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A NUMERICAL STUDY OF THE EFFECT OF TAIWAN ISLAND TERRAIN ON TYPHOON HAITANG (0505) TRACK

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Abstract: The track of Typhoon Haitang (0505), which passed through the Taiwan Island and landed again, has been successfully simulated by using the non-hydrostatic mesoscale atmospheric model MM5. Its structure is analyzed on the landing stage, and it is found that there exist good relationships between the typhoon abnormal moving track and its asymmetry structure. The effect of terrain of Taiwan Island on the typhoon Haitang, which made it rotate before landing and present a "V" type abnormal moving track in Taiwan straits, has also been simulated. Further analysis shows that the terrain of Taiwan Island not only directly affects the typhoon moving track, but also changes the typhoon track by affecting its asymmetric structure. Therefore, the typhoon asymmetric structure and the effect of terrain of Taiwan Island together results in the abnormal rotating track. The terrain of Taiwan Island tends to increase the SW-NE asymmetric structure of the typhoon and has different effect on SE-NW asymmetric structure during the landfall process of typhoon Haitang before entering and moving out of the Taiwan straits.

Key words: typhoon; asymmetry structure; moving track; terrain

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1 INTRODUCTION

Typhoon Haitang (No.0505) was marked by large intensity and coverage, long duration and complicated and changeable track. It brought long and intense rain to the southeast coast of Zhejiang that caused serious damage. As shown in some studies, the long-lasting effect on the area is significantly related with abnormal typhoon tracks. Apart from the area of landfall, it is therefore equally important to make accurate forecasts of the track. The latter has been one of the research issues receiving much attention [1 - 4]. West Pacific is a main source area for typhoons that eventually affect China and Taiwan Island is often situated right in their way moving towards it. The effect of the island on these typhoons has aroused much interest [5 - 8]. It is the aim of this work to discuss the terrain of Taiwan Island on the track of movement of Haitang. On the other hand, the structure of tropical cyclones and their changes are shown to have significant effect on their intensity and movement [9]. In a weak ambient field, the asymmetric field of the tropical cyclone is one of the main causes for abnormal track of motion [10]. With weak ambient steering, the tropical cyclone is affected by not only the internal structure and interactions between systems of different scales, but also the terrain factor [11]. It is the purpose of this work that the asymmetric structure of Typhoon Haitang and the terrain of Taiwan Island are studied in terms of their effect on the track of movement.

2 BRIEF ACCOUNT TO THE DESIGN OF NUMERICAL EXPERIMENTS

To investigate the effect of the island terrain on the motion track of Typhoon Haitang before and after the landfall on the island, the following four numerical experiments have been designed using the MM5V3.6, a mesoscale model from PSU/NCAR. They are

(1) a control experiment (CTL);

(2) an experiment that removes the island effect (NT). Compared with CTL, the island terrain is reduced to 0 while leaving all others unchanged;

(3) an experiment that retains 1/2 of the real island

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terrain (HT). Compared with CTL, no other changes have been made except the 1/2 reduction of the real terrain, and

(4) an experiment that increases the real terrain by 1/2 (DT). Compared with CTL, no other changes have been made except the 1 1/2 increase of the real terrain.

3 ANALYSIS OF THE SIMULATIONS

3.1 *Assessment of the simulated track*

Fig.1 gives the tracks of Typhoon Haitang simulated with MM5 and located at National Meteorological Center, China. From a comparison between the simulations and objective positioning, the model-simulated typhoon shows abnormal looping track over waters east of the island, though with 3-h advance in time; the simulated site of landfall is a little more northward than observation, a V-shaped track of movement is also reproduced in the model for its passage over the Taiwan Straits after passing the island, and the simulated site of landfall is only about 50 km from reality. It is then known that the model-derived track of Typhoon Haitang is good enough to be used to study the effect of the island terrain on its abnormal moving track.

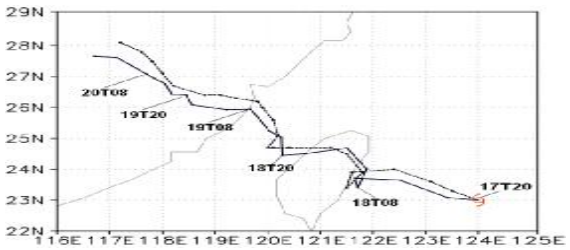

Fig.1 CTL-modelled track (the solid line) in comparison with that located at National Meteorological Center (the dashed line) concerning Typhoon Haitang.

3.2 *Characteristics of symmetric typhoon structure*

The variation of the vertical structure of Typhoon Haitang can be studied from both the vertical cross section of disturbance pressure going through the eye (Fig.2) and a line connecting SLP and the minimum center at 500 hPa. The 500-hPa location tells that the typhoon center moves towards northwest by west and the SLP location reveals that the center undertakes counter-clockwise looping from north to south and then back to north again. Over the island of Taiwan, the typhoon is generally inclined towards the south from low to middle and high levels and by a larger degree than over the sea. After entering into the Taiwan Straits, the inclination changes gradually from southwestward to northward and the transition leads to the appearance of a V-shaped track of movement in the low-level center.

To quantify the description of the asymmetric structure of the typhoon circulation, a northeast-southwest asymmetric structure parameter of K_{SW-NE} is introduced (Luo[12]). From the evolution of the K_{SE-NW} parameter for the southeast-northwest asymmetric structure, it is known that it is closely linked with the north-south motion of the typhoon -- $K_{SE-NW}>1$ is corresponding to the northward-moving component shown in the typhoon motion for the next few hours and $K_{SE-NW}<1$ is corresponding to the southward-moving component shown for the next few hours. The findings are consistent with a number of application indexes in an asymmetric structure by Zhou et al.[13].

4 ANALYSIS OF TERRAIN-SENSITIVE EXPERIMENTS

The terrain of the island has significant effect on the track of movement before and after the passage of Typhoon Haitang over it, as shown in a terrain-sensitive experiment (Fig.3). It is known from comparisons and analyses that model simulations with terrain tend to predict a more northward site of landfall on the island and the higher the terrain, the more northward the site of landfall. One particular point about this case is only that the northward site of landfall appears after looping, i.e. the typhoon first moves to the south and then to the north. For the passage through the island, the higher the terrain, the more northward the track as well.

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

5 CONCLUSIONS

With a simulation study on the effect of the terrain of Taiwan Island on Typhoon Haitang (No.0505) on the track before and after its passage over the island, the following results are presented.

(1) The variation of typhoon's inclination first to the west then to the south, and then to the north, is one of the main causes for it to make abnormal loops around the time of landfall on Taiwan Island. As shown in the terrain-sensitive experiment, the higher the island terrain, the more obvious the above inclination and more easily it will be for the looping to occur.

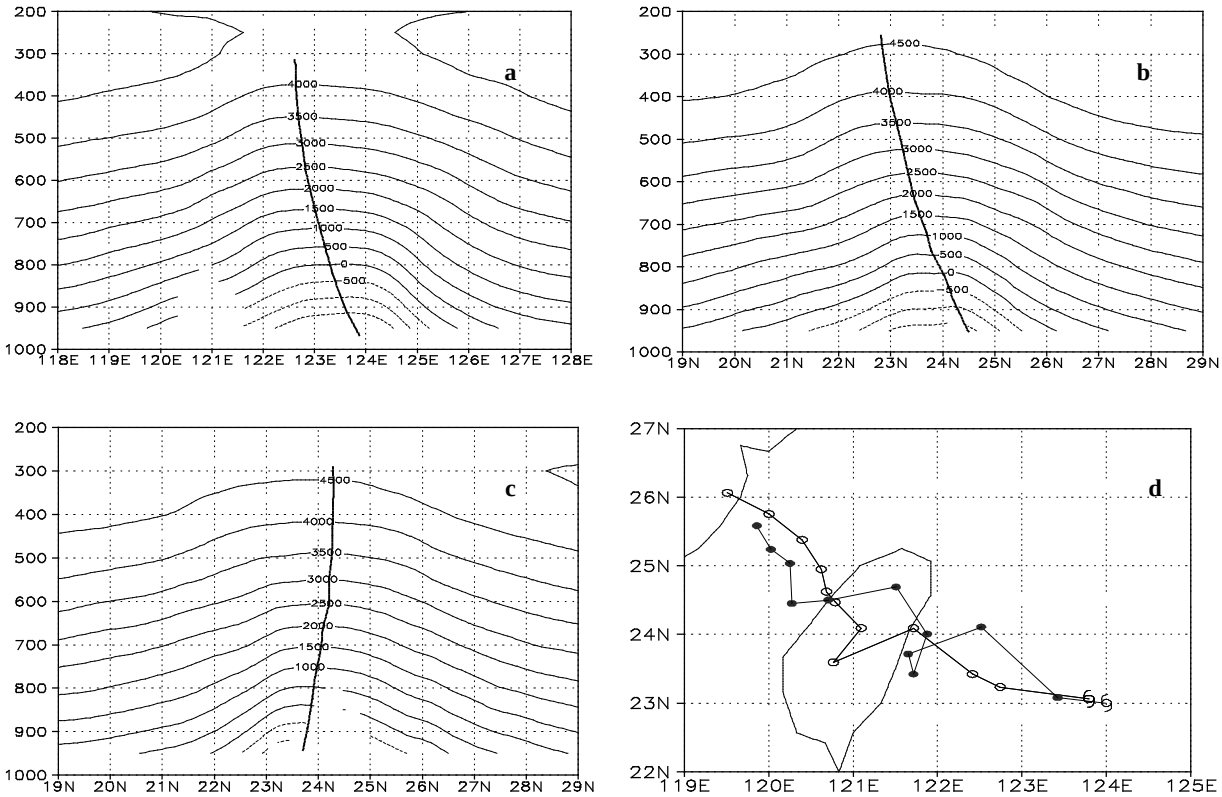

Fig.2 Zonal cross sections (unit: hPa) of disturbance pressure going through the eye in CTL at the interval of 3h (a), 6h (b) and 9h (c) and the track located in CTL (d), for which the solid circle stands for SLP location and the hollow circle for the location as determined with the 500-hPa geopotential height.

(2) The terrain of Taiwan Island is such that it tends to increase the asymmetry that marks with denser structure in the southwest quarter than the northeast one of the typhoon. Prior to its passage through the island, Typhoon Haitang is made to change from an asymmetric structure in which the northwest is denser than the southeast to one in which the southeast is denser than the northwest or to transform from an asymmetric structure in which the northwest is denser than the southeast. Over the Taiwan Straits, the island terrain tends to increase the southeast-northwest asymmetric structure of the typhoon.

(3) The island terrain not only affects the track of the typhoon movement directly, but also changes it by influencing its asymmetric structure. It is then concluded that the appearance of counterclockwise loopings before landing on the island of Taiwan is importantly attributed to a combined effect of the asymmetric structure of itself and the island terrain.

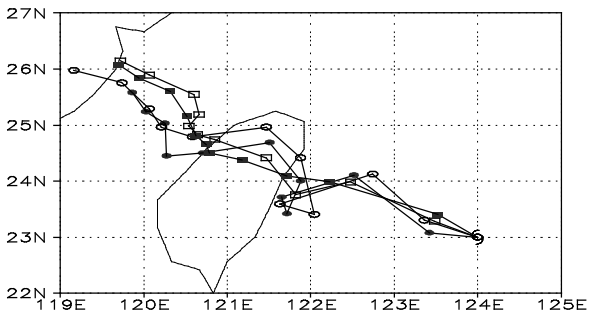

Fig.3 The tracks of Typhoon Haitang as simulated in the terrain-sensitive experiments. The solid square stands for NT, hollow square for HT, the solid circle for CTL and hollow circle for DT.

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