Ensemble Forecasting of Tropical Cyclone Motion Using A Baroclinic Model

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1. Introduction

While some studies have been conducted in the ensemble forecasting (EF) of tropical cyclone (TC) motion (Aberson et al. 1995, 1998; Cheung and Chan 1999a, b, hereafter CCa and CCb respectively; Cheung 2001), much more efforts are needed to establish EF as a viable alternative to the traditional single solution from a numerical-weather-prediction model for TC motion forecast.

In this paper, the lagged-averaged forecast (LAF) and regional breeding of growing modes (BGM) perturbation methods are applied to the baroclinic model of the University of New South Wales (Leslie et al. 1985) to estimate the effectiveness of these EF techniques in TC motion forecast. Five cases from three typhoons that occurred during the Tropical Cyclone Motion Experiment (TCM-90) are chosen for study.

2. Model and data

The model is a hydrostatic primitive equation model with a horizontal grid spacing of 30 km and 24 internal vertical sigma levels. The modified Kuo and Kain-Fritsch cumulus parameterization schemes are used. The initial fields are taken from the TCM-90 dataset. The bogussing scheme of the Typhoon Model (TYM) of the Japan Meteorological Agency is used in some of experiments after filtering the analysis vortex. Forecast time is up to 72 h.

The LAF perturbations are generated from the differences between the short-range forecasts. No vortex-environment flow separation is applied (Cheung 2001). The BGM perturbation scheme is similar to that of CCa, CCb. When employing the BGM technique, TC vortex–environment separation is applied (BGMV and BGME respectively). Six pairs of ensemble members are generated in all three methods: LAF, BGMV and BGME.

3. Forecast results

a. Typhoon Yancy

Typhoon Yancy of 1990 at the initial time of 00UTC 17 August (to be labeled as Y1700) is chosen as an example. In all three sets of experiments no bogus scheme is included because the analysis vortex seems to be well represented by the TYM-90 analysis. Most of the LAF members predicted the landfall of Yancy over Taiwan except one that passed to its north as the control (Fig. 1). Two of the landfall members showed a jump across the Central Mountain Range. The ensemble mean track is much closer to the best track than that in the control run. In the BGME and BGMV experiments, the mean forecast tracks also show an improvement over the control though landfall is not predicted (not shown).

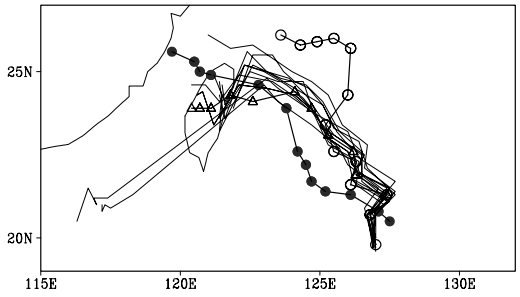

Fig. 1. Ensemble tracks (thin lines) of Yancy (Y1700) using the LAF technique. Best track – closed circle, control - open circle, ensemble mean – triangle. Positions are plotted every 6 h.

b. Ed and Flo

1) SENSITIVITY EXPERIMENTS

The forecast track of Ed turns towards the south instead of a steady westward movement, resulting in a 1000-km position error by 72 h (Fig. 2). Possible factors contributing to the failure of the forecasts of Ed such as cumulus parameterization,

bogussing scheme and lateral boundary, the influences of Flo and subtropical ridge are examined from 00UTC 14 September 1990 and 00UTC 15 September 1990 (to be labeled as E1400 and E1500 for the Ed, and F1400 and F1500 for the Flo respectively).

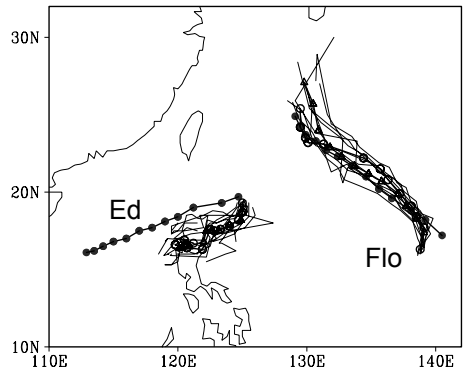

Fig. 2. As Fig. 1 except for Ed and Flo (E1400, F1400).

The tracks of Ed are surprisingly insensitive to the possible factors (not shown). The forecast errors of the environment, which includes the subtropical ridge and the outer flow of Flo, largely contribute to forecast failure of the movement of Ed. The weakening subtropical ridge over the South China is replaced by a continuously deepening trough. The northwesterly flow upstream of the westerly trough pushes Ed to the southeast. At the same time, the outer flows of Ed and Flo merge due to the lack of the interference of the subtropical ridge. When Flo moves to the northeast of Ed, the outer flow of Flo makes Ed accelerate and move to the southeast.

2) ENSEMBLE FORECASTS OF FLO AND ED

The three EF techniques are performed on the cases of Ed and Flo. For Ed, no significant improvement is obtained because the forecast of the western part of the subtropical ridge is not improved when the analysis is perturbed by the LAF errors (Fig. 2). For F1400, the control run performs well, and the position errors remain below 100 km from 48 to 72 h. The mean track is close to the best track except that it has a larger movement speed.

Bogussing scheme is used in the BGMV and BGME experiments. In the EF experiments of Ed, although some members have more westward movement when the vortex or the environment is perturbed, the evolution of the environment in EF forecasts is not improved apparently. The ensemble mean is similar to that of the control.

The forecast errors come not only from the errors of the initial state also from the model. According to the results of the sensitivity experiments and the EF experiments, the main problem in this study is the large forecast errors of Ed. The model cannot predict the evolution of the subtropical ridge correctly in any of experiments. It appears that the forecasts moved along with a certain attractor of the model.

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