The Effect of Interaction Between Meso-scale System and Typhoon on Its Motion and Structure Change

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1. Introduction

Tropical cyclone sudden structure change and irregular motion including meandering motion (Holland and Lander,1991), looping, sharp turning etc. are always resulted in big forecasting error. They are also the critical issues in operational numerical prediction. Most of the numerical models are invalid to forecast such sudden change of the tropical cyclone behavior.

Case analyses (Chen, 1991) show that those sudden change of tracks usually arise from the variation of large scale environmental steering flow field or the interaction with surrounding synoptic scale or meso scale weather systems. Some times it also can be arisen from the asymmetric structure of the cyclone circulation in a weak flow field such as col environment.

This paper shows that the interaction between different motion scale is able to trigger the evolution of the asymmetric structure of typhoons in the weak environmental flow field which would lead to the meandering or oscillations of tropical cyclone motion.

2. Model and Experiment Design

The quasi geostrophic barotropic vorticity equation

$$\frac{\partial}{\partial t}\nabla^2\psi + J(\psi, \nabla^2\psi) + \beta\frac{\partial\psi}{\partial x} = 0$$

is employed, where ψ is geostrophic stream function ,$\beta = \frac{df}{dy}$, f is the Coriolies parameter. The bisector of the beta plane is set on $\varphi = 25^0 N$.

The stream function can be divided into two parts of mean value $\overline{\psi}(y)$ and perturbation value $\psi'(x,y,t)$, where $\overline{\psi}(y)$ denotes stationary east or west basic flow field which is usually set to be zero if weak environmental flow is presumed. Consider the initial condition, we can set

$$\psi'(x,y,o) = \psi_1'(x,y,o) + \psi_2'(x,y,o)$$

Where $\psi_1'(x,y,o)$ delineates a circular symmetric typhoon vortex and it can be solved by the Poisson iteration method from an initial vorticity field (Chan and Williams, 1987).

$\psi_2'(x,y,o)$ denotes the small vortex in the peripheral area of the typhoon circulation. The initial perturbation stream function field could be produced by $\psi_2'(x,y,o)$ added $\psi_1'(x,y,o)$ where different scale vortices were coexisted.

The computational domain for the model is a square with the side length of 4000km, grid space $\Delta x = \Delta y = 40km$, 101*101 grid points. Five experiments with integral time of 120 hours were performed with time step of 10 minutes.

Experiment 1 is a standard experiment with $\psi_2' = 0$, it implies there is no interaction existed. In experiments 2-5 set $\psi_2'(x,y,o) \neq 0$ in first, second, third and fourth quadrant respectively of the typhoon circulation.

3. Result

In experiment 1, the track is quite smooth showing no oscillation in its motion. The experiment 2-5 with small vortex in four different quadrants of the typhoon circulation, the distinct oscillation of typhoon motion can be found. Especially typhoon would turn left wards with prominent oscillation when a small vortex appears in its first (North East) quadrant. Typhoon motion would have a little influence from a smaller scale system in the third (North West) quadrant of the typhoon circulation. On the other hand, tropical cyclone structure would also be changed after introducing a small vortex in those experiments.

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