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STRUCTURAL AND EVOLUTION CHARACTERISTICS OF THE EASTERLY VORTEX OVER THE TROPICAL REGION

YAO Xiu-ping (姚秀萍)[1, 2, 3], WU Guo-xiong (吴国雄)[3], LIU Huan-zhu (刘还珠)[4]

(1. Jiang State Key Laboratory of Severe Weather (LaSW) Chinese Academy of Meteorological Sciences, 100081 China; 2. China Meteorological Administration Training Center, Beijing 100081 China; 3. National Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029 China; 4. China Meteorological Administration National Meteorological Center, 100081 China)

Abstract: By employing the NCEP/NCAR reanalysis data sets (1000 – 10hPa, 2.5° × 2.5°), the characteristics have been analyzed of the structure and evolution of an easterly vortex over the tropical upper troposphere relating to the east-west direction shift of the subtropical anticyclone over the Western Pacific Ocean. It is shown that there exists a westward shift simultaneously between the anticyclone and the vortex locating south of it. The anticyclone retreats eastward abnormally while the easterly encounters with the westerly around the same longitudes as they move from the opposite directions. The former is an upper weather system, extending from mid-troposphere to the height of 50 hPa with the center locating on 200 hPa. The vertical thermal distribution illustrates the characteristics of being "warm in the upper layer but cold in the lower layer". The divergence effect and the vertical motion change largely within the east and west sides of the easterly vortex and ascending branch transforms to descending branch near its center.

Key words: easterly vortex; structural characteristics; east-west shift of subtropical anticyclone over the Western Pacific Ocean

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1 INTRODUCTION

As one of the members of the East Asian monsoon system, the west Pacific subtropical high has huge impacts on the heavy rain during Mei-yu (sustaining) rain in eastern China. Its seasonal shifts to the north and relationship with Mei-yu rain in the basins of the Yangtze and Huaihe Rivers were pointed out in the 1960s [1]. Detailed discussions have been made of the structure of the subtropical high and factors governing its activity [2] and efforts have been spent to probe into the characteristics of its east-west fluctuation and forecasting patterns [3]. In a number of studies on the characteristics and the east-west oscillation and northward jumps of the subtropical high [4 – 6], short-term variation of the subtropical high is thought to play a key role in precipitation anomalies, especially large-scale circulation background for regional and unusually heavy rains. Recently, the formation and variation of the subtropical high have been studied and summarized in terms of the dynamics to see more clearly the patterns of its evolution and relationships with the circulation in the tropics and westerly zone. The above and related works [12, 13] are mainly concerned with the climatological features of the subtropical high but shed little light on the patterns and mechanisms for variation on the transient or synoptic scales. Besides, because the interactions within internal circulation fields of the atmosphere are more involved, the issues of short-term fluctuation of the subtropical high interacting with the westerly system and tropical waves are pronounced. Much different from the forcing of external sources that are much stressed upon in climate issues, they have direct impacts on the medium- and short- term weather forecast, especially the weather forecast in China [14].

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Biography: YAO Xiu-ping, female, native from Fujian province, professor, M.S., mainly undertaking the study and teaching of synoptic dynamics of systems like heavy rains.

E-mail: yaoxp@mail.iap.ac.cn

There may be particularity in the short-term effects of different zonal circulation zones on the subtropical high over western Pacific [15].

In addition to the structural characteristics of itself, short-term variation of the subtropical high is also related with relevant synoptic systems. Previous studies have talked about the role of mid-latitude synoptic systems in the subtropical high (Ren et al.[16]). Then, does the subtropical high over the western Pacific have anything to do with the regimes inside the easterly zone of the low latitudes? If yes, what are the structures of these tropical disturbances and how do they evolve? In view of the close links between anomalous precipitation in the basins of the Yangtze and Huaihe Rivers in 2003 and anomalous western Pacific subtropical high [17 – 18], this work uses the daily mean 2.5° × 2.5° reanalysis data of NCEP/NCAR for the levels between 1000 hPa and 100 hPa to carry out a case study of the anomalous east-west progression of the subtropical high during the time when the first heavy rain took place in the Mei-yu season of 2003.

2 STRUCTURE OF TROPICAL EASTERLY DISTURBANCES AND THE TEMPORAL AND SPATIAL EVOLUTION

2.1 *Vertical structure*

It is known from an analysis of the meridional vertical cross section of vorticity and geopotential deviation of disturbance center (figures omitted) that the disturbances in relevant tropical easterly zone, which are closely associated with the east-west progression of the subtropical high, are the systems located on the mid- and higher- tropospheric layers and stratosphere. They are much more prominent from the upper troposphere to tropopause than at the tropospheric middle and lower levels.

2.2 *Evolution of the easterly disturbance*

It is known from the longitude-time evolution of divergence and vertical velocity averaged over 15°N - 20°N for the time June 18 – 28, 2003 (Fig.1 & Fig.2) that the easterly disturbance shows as a cyclonic vortex at 200 hPa during the westward progression of the

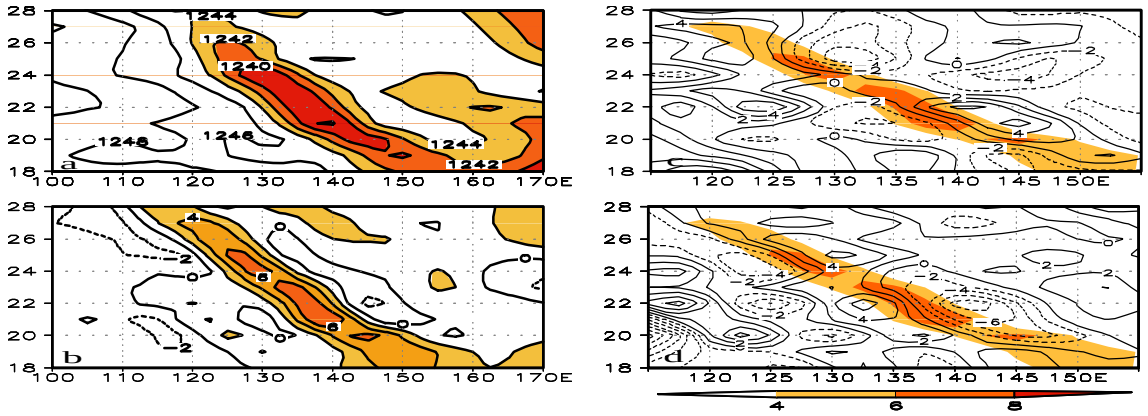

Fig.1 Longitude-time evolution of (a) geopotential height (unit: dagpm), (b) vorticity (unit: 10^{-5}/s), (c) divergence (unit: 10^{-6}/s) and vorticity greater than 4×10^{-5}/s (as indicated by the shaded area), and (d) vertical velocity (unit: 10^{-2} Pa/s) and vorticity greater than 4×10^{-5}/s, which are averaged over 15°N - 20°N for the time June 18 – 28, 2003.[5]/s.

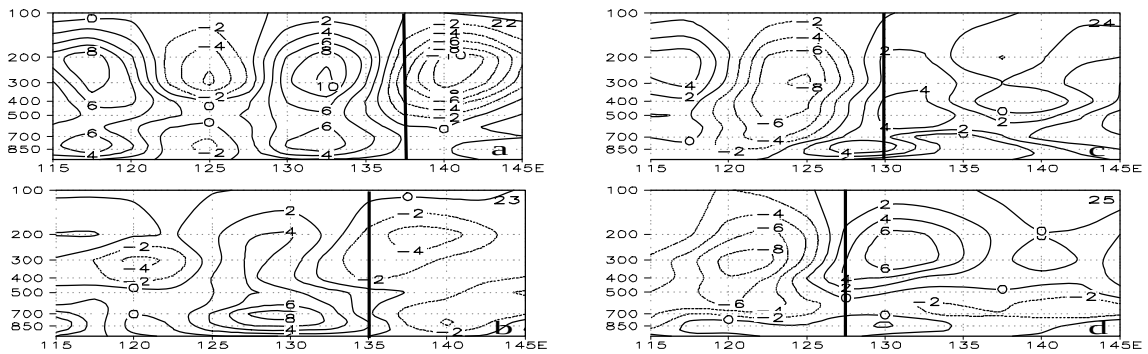

Fig.2 Zonal cross section of vertical velocity on 17.5°N for 22 – 25 June, 2003. (a) June 22; (b) June 23; (c) June 24; (d) June 25. The bold, straight lines are the position of the center of the easterly disturbance. Unit: 10^{-2} Pa/s.

disturbance bulk, accompanied with the centers of divergence and vertical velocity on the west and east sides, respectively. It is seen that the eastward retreat of the subtropical high is, in reverse, causing anomalies in the structure of the easterly disturbance.

2.3 *Anomalous characteristics of the easterly disturbance with the eastward retreat of the subtropical high*

The study above shows that the eastward retreat of the subtropical high is also accompanied with the appearance of anomalies in the structure of the easterly disturbance, which shows clearly in the cross section of the vertical velocity.

It can be seen from the zonal vertical cross section of the vertical velocity along 17.5°N (figure omitted) that before the retreat, an area of consistent descending motion appears in the whole column west of the disturbance center while ascending motion occurs east of it. The center of the descending motion is located near 700 hPa and 300 hPa while that of the ascending motion near 200 hPa.

3 DYNAMIC RELATIONSHIPS BETWEEN THE EASTERLY DISTURBANCE AND EAST-WEST SHIFT OF THE SUBTROPICAL HIGH

It is known from the matching relationships of the above fields of physical quantities that the easterly disturbance is mainly shown in the upper levels and the relationships between the easterly and westerly disturbances and the east-west shift of the subtropical high are displayed in Fig.3a.

To describe the interactions between the subtropical high and disturbances in the easterly and westerly zones, the longitude-time evolution is illustrated (figure omitted) of the vorticity field and ridge of the subtropical high. It shows that the east-west shift and anomalous eastward retreat of the subtropical high are closely related with the disturbances in the easterly and westerly zones south and north of it. In the meantime, the eastward retreat of the subtropical high also results in abrupt changes in the kinetic and thermodynamic structures of the disturbances.

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

4 CONCLUSIONS AND DISCUSSIONS

Our analysis of the characteristics of the structure and evolution of the easterly disturbances in the easterly zone over the tropical Pacific, which is linked with the east-west shift of the subtropical high in western Pacific during the first heavy rain in the Mei-yu period of the Yangtze and Huaihe River valleys in 2003, has achieved the following results:

(1) During the time, the subtropical high transforms from a lump-shaped distribution to a stripe-shaped one, which is accompanied by a vortex disturbance in the easterly near 17.5°N south of it and a westerly disturbance north of it. With the gradual westward progression of the bulk of the subtropical high, the easterly disturbance heads west while the westerly disturbance goes to the east when precipitation begins to enhance over the river valleys aforementioned. When the two disturbances meet on the same longitude, approximately at 130°E where the land meets the sea, the west-extending subtropical high breaks up and the bulk retreats to the east significantly. At this point, the area of precipitation pushes southward. It is apparent that the easterly vortex disturbance and westerly disturbance south and north of the subtropical high are closely related with the anomalous evolution of the latter.

(2) The vortex disturbance in the easterly zone is actually a deep low-pressure system from the mid- and upper- troposphere to the stratosphere, which is most dominant at the level of 200 hPa. Thermodynamically warmer at the upper levels than the lower levels, the

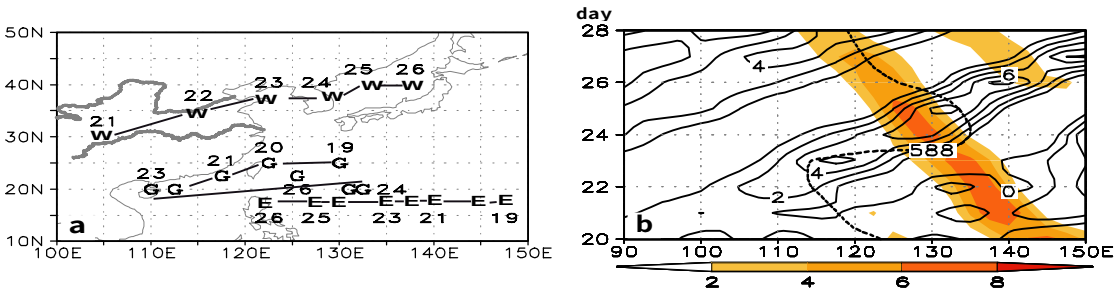

Fig.3 Dynamic evolution (a) of the centers of the easterly disturbance at 200 hPa (E) and the westerly disturbance at 500 hPa (W) and the westernmost point of the 588 dagpm contour (G) and (b) longitude-time evolution of vorticity averaged for 15°N – 20°N on 200 hPa (the shaded area) and that averaged for 35°N – 45°N on 500 hPa (the black, solid line) and the 500-hPa contour of 588 degpm on 25°N. Unit: 10^{-5} /s. The numerals on the ordinate indicate the date.

system is distributed so that its cold portion meets the warm one at 200 hPa, with the former being stronger than the latter.

(3) The subtropical high will break up and retreat to the east when the vortex disturbance in the easterly zone weakens during the westward movement (i), the positive vorticity areas of the easterly and westerly disturbances approach to each other while their scope of negative vorticity shrink (ii), and the ascending motion in the vortex disturbance in both the wind zones of upper troposphere merge in place of the descending motion near 130°E (iii).

The analysis above has suggested a link between the east-west movement of the subtropical high and the easterly disturbance. When the former retreats eastward anomalously, the structure of the easterly disturbance behaves abnormally at the upper levels of the tropics.

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