14B.3 CONTRIBUTIONS OF THE AFRICAN EASTERLY WAVES AND THE NORTHERN VORTICES TO ATLANTIC TROPICAL CYCLONE FORMATION

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1. INTRODUCTION

Indications of a northern vortex associated with the African Easterly Jet (AEJ) have been observed in many studies involving the AEJ. However, not a lot of research has been done to systematically document the frequency of occurrence, structure (especially in relation to the African Easterly Wave (AEW) to the south of the AEJ), and convection/precipitation associated with the northern vortex. Carlson (1969) found northern vortices around 20°N in the low levels and in a cloud-free area. Studies using ECMWF re-analyses have indicated a low-level circulation north of the AEJ with maximum amplitude between 850 and 950 mb (Thorncroft and Hodges 2001). This preliminary study will examine whether the existence, environmental characteristics, and relationship to the AEW can be established from the analyses of three operational numerical weather prediction models. By observing where the vortices (both northern and southern) develop over Northern Africa and move off the west coast, the environmental conditions that may lead to the development of the vortex into an Atlantic tropical cyclone can be examined.

2. DATA AND METHODOLOGY

The tropical vortex tracking program (VORTRACK) (Harr 2006) is an automated system for identifying and tracking tropical vortices that meet threshold values in operational global model analysis and forecast fields. The threshold vorticity value is a minimum 850 mb relative vorticity of $1.5 \times 10^{-5}\, s^{-1}$. If the relative vorticity is less than $3.0 \times 10^{-5}\, s^{-1}$, another requirement is that the curvature contribution to vorticity must be greater than that of the shear. The models examined in this study were Navy Operational Global Atmospheric Prediction System (NOGAPS), National Centers for Environmental Prediction Global Forecast System (GFS), and the UKMO Global Model. The analyses and predictions from these models are available on a 1° lat./long. grid. Each of these model forecast fields extend to 120 h at 6-h increments.

Using the VORTRACK system, all tropical vortices in each analysis that satisfy the above criteria are assigned a unique identifier. Fourteen environmental parameters that relate to tropical cyclone formation are extracted relative to the position of each vortex (Table 1). The tracks of the vortices in the new analysis are determined by matching it with the same vortex in the previous analysis according to permissible displacement criteria. Similarly, the vortices in the 6-h through 120-h forecasts are identified, and tracks established. By matching the forecast vortex with the analyzed vortex within specified spatial separations, the forecasts can be validated as each verifying analysis becomes available. Each identified vortex is entered with its environmental characteristics into a data base for ease in studying those that form or do not form tropical cyclones as well as those vortices that were false alarms (those that could not be matched with an analyzed vortex meeting the 850-mb relative vorticity threshold criteria).

Since the objective is to document the northern vortex and AEWs, a domain over northern Africa was defined that was large enough to detect the vortices and to track them as they crossed the West African coast over the tropical Atlantic Ocean. Thus, the longitudinal boundaries of this domain extend from 10°E (the farthest east the model data sets were available, even though Lin et al. (2005) found that some vortices to develop farther east) to 30°W. The northern and southern boundaries are 35°N and the equator. The time period of the study is from 1 June to 31 October 2005.

3. PRELIMINARY RESULTS AND DISCUSSION

Five months of initial vortex locations from the three global model (GFS, NOGAPS, and UKMO) analyses have been compared. In the first analysis, the locations of the initial vortices (i.e., only the first time the vortex surpassed the VORTRACK threshold parameters at the analysis time) were compared to find out where vortices form. The vortex may have existed before this time, but not meet the VORTRACK threshold criterion. As an initial proxy for designating the vortex as a northern vortex, i.e., it was in a negative relative vorticity environment that might occur north of an AEJ with maximum zonal winds in the 650-700 mb layer, vortices were color coded for average 850-500 mb relative vorticity < 1 x 10^{-5} s^{-1} and negative values.

Although each month from June to October 2005 was analyzed for the three global models, only the August vortices from the GFS (Fig. 1) are included in the preprint because of space limitations. Although there is some latitudinal variability, two bands of initial vortex locations exist over Africa. In the southern band, the vortices are most concentrated between 6°N and 11°with more scattered vortex positions from 12°N to 14°N. Preliminary comparisons with satellite imagery suggest frequent convection generally associated with this southern band. Future analysis will investigate whether the model vortices are related in space and time with these convective clusters that have a strong diurnal variability.

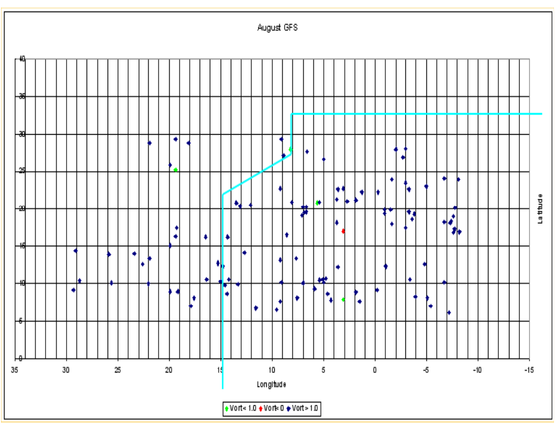

Fig. 1. Initial positions of vortices detected by the TCVTP from the NCEP GFS analyses during August 2005. Vortices in a region with 850-500 mb relative vorticities less than $1(10^{-5})s^{-1}$ are color-coded (see inset). The west coast of Africa is roughly indicated by the dark line for general reference.

The second band of vortices over land in Fig. 1 is generally centered on 20°N with variations from 17°N to 23°N during this month. Since the average position of continental monsoon trough (or ITCZ) on the Climate Prediction Center (CPC) website (http://www.cpc.noaa.gov) reaches 19°N in mid-August, the vortices in this band may be related to this trough.

All three model analyses had similar tendencies for a southern band of vortices and a somewhat separate northern band of vortices. The center of the northern band moved poleward from around 15°N in June to around 20°N in August (as in Fig. 1), and moved southward during September and by October was again around 15°N. As noted above, this evolution is consistent with the evolution of the CPC monsoon trough. The southern band of vortices also migrates from around 5°N in June to around 10°N in August (as in Fig. 1), and retreats in September and is near 5°N in October.

Some other similarities have been noted among the three global model analyses. The number of vortices over land greatly exceeds the number over the ocean region (Table 1), which agrees with the GATE analyses (e.g., Reed et al. 1977). All three models have a minimum number of vortices over the Atlantic Ocean in a band south of 17°N during June 2005, reach a maximum number of vortices during July 2005, have relatively fewer vortices during August and September 2005, and then a minimum during October. How this variability relates to the early season peak in the development of hurricanes during the 2005 season will be explored later.

Other vortices in the GFS analyses are noted along 25°N-30°N (Fig. 1). These vortices are more prevalent in June and again in September and October in all three global model analyses. In addition to those over Morocco and southeastern Algeria, a small cluster of vortices is found over the ocean to the southwest of the Canary Islands. Given the seasonality of the vortices in this latitudinal band, it is likely that they are related to midlatitude systems, especially since the satellite images indicate the greatest number of fronts in that region during those months. Since at this stage in the analysis they do not seem to play a role in tropical cyclogenesis downstream of West Africa, these vortices will not be investigated further.

In the use of the small or negative 850-500 mb relative vortices as a proxy for Northern Vortices, large differences are found in the numbers of such vortices satisfying this criterion. Although the GFS analyses have the largest number of vortices in the target area, they have the smallest number that satisfy the Northern Vortex proxy condition. By contrast, the UKMO analyses have the smallest number of vortices, but have the most vortices that satisfy the proxy condition.

The rationale for utilizing three global models to detect the vortices is based on the assumption that if all three (or even two of the three) models agree as to the location, timing, and track of the vortex, it is more likely to be real. After all, this region has few conventional observations and even the realism of the remotely sensed observations might be questioned over the Sahara Desert. Thus, a major input to the analyses is the background fields that are short-term integrations of the individual models. This investigation is considered as preparation for later studies when the African Monsoon Multidisciplinary Activities (AMMA) data sets become available, when better observations and better background fields will provide more confidence in the analyses.

Work in progress is examining the other 13 environmental parameters in Table 1 to establish the characteristics of the vortices, and especially those that may be characterized as Northern Vortices. The vortex tracks will be examined to determine the relationships among the AEJ, AEW, and Northern Vortices. A key question is whether the vortices merge and thereby increase in amplitude and perhaps play a role in Atlantic tropical cyclogenesis.

Table 1. Model parameters defined for every circulation center that meets the tracking criterion.

850 hPa relative vorticity (10^{-5} s^{-1})
850-500 hPa average relative vorticity (10^{-5} s^{-1})
Shallow vertical wind shear (500 – 850 mb) (m s^{-1})
Deep vertical wind shear (200 – 850 mb) (m s^{-1})
850-200hPa geopotential height thickness (gpm)
Convective Precipitation
Total Precipitation
Vertical motion at 500 hPa
700-500 hPa vapor pressure
Sea-level pressure (SLP) minimum (mb)
SLP difference between vortex and environment (mb)
700-500 hPa warm core (K)
700-400 hPa warm core (K)
700-300 hPa warm core (K)

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4. REFERENCES

Cowan, C., P. Harr, and G. Elliott, 2006: Objectively determined model-derived parameters associated with forecasts of tropical cyclone formation (13B.3).

Lin, Y.-L., K. E. Robinson, and C. H. Hill, 2005: Origin and propagation of a disturbance associated with an African easterly wave as a precursor of Hurricane Alberto (2000). *Mon. Wea. Rev*., **133**, 3275-3298.

Reed, R. J., D. C. Norquist, and E. E. Recker, 1977: The structure and properties of African wave disturbances observed during Phase III of GATE. *Mon. Wea. Rev*., **105**, 317-333.

Thorncroft, C. D., and K. Hodges, 2001: African easterly wave variability and its relationship to Atlantic tropical cyclone activity. *J. Climate*, **14**, 1166-1179.