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DIAGNOSTIC ANALYSIS OF A RAINSTORM IN SHANDONG PENINSULA INFLUENCED BY A DISTANT TROPICAL DEPRESSION

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Abstract: Based on the observational data as well as data of satellite, NCEP reanalysis and moist potential vortex, the heavy rainfall event that occurred away from the outer cycle of tropical depression Kaemi (No.0605) on July 27, 2006 in Shandong Peninsula has been analyzed. The results show that there are three severe convective cloud clusters during the heavy rainfall. The uprightness of coupling pattern between upper-layer jet and low jet and a divergence area, which appeared in the right of upper-layer jet, provided favorable environmental conditions for convective cloud clusters. The strong convective weather happens over the prefrontal warm sector and the storm rainfall mainly distributes in the front of a high-energy area. Positive vorticity distribution and transportation of warm advection in low levels provide dynamic and thermal conditions for the rainstorm. The spatial-temporal evolvements of physical variable fields and MPV2 as the horizontal component of moist potential vorticity show that the rain intensity change is determined by upper and low level jets and the area of MPV2＞0 occurs at the front of the low jet cores.

Key words: rainstorm; tropical depression trough; upper and lower level-jet; moist baroclinity; moist potential vortex1 Introduction

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1 INTRODUCTION

After landfall on the coast of eastern China, tropical cyclones generating over the waters of northwestern Pacific contribute to a favorable weather pattern for heavy rains to occur over Shandong Peninsula when they act with the westerly system in mid-latitudes. Forecasting heavy rain associated with distant typhoons has been one of the difficult points in real-time forecast operation and extensive study has been done of the mechanism responsible for the enhancement of heavy rains at the periphery of typhoons [1 – 3].

Induced by a tropical depression resulted from the weakened Tropical Cyclone Kaemi (No.0605) about 1500 km away, an exceptionally heavy rain taking place in Weihai July 27, 2006, has rain rates rarely seen among similar synoptic systems. With the 6-h 1°× 1° analysis data of NCEP, satellite cloud imagery and intensive observations from surface automatic weather stations, this study follows the approach of synoptic and kinetic diagnosis to identify the structural characteristics and physical mechanisms of a governing weather system in the hope to search for indicative physical quantities.

2 CHARACTERISTICS OF PHYSICAL QUANTITIES

2.1 *Vertical structure of the kinetic field for the rain area*

It is known from the divergence field for 02:00 July 27 (Fig.1b) that a vertical cell of circulation appears over the rain area in which low-level convergence is superimposed with high-level divergence. The contour of W is nearly vertical. With descending motion around, ascending motion is extending from low levels all the way up to 200 hPa and 450 hPa is the level where the maximum center is. It is obvious that the appearance of a secondary peak rain rate is resulted from the couplings of updrafts between jet streams from high and low levels.

Advection of strong positive ξ is over the rain area from 02:00 to 08:00 July 27 and it is located below 800 hPa at 08:00 (Fig.1a), showing that the appearance of a rainfall peak is associated with the

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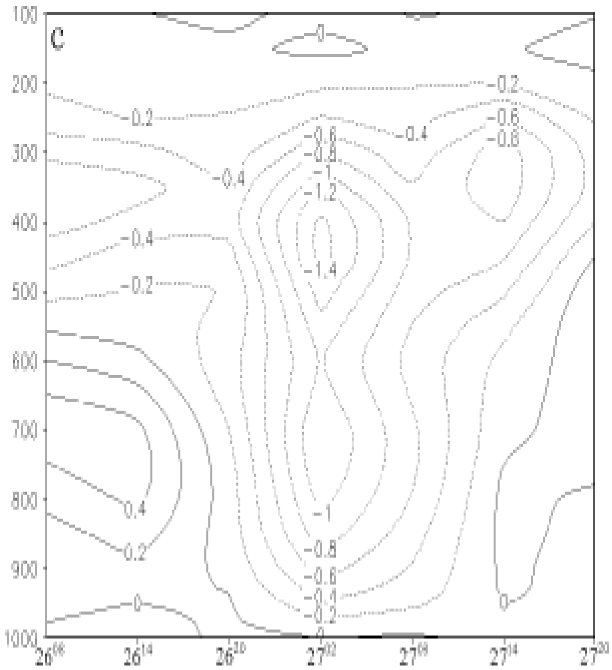
vortex effect at low levels and obviously due to the effect of the lifting of a low-level vortex on severe precipitation, the cloud top is lower.

A vertical cell of circulation is destroyed at 14:00. Upper-level anti-vortex and intense divergence are maintaining the precipitation and the updraft intrigued by an upper-level jet stream is increased once again so that a center of high updraft velocity appears on 350 hPa (Fig.1c). It is why the cloud top is high while the rain rate is much decreased.

2.2 *Relationships between pseudo-equivalent geopotential temperature and area of unusually heavy rain*

With the northeast extension of an inverse trough at 08:00 July 26, the atmospheric stratification becomes unstable geopotentially over the Shandong Peninsula, which is a pattern that favors the development of convection. It is known from an analysis of q_{se} at 850 hPa (Fig.2a) that an area of



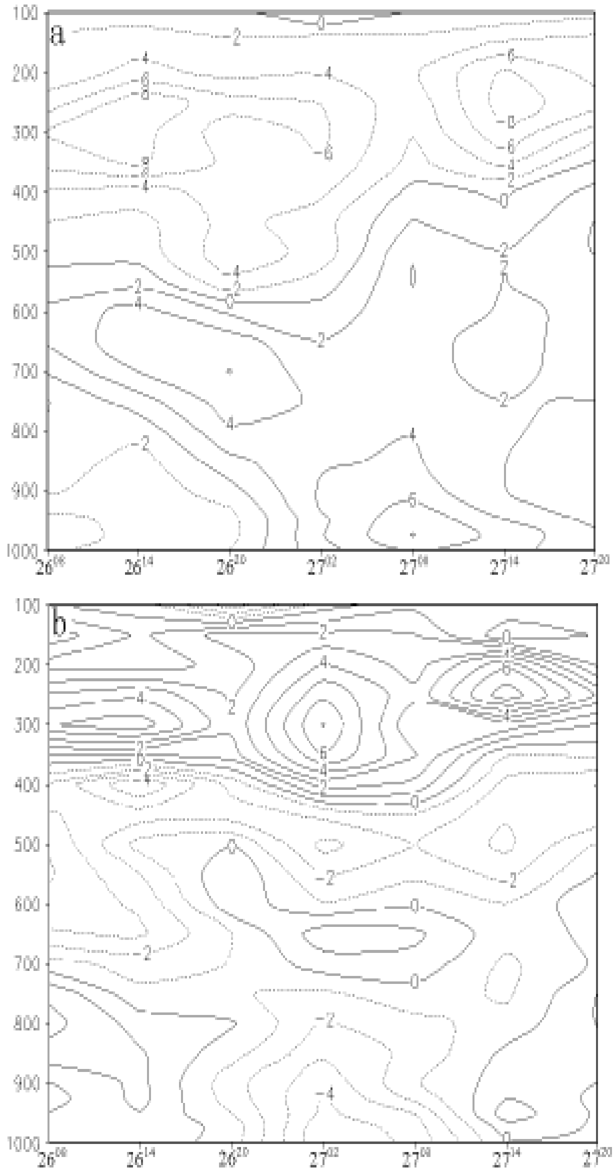


Fig.1 Time-altitude cross section of vorticity (a, unit: $10^{-5}s^{-1}$), divergence (b, unit: $10^{-5}s^{-1}$) and vertical velocity (c, unit: $10^{-2}hPa{\cdot}s^{-1}$) for the area of the unusually heavy rain (37°N, 122°E) in July 26 – 27, 2006.

high energy extends from South China to the southern part of the peninsula at 20:00 to enable warm and humid airflow to expand further towards the north and sharply increases unstable energy for the heavy rain area. In addition, a frontal zone of q_{se} forms on the northwestern side of the peninsula due to the effect of a cold advection. It attains its maximum at 02:00 July 27. The intensity of typhoon-associated heavy rain is positively correlated with that of the frontal zone of the energy field; the stronger the latter, the larger the rainfall[5]. The unusually heavy rain all precipitates within a frontal zone of intense q_{se}, which explains why rainfall is larger in the north of Weihai than the south of it during the event and also demonstrates the fact that a high q_{se} tongue is a supplier of energy for heavy rain and a humid, baroclinic frontal zone is essential to the occurrence of unusually heavy rains.

3 DIAGNOSTIC ANALYSIS OF HUMID VORTICITY IN THESE HEAVY RAINS

A sufficient condition for vertical vorticity to grow is $\mathrm{MPV2}/\frac{\partial q_{se}}{\partial p} > 0$, as given in Wu and Cai et al [6].

In this study, the focus is on the evolution of MPV2 at high and low levels to identify the role of jet streams at both upper and lower levels in precipitation as MPV2 transports over different phases.

The variation of 850-hPa MPV2 is studied for the time before the rain to the one after it. It is known from the distribution of MPV2 along a low-level jet stream (Fig.2a) that at 20:00 July 26, an area of MPV2＞0 is always in the front of the core of the low-level jet, which is marked by significant vertical wind shear and intensifying warm and humid airflow. At the same time, a southwesterly warm and humid airflow at the edge of the subtropical high merges over Shangdong Peninsula with a dry and cold airflow coming from the Bohai Bay. With further concentration and development of the low-level jet over the area of heavy rain, the overlaying atmosphere is getting more and more moist baroclinic so that the contour of MPV2＞0 distributes densely, ensuring the growth of vertical positive vorticity at low levels over the rain area and increasing the likeliness for intense precipitation to occur. By 02:00 July 27, the core of the low-level jet has moved to a region over the Yellow Sea and MPV2 has increased, making it likely for unusually heavy rain to take place. After 08:00 July 27, MPV2, which is much decreased with the eastward movement of the low-level jet, remains positive to maintain a cyclonic convergence field of positive vorticity at low levels, in favor of the persistence of precipitation.

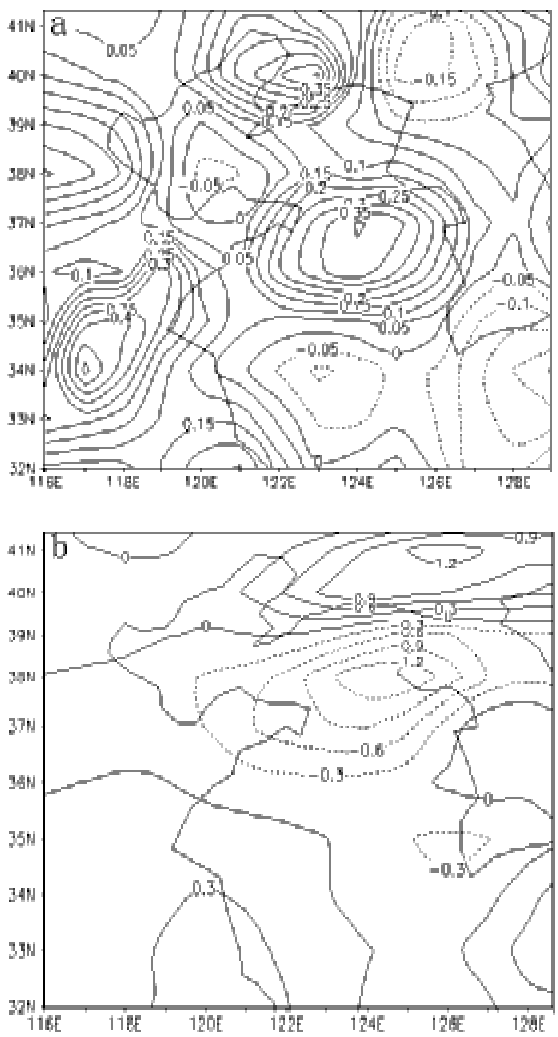


Fig.2 Distribution of MPV2 at 850 hPa (a) and 400 hPa (b) for 20:00 July 26, 2006. Unit: PVU

Then the variation of MPV2 is studied for the level of 400 hPa. At 20:00 July 26, the center of MPV2＜0 is located in the north of Yellow Sea (Fig.2b) when MPV1 ＜ 0, indicating that upper-level negative vorticity will grow, a sign that upper-level anti-vortex is playing a larger role. By 02:00 July 27, MPV2 turns positive, which in combination with high 850 hPa values, foretells the appearance of positive vorticity advection for the whole layer above the rain area. Anti-vorticity decreases at upper levels while low-level vortex strengthens at low levels. At 08:00 July 27, 400-hPa MPV2 turns negative again, which, in association with 850hPa＜0, indicates much increased negative vorticity at upper levels and a much larger role of intense upper-level divergence in precipitation than low-level jet streams.

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

4 CONCLUSIONS

(1) The unusually heavy rain in question is the result of interactions between tropical, subtropical and westerly systems after the zonal circulation is adjusted to meridional circulation. A convergence line with an inverse trough provides initial ascending motion for this hard rain process. The area of unusually heavy rain is well corresponding to the intense energy area of.

(2) It is known from the analysis of the physical quantities and the moist baroclinic term in the upper and lower vortexes that upper and lower level jet streams have different effect on rain rate. The secondary peak of rainfall for 02:00 July 27 is the result of the upper-level jet / intense divergence coupled with the lower-level jet / intense convergence. As the maximum rainfall for 08:00 is mainly resulted from a mesoscale vortex at low level, cloud-top height is relatively low; ascending motion for 14:00 is mainly caused by upper-level divergence, resulting in relatively high cloud-top height.

REFERENCES:

[1] LEI Xiao-tu, CHEN Lian-shou. An overview on the interaction between tropical cyclone and mid-latitude westerly systems [J]. J. Trop. Meteor., 2001,17(4): 452-461.
[2] HOU Jian-zhong, WANG Chuan, LU Yuan-ping, et al.

Activity of typhoons and extreme rainstorms in Shanxi province [J]. J. Trop. Meteor., 2006, 22(2): 203-208.
[3] ZHAO Yu, WU Zeng-mao, LIU Shi-jun, et al. Potential vorticity analysis of an torrential rain triggred by a neutercane in Shandong province [J]. J. Trop. Meteor., 2005, 21(1): 33-43.
[4] MENG Zhi-yong, XU Xiang-de, CHEN Lian-shou. T_BB -nudging four-dimensional data assimilation method and simulations on heavy rain process in Wuhan on 20 July, 1998 [J]. Chinese J. Atmos. Sci., 2002, 26(5): 663-675.
[5] ZHENG Feng. Study of Wenzhou heavy rain associated with Tropic Cyclone 9909 [J]. Meteor. Mon., 2005, 31(4): 77-80.
[6] WU Guo-xiong, CAI Ya-ping, TANG Xiao-qing. Moist potential vorticity and slantwise vorticity development [J]. Acta Meteorologica Sinica, 1995, 53(4): 387-404.

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