The Observational analysis of Tibetan Plateau Vortex activity that Induced Flood in China

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Abstract: By using synoptic, statistic methods and TRMM data, the moving out of Plateau low vortex activities are analyzed. The new recognition characteristic of main activity period of time, the vortex source regions and moving tracks of Plateau vortex are obtained. And some new observational facts of Plateau vortex changes are also got. All of these revealed that the characteristic change of the moving out of Plateau vortex is different with the characteristic of vortex that is active within the Tibetan Plateau.
Keywords: The Plateau vortex, moving out of the Tibetan Plateau, observational facts

1. INTRODUCTION

There are often vortices formed in summer over the Tibetan Plateau that are usually generated in the west half part and vanished in the east half part of the Plateau. Some vortices can move out of the main Plateau region that leads to the storm rainfall and torrential storm rainfall over a large area of China. For example, three continuous vortices moving out of the Plateau after the second mold rain over Changjiang river in August, 1998 led to storm rainfall in Sichuan Province and the 5^{th} , 7^{th} flood peaks in Changjiang river. The third Changjiang flood peak was also caused by a Plateau vortex. The most serious flood disaster over all of Changjiang river valley in 1998 from 1954 also had relationship with the Mesoscale Convective System （MCS） moving east out of the Plateau, which joined in the mold rain front and caused rainfall. The Plateau vortex caused a serious flood in Huang-Hui river valley in July, 2003. So, the vortex moving out of the Plateau has great influence on flood and storm rainfall in eastern China, Changjiang river valley and Huang-Hui river valley.

The Plateau vortex research had aroused attention by meteorologists. Important progress in the Plateau vortex research has been made since 1972 with the effort of the Plateau meteorology research cooperation group's and the analysis of the First Tibetan Plateau Science Experiment. Jijia Zhang, Baozheng Zhu, Fukang Zhu, Guowu Sun, Yihui Ding, Shiwei Luo, Yongfu Qian, Zhenan Qian, and Kuo, Y.H, among others, have conducted a lot of studies on the Plateau vortex and obtained results on its activity, the factors of generation, the structure and the topography influence of the Plateau vortex. Ye and Gao (1979) pointed out that the Plateau vortex moves out of the Plateau when there is a suitable upper air condition in the Plateau's shallow boundary layer. In recent years, Lianshao Chen, Jinxian Ma and Zhexiao Luo pointed out that the large topography has influence on vortex's movement. Guoping Li pointed out that the Plateau vortex moves out of the Plateau under given steering conditions. Minhong Song and Zhenan Qian pointed out that the average middle-east air column thickness of the Plateau is associated with the movement of the Plateau vortex. The researches indicate that the dynamical researches had been strengthened since the Second Tibetan Plateau Science Experiment and meteorologists started to study the Plateau vortexes moving out of the Plateau. The researches on the vortex moving out of the Plateau, however, are often case study.

2. DATA AND METHODS

The vortices moving out of the Plateau are mainly those that are generated over the Tibetan Plateau at 500hPa and later move out of the Plateau. They usually have an enclosed isohypse or have a cyclonic circulation for wind direction at three stations. They are different from the Southwestern vortices that are defined at 700hPa.

By using synoptic, statistical methods and TRMM data, this paper will concentrate on the observational analysis and activity behaviors of the Plateau vortex in years 1998 to 2004.

The number of occurrence, vortex source and trajectory will be analyzed in May to September from year 1998 to 2004 in the following.

3. THE ACTIVITY OF THE VORTEX MOVING OUT OF THE PLATEAU SINCE 1998

3.1 The activity of the Plateau vortex for every month of each year

The occurrence number of the Plateau vortex is shown in Table 1 from May to September from 1998 to 2004. We can see that: (1) The Plateau vortex appeared 12 times in the summer of 1999 summer which is the most in 7 years, 11 times in 1998 and 9 in 2003. There were only 3 times in 2000. The excessive vortices appearance in year 1998, 1999 and 2003 caused severe flood disasters in Changjiang river valley, in

Southwest China and in Huang-Huai river valley. This indicates that the Plateau vortex moving out of the Plateau is a very important synoptic weather system which influences the summer flood in China. (2) The preferred time period of the vortex moving out of the Plateau is from May to August. The number of the Plateau vortex moving out of the Plateau is almost the same for the months of May, July and August, which is different from the vortex activity over the Plateau. The number of active vortices over the Plateau is the most in May and less in August. The number of vortex moving out Southwestern China is the most in July and half in August, which is also different with the vortex moving out of the Plateau.

Table 1 The occurrence times of vortex moving out the Tibetan Plateau in each month

Year	May	June	July	August	September	Total
1998	0	2	4	4	2	12
1999	1	5	3	2	1	12
2000	1	0	2	0	0	3
2001	1	2	0	3	1	7
2002	1	1	2	2	0	6
2003	0	3	1	3	3	10
2004	1	1	1	0	0	3
Total	5	14	13	14	7	53

3.2 The source region analysis of the vortex moving out of the Plateau The distribution field of the generation source region of the Plateau vortex moving out of the Plateau more than 2 times in May to September from year 1998 to 2004 is presented in figure 1.We can see that in recent 7 years the most frequent source region is in the east of the Plateau, east of the 92°E, which is near Qumalai and Dege. This is different from the places where the Plateau vortex is generated, which is mostly generated in Qiangtang, Naqu, Chaidamu and Songpan. The source regions for the Plateau vortex moving out of the Plateau and for the Plateau vortex are different.

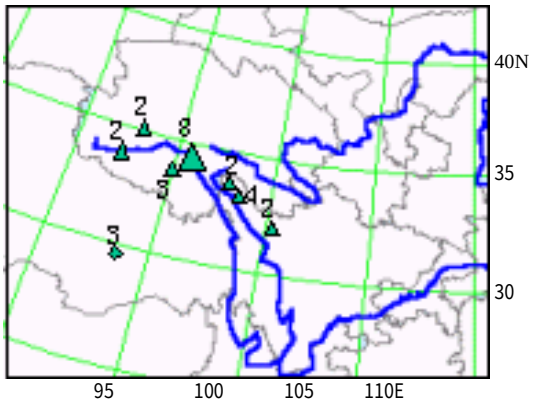

Fig.1 The original generation places distributing places of vortex moving out of the Plateau

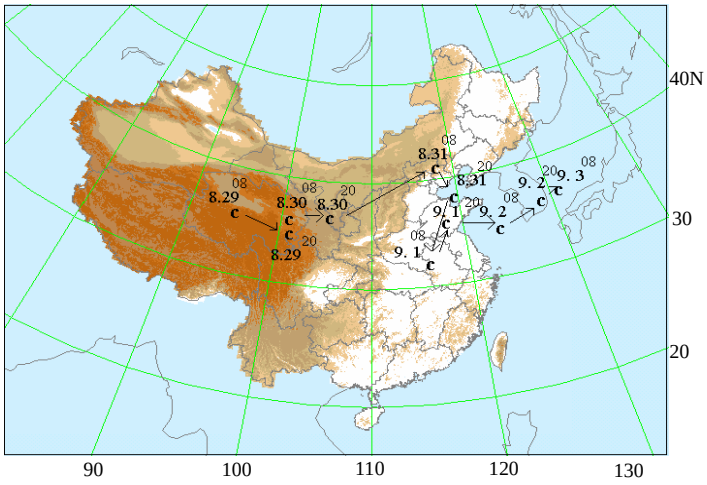

Fig.2 The moving process of the Plateau vortex during the 08z, 29th , August to 08z, 3th, Sep, 2001.

3.3 The track analysis of the Plateau vortex moving out of the Plateau

The Plateau vortex moving out of the Plateau track statistical data is given in table（table is omitted）. We can see that in recent 7 years most of the Plateau vortices moving out of the Plateau moved eastward, and some move southeastward or northeastward, but few move northward. This is different from the trajectory of the Plateau vortex which is active over the Plateau. The Plateau vortices active over the Plateau are most likely to move northeastward from May to September (30%). In June they mainly move eastward or northeastward, from July to August they propagate eastward or southeastward, and in September they move eastward (table omitted).

3.4 The active period analysis for the Plateau vortex moving out of the Plateau

The active period for the Plateau vortex moving out of the Plateau from May to September of years 1998-2004 is presented in table（table is omitted）. We can see that: (1) 55% of the Plateau vortices are weak and disappear in 12 hours after moving out of the Plateau, but some can last for 60 hours. (2) A few Plateau

vortices have an active time more than 100 hours and the longest is 192 hours.

4 VARIABILITY OF THE PLATEAU VORTEX AFTER MOVING OUT OF THE PLATEAU

After moving out of the Plateau, some of the vortices become stronger, and some become weaker. The intensity, characteristics, track changes and the underlying surface influences on the Plateau vortices' track are not clear.

4.1 The intensity and characteristic changes of the Plateau vortex after moving out of the Plateau

The characteristic changes of the Plateau vortex before and 12 hours after moving out of the Tibetan Plateau are given in table (table is omitted). We can see that: (1) The characteristics of the Plateau vortex before moving out of the Plateau: The vortices in east of the Plateau with an active time longer than 36 hours are mostly warm vortices (60%). The vortices in east of the Plateau have with an active time shorter than 24 hours are mostly baroclinic vortices. (2) The characteristics after moving out of the Plateau: The vortices moving out of the Plateau are mostly baroclinic vortices. 83% of the vortices that last 24 hours are baroclinic vortices, while 67% of those that last 36 hours are baroclinic vortices. (3) The Plateau vortex intensity changes after moving out of the Plateau: The vortices to the east of the Plateau with an active time longer than 24 hours are lower and their center geopotential height drops 12 hours after moving out of the Plateau and the vortices are stronger. The vortices to the east of the Plateau lasting less than 12 hours are weaker and the center geopotential height is higher. (4) The vortex center wind speed changes after moving out of the Plateau: The vortex to the east of the Plateau with an active time longer than 36 hours are lower and their center wind speed is bigger 12 hours after moving out of the Plateau. The vortices to the east of the Plateau with an active time shorter than 24 hours are weaker and the center wind speed is smaller.

From the above we can see that the characteristics and intensity of the Plateau vortex have different changes before and after moving out of the Plateau, corresponding to different active life times.

4.2 The rainfall intensity changes of the Plateau vortex after moving out of the Plateau

In table (table is omitted) the comparison of rainfall intensity changes of the vortex moving out of the Plateau and that before moving out of the Plateau from May to September during year 1998 to 2004 is given. From the table we can see that: (1) The rainfall intensity is strengthened after the Plateau vortex moving out of the Plateau. Weather the active time is long or short, 71% of the Plateau vortices make the rainfall intensified after they move out of the Plateau. For those with an active time longer than 36 hours, 93% of them result in an enhanced precipitation. (2) The vortex moving of the Plateau is generally associated with above average rainfall, some can lead storm rainfall or even heavy storm rainfall. Especially when the active time is more than 36 hours, 60% of the Plateau vortices lead to storm rainfall or heavy storm rainfall.

4.3 The underlying surface different changes of the Plateau vortex moving out of the Plateau

By analyzing the Plateau vortex moving to the sea from May to September during the years 1998 to 2004, we can see that there were four Plateau vortices moving to the sea, some of them even influenced the Korea peninsula and Japan. For example, the movement process of the Plateau vortex during time 8z29th, August, 2001 to 8z3rd, August, 2001(Beijing time) moved to the sea sky after 8z1st, September and moved past Korea peninsula and was close to Japan and influenced Japan(Figure 2).

By analyzing the rainfall of the four Plateau vortices moving to the sea we can see that the rainfall is intensified. For example, the movement process of the Plateau vortex during time 8z3rd, September, 1998 to 8z6th, September, 1998 moved to the Hangzhou sea gulf at 20z5th, September and moved to the sea surface. The TRMM data indicate that: Before moving out of the sea the rainfall intensity is 9mm/hr during 15-17z, 5^{th}, September and changes to 18mm/hr during 18-20z, 5^{th} just before moving out to the sea and it's rainfall has already influenced the sea (Figure is omitted). After moving out of the sea the rainfall intensity is 27mm/hr during 21-23z, 5^{th}, September and 24mm/hr during 00-02z, 6^{th}, September and the area of more than 18mm/hr has enlarged (Figure is omitted). Rainfall intensity is 25mm/hr during 03-05z, 6^{th}, and 27mm/hr during 06-08z, 09-11z, 6^{th} (Figure is omitted). From the above we can clearly see that the rainfall intensity is strengthened.

By analyzing the geopotential height of the four Plateau vortex processes moving out of the sea we can see that for 3 of them the geopotential height tends to be lower. For example, the movement process of the Plateau vortex during time 8z1st, June, 2001 to 8z5th, June, 2001 just before moving to the sea whose center reached 5730 meter in geopotential height and at 8z4th, it's center geopotential height was 5700 meters (Figure is omitted).

From the above we can see that when the Plateau vortices move to the sea underlying surface, the Plateau vortices will be intensified that leads to more rainfall, which is contrary to the typhoon result which becomes weaker after they landed.

4.4 The track changes of the Plateau vortex moving out of the Plateau influenced by different

weather systems

By analyzing the weather systems which influence the Plateau vortex moving out of the Plateau in May to September during year 1998 to 2004 we can see that: After the Plateau vortices move out of the Plateau, about half (43%) move to the east along with it's north, east trough or to the northeast with the trough contracting to northeast or to southeast with the trough southeast spreading. About 29% of them move to the leaning east direction in the shear background field and some of them move with the shear line to the east. 17% of them move northwestward with the northwest air flow before the ridge. And there are few that move with the Sub-Tropical high, about 9.5%. There are few that move with the South Trough. All of them are different from most of the Plateau vortex over the Plateau which move along with the shear line to the east[4].

We also find that: The Plateau vortex after moving out of the Plateau tends to be still when there are active tropical cyclones. For example, the movement process of the Plateau vortex during the time 20z2nd, July, 2000 to 20z7th, July, 2000 (Figure is omitted) was influenced by the tropical cyclone. During 20z5th, July, 2000 to 20z6th, there was a still tropical cyclone to the east of the Mainland and south of Japan which leads to still Plateau vortex between the boundary of Shanxi and Henan Province. During 8z7th, July, 2000 to 20z7th, there is a still tropical cyclone close to Japan which leads to still Plateau vortex in the south of Shanxi Province. The active tropical cyclone in the east of the sea has a blocking effect to the Plateau vortex.

We also find that: The Plateau vortex tends to be inactive with an inactive monsoon low and attracts its south tropical cyclone and makes it move closer. For example, the movement process of the Plateau vortex during time 8z12nd, August, 2002 to 8z20th, August, 2002 (Figure is omitted) was influenced by the tropical cyclone. During 20z14th, August 2002 to 8z15th and 8z16th, the Indian monsoon low is inactive and which leads to a still Plateau vortex between Ganshu and Shanxi province. During 20z18th, August, 2002 to208z19th, the South Sea tropical cyclone move northwestward close to mainland which leads to the Plateau vortex move southwestward from Chongqing to Guizhou. After that, the tropical cyclone and Plateau vortex move in opposite directions and meet at 20z20th over the north of Guangxi province and made the typhoon last on the land.

5. CONCLUSION

(1) The main active time of the Plateau vortex which influences the weather in eastern China is from June to August. For the Southwest vortex, the number of cases moving out of the southwest of China in July is 2 times of that in August. The region source of the Plateau vortex moving out of the Plateau is in Qumalai and Dege area, which is different with the source generation region of Plateau vortex over the Plateau.
(2) The Plateau vortex moving out of the Plateau moving track is mostly move along with its north, east trough to east or southeast direction, which is different with the Plateau vortex over the Plateau moving along with the shear line to the northeast direction.
(3) Most of the Plateau vortices disappear in 12 hours after they move out of the Plateau, some can last 60 hours, and even to 192 hours. They influence most of China region and even influence Korea peninsula and Japan.
(4) The intensity, characteristic of the Plateau vortex change after it moves out of the Plateau. The vortices in the east of the Plateau with an active time longer than 36 hours are mostly warm vortices before moving out of the Plateau and they become to baroclinic vortices after moving out of the Plateau and tend to be intensified, which in most cases leads to storm rainfall and heavy storm rainfall.
(5) There are some special changes of the Plateau vortex moving out of the Plateau: The Plateau vortex moving out of the Plateau changes with the underlying surface and leads to more rainfall when it moves to the sea surface, which often results in a lower geopotential height. The Plateau vortex is inactive with the inactive tropical cyclone. The Plateau vortex moving out of the Plateau is in an opposite direction with the south tropical cyclone and is inactive with the inactive monsoon low.

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