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A SIMULATION STUDY OF THE INFLUENCE OF LAND FRICTION ON LANDFALL TROPICAL CYCLONE TRACK AND INTENSITY

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Abstract: A quasi-geostrophic barotropic vorticity equation model is used to simulate the influences of topographic forcing and land friction on landfall tropical cyclone track and intensity. The simulation results show that tropical cyclone track may have sudden deflection when the action of topographic friction dissipation is considered, and sudden deflection of the track is easy to happen and sudden change of tropical cyclone intensity is not clear when the intensity of tropical cyclone is weak and the land friction is strong. The land friction may be an important factor that causes sudden deflection of tropical cyclone track around landfall.

Key words: land friction; landfall tropical cyclone; track and intensity; numerical simulation.

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1 INTRODUCTION

Being the country that is stricken the most by tropical cyclones in the world, China witnesses a yearly average of 7 – 8 landfallls that associate with the intensity of tropical storm or above. During the movement, tropical cyclones usually experience tracks of speeding up, stagnating, making loops, zigzagging or abruptly turning direction. During the time leading up to landfall, the coastal area in China will be exposed to great threats if the tropical cyclone unexpectedly turns away or land at unexpected sites. It is not uncommon to see such sudden intensification when the storm meets with landmass in the course ahead. Such abrupt changes in track and intensity are usually difficult to predict.

Much progress has been made in the research of tropical cyclones in China for the past few years [1, 2]. As is shown [3], sudden changes in basic airflow will lead to those in the track. With weak environmental field, the asymmetric structure inside the tropical cyclone can result in abnormal track [4 – 6]. Meanwhile, the interactions between systems of other scales, including those of mesoscale, can cause sudden changes in the track [7, 8]. The topographic effect and diabatic heating are also playing some role in affecting the track [9 – 13], though more efforts are worthwhile in analyzing the sudden change in track and intensity around the point of landfall. As shown in past observations, unexpected deflection of track or multiple landfalls sometimes occur with tropical cyclones going northwest towards the coast of South China. The current work focuses on the effect of land friction on the change by using a barotropic vorticity equations model that includes terrain and friction to simulate the role of land friction.

2 MODEL DESIGN

In the model, there is friction only over land and no friction over the ocean. During the time before and after the landfall, part of the circulation system is over land while the rest is over the sea. It is a time when friction is discontinuous in the atmosphere under which the sea meets the land.

During the model design, the maximum terrain height is set at 500 m and there are 110 gridpoints on the terrain width in the *X* direction and 20 gridpoints in the *Y* direction. The constructed terrain and tropical cyclone positions are similar to the case of northwest-going storms that eventually land on the coast of South

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China. The simulations can be used to explain the tropical cyclones that have made landfall in the area.

3 EFFECT OF LAND FRICTION ON THE TRACK AND INTENSITY IN THE CASE WITHOUT THE BASIC FLOW

First of all, the effect of land friction on the track and intensity of the tropical cyclone is discussed with the ideal assumption there is no basic flow. The following frictional coefficients are taken into account for friction over land (Tab.1).

Tab.1 Frictional coefficients without basic flow

fr00	g=0.0×10^{-5} s^{-1}
fr05	g=0.5×10^{-5} s^{-1}
fr10	g=1.0×10^{-5} s^{-1}
fr15	g=1.5×10^{-5} s^{-1}

Fig.1 gives the variation of track and intensity with different frictional coefficients without basic flow. It can be seen that the abrupt deflection of track usually takes place when the tropical cyclone is weak but land friction is strong and the stronger the land friction the earlier the deflection will take place; the deflection is not likely to occur if the tropical cyclone is strong but land friction is weak.

Tab.2 Frictional coefficients with basic flow

fr00	γ=0.0×10^{-5} s^{-1}
fr05	γ=0.5×10^{-5} s^{-1}
fr10	γ=1.0×10^{-5} s^{-1}

Fig.3 gives the variation of the track and intensity of the tropical cyclone with different land friction roles with the presence of basic flow. It is known that the tropical cyclone tends to have deflecting track when land friction is high. Additionally, when there is basic flow, the tropical cyclone moves relatively fast and with swings in track sometimes, which is similar to the case without basic flow in terms of the variation trends of intensity and track.

The force per unit of mass is studied to examine the deflection of tropical cyclone track. From the unit mass of components in the *X* and *Y* directions of land friction and total force exerted upon the storm with the presence of basic flow (figure omitted), it is known from the total force acted on the tropical cyclone per unit of mass that track deflection happens due to land friction, which leads to changes in the total force.

For analyses of other aspects, refer to the Chinese edition of the journal.

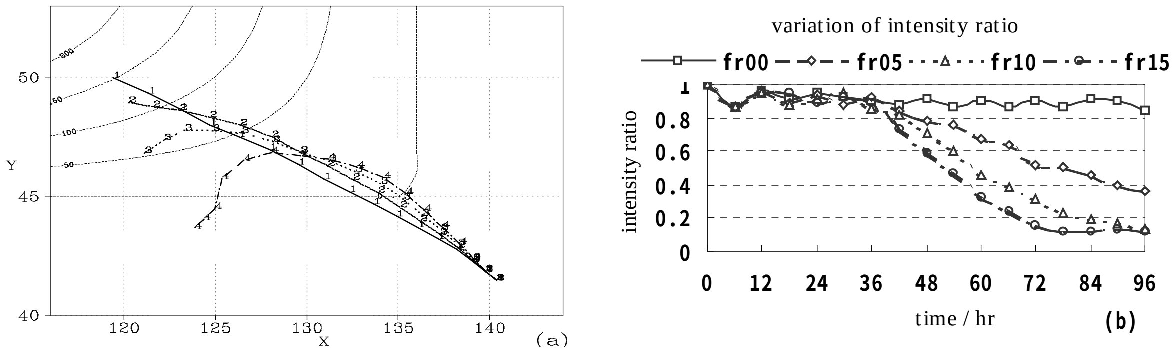

Fig.1 The track of the tropical cyclone with different land friction in the absence of basic flow (a: the dashed line is for the topographic contour in the unit of m, the *X* and *Y* coordinates are denoted with the serial number of gridpoints at the interval of 50km) and intensity (b) within the time from 0 to 96 hours. The frictional coefficient is listed in Tab.1. “1”, “2”, “3” and “4” are corresponding to “fr00”, “fr05”, “fr10” and “fr15”, respectively. The time interval is 6 hours.

For unit mass of components in the *X* and *Y* directions for land friction and total force, see Fig.2.

4 EFFECTS ON TRACK AND INTENSITY WITH BASIC FLOW

The effects are further discussed of land friction on the track and intensity of tropical cyclones with the presence of basic flow. The frictional coefficients are given in Tab.2 with the basic flow set at u=−4.0 m s^{-1}.

5 CONCLUSIONS AND DISCUSSIONS

With a quasi-geostrophic barotropic equations model that includes terrain and friction, the impacts have been studied of land friction on the track and intensity of the tropical cyclone that travels northwest towards the coast of South China and the following conclusions can be drawn.

(1) During the landfall, part of the circulation gets

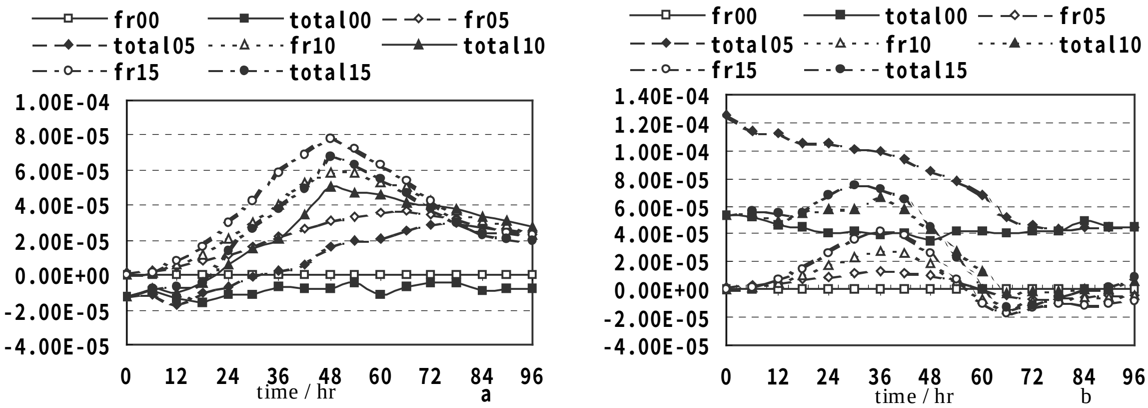

Fig.2 The variation of frictional force (fr--) and total force (total--) exerted on unit of mass of the tropical cyclone in the *X* (a) and *Y* (b) directions with the effect of land friction in the absence of basic flow within the time from 0 to 96 hours. The frictional coefficient is listed in Tab.1. "total00", "total05", "total10" and "total15" are corresponding to "fr00", "fr05", "fr10" and "fr15", respectively, in the unit of Newton. The time interval is 6 hours.

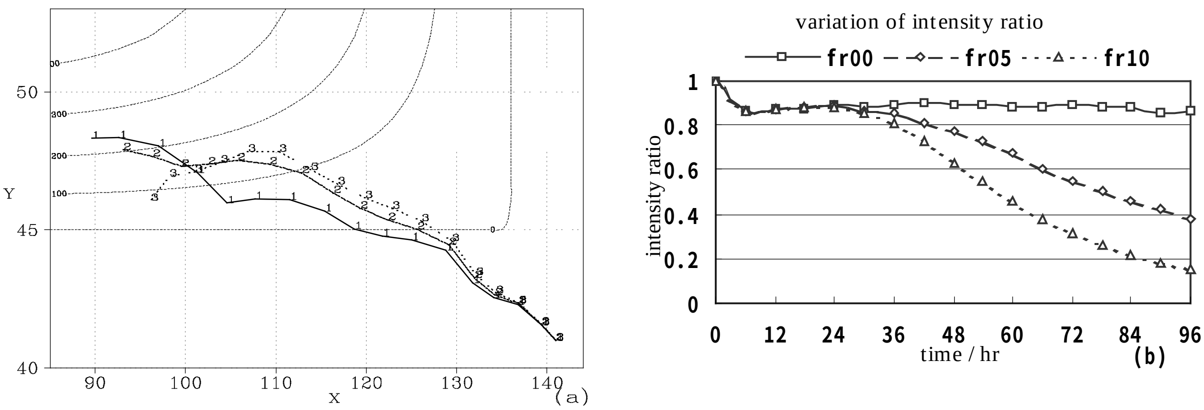

Fig.3 The track of the tropical cyclone with different land friction in the presence of basic flow (a: the dashed line is for the topographic contour in the unit of m, the *X* and *Y* coordinates are denoted with the serial number of gridpoints at the interval of 50km) and intensity (b) within the time from 0 to 96 hours. The frictional coefficient is listed in Tab.2. "1", "2" and "3" are corresponding to "fr00", "fr05" and "fr10", respectively. The time interval is 6 hours.

in touch with the land while the rest is still over the sea. With land friction, this pattern leads to the unexpected deflection of the track. Land friction may be one of the important factors responsible for the sudden deflection of the track around the point of landfall. With the presence of land friction, the phenomenon usually takes place when the tropical cyclone is weak but the friction is strong; it does not occur easily otherwise.

(2) During the landfall, the decrease of the intensity is mainly governed by the friction over land if diabatic heating is not taken into account. With increased land friction, the weakening of the tropical cyclone is hastened; with increased land friction and sudden deflection of the storm track, however, the intensity does not change as dramatically.

(3) With the presence of the basic flow, its steering role will result in a fast-moving tropical cyclone. With the frictional coefficient unchanged, the intensity and track changes are similar between cases with and without the basic flow; with strong land friction, the track may be deflecting.

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