5D.1 OBSERVING-SYSTEMS SIMULATION EXPERIMENTS FOR TROPICAL CYCLONE INITIALIZATION BASED ON FOUR-DIMENSIONAL VARIATIONAL DATA ASSIMILATION

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1. INTRODUCTION*

Studies from Zou (2000), Xiao et al. (2000) and Pu and Braun (2001) have presented a useful new direction for tropical cyclone initialization using bogus data assimilation (BDA). In this study, we performed a set of Observing-Systems Simulation Experiments (OSSE's) to address the important questions on BDA: (1) what are the most critical parameters for BDA; and (2) what can be done to improve the existing BDA procedures.

2. EXPERIMENT DESIGN

We first run the Penn State/NCAR mesoscale model (MM5) for 60h to create the best initial condition (BIC), which is regarded as the "nature" run). We then degraded the quality of the reference data by using a successive smoothing operator to create the degraded reference data. Based on the degraded reference data, another simulation is carried out to produce a set of data (denoted as FEC) that can serve as the control (no assimilation) experiment.

A series of OSSE's are then conducted to assess the potential impact of different parameters on BDA, based on the data assimilation experiments (using MM5- 4DVAR, Zou et al. 1997). By taking different observed data for BDA, each experiment produces its own initial condition and the ensuing 60h simulation to examine the track and intensity of the simulation.

3. RESULTS

3.1 Initial vortex structure

Figure 1 shows the west-east cross section, cutting through the storm center, of the potential vorticity (PV; solid line), wind speed (shaded) and temperature (dotted line) of the initial vortex. A much weaker initial vortex is represented by the FEC (Fig. 1a) as compared to the one in BIC (Fig. 1b), where high PV and warm potential temperature air are present in the storm core surrounded by an eyewall with a maximum wind of about 55 m/s on the east flank.

When a specified vortex (DA_SPC_VP) is assimilated (Fig. 1c), a hurricane-like vortex structure is produced, though the specification of an axisymmetric storm structure cannot well represent the asymmetric feature in the storm. Such incorrect specification of initial vortex turns out to affect the storm track, as will be shown in the next section. When the wind and pressure data from the core region of BIC (DA_R_VP) are both assimilated to FEC through BDA, an asymmetric vortex structure (Fig. 1d) consistent with (though not identical to) that of BIC (Fig. 1b) is produced.

If only the pressure field from BIC (DA_R_P) is assimilated, the maximum lower-level wind (Fig. 1e) cannot be recovered. On the other hand, by assimilating only the wind field from BIC (DA_R_V), most of the vortex structure (Fig. 1f) similar to DA_R_VP is recovered. This result indicates that the wind field is a relatively more crucial parameter to assimilate as far as the recovery of the initial storm structure is concerned.

3.2 Results of the simulations

Except for the first 6h simulation of DA_R_P, the simulation of tracks (Fig. 2a), minimum central SLP (Fig. 2b) and maximum wind (Fig. 2c) in DA_R_V and DA_R_VP and DA_R_ALL are similar. Compared to BIC, the track error of DA_R_P (DA_R_V; DA_R_VP) is 131 (90; 90), 79 (103; 77) and 103 (150; 102) km, for 24, 48 and 60h, respectively. Comparison experiments shown in Figs. 2a, b and c indicate that the assimilation of wind field within the storm core region can more or less recover the major structure of the initial vortex, as well as the follow-up track and intensity simulation.

For DA_R_V, even though the minimum central SLP is too high at the initial time, then it adjusts to a more reasonable value after a few hours of integration. On the other hand, when only the pressure field is assimilated (DA_R_P), the initial velocity field is totally off the line, and the minimum central SLP fills immediately after the integration starts. We believe that the above finding is related to the geostrophic adjustment process in the tropics, in which the mass field is adjusted to the velocity field. The above result also indicates that DA_R_P is dynamically imbalanced initially, and more adjustment takes place in the first 6h of integration. This improper initial vortex does result in larger track errors of DA_R_P in the first 12h. Even though the track and intensity simulation of DA_R_V at later periods is not very different from that of DA_R_P, it still does not rule out the possibility that for some cases the uncertainty in the initial vortex structure may affect the later track forecast more seriously. Nevertheless, as far as the initial vortex structure is concerned (see Figs. 2b and c), the above result appears partially consistent with Pu and Braun (2001) and shows that information from the velocity field is more important than the pressure field.

4. SUMMARY

Highlights of this work are as following:

- The assimilation of wind field is more effective than the assimilation of pressure field.
- The assimilation of an axisymmetric vortex tends to misrepresent the actual storm and leads to a large track prediction error. This suggests that the inclusion of the asymmetric component of the tropical cyclone vortex is important for vortex initialization.
- Direct replacement of BIC data to FEC may result a vertically incoherent initial vortex, while BDA is able to recover a more balanced initial vortex structure.
- Assimilation of wind at individual level(s) only slightly improves the initial vortex structure and its track simulation. This suggests that for a better representation of the tropical cyclone and a better storm simulation, comprehensive and more vertical

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levels of observed data are needed.

- Both the improvement on the initial vortex structure and the environmental wind and mass information affects the track evolution, suggesting the need for near storm, as well as storm environment, observations in order to improve the track simulation.

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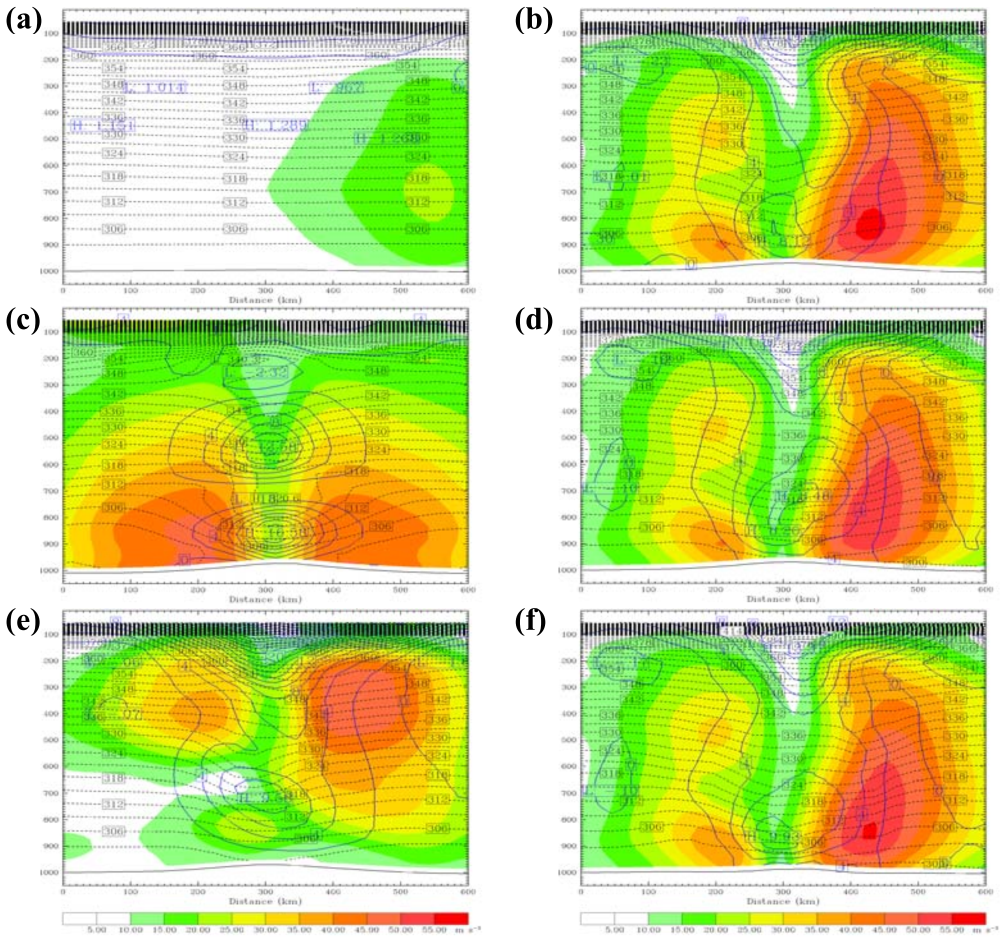

Fig. 1. West-east cross section, cutting through the storm center, of potential vorticity (PVU; solid line), wind speed (m/s; shaded) and potential temperature (K; dotted line) of initial vortex structure: (a) FEC; (b) BIC; (c) DA_SPC_VP; (d) DA_R_VP; (e)DA_R_P; (f) DA_R_V.

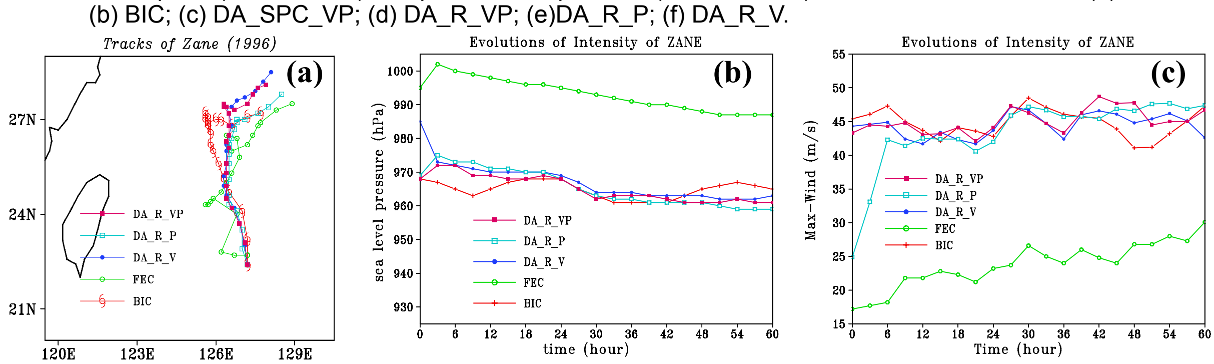

Fig. 2. (a) Tracks of experiments BIC, FEC, DA_R_V, DA_R_P, and DA_R_VP for every 3h; (b) minimum central sea surface pressure; (c) maximum wind at lowest level (sigma=0.98).