5B.6 INITIATION OF MESOSCALE CONVECTIVE COMPLEXES IN EASTERN AFRICA: A PRECURSOR TO TROPICAL CYCLOGENESIS

Christopher M. Hill * and Yuh-Lang Lin
North Carolina State University, Raleigh, North Carolina

1. INTRODUCTION

In the course of tropical cyclone research, cyclone points of origin have been found to be important in determining the potential track and intensity of the cyclones (Erickson, 1963; Simpson et al., 1968; Carlson, 1969; Laing and Fritsch, 1993). Tropical disturbances that emerge from the West African coast — as products of easterly waves — are the known nuclei for these tropical cyclones. Simpson et al. (1968) and Carlson (1969) showed that tropical cyclones could develop from disturbances first observed in the western and central Sahel in Africa, while Erickson (1963) showed that such disturbances could begin developing into tropical cyclones before emerging from western Africa.

Tropical disturbances and tropical cyclones usually comprise of one or more mesoscale convective complexes (MCCs) (Laing and Fritsch, 1993a; Simpson et al., 1997). From MCCs several byproduct mesovortices (MVs) can be initiated within the convection (Fritsch et al., 1994; Simpson et al., 1997). The similar environments of MCCs and tropical cyclones would explain the propensity of MCCs to give rise to, and become a component of, a tropical cyclone. This idea was illustrated by Laing and Fritsch (1993), in which three tropical cyclones were traced from MCCs in western Africa, and the MCCs themselves developed in the African Sahel.

With regard to lee-vortex production in Africa, Mozer and Zehnder (1996) suggest that such lee vortices originate from the Hoggar and Tibesti Mountains in central Africa. Frank (1970) briefly mentions the possibility that easterly waves may develop downstream of the Ethiopian Highlands (EH) as a result of lee trough development within the easterly flow. In contrast, Burpee (1972) concludes that easterly waves do not develop immediately downstream of the EH. This finding, however, was based on a spectral analysis of scarce upper air observations from Khartoum, Sudan, (~ 750 km west of the northernmost EH) and was not based on satellite evidence.

Hurricane Alberto was traced as a MCC back to the EH, where the MCC first developed late on 28 July 2000. The disturbance quickly developed into a tropical storm on 04 August 2000 in the eastern Atlantic, and became a hurricane on 05 August 2000. Hurricane Alberto was a long-lived hurricane with a peak intensity of category-four.

* *Corresponding author address*: Christopher M. Hill, North Carolina State University, Box 8208, Raleigh, NC, 27695-8208.

2. METHODOLOGY

2.1 *Satellite imagery analysis*

To track the life span of the tropical system "Alberto", Meteosat-7 visible-wavelength was examined. Visible satellite imagery was examined at 0830 UTC and 1430 UTC during the period of 28 July 2000 through 03 August 2000, and at 1100 UTC, 1400 UTC, and 1700 UTC for the period of 03 August 2000 to 04 August 2000.

2.2 *MASS model specifications*

In preparing the Mesoscale Atmospheric Simulation System (MASS) model, a 45-km grid resolution was set in a domain of 136 × 86 grid points. The model domain was specified, from southwest to northeast, at 2°S, 8°E to 32°N, 63°E. NOGAPS 12-h datasets (0000 UTC 28 July 2000 through 0000 UTC 30 July 2000) with 15 vertical levels were used to initialize the MASS model and to set boundary conditions every 12 h. Terrain data from the CIA, with five-minute resolution, and BATS land-use data were used in preprocessing the model. The model-time increment was set to 60 seconds, with the total time integration set to 48 h. The Kain-Fritsch cumulus parameterization scheme was employed, and model microphysics were set to be diagnostically calculated. A total of 42 vertical sigma levels were interpolated in the model.

3. RESULTS

The first image identified to be the "Alberto" MCC was for 1430 UTC 28 July 2000 (Fig. 1a). The MCC is seen to be developing in the late afternoon (~1730 LST). At 0830 UTC 29 July 2000 (Fig. 1b), the MCC is more organized and even exhibits banding features, indicative of circulation within the MCC. These banding features are also evident at 1430 UTC 29 July 2000 (Fig. 1c), though the MCC has diminished. The leftmost cross-hair in Figs. 1a and 1b denotes 10°N, 30°E, with other cross-hairs corresponding to an increment of 10° latitude and longitude.

To corroborate the MCC and MV development observed from satellite imagery, a MASS model simulation was conducted starting at 0000 UTC 28 July 2000 and ending 48 h later. Figures 2a through 2c show plots of the wind field and relative vorticity at the 660-mb level for 18, 30, and 36 h of the simulation. At 18 h (Fig. 2a), two areas of maximum relative vorticity (MVs) are seen to have developed near the northern EH, with magnitudes of 12×10^{-5} s^{-1} and 24×10^{-5} s^{-1}. By 30 h (Fig. 2b), the lee-side MV is increasing in magnitude while the stronger MV dissipates. The smaller, lee-side MV becomes the dominant area of relative vorticity by 36 h with a magnitude of 36×10^{-5} s^{-1} (Fig. 2c).

4. CONCLUSIONS

Satellite data show that an MCC begins to develop over the northern EH near the time of 1430 UTC 28 July 2000, traverses the Sahel of Africa for four days, and emerges over the eastern Atlantic Ocean to become Tropical Storm Alberto on 04 August 2000. The satellite imagery also suggests the presence of a MV with the MCC starting on the morning of 29 July 2000. In a preliminary MASS simulation of the MCC-MV system, plots of relative vorticity at the 660-mb level showed the development of two MVs, with the dominant MV nearly collocated with the vortex signature depicted in satellite data.

Based on a broader examination of NOGAPS analyses and MASS model data not shown here, the delineation of the AEJ and westerly monsoon flow at the 600-mb level appeared to be at the EH. The conglomeration of the flows — which comprise the monsoon trough over the Gulf of Aden — may have served to enhance the relative vorticity over the EH. Possible explanations for the development of the MV include lee cyclogenesis downstream of the EH, from maximum diurnal heating late in the afternoon of 28 July 2000, and from divergence forced by an easterly monsoon jet at the 200-mb level and, potentially, at the 100-mb level.

In future work, more cases of MCC development preceding tropical cyclogenesis will be sought, and a more detailed study on the scope of processes involving the MCC development and the incipient MV generation near the EH will be conducted.

Acknowledgments. The satellite data has obtained from the University of Nottingham, U.K. (http://satpix.nottingham.ac.uk). The MASS model was developed by Meso, Inc.

REFERENCES

Burpee, R. W., 1972: The origin and structure of easterly waves in the lower troposphere of North Africa. *J. Atmos. Sci*., **29**, 77-90.

Carlson, T. N., 1969: Synoptic histories of three African disturbances that developed into Atlantic hurricanes. *Mon. Wea. Rev.*, **97**, 256-276.

Erickson, C.O., 1963: An incipient hurricane near the African west coast. *Mon. Wea. Rev.*, **91**, 61-68.

Frank, N. L., 1970: Atlantic tropical systems of 1969. *Mon. Wea. Rev*., **98**, 307-314.

Fritsch, J. M., J. D. Murphy, and J. S. Kain, 1994: Warm core vortex amplification over land. *J. Atmos. Sci.*, **51**, 1780-1807.

Laing, A. G., and J. M. Fritsch, 1993: Mesoscale convective complexes in Africa. *Mon. Wea. Rev.*, **121**, 2254-2263.

Mozer, J. B., and J. A. Zehnder, 1996: Lee vorticity production by large-scale tropical mountain ranges. Part II: a mechanism for the production of African easterly waves. *J. Atmos. Sci*., **53**, 539-549.

Simpson, J., E. Ritchie, G. J. Holland, J. Halverson, and S. Stewart, 1997: Mesoscale interactions in tropical cyclone genesis. *Mon. Wea. Rev*., **125**, 2643-2661.

Simpson, R. H., N. L. Frank, D. Shideler, and H. M. Johnson, 1968: Atlantic tropical disturbances 1967. *Mon. Wea. Rev.*, **96**, 251-259.

Figure 1. METEOSAT-7 VIS images for a) 1430 UTC 28 July 2000, b) 0830 UTC 29 July 2000, and c) 1430 UTC 29 July 2000. Leftmost cross-hair denotes 10°N, 30°E. Images from University of Nottingham, UK.

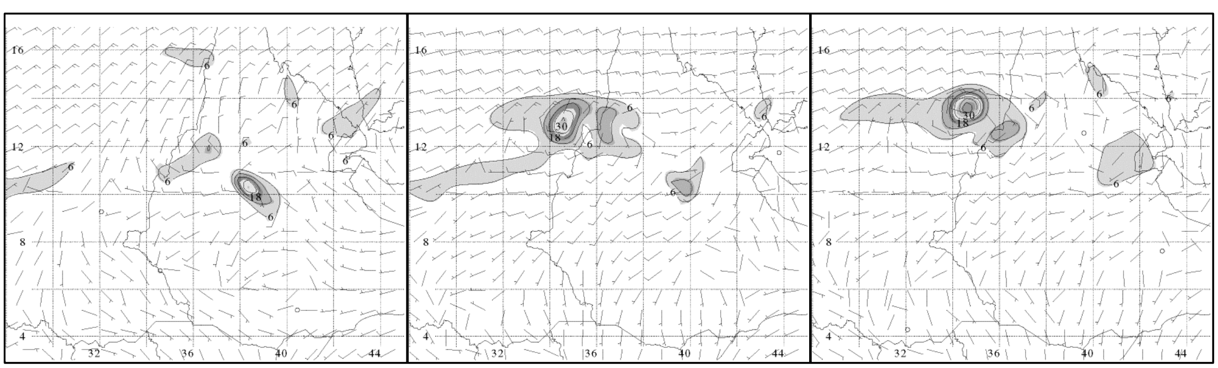

Figure 2. MASS-simulated relative vorticity and wind vectors at 660 mb corresponding to a) 1800 UTC 28 July 2000, b) 0600 UTC 29 July 2000, and c) 1800 UTC 29 July 2000. Vorticity contoured and shaded every 6 x 10^{-5} s^{-1}. Wind vectors in units of ms^{-1}.