The Effect of Convective Parameterization On Tropical Cyclone Motion and Intensity

XIAQIONG ZHOU[1*], JOHNNY C L CHAN[2] AND CHENXI WANG[1]
[1] *Shanghai Typhoon Institute, China Meteorological Administration*
[2]*Laboratory for Atmospheric Research*
Department of Physics and Materials Science, City University of Hong Kong
*Email: zhouxq@mail.typhoon.gov.cn

1. Introduction

Stensrud et al. (2000) showed that an ensemble with different model physics could give more improvements in short-term forecasts than that from perturbations of initial conditions due to a larger ensemble spread. In this study, the effects of uncertainties in tropical cyclone (TC) model physics on TC forecasting are investigated by comparing the sensitivity results from different convective parameterization schemes and different values of the parameters in the schemes.

2. Sensitivity experiments

A nonhydrostatic version of Pennsylvania State University-National Center for Atmospheric Research Mesoscale Model Version 5 (MM5) is used in this study. The domain of 301×301 points has a horizontal grid spacing of 15 km with 23 vertical sigma levels. All experiments are run on a beta plane in a resting environment with a TC bogus using the Typhoon Model of the Japan Meteorological Agency. Four different convective parameterization schemes are used: Betts-Miller (BM), Anthes-Kuo (AK), Grell and Kain-Fritsch (KF) schemes.

3. Results

a) Track forecasts from the four schemes

The 72-h track forecasts from the four convective parameterization schemes show that the position difference between any two convective schemes can be quite significant, especially at long forecast times (Fig. 1a). The northwestward movement of the TC is fastest in the AK scheme while those for the other three schemes are quite similar. The intensities from the four schemes also differ (Fig. 1b). The TC in the BM and AK schemes intensifies rapidly from 990 to 953 hPa in the first 24 h, then weakens in AK but maintains a similar intensity in the BM scheme. In contrast, the TC intensities in KF and Grell are generally lower.

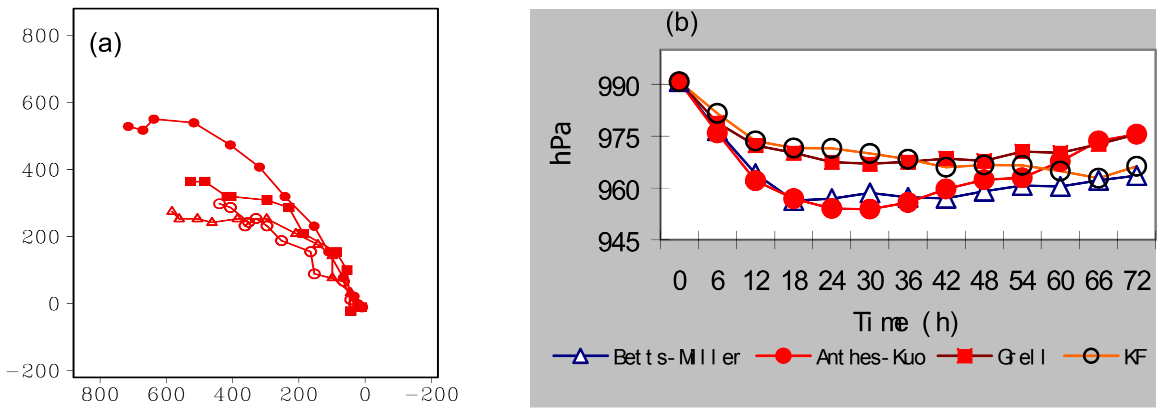

Fig. 1. Predicted (a) tracks, and (b) minimum sea level pressure (MSLP) of TCs using four convective parameterization schemes.

b) Changing the parameters in AK and BM schemes

The AK and BM schemes are chosen to study the kind of uncertainty associated with some crucial parameters in the schemes by perturbing their values.

In the AK scheme, convection is determined by the vertically-integrated moisture convergence. Three parameters can be perturbed: the threshold value *Mt* of the vertically integrated moisture convergence used to check if convection is possible, the vertical profiles of heating *Nh* and a parameter *b* that determines the moistening amount and the condensing and precipitating parts. The *b* parameter is found to have almost no effect on TC motion but the TC intensity is sensitive to its value (not shown). For the convective heating profile, *Nh*, the position of the maximum in the upper half of the cloud is perturbed. When the maximum is rooted in the middle of the cloud instead in the upper level as in the control, the TC position is 300 km east and the MSLP at the TC center is 10 hPa less than that in the control at 72 h. A relative small perturbation to the value of *Mt* also causes a divergence in the forecasts of TC movement and intensity.

The BM scheme is based on the simultaneous relaxation of temperature and moisture fields towards the observed quasi-equilibrium thermodynamic structure. The adjustment time scale τ, saturation pressure departure and the instability parameter *a* (that determines the slope of the temperature profile in relation to the virtual equivalent potential temperature isopleth) are changed according to the sensitivity experiments in Betts (1986a, b). The adjustment time scale for determining the lag of the convective response to large-scale forcing is 50 mins in the control; no obvious effect can be seen when a perturbation of 20 mins is added to or subtracted. A negative perturbation of a relative small value (0.1) of the instability parameter *a* has greater effect than a positive one, with the former producing a faster northwest movement than the control but no apparent change in the latter. The effect on intensity is also similar. Saturation pressure departure is closely related to subsaturation, and changing it alters the equilibrium relative humidity. A perturbation value of 10 hPa gives a forecast MSLP difference is ~ 10 hPa while the forecast position has a ~ 300 km difference.

4. Discussion

Results from these sensitivity experiments suggest that uncertainties in the physics in the convective parameterization schemes and in the values of some parameters in these schemes can have significant effects on the forecast of TC intensity and movement. These uncertainty factors should be considered in TC ensemble forecasting. How these factors influence the intensity and movement of TC will also be the subject in the later study.

Acknowledgments. This study is supported by the Natural Science Foundation of China Project 40005003 and the Research Grants Council of the Hong Kong Special Administrative Region, China Project CityU 1015/01P.

References

Betts, A. K., 1986a: A new convective adjustment scheme, Part I: observational and theoretical basis. *Quart. J. Roy. Meteor. Soc.*, **112**, 677-691.

Betts, A. K., 1986b: A new convective adjustment scheme, Part II: Single column tests using GATE, BOMEX, ATEX and arctic air-mass data sets. *Quart. J. Roy. Meteor. Soc.*, **112,** 693-709.

Stensrud, D. J., J. W. Bao and T. T. Warner, 2000: Using initial condition and model physics perturbations in short-range ensemble simulations of mesoscale convective system. *Mon. Wea. Rev.*, **128**, 2077-2107.