5D.5 Hurricane initialization using reconnaissance data in GFDL hurricane forecast model

Qingfu Liu*, Stephen Lord, Naomi Surgi, Hua-Lu Pan, and Frank Marks (HRD)

EMC/NCEP/NOAA

1. Introduction

Occasionally, a hurricane forecast fails in the operational GFDL model, and the forecast storm moves in the opposite direction compared to the observed and also that of the parent global (AVN/MRF) model (e.g. Hurricane Olga on Nov. 30, 00z, 2001). These failures can be traced to the GFDL vortex initialization technique. Hurricane intensity forecasts have essentially no skill in the GFDL model guidance. Part of the reason is also due to the hurricane initialization in GFDL model. To ameliorate these problems, NCEP has initiated a project to build a hurricane data assimilation system based on the GFDL model. This assimilation system will take advantage of reconnaissance data (especially the P-3 airborne Doppler radar data) to give a more realistic depiction of hurricane wind and thermodynamic structure for model initialization. Our preliminary version is based on ETA model analysis. We will eventually combine this system with the Weather Research and Forecast (WRF) model data assimilation system to initialize the operational hurricane forecast model.

In section 2, we give a brief description of the hurricane initialization in AVN/MRF model. Section 3 demonstrates the impact of hurricane vortex relocation in a data analysis system. Section 4 outlines the procedures in the future hurricane analysis system for the GFDL model. Section 5 concludes this paper.

2. Hurricane initialization in AVN/MRF model

The AVN/MRF model is currently using a hurricane relocation algorithm to initialize hurricanes (Liu et.al., 2000). The relocation system can be summarized as follows: 1) locate the hurricane vortex center in the background field, 2) separate hurricane model's vortex from its environmental field using digital filters (Kurihara et al, 1995), 3) move the hurricane vortex to the TPC's official position, and 4) if the vortex is too weak in the background field, add synthetic data in the analysis.

The hurricane relocation is applied to the following fields: Mean sea-level pressure (later converted to surface pressure), temperature, divergence, vorticity and water vapor mixing ratio. The removal of the synthetic data (which interfere with the background vortex) gives more consistent track guidance among consecutive forecast cycles.

Prior to the 2000 hurricane season, synthetic data were used to initialize hurricanes in the AVN/MRF model (Lord, 1991). As a result, binary vortices or "side lobes" in the hurricanes often appeared in the analysis fields. They were due to the difference between the hurricane position in the background fields and observed location as represented by the synthetic data and/or real observations. The poor analysis in the hurricane region resulted in large AVN/MRF forecast errors, and also a negative impact on GFDL model forecasts. Since the implementation of the relocation algorithm in the AVN/MRF model, there was 30% reduction from 1995-99 to 2000 in forecast track errors. Studies by Brown et. al. (2000) also show that similar problems are pronounced in NOGAPS, UKMO and ECMWF global models. Those erroneous binary cyclone interactions accounted for 31%, 28% and 38% of poor forecasts during the 1997-1998 hurricane season in the NOGAPS, UKMO, and ECMWF models, respectively.

3. Impact of hurricane relocation

Since our model is not perfect, phase errors (hurricane position errors) are frequently seen in the hurricane forecasts. We have seen more than 300 km initial center position errors in the operational AVN/MRF model (hurricane Keith in year 2000) without relocation. If GFDL bogus vortex is replaced with 3-D VAR system, similar problems will occur. The large initial position error is due to the accumulation of the position errors in the previous analysis cycles.

To illustrate the problems which may occur during hurricane data analysis using the P-3 data, we use a simple hurricane tangential wind profile given by Chan and Williams (1987):

V(r)= Vmax*(r/Rmax)*exp((1-(r/Rmax)**b)/b)

Where V(r) is the tangential wind, r is radius, Rmax is the radius of maximum wind, and Vmax is the maximum wind, b is a parameter controlling wind profile of the hurricane outer structure. Here we choose Vmax=50m/s, Rmax=111 km (roughly 1 degree), b=1.0.

We assume the tangential wind has the same structure in the background field and the observational field, and the two vortex centers are separated by 222 km. The analysis grid intervals are specified as 1/6 degree which is the same as those of the inner-most nest grids in current GFDL operational model.

3.1 Analysis when data are rejected

We first assume the observational data will be rejected if the difference between the observational wind and background wind is larger than 25 m/s. Assuming that

* Corresponding address: Dr. Qingfu Liu, EMC/NCEP
5200 Auth Road, Camp Springs, MD 20746

the error covariance matrices in both the background and the observation are unit matrices, then the least square estimates of the analysis are:

Fa=0.5*(Fo+Fb) If data accepted
Fa=Fb If data rejected

Where Fa, Fo, and Fb are the variables of analysis, observation, and background, respectively.

Due to the difference in wind direction, there is a significant amount of data being rejected. Fig. 1 shows the final analysis (solid contour) and the observation (dashed contour) for the vorticity field. The observations were ineffective in translating the hurricane vortex to the proper location.

3.2 Analysis when data are accepted

Fig. 2 shows the final analysis for the vorticity field if the observational data are accepted. The unrealistic double vortices appear in the vorticity field similar to the operational problem (section 2), which will cause bad forecasts in both track and intensity.

If we relocate the hurricane vortex in the background field to the observational position, these problems are reduced. We would have a clean analysis field close to the observed vortex in this case.

4. Hurricane initialization in GFDL model

We will use similar vortex relocation procedures as those in AVN/MRF to initialize hurricanes in GFDL model. In the future hurricane data analysis system, P-3 Doppler radar data will be first processed to obtain superobs from high resolution data. The vortex in the background field will be relocated to the observational position. The superobs and the new background field will then be used in Eta analysis initially with migration to the WRF later.

5. Discussions

We have briefly reviewed the hurricane initialization in AVN/MRF model, and outlined the procedures of the hurricane initialization in the future GFDL hurricane analysis system. We have demonstrated the need to add vortex relocation in the new hurricane data assimilation system. We emphasize here that the initialization should be consistent with the model dynamics and model physics for better track and intensity forecasts. If there are too large differences between the background fields and the observations, adding the observations to the analysis can make the forecast worse.

References

Brown, D.S., M.A. Boothe, L.E. Carr, III and R.L. Elsberry, 2000: Evaluation of Dynamic Track Predictions for Tropical Cyclones in the Atlantic During 1997-1998, 24th Conference on Hurricanes and Tropical Meteorology, Fort Lauderdale, FL. 29 May- 2 June 2000. P 390-391.

Chan, J.C.-L., and R.T. Williams, 1987: Analytical and numerical studies of the beta-effect in tropical cyclone motion. Part I: Zero mean flow, J. Atmos. Sci., 44, 1257-1265.

Kurihara, Y., M.A. Bender, R.T. Tuleya, and R.J. Ross, 1995: Improvements in the GFDL Hurricane Prediction System. Mon. Wea. Rev., 123, 2791-2801.

Liu, Q.L, T. Marchok, H.-L. Pan, M. Bender, S.J. Lord, 2000: Improvements in Hurricane Initialization and Forecasting at NCEP with Global and Regional (GFDL) models. EMC Technical Procedures Bulletin 472.

Lord, S.J.: A bogusing system for vortex circulations in the National Meteorological Center global forecast model. Preprints, 19th AMS Conference on Hurricanes and Tropical Meteorology. May 6-10, 1991, Miami, Florida.

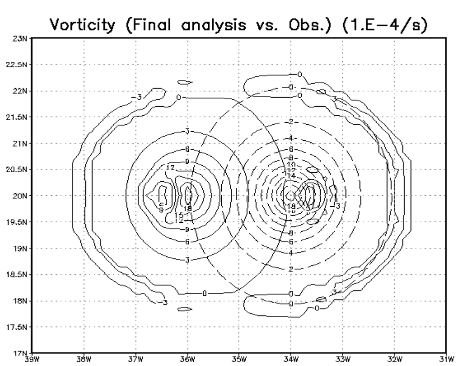

Fig.1 Vorticity fields from final analysis (solid contour) and observation (dashed contour), if some of the data are rejected.

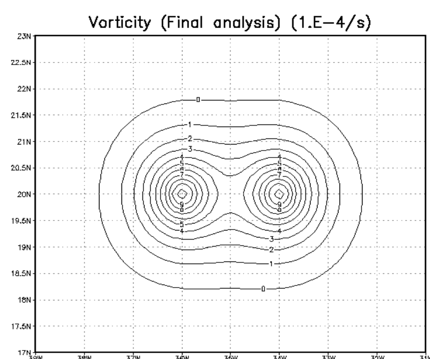

Fig. 2 Vorticity field from the final analysis, if all data are accepted