Diagnosis of Effect of Southwesterlies on Tibetan Vortex Moving East

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ABSTRACT

Tibetan Plateau Vortices (TPV), when moving eastward out of the plateau, usually cause catastrophic weather in East China. This study diagnoses the effect of southwesterly wind along the south periphery of Tibetan Plateau (often called the south branch of the subtropical westerly jet) on three such unique TPVs moving eastward out of the plateau (with their lifespan >48 hrs downstream) by means of the 325K isentropic surface, 500 hPa vapor transfer and cyclonic vorticity advection with NCEP reanalysis data. Evidence suggests that i) the TPVs are located on the NE – SW sloping isentropic surface, with southwesterly flows to the east that are reinforced when the TPVs migrate off. The three TPVs are associated with the Tibetan shear, the transverse shear line to the north of Hetao, and the shear at the trough line end. The southwesterly affects more on the former two than the latter one; ii) The TPVs travel faster when the southwesterly is amplified, shifting eastward and vice verse. When close to the southwesterly, the TPV is displaced quickly with it and vice verse; iii) the TPV-associated soththwesterly is responsible for transporting vast amounts of vapor into the vortex, invigorating rising motion and producing stronger cyclonic vorticity along with its advection inside, a situation favorable for TPV moving out of the tableland and persisting for long (>48 hr) downstream. These fruits, thus, expands the scope of knowledge of east-traveling TPVs, providing a scientific basis for predicting TPV-related rainstorms and flooding events in the plateau *per se* and downstream.

Keywords: Tibetan plateau vortex Southwesterlies diagnosis

1. Introduction

Located in central Asia, the Tibetan Plateau covers 2.3×10^6 km^2 area with the elevation of 3000 m, on average（Li et al.,2006）. Quite often in summer there occur vortexes, some of which travel eastward enough to be out of the plateau, bringing about rainstorms, and even exceptionally heavy rainfalls to afflict the vast expanse to the east (Yu, 2001; Zhang et al., 2001). The Tibetan Plateau vortex (TPV), when leaving the source, will affect not only the adjacent area but the middle ~ lower valley of the Yangtze, the Yellow riverbasin, Huaihe riverbasin and even the Korean Peninsula (Yu and Gao, 2006) during their longer lifespan downstream. For this reason, it is of particular importance to make researches into the source-leaving TPV.

During recent 10 years, a series of plateau experiments have been conducted, including the

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Global Energy and Water Cycle Experiments (GEWEX) Aisan Monsoon Experiments (GAME) in Tibet, 1998, the Second Tibetan Plateau Experiments (TiPEX), Coordinate Enhanced Observing Period (CEOP) Project, and Tibet Observation and Research Project (TORP). Accordingly, the plateau hydrometeorological research was re-activated, but most of these studies focus on the water and energy cycle over the plateau (e.g. Yang et al. 2004; Yamada and Uyeda 2006; Yang et al. 2008) and have not extended to the plateau vortex. During this period, Chinese Meteorological Administration (CMA) also published Automatic Weather Station (AWS) data around the country including Tibet. This comprehensive data set also provides the basis for many hydrometeorological studies, and many of them investigate the relationship between the plateau snow cover/snow depth conditions and East China rainfall, but there are very few studies on the TPV (e.g. Qian et al. 2003； Zhang et al.2004；Wu and Kirtman, 2007). As a result, research activities on the TPV have not been conducted worldwidely. Yeh and Gao (1979) pointed out that shallow synoptic systems inside the plateau boundary layer, when in an appropriate situation, are likely to develop themselves enough to travel out of the plateau. As indicated by Li (2002), the TPV migration out of the source occurs under effect of certain steering flows. Also, Song and Qian (2002) showed that a certain depth of the air column averaged over the central – eastern Plateau is indicative of TPV shift to happen. The upper-level divergent field serves as one of the indispensable conditions, which causes rainstorm to hit 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 an indication of the TPV activities, and also, Yu et al. (2007; to appear in 2008) address the effect of cold air upon the TPV motion towards the east, and explore the circulation situation in the mid-upper troposphere during its migration out of the Plateau (Yu et al., 2007). As shown in Gao and Ping, (2004), a lee vortex, once formed on the east side of the plateau, will be decaying due to its rotational effect, or propagating downstream as wave. Wang (1987) and Yasunari and Miwa (2007) showed that released latent heat in the atmosphere will lead to the TPV development. Besides, Takahashi (2003) reported that cold air is answerable directly for intensifying the lows in the northern Plateau (1992). All the above studies provide plethora of knowledge of the TPV traveling towards the east. Nevertheless, little is reported about the Southwesterlies impacts upon the TPV that is migrating out of the plateau. This is the motivation of this study.

2. Method and data

Out of the east-traveling TPVs recorded since 2001 were selected three events that have lifespan >48 hr after their leaving the Plateau for synoptic study.

The TPVs are of origins in the Sog, Qumarleb and Tuole regions [denoted hereafter as SoV [(centered initially at ~31.9^{0}N, 93.8^{0}E); QuV (~34^{0}N, 95^{0}E) and TeV (~38.7^{0}N, 98.3^{0}E)], respectively, in June 1-5, 2001, August 29 – September 3, 2001 and August 12-20, 2002. Based upon NCEP provided fourfold daily reanalysis at horizontal resolution of $1^0\times1^0$ lat./long., in conjunction with upper observations on a synchronous basis for diagnosis of 325K isentropic surface, 500 vapor transport and vorticity advection in order to apprehend the TPV activities.

The isentropic surface analysis consists of isobars, barbed arrows and isolines of relative humidity over the surface with 325K potential temperature.

The diagnosis uses the following expressions：

1) for the vapor flux intensity $\frac{1}{g}|\vec{V}|\bullet q$, with the vapor transfer in the same direction as the wind

2) for vorticity advection $\vec{A}$=-(u$*\frac{\partial\varsigma}{\partial x}$+v$*\frac{\partial\varsigma}{\partial y}$).

In the diagnosis the vortex domain refers to a circle with the vortex center as the origin and 3 latitudes/longitudes as the radius and the TPV activity recorded for the last time interval when it remains over the plateau is employed to imply that it is about to be out such that the subsequent 6 and 12 hr intervals denote its related activity stages outside (i.e., downstream).

3.Observed facts of Southwesterlies impacted TPV leaving the Plateau

As stated earlier, the selection of the 3 unique events that were associated with shearing and had >48 hr lifespan downstream was done, according to the statement that most of such vortexes persist for long after their departure from the Tibetan region (Yu et al., 2007). In what follows we investigate their movement under Southwesterlies effects.

The SoV appeared on the Plateau shear around Sog at 0000 UTC, June 1, 2001, when the flows of origin in the Bay of Bengal stretched into the vicinity of 32^0N, 98^0E and the SW currents ran eastward along 30^0N from the outer part of the subtropical high. Subsequently, the vortex stayed for some time before migrating eastward. At 0000 UTC, day 2 (of the month) it came to Yinkuang, and at that time SW flows of the subtropical high were steady, with their western portion marching northward. The Southwesterlies had a strong wind core of 14 m/s, about 10 m/s higher than 12 hrs earlier, and the core made movement eastward. Afterwards, the strong wind core was made to be re-intensified (22 m/s) and travel east owing to the plateau shear shifted southward (refer to table 1). At 1200 UTC, day 2, the SoV moved along the shear out of the plateau, staying around Mianyang of Sichuan, followed by its movement northeastward, by way of Yichang – Guanhua – Bangbu – Shiyang – Rizhao – the Chaolian island (see Fig.1), with the related intense wind center translated to the southeast, fluctuating in strength.

At 0000 UTC, August 29, 2001, another vortex formed in the saddle about Qumarleb (i.e., the QuV), and the SW currents from the Bay of Bengal came into the plateau around 36^0N, 95^0E, arriving at 37^0N, 101^0E posterior to 12 hrs. Due to the transverse trough moving slightly eastward, the vortex was on the shearing at the end of the trough line, reaching Gangca at 0000 UTC, day 30. At that time, the SW air from the outer part of the subtropical high stretched marginally east and shifted northward, with the core of vigorous winds of 14 m/s increased by 6 m/s compared to that 12 hr earlier, and marching east later. At 1200 UTC, day 30, the QuV moved off the plateau to the vicinity of Tongxin (Note that the vortex left the plateau together with the shear at the end of the transverse trough line). Afterwards, it traveled northeast-, turning south- and moving eastward, passing Yebaishou – Yangjiaogou – Fuyang – Yangcheng – the central Yellow Sea – Yongju of southern Korea – its Ulrung-do island (see Fig.1). The strong wind center in the outer part of the subtropical high to the southeast of the vortex had its winds veering from SW to west to south, fluctuating in vigor, with the peak force reaching 26 m/s.

When a vortex was formed around Tuole (TeV) in the shearing flow field between a Mongolian and the subtropical highs at 1200 UTC, August 12, 2002, the SW airflows of the Bay of Bengal origin stretched into the vicinity of 32^0N, 109^0E in NE Sichuan basin, indicating a 16 m/s wind core. Later, the subtropical high stretched west and the Mongolian high shifted southeast, thereby intensifying the former shearing flow field, and a shear line appeared to the north of Hetao that made the TeV move out of the plateau. At that time, the wind core increased 4 m/s compared to that 12 hr earlier, marching northeast, leading to the fact that the vortex was around Jilantai at 1200 UTC, day 12. Note that the vortex moved out of the plateau by means of the shear. From that time onward till 1200 UTC, day 16 the subtropical high began weakening gradually and retreated east, making the TeV shifted southeast to Guanghua, followed by the core of strong winds of the SW air to the southeast weakened to 12 m/s. Subsequent to that, there was a tropical depression marching northward over the South-China Sea, and the TeV shifted southwest with the consequence that the vortex was combined with the depression in the Fengshan region of Guangxi at 0000 UTC, day 20. During the southwestward movement of the vortex, the Southwesterlies to its southeast veered from southwest into south, with the core of strong winds intensified bit by bit to 18 m/s.

Evidently, the 3 TPVs departing from the plateau were associated with amplification of southern to SW airflows in their activities.

4. Diagnosis of TPV made to leave the Plateau under Southwesterlies impacts

a. Comparison of features of flows around the vortices over the 325K isentropic surface

1) Comparison of flow structures about the TPVs on the surface

From the analysis of 325K isentropic surface pressure and wind fields before and after TPVs leaving the plateau the flow structures experienced variation. As depicted in Fig.2, the 325K surface showed undulation, with higher pressure related to the lower part of the isentropic surface and v.v. The flow structures over the vortexes were like this: for the SoV (Fig.2a) and TeV (2e) about to move out, both were on the NE – SW sloping surface. There were NW air flowing from higher into low levels in the troposphere to the west of the SoV and the TeV, with SW air coming from 500 hPa to the east of both the vortices. The QuV was in a concave high in the east and west and low in the middle (Fig.2c), with NW air (from 400 hPa) flowing into the western and SW air into the eastern segment of the vortex weaker than those into the SoV and TeV. 12 hrs after all of them leaving the plateau (Figs.2b, d, f) and the 3 entities were on a surface sloping NE – SW (high to lower), with their western part with its vicinity under the control of NW or north flows and their eastern segment under the effect of southwesterly currents that were somewhat amplified compared to the condition of the vortices about to leave. For the SoV and TeV the northern-branch flow was weaker compared to the southern equivalent as opposed to the case of the QuV, and for all the vortices**,** they were forced to depart from the plateau under the joint effect of northern branch cold air descending from higher levels towards the SW and 500-hPa SW currents. As for the QuV moving off the plateau, it seems that the entity was influenced more by cold air than the other counterparts, the SoV and TeV leaving the plateau under greater impact of the Southwesterlies than the QuV.

2） Comparison of the Southwesterlies evolution around the TPVs on the isentropic surface

For investigating Southwesterlies effect we shall examine Fig.2 for its evolution by use of relative humidity isopleths on the 325K surface (figure not shown).

As the SoV was leaving the plateau (0000 UTC, June 2, Fig.2a) a vast area was available of SW flows at 12-16 m/s to the southeast, which originated in the western Pacific, flowing westward into the Bay of Bengal and then turning towards the northeast. The coming 500-hPa flows were highly wet with relative humidity at ≥ 90%, shifting marginally east and becoming stronger 6 hr afterwards with the result that the vortex was made to depart from the plateau (figure left out). At 1200 UTC, day 2, the westward air of the Pacific origin into the Bay was positioned more westward by 2 longitudes than it was about to leave the plateau (Fig.2b), leading to the fact that the resultant SW flows covered a wider belt in comparison to the condition when the SoV was about to leave the plateau, with the Southwesterlies reinforced to reach the central intensity of 24 m/s such that the SW winds to the southeast increased 6 m/s to reach 14 m/s as compared to the force when the vortex was about to depart. As a result, the SoV moved east once more.

For the QuV that was about to depart (0000 UTC, August 30, 2001, Fig.2c), the SW air to the south came from the Arabic Sea and Indian Ocean, with part of the flows traveling east into the Bay of Bengal and South-China Sea where it connected the SW air on the east side of the tropical cyclone around the Hainan Isle, flowing northward, and changing into SW current over Guiyang of Guizhou, which was wet and warm enough to reach 90% relative humidity, ascending from 550 to 500 hPa but its coverage was smaller than that covered by the SoV. For the subsequent six hours, the SW flow made a slight eastward shift so that the vortex left the plateau (figure not shown). In view of the fact that the 500 hPa west airflow coming into the western plateau changed into SW air, arriving at the Hami area of Xinjiang, and heading northwestward to enter the western part of the QuV, followed by changing into SW air through the QuV southeastern portion, which intensified the SW wind force by 10 m/s (reaching 14 m/s) to the southeast compared to the wind when the vortex was about to leave the plateau. At 1200 UTC day 30, the SW air traveling over the long journey connected the reinforced NW flow to the south of the vortex, to the north of the Yangtze and east of 106^{0}E, and both flows were combined into west airflows (refer to Fig.2d), and invigorating the wind force to arrive at 16 m/s to the south and southeast of the QuV such that is was made to continue its shifting eastward.

For the TeV that was about to depart from the plateau at 0000 UTC, August 12, 2002 (Fig.2e), there was SW air starting from the western Pacific and moving west as far as the Hainan Isle, where it moved northward, which turned to the northeast at Youyang, thus becoming SW air. The resultant SW air was large-scale and had ≥90% relative humidity at 500 hPa, distant from the TeV by 4 latitudes and 4 longitudes, a distance longer compared to the case of the SoV and QuV. To the southeast of the TeV, the SW winds traveled northeast from the Caspian Sea, turning into southeast flows at the Habar River into the vortex. In the sequent 6 hrs the SW air originating in the Bay of Bengal ascended from 550 to 500 hPa connected another SW flow of western Pacific origin in the mid – lower basin of the Yangtze, thus widening the flow size that was made to shift eastward (figure left out), with the consequence of the vortex movement out of the plateau. The SW wind from the Caspian Sea to the southeast of the TeV got somewhat amplified compared to the force when the vortex was about to depart from the plateau. At 1200 UTC, day 12 (Fig.2f), the SW flows to the south of the vortex made a slight eastward movement compared to the position 6 hr earlier, weakened more or less (16 m/s from 18 m/s). The SW flows to the SE veered to WSW winds, with unchanged intensity and the TeV shifted marginally eastward. The 12-hr distance the TeV moved out of the plateau was the smallest among all the three.

As indicated in diagnosis of the 325K isentropic surface, the TPVs varied from one to another in the SW airflow source and its path to the vortex. To the east, typically, the TPV had a zone of ≥ 90% humidity SW flows, which moved east and intensified in its journey, whereupon the TPVs were made to be outside the plateau. When the SW flows migrated east and invigorated markedly, the vortex accelerated its movement, and v.v. Moreover, the interval between SW air and TPV had effect on the shifting velocity and the vortex moved the relatively faster, the smaller the distance between them in general. When the entity moved from the plateau, the Southwesterlies ascended unremarkably. For the SoV, the SW currents were at 500 hPa level while for the QuV and TeV the flows rose from 550 to 500 hPa, a result differing from the statement that SW airflows have to ascend to still higher levels to cause exceptionally heavy precipitation (Zhao et al., 2005).

b. Comparison of vapor transfer and vertical velocity features of east traveling TPVs

From the 500 hPa vapor influxes (Fig.3) and vertical speeds (figure not shown) we see that the Southwesterlies to the south of the vortices is responsible for conveying higher-value vapor fluxes towards the NW. And what are the features in vapor flux and vertical velocity answerable for TPVs east traveling in relation to different Southwesterlies?

For TPVs about to depart from the plateau, to the south of the SoV (Fig.3e) and TeV there is a vast elongated zone NE – SW directed of vapor transport, with the fluxes larger than 1000 units (one is defined as 10^{-2} g s^{-1} cm^{-1} $hPa^{-1}$for easy illustration on the map) with a related rising zone oriented in the same direction, both having their centers not in coincidence. The high-valued fluxes and the rising zone were close to the SoV whereas they were away by 4 latitudes/longitudes from the TeV. Besides, the SoV had inside 500-600-unit vapor fluxes and –20-unit rising speed (one unit being 10^{-2}Pa/s), of which the flux was 200 times that of the TeV and the speed slightly higher. As to the Southwesterlies vapor transport to the south of the QuV the vapor flux zone with its intensity in excess of 1000 units and the area of rising motion ≥ -20 units were distinctly smaller compared to those of the other counterparts (3c) and inside the QuV the fluxes were within 100-200 units and the rising stronger, reaching ≤ -40 units in some cases.

In the subsequent 6 hours, the TPVs were outside the plateau. At that time the high-valued flux zone to the south of SoV and TeV was stronger than 6 hr earlier, leading to appreciable increase in vapor inside the vortices to 700 and 500 units, respectively, (figures not shown), with intensified flux convergence in the TeV. The NE – SW updraft area near by the SoV had an expanded size that extended more eastward and the TeV was invigorated, too. The rising motion was intensified in the SoV and particularly TeV. No distinct change was observed in the strength of SW vapor transfer to the south of the QuV in the 6-hr interval but the transport belt was connected with the vortex itself, leading to the explosive vapor increase inside the entity (figure not shown) to reach 900 flux units, a figure that was bigger than those of the other counterparts. The rising zone in the vicinity of the QuV extended northeast, whose center coincided with the vortex core, with the updraft inside increased in intensity by 20 units.

12 hours after the TPVs moved outside, the NE-SW zone of maximum vapor fluxes to the south of the SoV (3b) and TeV (3f) was stronger than 6 hr earlier, with the TeV-related zone shifted slightly eastward, thereby allowing greatly increased (somewhat decreased) vapor transfer into the SoV (TeV), but both exhibited remarkable convergence inside. To the south of the two vortices a large-scale rising zone NE-SW directed was kept (figure not shown), with a widened updraft band inside except reduced vigor compared to the condition 6 hr after they had been outside the plateau. The vapor transfer zone to the south of the QuV was southeastward of the former position and intensified (Fig.3d), conveying more vapor inside, and around the vortex there remained a vast rising zone, with its center located in the vortex core, which, however, reduced in vigor compared to the condition 6 hr earlier after it had left the plateau (figure left out).

From the above we see that the vortex-associated Southwesterlies contributed to vapor transfer and rising motion, differing only in the strength and region where they stayed, the TPVs moved out of the plateau when vapor transport into, and rising motion inside got noticeably amplified, and the TPVs would be maintained if the vapor transfer continued to increase or its fluxes converged markedly, with $\leq$**-20** unit rising in the south of each of the TPVs.

c. Analysis of 500 hPa vorticity and vorticity advection

Examination of the vorticity diagram (Fig.4) and the vorticity advection (not shown) yields that to the south of the TPVs there was an Southwesterlies -related NE-SW oriented cyclonic vorticity zone. Now let us examine the evolution of the vorticity and its advection in association with the departure of each of the entities from the plateau.

At the time interval for the vortex about to leave the plateau, to the south of the SoV (4a) and TeV (4e) there was a large NE – SW elongated zone of positive vorticity >2 units (one defined as $10^{-5}s^{-1}$) and a vorticity advection zone, with central value greater than 2 units (one defined as 10^{-9} s^{-2}), positioned close to the SW flows on the isentropic surface. The >2 unit vorticity and > 2 unit (at the core) advection zones were larger in area for the SoV than for the TeV. Their cyclonic vorticity was 6 units, with weak advection inside ($\leq$ 1 unit), whose domain was greater in the TeV than in the SoV. To the south of the QuV, the SW flow-associated positive vorticity (4c) and its advection region as well as the vorticity area inside the entity were considerably smaller compared to the counterparts of the SoV and TeV, with the locations close to Southwesterlies on the 325K surface. The vorticity advection zone inside the QuV was significantly smaller than that of the TeV, but comparable to that of the SoV.

6 hrs after the TPV left the plateau, the NE – SW flows-associated positive vorticity and

its advection zones in conjunction with the advection band inside the SoV remained almost unchanged, keeping fairly high central values, with the inside positive vorticity increased by 6 units and its advection zone expanded to some extent. To the south of the TeV, on the other hand, the NE-SW directed cyclonic vorticity and its advection band were amplified by 2 and 0.3 units, respectively, with inside positive vorticity changed in vigor insignificantly except the enlarged advection domain. To the south of the QuV, the NE-SW flow associated positive vorticity reduced its size slightly but its strength increased 2 units (in excess of 2×10^{-5} s^{-1}), with the almost steady 2.4×10^{-9} s^{-2} advection belt extending northeast, and the inside positive vorticity and its advection were reinforced 2 and 0.9 units (the latter increased nearly threefold), in order, arriving at 6×10^{-5} s^{-1} and 1.4×10^{-9} s^{-2}. On the other hand, the vorticity advection augmented its size inside the SoV and TeV while cyclonic advection was explosively in the QuV region, all in association with SW air flowing into the southeast of the TPVs, as shown on the isentropic surface.

12 hrs posterior to the departure, the positive vorticity zone to the south of the SoV (Fig.4b) and TeV (4f) was invigorated to some degree compared to the condition 6 hr earlier, but with marked increase (marginal decline) of the advection belt related to the SoV. (TeV). The SoV (TeV) had its inside increased vorticity zone of >8 units (an expanded area larger than 8 units), with the internal vorticity advection zone changing a little (expanded) in comparison to the state 6 hr earlier. To the south of the QuV, the SW air associated positive vorticity and its advection zones varied very little as compared to the condition 6 hrs earlier, only with the corresponding domains increased by 8 and 3 units

It follows that the TPV-related Southwesterlies impacted cyclonic vorticity and its advection in domain and strength had effect, varying from one vortex to another. Evidently, these TPVs left the origin due to the expanded (or amplified) zones of cyclonic vorticity and its advection and they would be maintained if the internal cyclonic vorticity were invigorated.

This diagnostic study shows that these vortices behaved just under the effect of the Southwesterlies eastward marching and amplification in their journey as the key factor of the east moving TPVs that left their source zones when vapor transport into them was appreciably reinforced, with amplified inside rising motion amplified and strengthened cyclonic vorticity with its expanded advection. The TPVs kept on activities east of the plateau as vapor transfer continued to increase or the fluxes converged pronouncedly, an updraft zone of ≤**-20** units emerged as well as increased cyclonic vorticity in the south of the TPVs. For the sake of visualization, the Southwesterlies effects upon the TPVs east-moving till its departure from the plateau are illustrated in Fig.5.

It is noted that the meteorological features of TPVs leaving the plateau differed from one TPV to another: 1) For the SoV and TeV there must be zones of NE-SW elongated high-valued vapor flux, rising motion, positive vorticity with its advection, which were considerably larger compared to those of the QuV, and bigger for the SoV than for TeV; The SoV had its NE-SW maximum vapor flux and updraft zones close to the vortex *per se* compared to the locations 4 latitudes/longitudes away from the TeV; 2) Around the TPVs leaving the plateaus the rising motion in the NE-SW oriented zone got amplified, and the internal cyclonic vorticity advection area was enlarged, particularly with respect to the TeV but as far as the increase in vapor transport and positive vorticity advection inside were concerned, the SoV ranked first.

5. Summary

From the foregoing analysis, we come to the following conclusions.

The TPVs are examined on the NE-SW sloping 325K isentropic surface with northwest or north winds to the west and its contiguous area and southwesterlies to the east of the vortices, and only when the southwesterly flows are invigorated is the TPV about to move out of the plateau The departure from the plateau is under greater Southwesterlies impacts for the SoV and TeV compared to the QuV.

These vortices differ in the Southwesterlies source and path. Typically, they are under effects of warm and moist SW air at ≥90% relative humidity. When the airflow gets increased (decreased) in its eastward movement, the vortex accelerates (decelerates) its velocity eastward. Additionally, the shorter the distance is between the SW air and vortex *per se*, the faster the vortex would move and v.v. However, the ascent of Southwesterlies is unremarkable prior to the departure, generally, with the ascent in the vicinity of 500 hPa, a situation differing from that for producing exceptionally heavy precipitation for which the Southwesterlies has to go up to still higher levels.

The vortex-associated Southwesterlies is responsible for vapor transport and the consequent rising motion, which leads to the fact that the TPV leaves the plateau when the vapor transfer and rising speed are amplified inside the vortex. Only when the vapor transport continues to increase or the vapor converges pronouncedly, with stronger rising motion in the south, is the vortex maintained.

The domain and strength of the Southwesterlies affect those of cyclonic vorticity and its advection inside the vortex. When there is stronger vorticity and strengthened or enlarged cyclonic vorticity advection zone inside the TPV, the entity travels out of the plateau. And it is maintained if the cyclonic vorticity is increased inside.

The Southwesterlies of different origin varies in the effect on the TPVs for their departure. For the SoV and TeV under impacts of the flows originating from the western Pacific and turning in its way, there are elongated belts of high-valued vapor fluxes, rising motion, positive vorticity and its advection, which are considerably bigger compared to those of the QuV that has the Southwesterlies of origin in the Arabic Sea, turning on the way to the vortex. Such zones are larger relative to the SoV than to the TeV. Just before the vortex about to leave, Rising motion is increased in the NE-SW zone, with the positive vorticity inside has its size expanded, particularly with respect to the TeV, but as regards amplified vapor transport and positive vorticity advection the QuV ranks first.

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Figure and table

Fig.1. The movements of the 3 TPVs, denoted by 1, 2 and 3 for the SoV, QuV and TeV, respectively, with the shading referring to the plateau part at ≥ 2500 m above *MSL*.

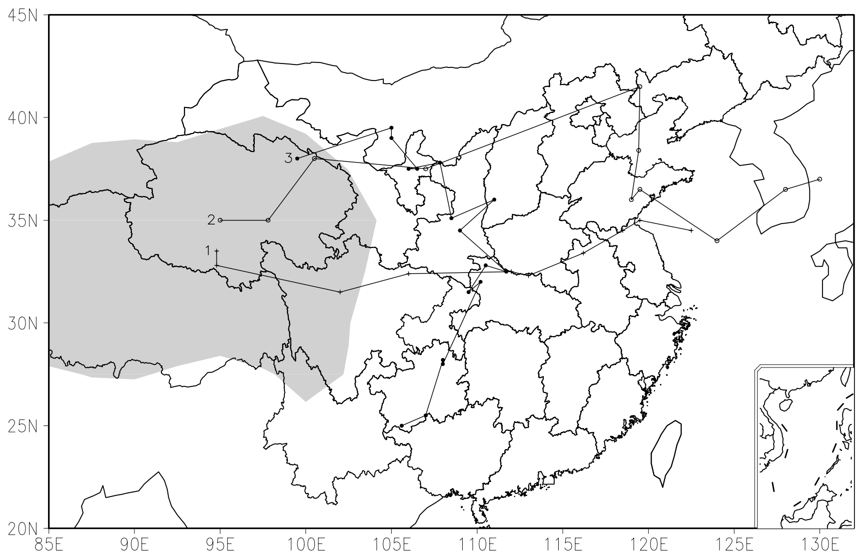


Fig.2. The pressures and winds on the 325K isentropic surface, with 0000 (a) and 1200 UTC (b), June 2, 2001; 0000 (c), and 1200 UTC (d), August 30, 2001; 0000 (e) and 1200 UTC (f), August 12, 2002

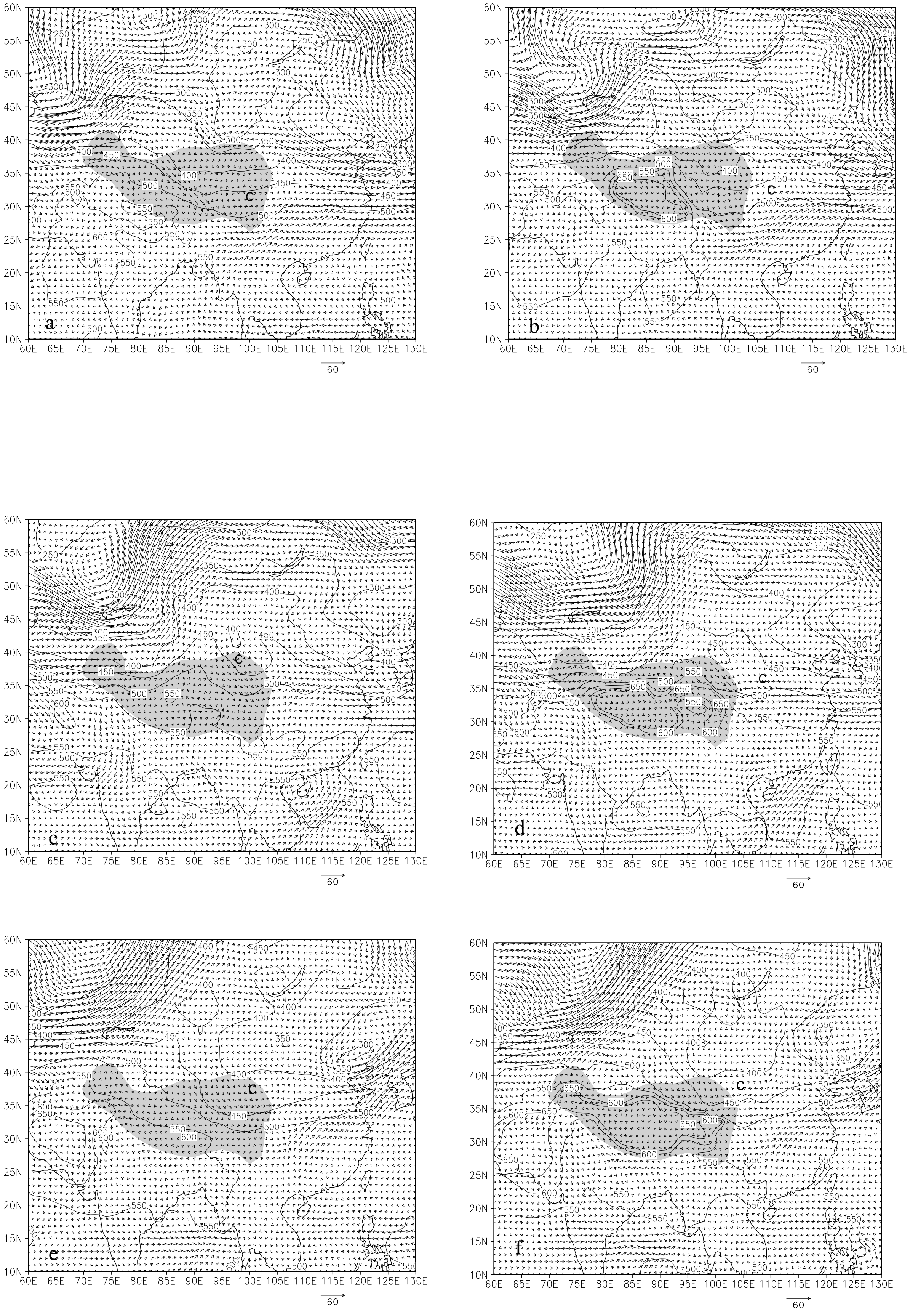
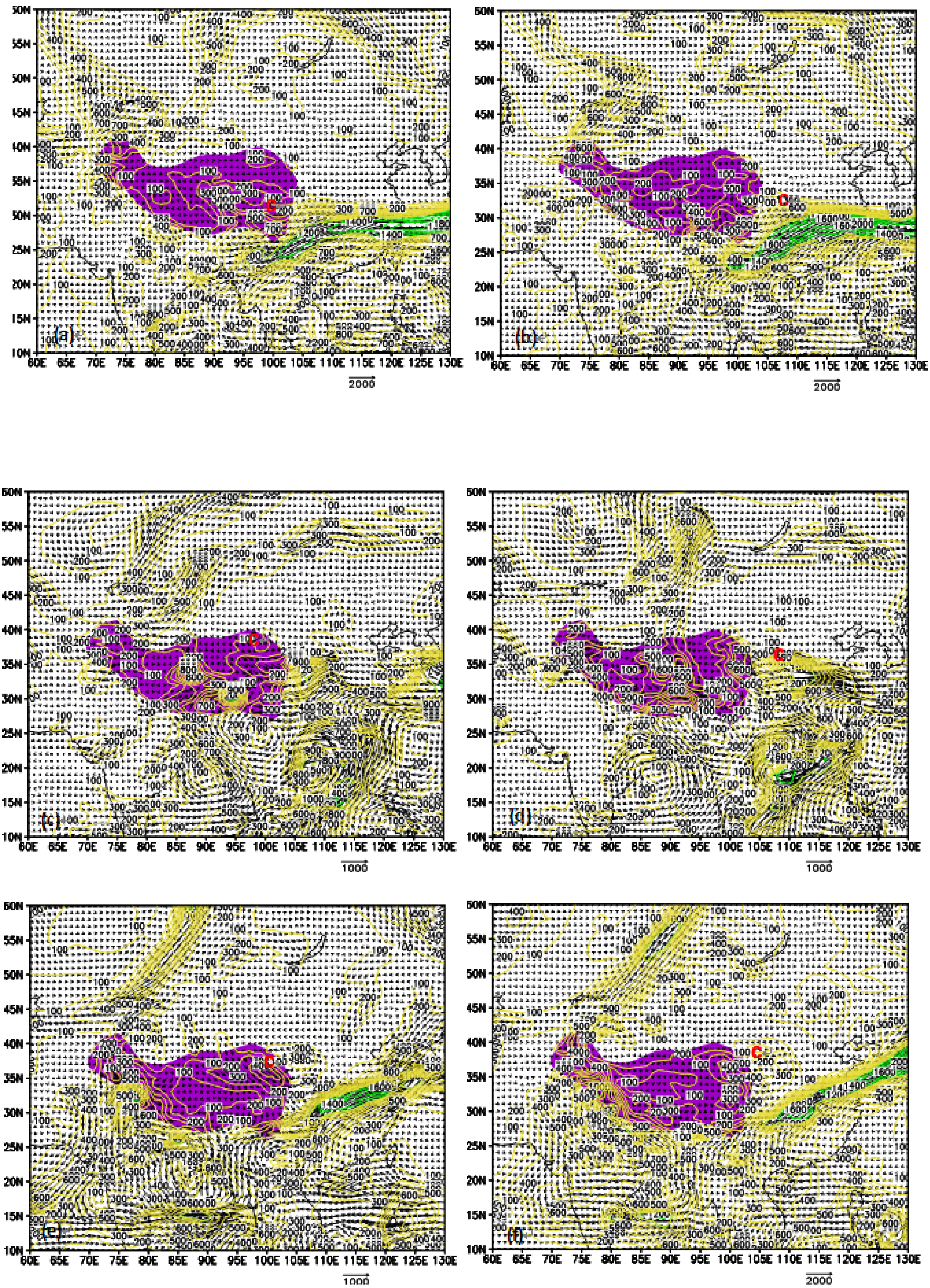

a
b
c
d
e
f

Fig.3. Vapor fluxes at **500** hPa level, with the panels denoting the corresponding time for the TPVs, The (directions of) fluxes are given by vectors and the values by solid lines. TPVs,



Fig,4. TPVs moving east-related 500 hPa vorticity evolution, with the same times as indicated in Fig.1.

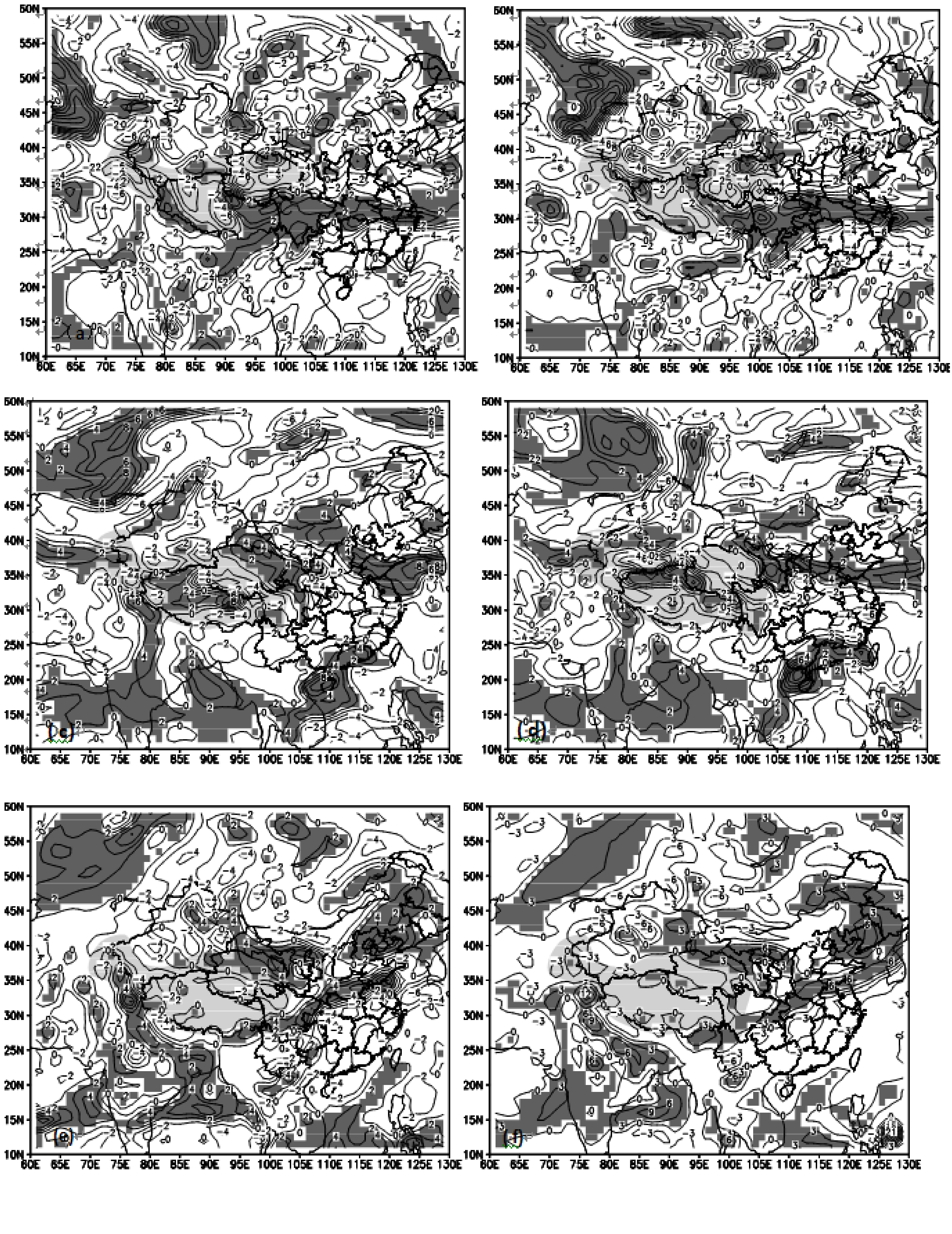


Fig.5. A conceptual model of the Southwesterlies impacting the TPV east moving till its departure from the plateau.

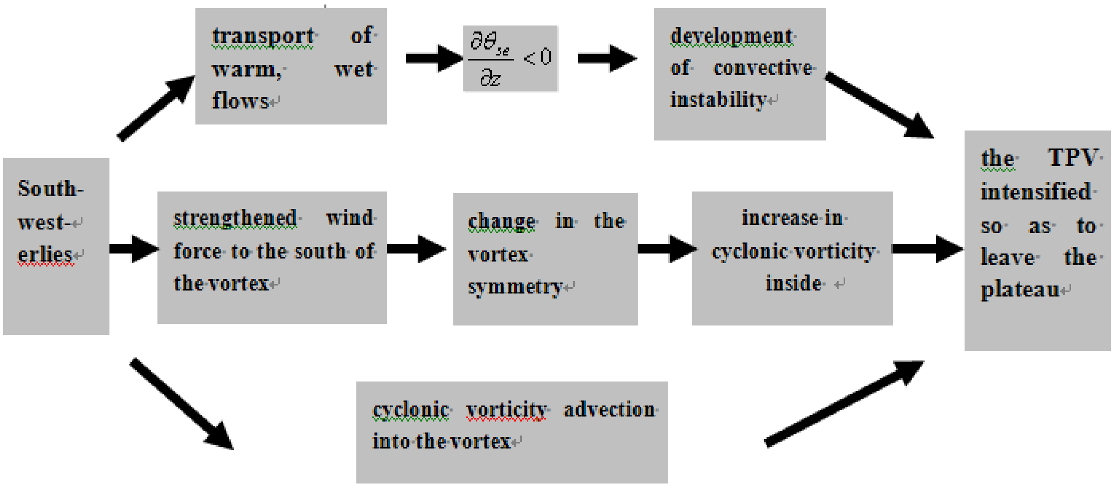


Table 1. The 500-hPa Southwesterlies characteristics related to the TPVs having their lifespan >48 hr downstream.

period in the source 588-dam (name)	affecting system for TPV outside	TPV type	SBF effect(m/s) (1)	(2)	western end*
June 1-5, 2001 (SoV)	plateau shear	shear	SW 14	WSW 22	18^0N, 105^0E
Aug. 29 – Sept. 3 (QuV)	shear at the end of the trough line	ditto	SW 14	SW 20	24.5^0N , 124.5^0E
Aug. 12 – 20, 2002 (TeV)	moving off with the transverse shear¤	ditto	SW 16	SW 20	21^0N, 103^0E

NB: (1) denotes the wind when the TPV was about to leave the plateau and (2) the wind 12 hr after TPV left.

* The point reached by the 500 hPa 588 dam

¤The TPV moves off with the transversal shear to the north of Hetao.