3D.4 FORECASTING TROPICAL CYCLOGENESIS IN THE NCEP GLOBAL MODEL

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1. INTRODUCTION

A major goal of tropical meteorology is to improve our understanding and prediction of tropical cyclogenesis. Operational tropical cyclone (TC) forecasts have mainly been limited to predicting the position and intensity of pre-existing TCs. However, as lead times for these forecasts increase (e.g. from three days to five days), there is a greater likelihood that a TC that is not even present at the initial time could form, and have significant impact, during the forecast period. It would be a major advance to specify the point of TC formation as well as to predict the subsequent track and intensity in operational forecasts. Therefore there is an increased need for skillful numerical guidance on tropical cyclogenesis. Up until only a few years ago, the ability of dynamical models to predict TC formation was rather limited. For example a serious false alarm problem, the spurious "spin-up" of low-level tropical vortices, limited the usefulness of forecasts from the National Centers for Environmental Prediction (NCEP) global model (Beven 1999). Lately, however, significant progress has been made at NCEP's Environmental Modeling Center to ameliorate this situation.

2. THE NCEP GLOBAL FORECAST SYSTEM

The NCEP Global Forecast System (GFS) has undergone several improvements during the past two years which are relevant to the forecasting of tropical cyclones. In 2000, the resolution of the global spectral model was increased to T170L42 (triangular 170 waves, roughly a 75 km horizontal grid size, with 42 vertical levels),and the model initialization was modified to include a relocation scheme to move an erroneously-positioned storm in the first guess to the observed location. In 2001, the incorporation of microwave data from polar- and near-equatorial-orbiting satellites contributed to a better description of the tropospheric moisture field. Also in 2001, the addition of prognostic cloud water/ice and a parameterization of cumulus momentum mixing led to better simulation of the tropical circulation as well as a major reduction of the false alarm storms in the forecasts. It is remarkable that, although the false alarm problem has been substantially reduced in the model, the GFS is able to depict *observed* cyclogenesis with excellent fidelity in many cases. For example, during the peak of the 2001 season, the GFS predicted the formation of Atlantic cyclones Erin, Felix, Gabrielle, and Iris, as well as Juliette, Kiko, and Lorena in the eastern Pacific.

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3. CASE STUDY

Hurricane Erin formed from a tropical wave over the eastern Atlantic at 1800 UTC 1 September 2001 near 12.5N 34.3W. Figure 1 shows the initial state for the global model forecast from 28 August at 0000 UTC. The pre-Erin tropical wave was still located over western Africa at this time, in the vicinity of the Greenwich Meridian, while another fairly well-defined tropical wave was situated farther to the west, in the vicinity of the Cape Verde Islands. Both systems exhibited a weak cold core in the low- to mid-troposphere at the initial time. The wave to the west failed to develop, and as can be seen in Figs. 2 and 3, the global model shows this system weakening in the three- to five-day forecast. In contrast, for the system that develops into Erin, the model's five-day forecast depicts the formation of a closed surface low, albeit a few degrees to the northeast of the observed genesis location, with a developing warm core. Cross sections through the model's atmosphere (Fig. 4) reveal that the developing system had a deep tropospheric extent, i.e. was not merely a low-level spin-up. These cross sections also suggest that the disturbance develops both downward and upward from a maximum near the 700 mb level. This is fairly consistent with operational experience with tropical cyclogenesis, in which the formation of a surface circulation is usually preceded by the development of a mid-level vortex.

Tropical cyclogenesis in the model can also be investigated by looking at the contributions to the local tendency of relative vorticity. Aside from horizontal advection and the beta term (which contribute to

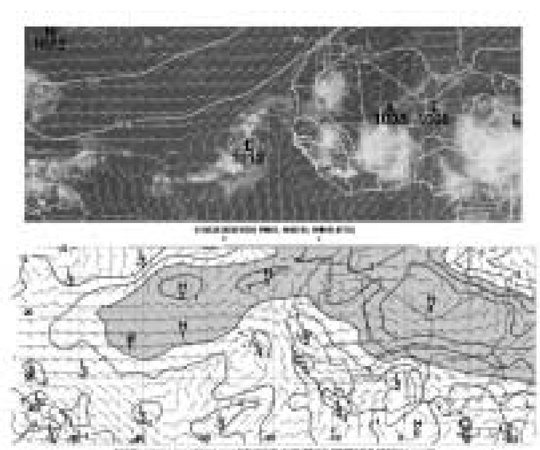

Figure 1. Initial condition for the NCEP global model forecast from 28 August 2001 at 0000 UTC. Top: sea level pressure (isobar interval 4 mb) and boundary layer winds with infrared satellite image; bottom: 700 mb winds and temperature perturbations (from the zonal global mean; contour interval 1 K)

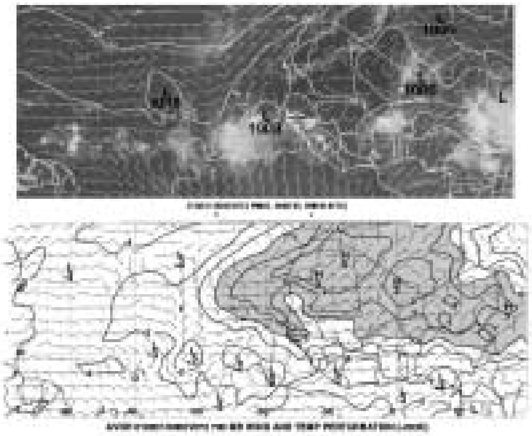

Figure 2. As in Fig. 1, except for the 72 h forecast.

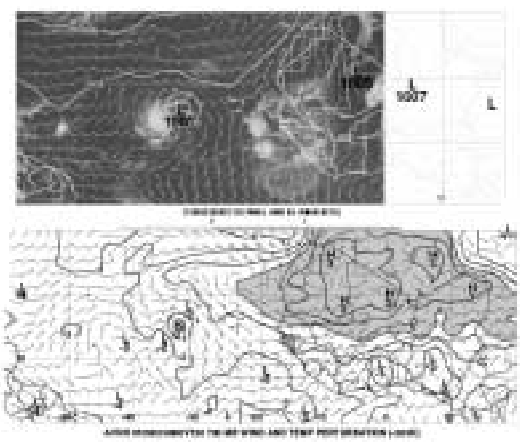

Figure 3. As in Fig. 1, except for the120 h forecast.

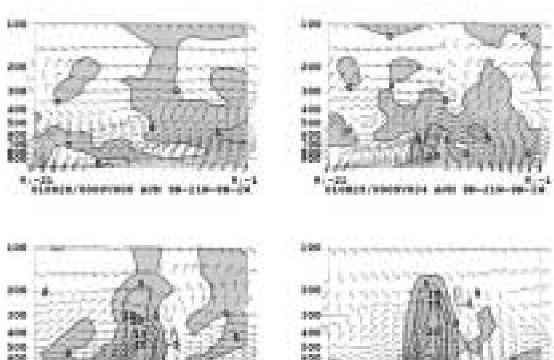

Figure 4. Vertical cross section of winds and relative vorticity (contour interval $5x10^{-5}$ s^{-1}) along 9N 21W-9N 1W at 0 h (top left); 24 h (top right); 13N 30W-13N 10W at 72 h (bottom left); and 16N 42W-16N 22W at 120 h (bottom right) from the initial time in Fig. 1.

disturbance propagation), scale analysis of the vorticity equation indicates that the convergence term, i.e. absolute vorticity multiplied by horizontal convergence, is an important contributor. Figure 5 is a plot of the convergence term at low levels, as well as the convective precipitation for the 72 h forecast. There is a pronounced maximum in the convergence term near the center of the developing disturbance. Comparing this to the precipitation field it can be seen that there is a maximum in rainfall very near the maximum vorticity tendency. This implies that the boundary layer convergence maximum, which is producing the precipitation maximum, is also leading to a maximum in cyclonic vorticity tendency at low levels. The co-located deep convection probably leads to vertical development of the system through some combination of i) an associated deep layer of convergence, ii)the vertical advection of vorticity, and iii) the vertical transport of momentum by the cumulus convection (which is now included in the model's physical parameterizations).

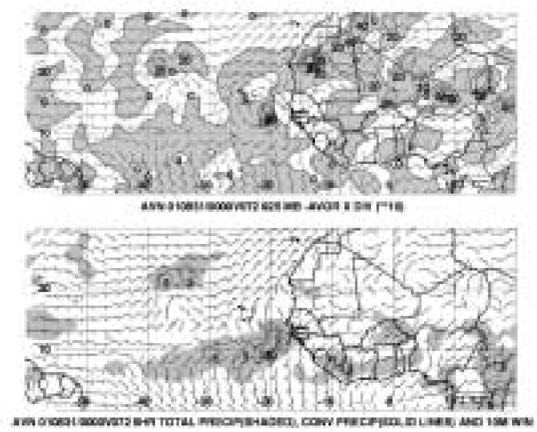

Figure 5. Top: relative vorticity tendency due to convergence (contour interval $20x10^{-10}$ s^{-2}) and winds at 925 mb. Bottom: 6-h accumulated total and convective precipitation (contour interval 5 mm) and 10 m winds. All for the 72 h forecast from the initial time in Fig. 1.

4. CONCLUSIONS

Recent advances in the NCEP GFS have enabled greater skill in the prediction of TC formation. The ability of a global model, with reasonably good resolution, to simulate tropical cyclogenesis indicates that synoptic- and larger-scale mechanisms play an important role in the genesis process. Additional diagnoses of the model output are required to gain more understanding of these mechanisms.

5. REFERENCES

Beven, J. L. II, 1999: The boguscane - a serious problem with the NCEP medium range forecast model in the tropics. *Preprints, 23rd Conf. Hurr. Trop. Meteor.*, Dallas, Amer. Meteor. Soc., 845-848.