs were best developed. Observed precipitation is based on TRMM and SSM/I algorithms. The SE forecasts have the lowest errors in comparison to the member models and the EM for all forecast days 1-3.

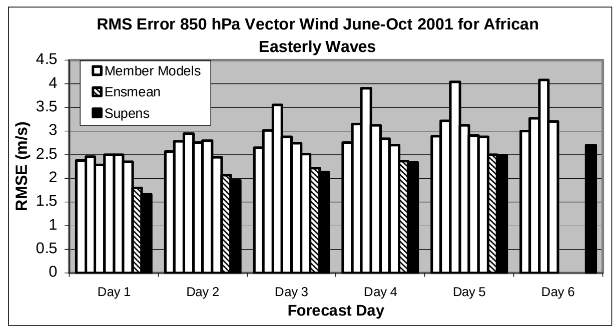

Fig. 1: RMSE (m s^{-1}) in 850 hPa vector wind by forecast day for the period June-October of 2001 in the region 35 W-15 E and 5 S-30 N.

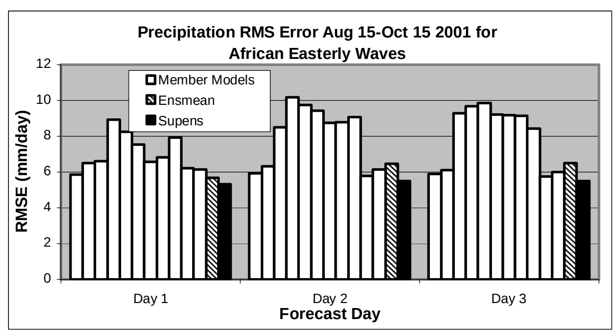

Fig. 2: RMSE (mm day^{-1}) in precipitation by forecast day in the region 35 W-15 E and 5 S-30 N for the period from Aug 15 – Oct 15, 2001.

These figures suggest that 850 hPa winds and precipitation associated with AEWs are better forecast by the SE than by the ensemble member models or the EM. This statement assumes that the 850 hPa winds and precipitation in this region are largely modulated by the passage of AEWs, a reasonable assumption for the period June-October.

4. SYNOPTIC RESULTS

Hovmuller diagrams, wave track maps (based on tracking the cyclonic vorticity center associated with the wave trough), and individual case studies were used to document the synoptic behavior of the AEWs at 850 hPa during June-October of 2001. The region of wave activity to the north of the jet was most prominent in June and July, while the region to the south of the jet grew to be of equal, or greater importance, by August and September. The relatively dry waves of the northern region were generally well forecast by the SE and the ensemble member models. The wetter waves of the southern region were generally not well forecast by the ensemble member models, particularly in terms of wave amplitude, possibly due to errors in the feedback between latent heating/precipitation and the wind flow in the model. The SE provided better forecasts of these waves, and it should be noted that the technique forecasts wind and precipitation independently of each other based on separate training procedures for these variables.

The low level AEW activity exhibited rich diversity. The tracks of the waves for the two wave regions were found to merge off the West African coast, but it was the exception rather than the rule for the cyclonic vorticity centers to merge. In addition to merging, vorticity centers underwent splitting and dissipation.

Figure 3 shows the tracks for the 850 hPa AEW activity over Africa and the adjacent Atlantic during September 2001. The monthly mean positions of the surface monsoon trough and the 700 hPa AEJ are indicated. Eight AEWs were followed, and the two previously mentioned regions of wave activity are evident. The tracks of waves from the two wave regions are seen to merge over the Atlantic. Waves 1, 5, and 8 had vorticity centers originating in the southern wave region. The vorticity centers for waves 2, 3, 4, and 6 originated in the northern wave region, while wave 7 had vorticity centers originating in both regions, with the northern center dissipating. Wave 4's vorticity center also dissipated. Waves 2, 3, 4, and 6 all had their vorticity centers cross from the northern to the southern side of the mean position of the AEJ. Wave 3 originally had two vorticity centers, both to the north of the jet. These moved southward and merged over the Atlantic just to the south of the mean position of the AEJ near 30 W (See Fig. 3). This consolidated vorticity center subsequently developed into Tropical Depression 9. Tropical Storm Barry (July) and Tropical Storm Dean (August) also developed from cyclonic vorticity centers that originated in the northern wave region and then crossed to the south of the mean position of the AEJ. Clearly, the northern 850 hPa wave activity can play an important role in Atlantic cyclogenesis. Waves 7 and 8 in September (Fig. 3) originated to the south of the AEJ and developed into Hurricane Iris and Tropical Storm Jerry, respectively. Hurricane Erin (August) also developed from a wave with its origin in the southern wave region. It is clear from the foregoing that the northern and southern wave regions contributed equally to Atlantic cyclogenesis in 2001 and that the northern wave vorticity centers that underwent development did so after crossing to the south of the mean position of the AEJ.

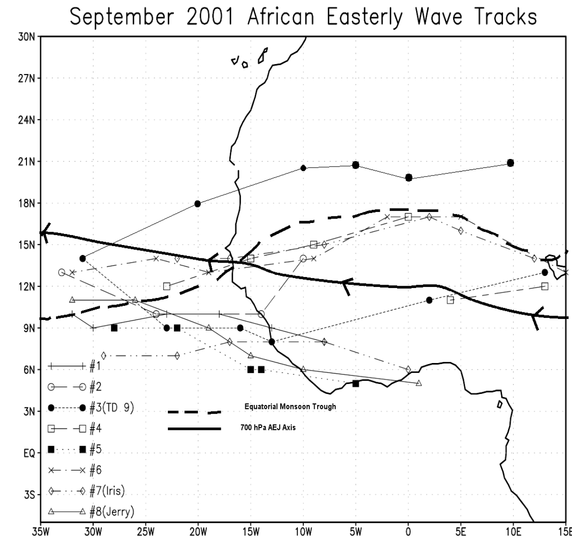

Fig. 3. Tracks of the African easterly waves for Sept 2001.

Three case studies were undertaken to illustrate the diversity in wave behavior. The SE outperformed the ensemble member models in the 24 and 48-hour forecasts of the circulation and precipitation for these three disparate waves by revealing detail that was in greater agreement with observations. These case studies, as well as a full treatment of all the research which is briefly summarized here, can be found in Ross, et al (2003)

More studies are needed to better understand the complex interactions of waves found in the two wave regions and of the dynamics of those waves from the northern wave region that undergo development into depressions and named storms.

5. References

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