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COMPARATIVE ANALYSIS OF THE INTENSITY AND DISTRIBUTION OF HEAVY RAINS IN ZHEJIANG PROVINCE CAUSED BY TYPHOONS HAITANG AND MATSA

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Abstract: Study was carried out on two landfall typhoons Haitang and Matsa, which affected Zhejiang province seriously in 2005. Firstly, the similarity and difference between the two typhoon-induced heavy rains were compared and it was pointed out that both of them brought strong large-scale precipitation and the maximum centers of rainfall were located on the north side of the landfall site. Making landfall on Fujian, Haitang was weaker than Matsa in intensity but surpassed it in rainfall. Then with focus on intensity, moving speed, structure of typhoon, circulation and terrain, the two typhoon-related heavy rains were compared and analyzed. Results show that the asymmetrical distribution of rainfall was closely related to the structure of typhoons themselves, moisture transportation and mesoscale terrain. In contrast to the south side, the north side was hotter and wetter and water vapor was also more abundant. The phenomenon of more rainfall induced by Haitang was in connection with the following reasons. Invading cold air led to rainfall increases, weakened dynamic field and slower movement both benefited precipitation. For the last part, the cold characteristic of air mass over Zhejiang was also a favorable factor for the rain.

Key words: landfall typhoon; intensity of precipitation; distribution of rainfall; comparison and analysis

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1 INTRODUCTION

Typhoon-induced heavy rain has long been a focus that draws much attention. In the past dozen years or so, new advances have been made in the theory of long-distance typhoon-induced heavy rain[1] and formation of spiral rain belts, the effect of typhoon systems on precipitation in middle latitudes[3, 4], distribution of heavy rain[5], effect of underlying surface on heavy rain[6, 7], and abrupt amplitude increase of heavy rain. The studies have enabled us to better understand the generation and development of typhoon-induced heavy rain, though the forecast of such rain, especially the rain intensity in landfall areas and its distribution, remains difficult and a number of issues are to be studied in much more detail.

In this work, conventional surface and upper-level sounding data and NCEP reanalysis data are used to analyze two typhoons making landfall in Zhejiang in 2005 from the following three aspects of the inherent relationship between the intensity, movement velocity and structure of typhoons and the intensity and distribution of heavy rains (1), the effect of the environment on the generation and development of heavy rains (2), and the dynamic action of mesoscale terrain on heavy rains. The attempts have been made to learn more about the external environment for the survival of the two heavy rains caused by typhoons and the relationship between the internal physical structure and the intensity and coverage of the rainfall to increase the ability of relevant forecast.

2 BRIEF ACCOUNT OF OBSERVED WEATHER SITUATION

In less than 20 days in July and August of 2005, Zhejiang was hit by two consecutive typhoons, No.0505 and No.0509 (Haitang and Matsa). With large rain rates, coverage and long duration, the two typhoons caused serious damage in the province.

It is known from an analysis of the heavy rain induced by the typhoons (Fig.1) that the two processes are both similar and different in rain rate and area receiving heavy rain. In similarity, both of the typhoons

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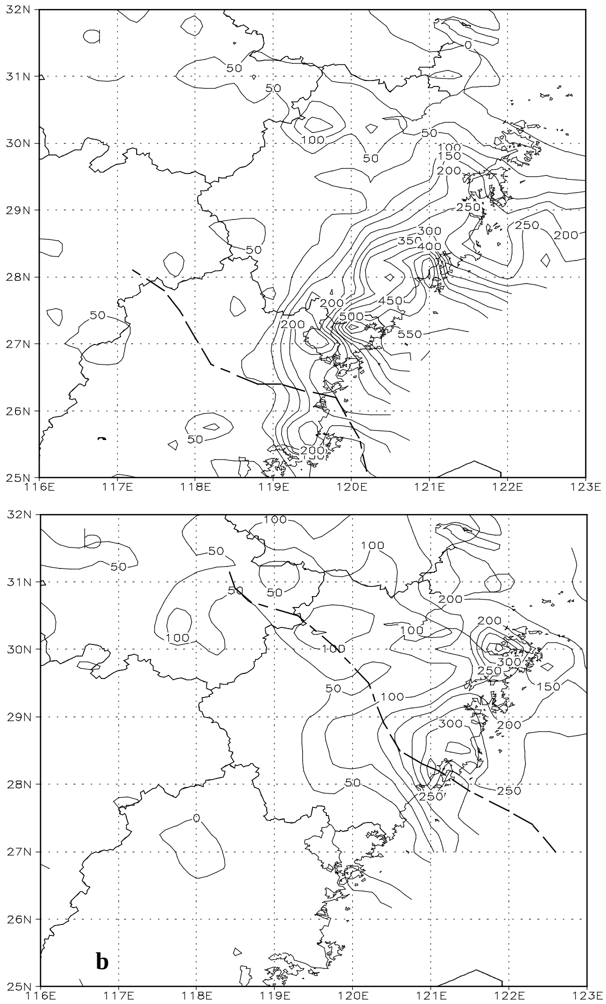

Fig.1 Distribution of accumulated rainfall. a. Haitang (08:00 July 18– 08:00 July 21); b. Matsa (08:00 August 4 – 08:00 August 7). Unit: mm. The dashed lines are the tracks of the typhoons.

brought heavy to unusually heavy rain to Zhejiang with exceptionally heavy rain in some places. Both of the two raining processes were mainly caused by the circulation of the typhoons. Areas of intense rainfall mainly appeared in the coastal part of the province and precipitation distributed asymmetrically along the path of movement. Large-scale raining areas were on the northern side of the landfall sites in two separate centers of rainfall maxima. It is also found from the rain rates determined for the time around the landfall that the rainfall center that was closer to the site of landfall generated before the landfall while the one that was farther away occurred after it. It is seen from their differences that Matsa, though being stronger than Haitang at landfall and staying inside Zhejiang for as long as 18 hours, had smaller cycle rainfall and maximum rainfall (by 200 mm) than the latter. It is also known from the distance of the rainfall center from the landfall site that the rainfall center of Haitang was farther away from the site of landfall than Matsa.

3 EFFECT OF TYPHOON INTENSITY AND MOVING SPEED ON PRECIPITATION

Though with lower intensity at landfall, Haitang had a much greater cycle rainfall than Matsa. It is apparent that such abnormal phenomenon is difficult to explain properly only from the viewpoint of landfall intensity. It needs to be studied from the maintenance of convective precipitation systems in typhoons. Studying the horizontal flow field of the two typhoons just before landfall (Fig.2), one knows that just like Matsa, Haitang also shows a circular outflow in cyclonic divergence on the 200-hPa flow field in the upper troposphere, which is consistent with the characteristics of flow field at the top of mature typhoons in which air currents flow outward from the

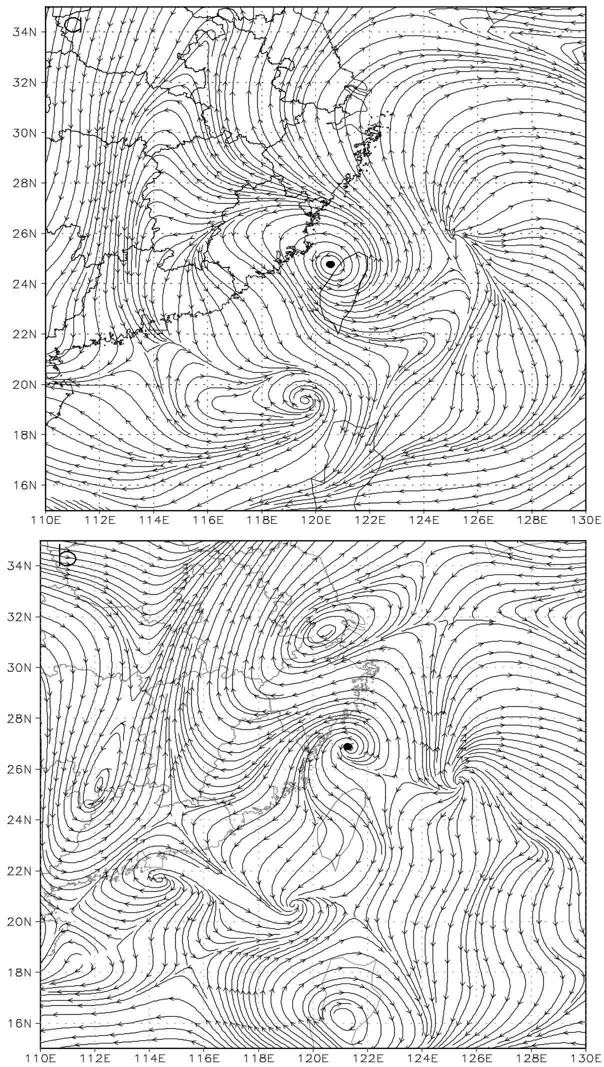

Fig.2 200-hPa flow field just before the landfall of the typhoons. Other cations are the same as Fig.1. "●" is the center of the upper-level circulation of the typhoons.

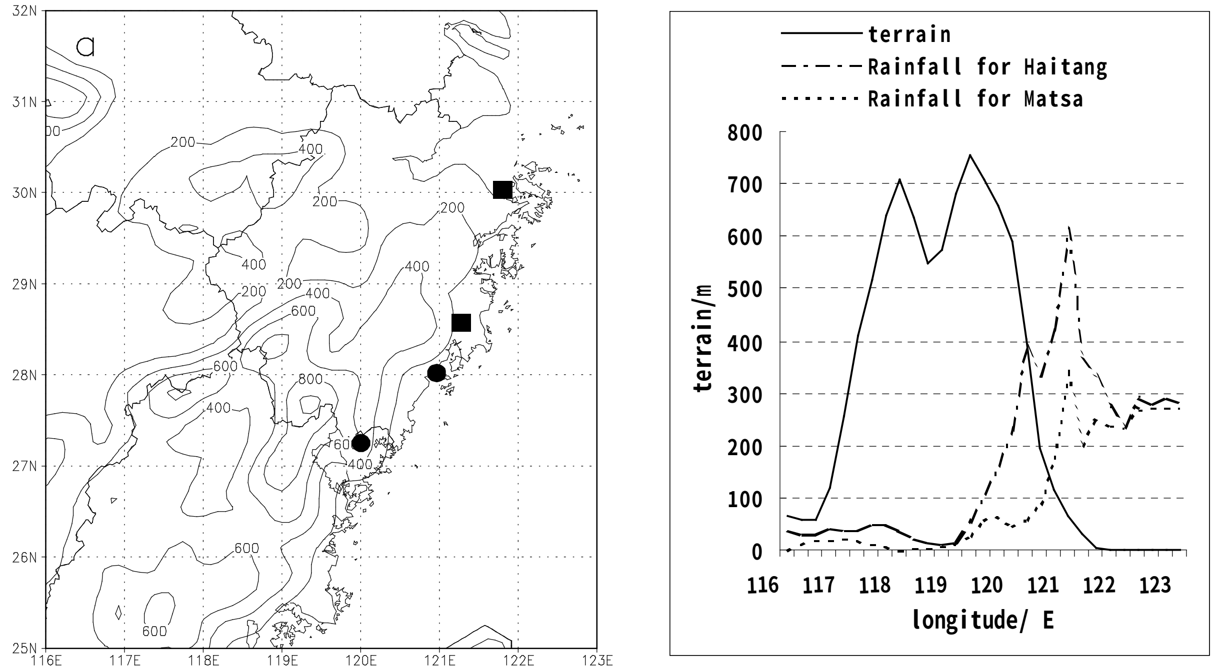

Fig.3 Terrain and precipitation. “●” and “■” in the left panel stand for the centers of maximum rainfall for Haitang and Matsa, respectively. The contours are the altitude of terrain in the unit of m. The right panel shows the profile of terrain (unit: m) and precipitation (unit: mm) on 28°N.

eye. It shows that the weakening effect due to friction during its passage over the terrain of Taiwan does not change much the upper-level flow field of Haitang so that the low pressure area is still at levels as high as it could be and the typhoon remains a deep convective system. It is the immediate cause for the intense precipitation. In the meantime, the intense divergence of outgoing air flows at upper levels facilitate the persistence of ascending motion, which is also an important mechanism for precipitation to persist and typhoons to maintain over land.

The duration of precipitation governs the rainfall. Slow speed of typhoon movement helps lengthen the duration of rain and otherwise is true. Tab.1 gives the mean speed of movement of the two typhoons every 6 hours during the landfall. It shows that the typhoons generally move relatively fast before landfall, slow down significantly after landfall and then tend to speed up again. Haitang is slower than Matsa in terms of 48-h mean speed. It is then known that a slowing-down or stagnating typhoon system is more favorable for the formation of heavy rain under specific weather situations.

Tab.1 Mean speed of movement of the two typhoons every 6 hours during the landfall

Time section	0 - 6 h	6 - 12 h	12 - 18 h	18 - 24 h	24 - 30 h	30 - 36 h	36 - 42 h	42 - 48 h	48 h mean
Haitang	17	18	7	17	10	10	18	14	12
Matsa	9	17	20	16	12	13	22	21	16

4 EFFECT OF TYPHOON STRUCTURE ON PRECIPITATION

The vertical profile (figure omitted) is analyzed of the difference between the temperature from north to south through the eye and the mean ambient temperature just before the landfall of the two typhoons, which reflects on the variation of warm-core structure. The warm core is maintained by large amount of warm and humid air inside the typhoon that keeps ascending while releasing latent heat from condensation. Strong release of latent heat is indicative of strong precipitation. With the reduction of convection after landfall, the warm core also weakens gradually. The vertical profile (figure omitted) is also studied of the equivalent potential temperature right before the landfall. A common feature is that there is an area of low values in the middle of the troposphere and the central area of low-level typhoon is where relatively high values concentrate, while high-value areas are significantly asymmetric on the south and north sides of the eye.

5 EFFECT OF AMBIENT SYSTEMS ON PRECIPITATION

Abundant water vapor is a necessary condition for heavy rain to occur. It is known from the study of the superposition of 850-hPa wind vectors and channels of water vapor right before landfall (figure omitted) that there is input of high-flux water vapor in both regions of the typhoons, which connect with a low-level jet stream, with areas of large values of water vapor flux on the low-level jet stream. It indicates that the southwesterly low-level jet stream is the main transportation channel of water vapor for the typhoons. From the wind field, their sources can be traced as far back as the Bay of Bengal. It was the existence of such jet stream that abundant amount of water vapor was supplied, vertical ascending motion strengthened and typhoon circulation maintained for the heavy rains in Zhejiang.

6 EFFECT OF MESOSCALE TERRAIN ON PRECIPITATION

The intensity and distribution of typhoons are closely linked with the terrain. Zhejiang is a hilly region that is generally higher in the southwest than the northeast. The moving direction of both Haitang and Matsa was almost in vertical intersection with the orientation of the mountain ranges so that the topographic lifting increased both condensation heating at lower tropospheric layers and ascending motion. The consequence is that the convergence and lifting on the windward slope confined most of the intense precipitation to the coastal part of the province (Fig.3). Precipitation was much less in areas west of 120°E, which differs by 8 – 10 folds.

7 CONCLUSIONS

Both of the storms brought heavy rain to large parts of the province with the centers of maximum rainfall all appearing north of the sites of landfall. It is also noted, however, that Matsa had smaller rain rates than Haitang, though the former was stronger at landfall. Then, comparisons have been made of the intensity, moving speed, structure, ambient field and terrain, to study the processes of heavy rain they caused, and some conclusions have been drawn.

(1) Both the heavy rains were mainly caused by the circulation of the typhoons themselves. Being deep convective systems, they had well-defined structure of warm cores before landfall. Persistent upper-level divergence, low-level convergence and transportation of abundant water vapor were playing a key role in the enhancement of the heavy rains. The well-defined asymmetric distribution of typhoon-induced precipitation is related with such factors as the structure of typhoons, water vapor condition and terrain. North of the landfall site was an area of convective instability with high temperature and humidity but convection was checked to some degree on the southern side. Water vapor was more abundant in a southeasterly jet stream on the northern side than on the southern side. The terrain of the SW-NE oriented mountain ranges in Zhejiang are vertically intersected with the direction in which the typhoons move so that the dynamic lifting effect of the terrain confined most of the precipitation to the coastal areas on the windward side.

(2) The larger rain rate of Haitang was resulted from the combined action by multiple factors. The intrusion of mild cold air further triggered the release of unstable energy due to convection and caused extensive heavy rain in the province. Viewing from the dynamic structure, Haitang weakened at slow paces than Matsa, which facilitated the persistence of precipitation. In addition, the so-called “cold field ” of the air mass above Zhejiang before the arrival of Haitang and its slower speed of movement than Matsa were also responsible for the enhancement of the heavy rain.

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