Large-Scale Conditions of Tibet Plateau Vortex Departure

12.5

ShuHua Yu*， WenLiang Gao

Institute of Plateau Meteorology, China Meteorological Administration, Chengdu 610072, China

ABSTRACT

Based on the circumfluence situation of the out- and in- Tibet Plateau Vortex (TPV) from 1998 - 2004 and its weather-influencing system, multiple synthesized physical fields in the middle – upper troposphere of the out- and in-TPV are computationally analyzed by using re-analysis data from National Centers for Enviromenal Prediction and National Center for Atmospheric Research (NCEP/NCAR) of United States. Our research shows that the departure of TPV is caused by the mutual effects among the weather systems in westerlies and in the subtropical area, within the middle and the upper troposphere. This paper describes the large-scale meteorological condition and the physics image of the departure of TPV, and the main differences among the large-scale conditions for all types of TPVs. This study could be used as the scientific basis for predicting the torrential rain and the floods caused by the TPV departure.

Key Word: Tibet Plateau vortex, Large-scale meteorological condition,physics image

1. Introduction

During the summer and in the certain circumstances, the Tibet Plateau Vortex (TPV) sometimes moves out of the Tibet Plateau, and triggers heavy rain, even torrential rain to the east of the Tibet Plateau which results in severe flash floods (Yu, 2001; Zhang et al., 2001). The eastward movement of the TPV has attracted a good deal of attentions in meteorological research. DuZheng Ye and GAO YouXi Gao (the leading Chinese meteorologists) pointed out in 1979 that in an appropriate situation,the shallow synoptic systems inside the plateau boundary layer are likely to develop themselves enough to travel out of the plateau. Chen et al. (2000) further showed that terrain influences the movement of the TPV. As indicated by Li (2002), the migration of the TPV can occur under the certain steering flows.

Futher Song and Qian (2002) showed that a certain depth of the air column averaged over the central – eastern plateau could be used as an indication of the TPV movement. The upper-level divergence field serves as one of the indispensable conditions that causes the rainstorm in the Sichuan province during TPV eastward movement (Liu and Fu, 1986). In their study of vapor images, the present author Yu and her co-worker (2002; 2003) discovered that the vapor vortex in the middle – upper troposphere is another indicator of the TPV activities. The research from Hideo TAKAHASHI (2003) reported that the low pressure over the northern Tibet Plateau is affected directly by the cold air.

Viewed as Qiao and Zhang (1994), the movement of TPV is led by upper airflow. In the view of Chen and Ming (2004), when TPV is superposed by a southwest vortex, the two vortexes can enhance one another simultaneously. Yu et al.(2008) showed that the TPV migrates out of the plateau when it is of baroclinicity and under the control of mostly cold air. Yu et al.(2007) also studied (2007) on the

* Corresponding author address: Shuhua Yu ,professor of Chengdu Institute of Plateau Meteorology ,Chengdu 610072,China;E-mail： shuhuayu@mail.sc.cninfo.net

average circular characteristics while the TPV moves out of the plateau, and the middle-upper circular characteristics of the TPV activities responsible for floods in China. All these studies enrich the understandings of the eastward movement of the TPV. But study of the large-scale conditions and physics image of TPV movement is still missing. This paper aims to find favorable large-scale circumstance and physics image for the TPV's move-off, based on the comparisons of the multiple physical fields.

2. Data and Method

The data used in this paper are NCEP/NCAR reanalysis data at 00UTC and 12UTC with the resolution of $2.5^{o} \times 2.5^{o}$, and the historical charts shown on Meteorological Iinformation Comprehensive Analysis and Processing System (MICAPS) during 1998-2004 provided by China Meteorological Administration (CMA).

After universal analysis of the circumfluence position and the weather influencing systems, physics fields are synthesized for classified out- and in-TPV with different weather influencing systems. Here out-TPV indicates a TPV that migrates out from the plateau, while in-TPV means a TPV not able to move off.

The steps of synthesis are as follows:

1. Three times are defined: 0hr is the last time a TPV exists within the plateau; -1hr means12 hours before 0hr, and 1hr-equals 12 hours later than 0hr.
2. Out-TPVs and in-TPVs are sorted by circumfluence position at 0h to the north of 40° N over the area of eastern Asia, say, in a two-trough-one-ridge pattern, one-trough-one-ridge pattern.
3. Arithmetic averaging is carried out among various out- and in-TPV at three times under certain circumfluence positions.

The synthesis location of TPV is geometric center on average of TPVs. while synthesized fields are potential height(H) on 200 and 500hPa, stream field on 200, 300 and 500hPa, together with temperature (T) and vapor flux field on 500hPa .

3. Facts analysis of out- and in-TPV during 1998-2004

We defined out-TPV as a low pressure with a close contour or with cyclone winds at three stations around on 500hPa over the plateau, which moved out of plateau afterwards(Yu and Gao, 2006). The Tibet Plateau area in this paper includes Tibet Autonomous Region, Qinghai province and neighborhood with height above sea level greater than 2500 meter. The analysis of incidence, influence range, and related weather systems of out- and in-TPV from May through September. during 1998 through 2004 are given in this section.

3.1 The activity of out- and in-TPV

Table 1 shows number of out- and in-TPV from May through September during 1998-2004. The total is 146 in seven years, with annual average of 21. 53 of them moved off. On average, per year 7.6 TPVs migrate out the plateau. TPV are generated mainly during May through August., most out-TPVs are generated in June., July. and August.

3.2 The weather influencing system

Statistic (Yu, 2006) show that nearly half (43 percent) of out-TPV leave the plateau along with the trough to its north or to its east; 29 percent of them migrate east out in a sheared stream field, a few following the shear line eastward; led by northwest airflow in front of ridge, 17 percent of them go southeast; 9.5 percent of them act with Subtropical High; and a few depart after the southern trough. differently, when in the plateau, TPV goes east along with shear line(Research Panel on Tibet Plateau Meteorology, 1981). Based on preceding the figures, the main weather-influencing system could be approximately sorted into two, one is called a trough sort in which TPV moves off following trough; the other is a shear sort, namely, TPV migrates out in the sheared field.

Detailed analysis reveals that 56.5 percent of out-TPV in trough sort (Table 2) leaves the plateau placed in foreside of a westerly trough, other 43.5 percent, move together with a trough to the north of TPV. thus, the trough sort is classified in detail as a westerly trough foreside sort (WTFS), and trough north and vortex south, simply as TNVS. Likewise, the shear sort is classified as sheared stream field sort (SSFS), accounting for 67 percent of shear sort, and the shear line sort (SLS) is the remaining 33 percent of the shear sort. As shown in analysis, the out-TPVs in WTFS are generated mainly in June. and July.; the out-TPVs in SSFS is usually generated in July. and August.; the out-TPVs in TNVS is created mostly in August. and September.; few TPVs can migrate out from the plateau along a shear line, which is consistent with the research from Qiao (1994).

The duration of out-TVP on the eastern portion of the plateau is different from one sort to another. Comparatively, SLS has the longest duration more than 48 hours, and once as much as 192 hours; TNVS and SSFS are the shortest, about 12 hours, WTFS usually last 36 hours or more. Few of SLS could depart from the plateau, but once leaving, an SLS can maintain longer duration and trigger torrential rain and flood as it heads east.

4 Circumstances in middle-level of troposphere related to kinds of TPV

In this section, the relationship between circumfluence position at 0 hr over eastern Asia at the north of 40° N and various sorts of out- and in-TPV are examined.

For TNVS, the main pattern of out-TPV is two troughs and one ridge which occupied 70 percent of the total, 71 percent of those had the ridge line position from Balks Lake to Baikal Lake, while 30 percent of in-TPVs are in the pattern of two troughs and one ridge. For WTFS, 38 percent of out-TPV is in the pattern of one trough and one ridge, while 44 percent of in-TPVs are in the pattern of two troughs and one ridge. For SLS, 54 percent of out-TPVs are in the pattern of two troughs and one ridge, among them, 71 percent are with low pressure in the northeastern part of China. Thirty-one percent of in-TPVs are in a pattern of two troughs and one ridge with low pressure trough in the northeastern part of China. For SSFS, 40 percent of out-TPVs are in the pattern of two troughs and one ridge, and 35 percent of in-TPVs are also in the same pattern. The preceding percentages reveal that the out-TPVs, apart from WTFS, and all in-TPVs are mostly related to the pattern of two troughs and one ridge. Thus it is of importance to discuss the difference between out- and in-TPV in circumstances in middle troposphere.

According to the selecting standard mentioned previously, the number of various sorts of TPV and the circumfluence pattern are listed in Table 3: five of TNVS and four of SLS and SSFS migrate out from the plateau in the pattern of two troughs and one ridge, three of TNVS, five of SLS, and six of

SSFS disappear within the plateau; five of WTFS move off, and one fades away in pattern of one trough and one ridge. In conclusion, the pattern of one trough and one ridge pattern is the main for TPVs of WTFS to depart from, while pattern of two troughs and one ridge is relatively favorable to SSFS and SLS, despite being of the most hard to move off the plateau.

From now on, the analyses are done on the synthesis of height, temperature, stream fields, and vapor flux fields on 500hPa at -1hr, 0hr, and 1hr.

Weather systems of influencing TPV and the variation in their intensity

When a TPV of Westerly Trough Foreside Sort (WTFS) is starting to leave, there is usually a trough over the eastern plateau, plus another one located to its north in the same phase (Fig.1a) and cold air advection in the back, intensifying the trough. On the contrariwise, a TPV of the WTFS is seldom leaves if a trough exists in the middle of the plateau (Fig. 1b), with a ridge to its north and no cold air advection to its back, because the trough diminishes gradually as a result of warm air.

For a TPV of TNVS to be off, a trough from northern China to northern Sichuan is necessary, along with weak cold advection to the south of the trough which enhances the trough (Fig.1c). To in-TPV a trough is commonly stretched to the southeastern plateau, furthermore without cold advection followed (Fig.1d).

The synthesized circumstance for an out-TPV of SLS displays as follows: a transverse shear line that originated in northeastern China stretches into the plateau (Fig.1e); and is strengthened by the Bengal Bay monsoon low pressure enlarging in both northward; and eastward. But if the transverse shear line extends into Sichuan (Fig.1f), and India monsoon low pressure is fading, a TPV of SLS has difficulty to migrating out.

If the sheared steam field is formed by Subtropical High with the east-inclined ridge spreads from the western plateau to Xingjiang (Fig.1g), and the ridge moves eastward with its intensity increasing, a TPV has relatively ease in departing. However, in a sheared-stream field shaped by a Subtropical High and a ridge extending from the northeastern plateau to Baikal Lake (Fig.1h), a TPV has difficulty leaving, especially when the ridge moves less with a decrease in its intensity.

4.1 Influence of cold air on TPV

The effect of cold air varies with sort of TPV and its movement. The out-TPV of WTFS is a baroclinic vortex as a result of cold air infusion (Fig.1a), while a WTFS in-TPV, as situated in warm area, becomes a warm vortex (Fig.1b), The same to SLS and SSFS. However, both the out- and in-TPV of TNVS are of weak baroclinicity because of the colder airflow in the northeast of the vortex (Fig.1c, d).

4.2 Southern and northern air flow and vapor transportation

The location, intensity and time-variation of westerly airflow-northerly airflow, and southwester jet are the key factors of various sorts of out- and in-TPV. The general configuration of airflows and vapor transportation are described in different sorts.

Westerly Trough Foreside Sort: For out-TPVs, on the one hand, a stronger westerly belt to the north of the plateau shifts gradually down south, not only enhancing the northwest airflow in the northern plateau but also meeting with the northward airflow from Bengal Bay; on the other hand, a large-scale west-southwester jet, beginning from the southern plateau, through Henan in the middle, finally to the eastern Japan, joining a mesoscale southwester jet situated between Hongyuan and Huajiaceng, transports vapor to out-TPVs, as it moves a little east and close to out-TPV (Fig.2a). Consequently, the out-TPVs is sited to the left of the southwester jet, a favorable place for out-TPV's sustentation. As for in-TPVs, apart from being without southwester jet, the northern airflow-westerly is comparatively further north, and vapor termination further south (Fig.2b),and with their intensity decreases, it is less beneficial for TPV of WTFS to sustain for longer durations.

Trough North and Vortex South Sort: Northern airflow for out-TPVs is similar to WTFS, in the stage of enhancing and dropping down south, while the southern airflows, originating from Bengal Bay and the South China Sea, transport vapor to the eastern plateau (Fig.2c), covering a larger area. The westerly jet to the north of a Subtropical High moves southeast and converges with the northern airflow. As a result, the Subtropical High recedes, better environment for out-TPV to live. Dissimilarity of in-TPV is in the intensity of northern airflow and the destination and scope of vapor transportation (Fig.2d) as well as the stability of a Subtropical High with, in detail, weaker northern airflow, farther north location, smaller scope of vapor transportation, and less movement of the jet.

In SLS, the out-TPV is situated in the circumstance that the northern wind in the northern plateau strengthens and expands south, along with stable vapor transportation to the southeastern plateau (Fig.2e); the westerly jet to the north of Subtropical High, after jumping northward, is stabilized, thus increasing the convergence at the location of the shear line. Contrarily, when in-TPV is placed in unfavorable environment, not only are the intensity of the northwester, but also the vapor transportation by southern airflow and westerly jet are at low ebb (Fig.2f), but also their sites become away from in-TPV with time.

For out-TPV of SSFS, in the north, the norther in the middle, northern, and northeastern plateau increases in intensity, meanwhile in the south, vapor respectively from the Arabian Sea, Bengal Bay and the South China Sea are transported to the eastern plateau (Fig.2g), the largest among the four sorts of TPVs; the southwester jet beside the Subtropical High is stable and increasing, advantageous to shear stream field, and of course to the persistence of out-TPV. As for in-TPV, the wind in the north turns the direction from north into northwest with intensity decay; vapor is transported farther east, around the area from northeastern plateau to northern Shanxi (Fig.2h),and the southwester jet moves farther away instead of nearer.

From the above, it is clear that the common characteristics of four sorts of out-TPV are that the weather-influencing systems decline in their intensity; out-TPVs have been infused into cold air and of baroclinicity; the northern airflow over the northern plateau reinforces; vapor is transported continuously to the eastern or southeastern plateau. The difference is, apart from the different weather-influencing systems, WTFS and TNVS are strengthened by cold advection in back of a trough, while the sheared property in SLS and SSFS are enhanced by northward-moving monsoon lows and east-inclined Xinjiang ridge; the northern airflow in WTFS and TNVS is strong westerly along with eastward movement of westerly jet to the north of Subtropical High, but northerly together with north jump of westerly or southwester jet in SLS and SSFS; the scope impacted by cold air in WTFS and TNVS is larger than that in SLS and SSFS. Noticeably, the circumfluence suitable to TPVs leaving and generation on 500hPa (Luo, 1992) are different.

5 Analysis of circumstances in upper troposphere for four sorts of TPV

TPV departure is influenced not only by the environment around it but also under the lead of the weather systems in the upper troposphere. Thus height and stream fields on 200 hPa and stream fields on 300hPa are synthesized as follows.

5.1 South Asia High

WTFS: For out-TPV, South Asia High (SAH) is strong, with large area greater than 1256gpm and with the ridge sited at 27-30° N (Fig. 3a). Out-TPV is under the westerly in front of the SAH ridge. For in-TPV, the ridge line of SAH is farther south, at 20-24° N (Fig. 3b), in addition to having no area higher than 1252gpm. Despite in-TPV being still under the westerly but far from the ridge. In short, SAH related to out-TPV is stronger, farther north and an obvious eastern extension.

TNVS: The ridge of SAH corresponding to out-TPV is in 25-38° N, and the area greater than 1248gpm, stretches to 134° E, out-TPV, under the westerly of SAH, is 6-8° longitude away from the center of SAH (Fig.3c) if in the same level. While the ridge of SAH related to in-TPV in 24-28° N, the 1248gpm line reaches only 119° E, and in-TPV, more than 10° longitudes far away from the center of SAH (Fig.3d), is under the west-northwester in front of the ridge of SAH. In short, SAH related to out-TPV spreads farther east and has larger divergence in the upper air, which is much more favorable for TPV to sustain.

SLS: SAH associated with out-TPV humps up north, with the ridge in 24-28° N (Fig.3e) and with larger an area greater than 1256gpm, while out-TPV is under the lead of northwest airflow in front of SAH. SAH companied with in-TPV recedes with ridge in 25-28° N, without area greater than 1256gpm (Fig.3f). In-TPV is under the northwest airflow in front of ridge of SAH. Stronger SAH is the key factor for TPV in this sort to move out of the plateau.

SSFS: SAH related to out-TPV is sited a little farther north, with the ridge in 25-28° N and stretching obviously east, 1252gpm reaches to 129° E (Fig.3g), while out-TPV is covered by west-northwest airflow in front of the ridge of SAH. For SAH related to in-TPV, its ridge is in 26-33° N, and a 1252gpm line stretches only to 94° E (Fig.3h), in-TPV is under the northwest airflow in front of the ridge of SAH. In short, SAH corresponding to out-TPV is stronger.

5.2 westerly jet on 200hPa

WTFS: For out-TPV, the westerly jet on 200hPa is situated at approximately 35° N over the plateau, and the velocity of 34m/s in the jet center over the out-TPV is stable. For in-TPV, the jet is situated at approximately 35° N, and the jet center is 10-15° longitudes horizontally far away from the in-TPV. The velocity over the in-TPV decreases from 29m/s at -1h to 27m/s at 0h and 1h. This means that compared to in-TPV, the upper front is more stable and nearer to out-TPV. Iin other words, baroclinicity of westerly trough and the vortex increase, in favor of development of low weather system on 500hPa.

TNVS: For out-TPV, the westerly jet on 200hPa drops down south to 35° N over the middle and eastern plateau, and the velocity of 28m/s over the northern out-TPV is stable. For in-TPV, the jet drops down south to 37.5° N, more than 5° longitudes horizontally far away from the in-TPV. It's obvious that the upper front is closer to out-TPV than to in-TPV. In comparison with WTFS, for out-TPV the upper front in TNVS is spaced farther, in addition to being weaker in intensity, it is inferior in environment on 500hPa.

SLS : For out-TPV, the westerly jet on 200hPa divides into two: one is in the western plateau, and the other in the northeastern plateau and to the east. The eastern part of the jet drops down south to 32.5° N, and out-TPV is located at the entrance of the jet. The southward movement of the east part of the jet is the result of southern drop of the upper front, of benefit to the shear line generated from the transverse trough. For in-TPV, the jet is sited around 37.5° N, more than 5° longitudes horizontally away from in-TPV center, and having a northward advance.

SSFS: For out-TPV, the westerly jet in the mid-eastern portion plateau of 35° N on 200hPa goes eastward. The wind speed in the upper level of the northern TPV is 31m/s, and stable. contrariwise, the westerly jet on the western plateau around 37.5N, accompanied with in-TPV, recedes west. Comparatively, the upper air front together with out-TPV is stronger and farther southeast than that with the in-TPV, or nearer to out-TPV.

5.3 Wester-deflected airflow on 300hPa

Table 4 reveals that airflow on 300hPa related to out-TPV is stronger than that related to in-TPV; in detail, the airflow accompanied with out-TPV of WTFS is the strongest, with the velocity greater than 20m/s. The other three out-TPVs are the strong (≧13m/s) and becoming stronger, while all in-TPVs wither. In addition, out-TPVs depart under the leading of airflow on 300hPa, in accord with the conclusion by Qiao (Qiao, 1994).

From the preceding analysis, there are obvious commons and difference for out-TPV of four sorts. The commons are that the ridge of SAH is in 24-30° N; out-TPVs have been influenced in the upper by westerly jet on 200hPa (≧28m/s); the leading airflow on 300hPa-west or west northwest airflow are respectively strongest in WTFS, or become stronger in the other three sorts. The difference are that the ridge of SAH in WTFS and TNVS is in 25-30° N, farther north than SLS and SSFS, and SAH in SSFS is strongest and stretch farther east compared to the other three, in which the TNVS is the most feeblest. in addition to the difference in length and location of westerly jet on 200hPa and in intensity of westerly jet on 300hPa.

6 Physics image of TPV moving-off

The general feature could be graphed as follows (Fig.4): on 500hPa, weather-influencing systems and northern airflow are enhancing; meanwhile, out-TPVs are of baroclinicity because of an infusion of cold air, and vapor is transported to the plateau, close to out-TPVs. On 200hPa, the ridge of SAH is in 24-30° N, and out-TPVs are influenced by a westerly jet (≧28m/s); wester-deflected airflow on 300hPa, more than 13m/s or even 20m/s, is still reinforcing.

7 Summary

The following points summarize the discussion in this paper:

• According to the weather-influencing system, the out-TPV can be classified into two categories: one goes with a trough, and the other acts in a sheared stream field. In detail, the trough-related Out-TPV could be further classified into the westerly trough foreside sort (WTFS) and the trough north vortex south sort (TNVS). The shear Out-TPV related is further divided as the sheared stream filed sort (SSFS) and the shear line sort (SLS). The TNVS with two troughs and one ridge and the WTFS with one trough and one ridge have less difficulty migrating out from the plateau.

• The departure of TPV is caused by the mutual effects of the weather systems in the westerly belt and in the subtropical area as well as the weather systems within the middle and the upper troposphere. Although the weather-circumfluence configuration accompanied with out- and in-TPV in the eastern Asia farther north of 40° N in the same sort are named as the same, remarkably the differences exist: the weather-influencing system in the middle troposphere for out-TPV is strengthening, but it is weakening for in-TPV; out-TPV is of baroclinicity, while in-TPV is warm vortex; by comparison, the westerly or northerly related to out-TPV in the northern portion of or to the north of the plateau, and vapor transportation is stronger and becoming more so; the westerly jet on 200 hPa is sited farther south, closer to out-TPV; westerly-deflected on the 300hPa upper out-TPV is strong or gaining strength.

• The common large-scale features of the four kinds of out-TPVs include the follow: All weather-influencing systems are enhancing; out-TPVs have been infused by the cold air of baroclinicity; the northern airflow in the northern plateau or its neighborhood is reinforcing; vapor is transported stably to the eastern or southeastern plateau by the southern airflow; the ridge line of the South Asia High is situated at 24-30° N; the westerly jet on 200 hPa exists just over the weather-influencing system on 500hpPa and has reached the upper area of out-TPV; the leading airflow on 300hPa-westerly or west-southwester is strong or becoming stronger.

• The differences between trough-sorted and shear-sorted are as follows: The trough is usually reinforced by cold advection in the back, while the shear line is often enhanced by northward-enlarging of the monsoon low, and the sheared-stream field is strengthened by eastward movement of the east-inclined ridge in Xingjiang; the northern airflow related to the trough-sorted is westerly with eastward movement of westerly jet in the north side of Subtropical High, but norher for the shear-sort, together with north jump or stable enhancement of westerly or west-northwester jet outside the Subtropical High. Compared to the shear-sorted, trough-sorted is affected over a larger area; the ridge line of South Asia High is situated between 25-30° N, farther north; and the length of westerly jet within the plateau is longer.

• The differences in the large-scale weather circumfluence position between the trough-sorted one and the shear-sorted one are obvious. Generally, when compared to TNVS and SSFS, the circumfluence position in WTFS and SLS is in favor of the out-TPV's development and the eastern movement. Therefore, the out-TPVs of WTFS and SLS can last longer than the Out-TPVs of TNVS and SSFS.

Acknowledgments:

Supported by the Natural Science Foundation of China, No 40475020, and Special Project of National Sci./Tech. Basic Research No 2006FY220300.

REFERENCES

Yu SH, 2001. Primary analysis of impact of the plateau weather systems on the peak floods in Yangzi River in 1998. Reason and prediction application study of severe torrential rain in the drainage areas of Yangzi River and Neng River in 1998. China Meteorological Press, 359–364. (in Chinese)

Zhang SL, Tao SY, Zhang QY, et al., 2001. Meteorological and hydrological characteristics of heavy rain and flood in the summer of 1998 in China. Application Meteorological Transaction, 12(4), 442–457. (in Chinese)

Ye DZ, Gao YX, et al., 1979. Meteorology of the Tibetan Plateau. China Science Press, 122–126.145–146.259–260. (in Chinese)

Chen LS, Ma JX, et al., 2000. Impact of large terrain on vortex movement, evolution of theory research in the second science examination of Tibet Plateau (3), Meteorology Press, Beijing, 90–97. (in Chinese)

Li GP, 2002. Dynamic Meteorology of the Tibetan Plateau. China Meteorological Press, 22–23. (in Chinese)

Song MJ, Qian ZA, 2002. The impact of the plateau and the cold air on the Subtropical High over the western Pacific in years 1991 and 1998. Plateau Meteorology, 21(6), 556–564. (in Chinese)

Liu FM, Fu MG., 1986. Study of eastward movement of Tibetan Plateau vortexes. Plateau Meteorology, 5(2), 125–134. (in Chinese)

Yu SH, 2002. Vapor image of eastward movement of the plateau vortex. Plateau Meteorology, 21(2), 199–204. (in Chinese)

Hideo T, 2003. Observational Study on the Initial Formation Process of the Mei-Yu Frontal Disturbance in the Eastern Foot of the Tibetan Plateau in Middle- to Late-June 1992. Journal of the Meteorological Society of Japan, 81(6): 1303–1327.

Qiao QM, Zhang YG, 1994. Tibet Plateau synoptic meteorology, Meteorology Press, Beijing, 147–155. (in Chinese)

Chen ZM, Ming WB, et al., 2004. A case diagnosis of coupling of plateau vortex and southwestern vortex, Plateau Meteorology, 23(1): 75–80. (in Chinese)

Yu SH, Gao WL, et al., 2008. Analysis of two cases of impact of cold air on TPV departure, Plateau Meteorology, 27(1): 96–103. (in Chinese)

Gao WL, Yu SH, 2007. Analysis of impact of averaged circumfluence on TPV departure, Plateau Meteorology, 26(1): 204–212. (in Chinese)

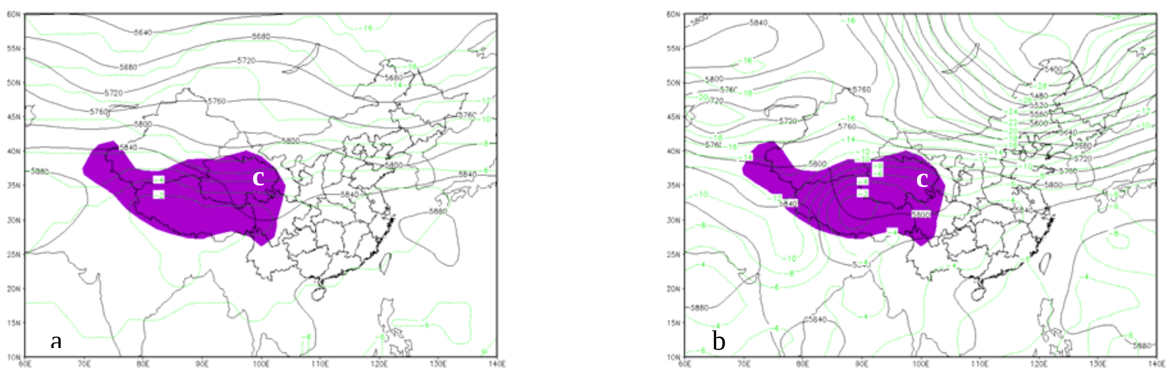
Yu SH, Gao WL, et al., 2007. Analysis of circumfluence feature in the middleupper troposphere for TPV related to flooding in China in recent years, 26(3): 466–475. (in Chinese)

Yu SH, Gao WL, 2006. Observational analysis on the movement of vortices moving out the Tibetan Plateau. Acta Meteorological Sinica, 64(3): 392–399. (in Chinese)

Research Panel on Tibet Plateau Meteorology, 1981. Study on vortex and shear line on 500hPa in summer on Tibet Plateau, Science Press, 122. (in Chinese)

Luo SW, et al., 1992. Study on a few sorts of weather systems over the Tibet Plateau and the neighborhood, Meteorology Press, Beijing, 12–13. (in Chinese)

ILLUSTRATIONS and TABLES



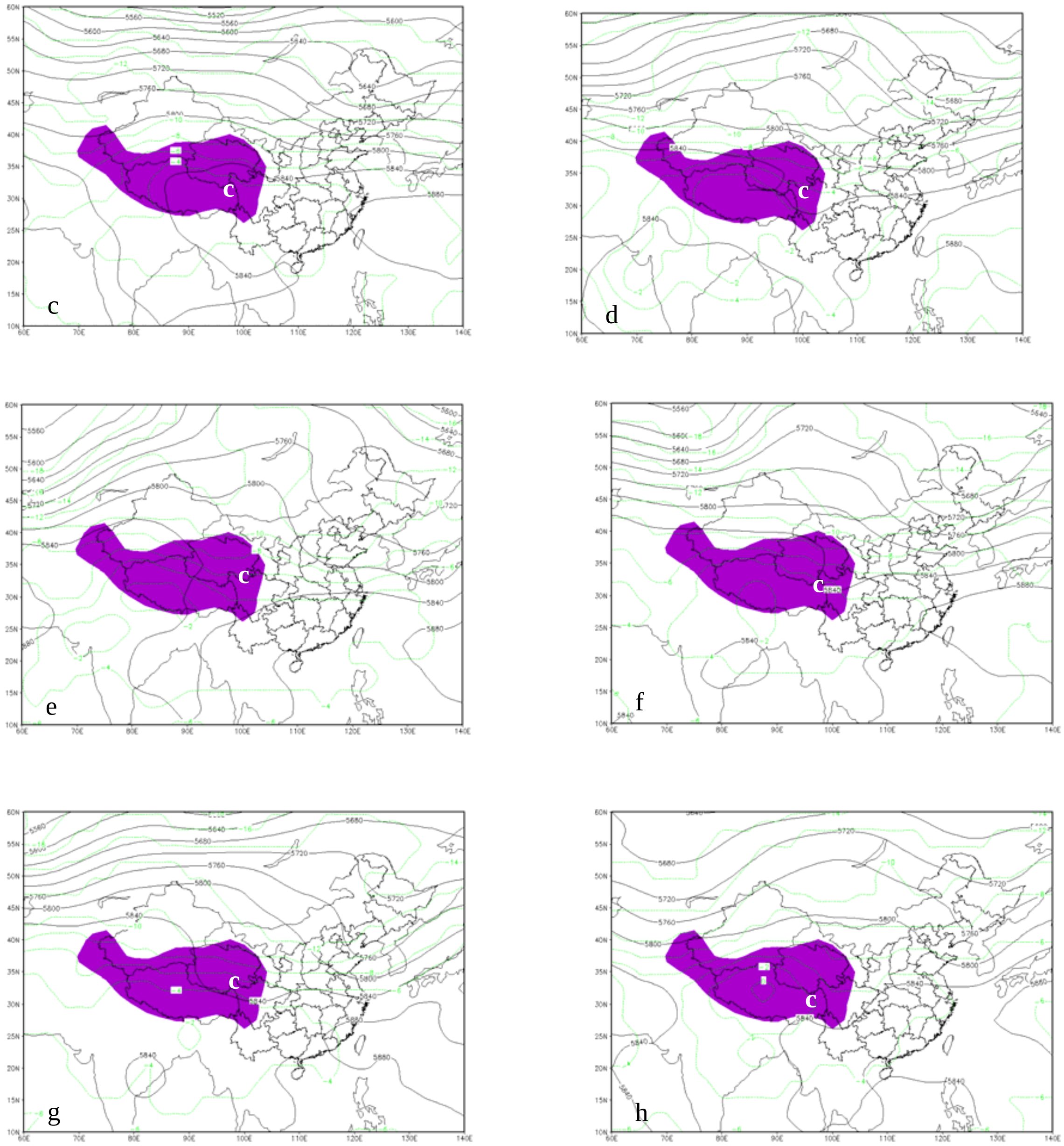


Fig.1 Synthesis of height and temperature on 500hPa at TPV about to leave

a. out-TPV of WTFS b. in-TPV of WTFS

c. out-TPV of TSVN d. in-TPV of TSVN

e. out-TPV of SLS f. in-TPV of SLS

g. out-TPV of SSFS h. in-TPV of SSFS

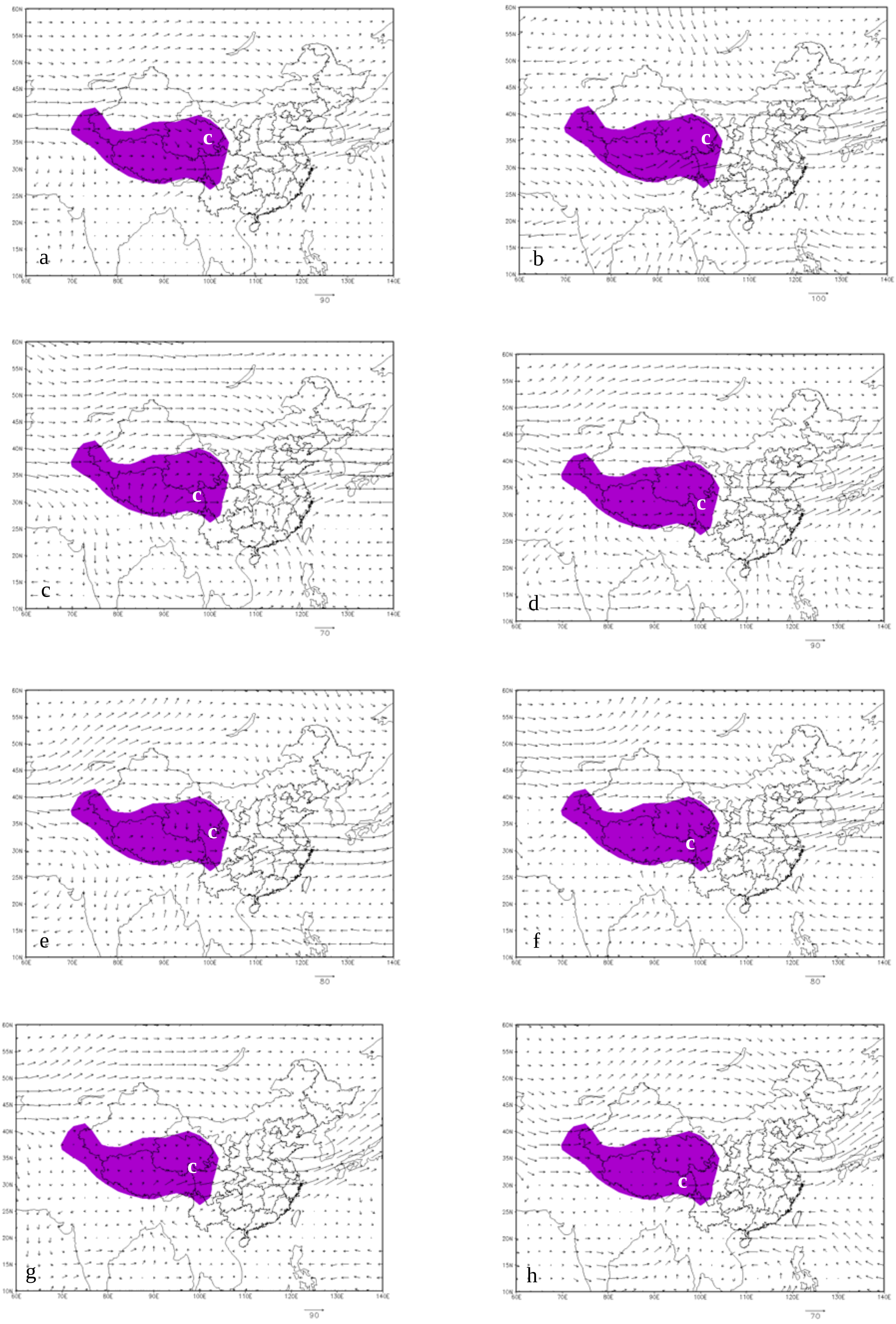


Fig2. Synthesis of vapor flux on 500hPa at TPV about leaving

a. out-TPV of WTFS b. in-TPV of WTFS

c. out-TPV of TSVN d. in-TPV of TSVN

e. out-TPV of SLS f. in-TPV of SLS

g. out-TPV of SSFS h. in-TPV of SSFS

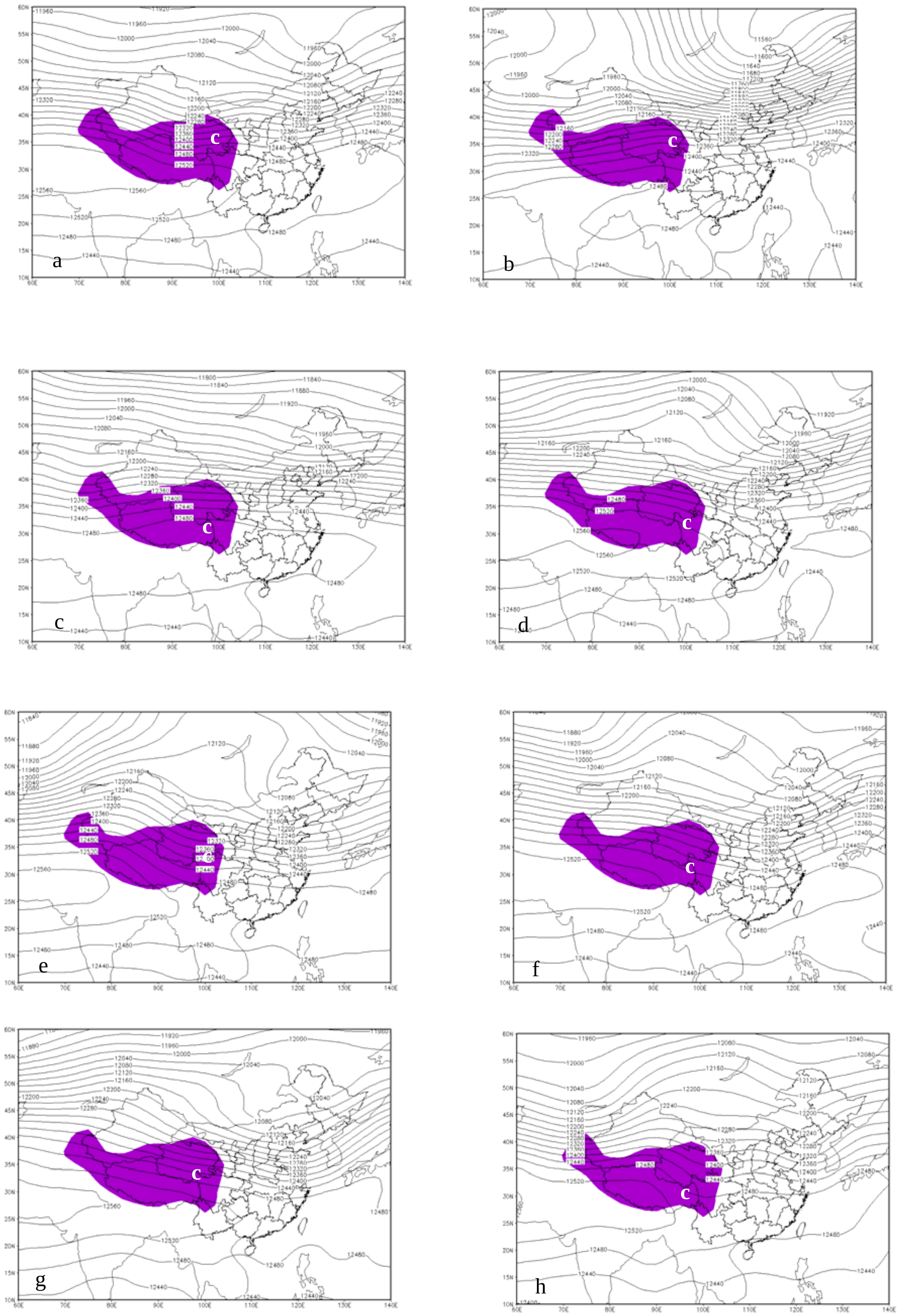


Fig3 Synthesis of height on 200hPa at TPV about leaving

a. out-TPV of WTFS | b. in-TPV of WTFS
c. out-TPV of TSVN | d. in-TPV of TSVN
e. out-TPV of SLS | f. in-TPV of SLS
g. out-TPV of SSFS | h. in-TPV of SSFS

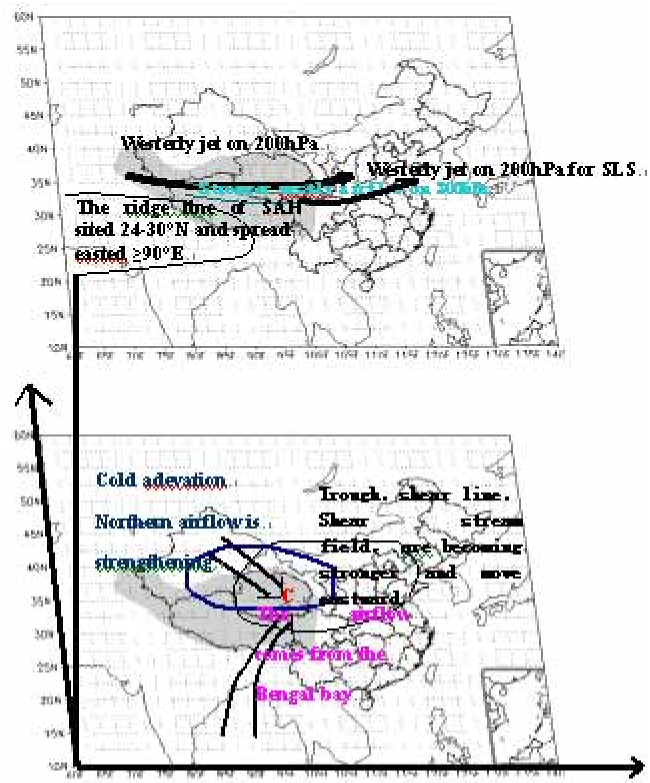


Fig. 4 The large-scale condition model of the plateau vortex moving out of the plateau.

Table 1 Statistics of out-TPV in 1998-2004

Year	Total number of TPV					Out-TPV									
						To the west of 110°E					To the east of 110°E				
	May	Jun.	Jul.	Aug.	Sept.	May	Jun.	Jul.	Aug.	Sept.	May	Jun.	Jul.	Aug.	Sept.
1998	3	4	10	8	3	0	1	4	4	1	0	1	0	0	1
1999	4	8	9	7	2	1	5	2	2	1	0	0	1	0	0
2000	1	1	2	3	0	1	0	2	0	0	0	0	0	0	0
2001	8	5	2	4	1	1	1	0	2	1	0	1	0	1	0
2002	6	3	8	4	6	1	1	2	1	0	0	0	0	1	0
2003	6	4	5	4	3	0	2	0	3	3	0	1	1	0	0
2004	7	1	4	0	0	1	1	1	0	0	0	0	0	0	0
Total	35	26	40	30	15	5	11	11	12	6	0	3	2	2	1

Table 2 the main weather-influencing system to out-TPV during 1998-2004

Environment		May	June.	July.	August.	September.
Trough-sort	WTFS	1	4	4	3	1
	TNVS	1	2	1	3	3
Shear-sort	SSFS	0	2	3	4	1
	SSS	1	1	1	2	0

Table 3 TPVs seleted for synthesis

Sorts	Out-TPV		In-TPV	
	Lifespan	About leaving	Lifespan	About leaving
TNVS	Jul. 7^{8}–7^{20} 1998	08BST 7th	Jun. 30^{20}1998	20BST 30th
	Jun. 6^{20}–7^{20} 1999	08BST 7th	Jun. 27^{8} 2001	08BST 27th
	Jun. 8^{8}–10^{8} 1999	20BST 9th	Aug. 8^{8}–9^{8} 2002	08BST 9th
	Sept. 4^{20}–7^{8} 1999	08BST 6th		
	Sept. 8^{8}–8^{20} 2003	08BST 8th		
WTFS	Jul. 8^{20}–10^{8} 1998	20BST 9th	May. 28^{20} 2004	20BST 28th
	Jul. 9^{20}–11^{8} 1999	20BST 9th		
	Aug. 23^{8}–23^{20} 1999	08BST 23rd		
	Sept. 8^{20}–10^{20} 2001	08BST 9th		
	Jul. 12^{8}–14^{20} 2003	20BST 12th		
SLS	Jul. 14^{8}–16^{20} 1999	20BST 14th	Aug. 11^{8}1998	08BST 11th
	Jun. 1^{8}–5^{20} 2001	08BST 2nd	Aug. 21^{8}1999	08BST 21st
	Aug. 21^{8}–22^{20} 2001	20BST 21st	Aug. 30^{20}1999	20BST 30th
	Aug. 12^{8}–20^{8} 2002	08BST 12th	Aug. 22^{8}2002	20BST 22nd
			Jul. 7^{8}2003	08BST 7th
SSFS	Aug. 27^{8}–28^{20} 1998	08BST 28th	Jul. 19^{8}–19^{20}1999	20BST 19th
	Sept. 2^{8}–2^{20} 1998	08BST 2nd	Jul. 21^{8}–21^{20}1999	20BST 21st
	Jul. 10^{8}–13^{8} 2000	08BST 11th	Jul. 23^{8}1999	20BST 23rd
	Aug. 11^{8}–11^{20} 2002	08BST 11th	Jun. 26^{20}–27^{8}2000	08BST 27th
			Aug. 21^{8} 2000	08BST 21st
			Jul. 9^{8}2003	08BST 9th

Table 4 The comparison of airflows on 300hPa upper out- and in-TPV

Sort	Out-TPV			In-TPV	
	0h	1h	Moving direction	0h	1h
WTFS	WSW 23 m/s	WSW 20 m/s	ENE	WSW 14 m/s	WSW 11 m/s
TNVS	W 13 m/s	W 14 m/s	E	WNW 9 m/s	WNW 13 m/s
SLS	W 14 m/s	WSW 19 m/s	E	WNW 13 m/s	WNW 13 m/s
SSFS	W 18 m/s	W 23 m/s	E	WNW 9 m/s	NW 8 m/s