INFLUENCE OF 200 hPa DIVERGENCE CIRCULATION ON THE TRACKS OF TROPICAL CYCLONES

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Received 9 November 1992, accepted 20 June 1994

ABSTRACT

The characteristics of 200 hPa divergent wind and velocity potential have been analysed for four kinds of tropical cyclone tracks having impact on the South China Sea. It is found that the difference of monsoon circulation in 200 hPa divergence wind field may affect the medium-range movement characteristics of tropical cyclone tracks. Corresponding to the west Pacific subtropical high, the orientation of 200 hPa secondary convergence line and its extension to the west may indicate the variability of track types. The direction of tropical cyclone movement is 2 longitudes west of and parallel to the 200 hPa secondary divergence line.

Key words: 200 hPa secondary height, divergent circulation, typhoon track, steering flow

I. INTRODUCTION

At present, the majority of forecast methods of tropical cyclone tracks depend on the steering current fundamental principle obtained by processing approximately the typhoon motion equation, of which a few of influence factors (including the energy exchange between the tropical cyclone itself and ambient field) are neglected. Furthermore, it is very difficult to select accurately the steering surface. Actually, the complete steering concept is a synthetic effect of thermodynamic and dynamic processes of the whole layer atmosphere. Ding et al. (1990) shows that the distribution of macroscale divergence circulation in the tropical area, which is actually the effect of dynamic adjustment of local unbalanced heating, is very much connected with the heating field. Therefore, 200 hPa divergence circulation may restrict tropical cyclone tracks to certain degree. This paper will discuss the influence of 200 hPa divergence circulation on each of the four tropical cyclone tracks by analysing corresponding pattern of the circulation.

II. DATA AND PROCESSING

Tracks, along which the tropical cyclone in the west Pacific move westward and reach areas west of 130°E, are divided into four types: Track A—along which the tropical cyclones change direction or move northward east of 120°E and do not enter into the South China Sea; Track B—along which the tropical cyclones land in the east of the Pearl River Mouth after entering into the South China Sea; Track C—along which the tropical cyclones land in the west of the Pearl River Mouth or Hainan Island after entering into the South China Sea; Track D—along which the tropical cyclones move west-southwest and land in the middle or south of Vietnam after entering into the South China Sea. For four types of tracks crossing the 130°E, the 200 hPa divergence wind and velocity potential are classified and composed. The number of composite cases of each type are 7, 8, 11, and 6, respectively.

The composite data is obtained from ECMWF 2.5×2.5 grid-points data. The domain computed is 50°N-30°S, 50°E-180°E. The velocity potential and divergence wind are computed by

$$\frac{\partial^2 \chi}{\partial x^2} + \frac{1}{\cos\ \varphi} \frac{\partial}{\partial y}\left(\cos\ \frac{\partial \chi}{\partial y}\right) = -\ D,$$

$$\vec{V}_x = -\ \nabla \chi.$$

The boundary condition is $\chi = 0$. We do not iterate the Poisson equation until the difference value of each grid-point result between any two neighbouring times is $\leqslant 10$.

The design for a composite method is easy. For the tropical cyclone of each composite case crossing 130°E, we will compose the grid-point data in terms of four types of tropical cyclone tracks. Since the cases are composed on the basis of track types, the position of individual tropical cyclones are not much different at the moment of composition. The composite effect proves that this method is viable.

Ⅲ. THE FUNDAMENTAL CHARACTERISTICS OF DIVERGENCE CIRCULATION FOR ALL TRACK TYPES

1. *Track*

In the Northern Hemisphere there are three major divergence centres for Track A in 200 hPa divergence wind field. (Fig. 1) Except for the centre (abbreviation F) which corresponds to the tropical cyclone centre and is situated over the sea surface east of the Philippines, the other two centres are respectively situated in the southern part of Bay of Bengal (I) and near 35°N, 170°E (T), corresponding to the India monsoon trough in the lower level and the South Asia pressure ridge in the upper level, respectively. The three centres make a great divergence belt. In the Southern Hemisphere the divergence centre (S) is situated at 15°S, 117. 5°E. The southward divergence wind from F and the northward divergence wind from S converge near the equator and form a convergence belt for the equatorial anticyclone in the middle or lower level; the southward divergence wind from T and divergence wind flowing from F converge near 15-20°N and maintain

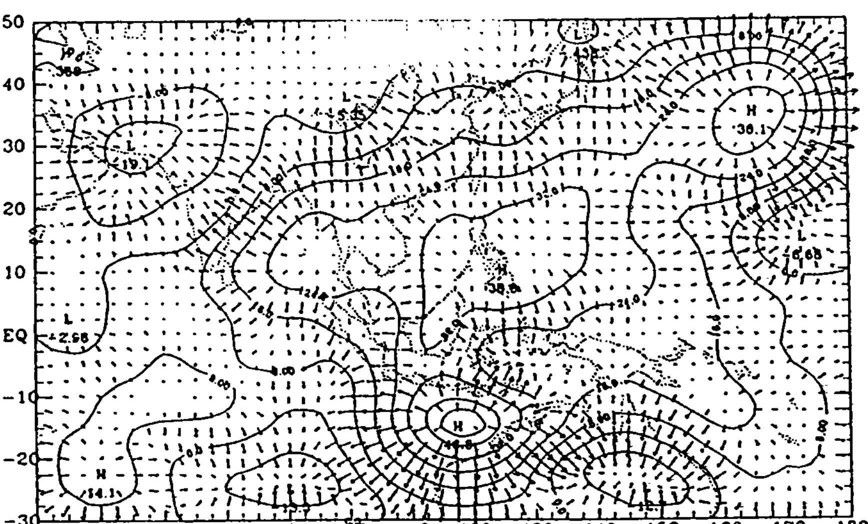

Fig. 1. 200 hPa divergent wind for Track A.

the west Pacific subtropical high. The western sector of the convergence line stretches to the northwest. The distribution of 200 hPa divergence wind field shows the general picture of monsoon circulation in eastern Asia in which cold air in the Southern Hemisphere is strong and advances to the Northern Hemisphere; the equatorial anticyclone is strong; in the Northern Hemisphere southwest monsoon in the middle and lower level is active and reach higher latitudes so that the trade winds in the Pacific are displaced to the east and north. Obviously, this kind of circulation background is advantageous for the tropical cyclones to change direction and move northward and to stay away from the South China Sea.

2. *Tracks B and C*

Except for the point of landing, Track B is similar to Track C. The 200 hPa divergence circulation of the two types are also approximately similar (Fig. 2). Though

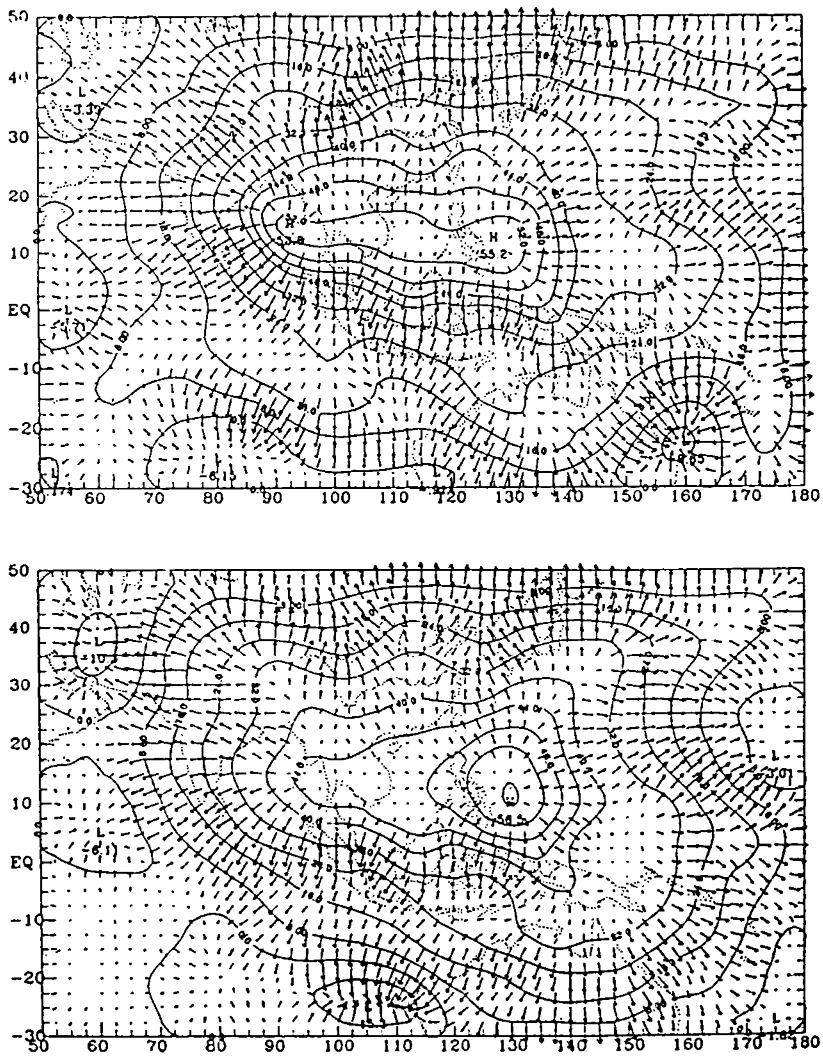

Fig. 2. 200 hPa divergent wind field for Tracks B(a) and C(b).

there is no Center T, the divergence line stretching toward northeast from Centre F still exists; Centre I, from which the southward divergence wind stretches to the subtropical area in the Southern Hemisphere, still exists; the southward divergence current from Centre F goes directly to the subtropical area in the Southern Hemisphere; the convergence region for the equatorial anticyclone does not exist; the ITCZ divergence line stretches directly to the vicinity of 170°E from both Centres I and F. The divergence currents of the upper eastward-stretching ridge of the South Asia high converge with the upper divergence wind for the eastern sector of the lower level ITCZ near 25°N and maintain the west Pacific subtropical high. The divergence line retains an east-west orientation. The divergence circulation of the track types shows that the monsoon and trade currents in East Asia have a quasi-zonal distribution, and that the subtropical high and ITCZ also retain an east-west orientation. The kind of circulation background makes it advantageous for the tropical cyclones to enter into the South China Sea and land on the coast of South China.

3. *Track D*

In the Northern Hemisphere there are three divergence centres by the track type (Fig. 3). The southward divergence currents from Centres I and F converge in the subtropical area in the Southern Hemisphere. The ITCZ divergence line also has an east-west orientation and stretches to 160°E. The west Pacific subtropical high is maintained by the converged divergence wind flowing from ITCZ and Centre F and is orientated southwest-northeast. Centre I is about 8 latitudes more southern than that for Track B or C and is located near 5°N. A general picture of the East Asia circulation as shown by this type of divergence wind circulation is that Centre I is more to the south so that the line, which joins together three strong divergence centres I, F and T, has a southwest-northeast orientation. The convergence line in the subtropical high region also has a southwest-northeast orientation, being favourable for the typhoons to enter into the

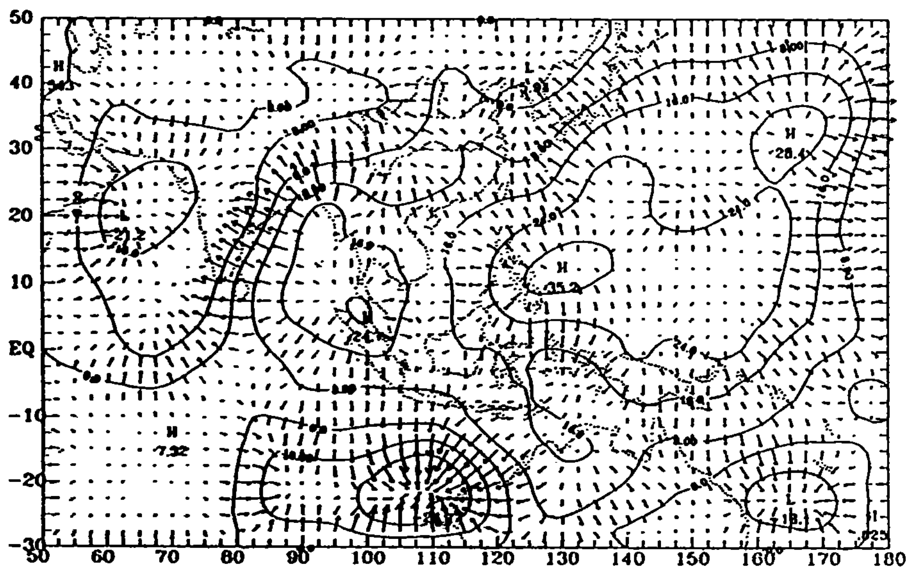

Fig. 3. 200 hPa divergent wind field for Track D.

South China Sea and land on the middle or south coast of Vietnam along a west to southwest track.

IV. EFFECT OF THE SECONDARY DIVERGENCE AND CONVERGENCE LINES ON TROPICAL CYCLONE TRACKS

The analysis above shows that the fundamental characteristic difference of 200 hPa divergence circulation may affect the west Pacific tropical cyclone tracks. Moreover, Figs. 1-3 also show that the distribution of potential isovel has some secondary swirls piling on their planetary scale centres. There are secondary divergence lines cooperating with the outward isoline tongues from divergence centres and the inward swirls between any two tongues. According to the analysis of the fundamental theory of influence of large domain circulation adjustment on tropical cyclone tracks, Chen et al. (1979) found that the following two secondary systems directly influenced typhoon tracks.

(1) The convergence line in subtropical high

In the upper-level divergence wind field the middle and lower level west Pacific subtropical high ridge is expressed as a sector of secondary convergence line cooperating with velocity potential isoline bending towards the divergence centre (Figs. 1-3). The convergence lines of divergent wind for the main body of the subtropical high usually retain a quasi-east-west orientation and are located over sea surface west of 140°E. They are maintained by the convergence of the divergent wind of South Asia high ridge and ITCZ ,so this system belongs to the main body of the subtropical high. Moreover, there are some secondary convergence lines with a south-north orientation over mainland China and the subtropical sea surface west of 140°E. This kind of convergence line, which is usually maintained by the convergence of northward divergent wind from both Centres I and F, must be part of the maintenance of a westward-stretching ridge of the subtropical high in the upper level. Obviously, the dynamic mechanisms of the main body and westward ridge of the west Pacific subtropical high revealed here are different. In the previous analysis, the certain influence of the convergence line characteristics for the west Pacific high on the tropical cyclone medium-range movement tendency has been involved partly. Fig. 4 shows the whole influence of the type. When the west end of the main body of convergence line orientates northwest-southeast, it makes it favourable for the tropical cyclones to change directions to move northward; when the main body of convergence line orientates southwest-northeast, it makes it favourable for the tropical cyclones to move toward the west; when the main body of convergence line orientates east-west, it makes it favourable for the tropical cyclone to move toward west to northwest and land on the coast of South China (the more west the place of the west end of the convergence line is, the more west the sector of the tropical cyclone landing area will be). The reason is that the characteristics of subtropical high determine the direction, the intensity and the westward-strecthing point of the trade winds south of it. (Observations indicate that most tropical cyclones move along the trade wind currents) Actual operational

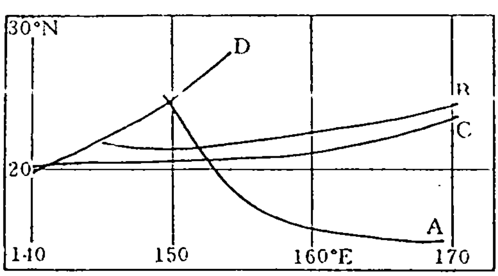

Fig. 4. 200 hPa secondary convergence line for tropical cyclone for all types of track.

forecast work verifies that the key of tropical cyclone extended-term forecast is whether the forecast of the west Pacific subtropical high is accurate. This view is identical with the conclusion here while the latter is more scientific than that by the traditional method when it is applied to the actual forecast. The traditional method expresses the subtropical high using the characteristic line of 5889 gpm at the 500 hPa level and fails to reveal the accurate dynamic and themodynamic structure of the subtropical high and its westward-stretching ridge . In the 200 hPa divergence wind field this problem can be well solved and the state of subtropical high is succintly shown. The state of subtropical high also well corresponds to all types of tropical cyclone tracks.

(2) The secondary divergence line north of tropical cyclone divergence centres

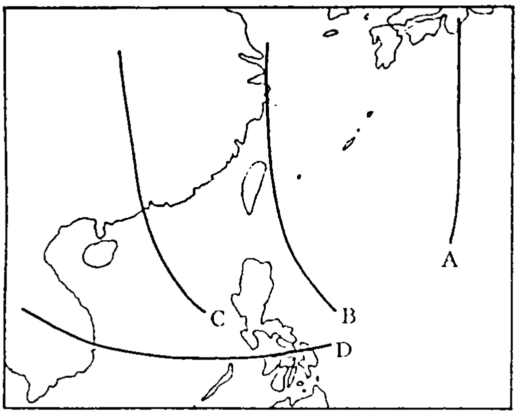

Fig. 5. 200 hPa secondary divergence line for all types of track.

In Figs. 1-3, except for the ITCZ north of tropical cyclone divergence centres, there are the outward-projecting velocity potential tongues cooperating with the divergence lines of divergent wind. In Fig. 5, the divergence line with an approximate south-north orientation indicates that the direction of tropical cyclones movement is 3 longitudes west of and parallel to the divergence line; and the divergence line with a quasi-east-west orientation means that the direction of tropical cyclones movement inclines to the west. Because in lower latitudes there is a convective condensation weather process in the upper level divergence region, it is reasonable that tropical cyclones move toward the region.

V. CASE CHARACTERISTICS

What is revealed above is a composite analysis effect. It expresses that the convergence and secondary divergence lines of 200 hPa divergent wind circulation in the subtropical high area play a certain restraining role to tropical cyclones' movement tendency. Each case, which takes part in composition, is analysed below:

(1) The type of changing direction

In 7 tropical cyclone cases of this type, their western ends of convergence lines of 2 cases in the subtropical high are to the east of 150°E, and the other 5 cases do not have obvious convergence lines; the secondary divergence lines all orientate quasi-southwest-northeast and are located to the east of 127. 5°E. The tropical cyclone 8104, for which the convergence line in the subtropical high is located near 155°E, is a typical case. According to the composite effect, we forecast that 7 cases all change direction and do not enter into the South China Sea.

(2) The type of landing in the east of Guangdong province

In the 8 tropical cyclone cases of this type, the west ends of divergence lines in the subtropical high of 7 cases are to the east of the 140°E, 1 case is at 132. 5°E; when the

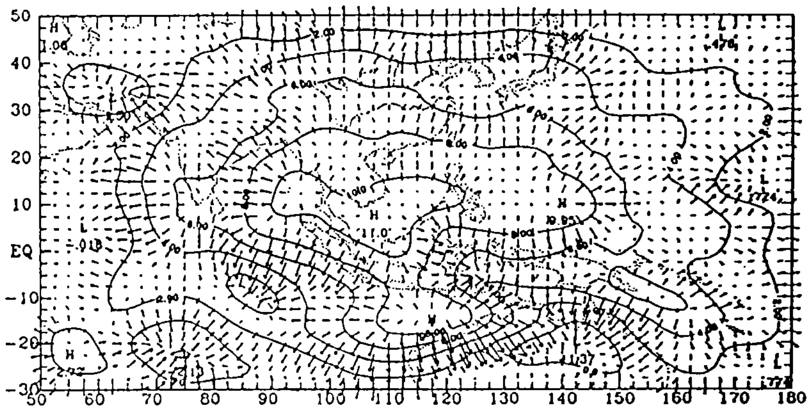

Fig. 6. 200 hPa divergent wind field associated with typhoon 8104 crossing 130 °E.

secondary divergence line orientates quasi-southeast-northwest, only one case is at 125° E, the other divergence lines intersect the coastal line between 117. 5°E and 122. 5°E. According to the composite effect, we forecast that only one case land in the southeast coast of China and the others in sectors of land area in the east of Guangdong Province. The tropical cyclone 8116, for which the divergence line in the subtropical high is near 150 °E and the secondary divergence line intersects the coastal line at 117. 5° (Fig. 7), is a typical case.

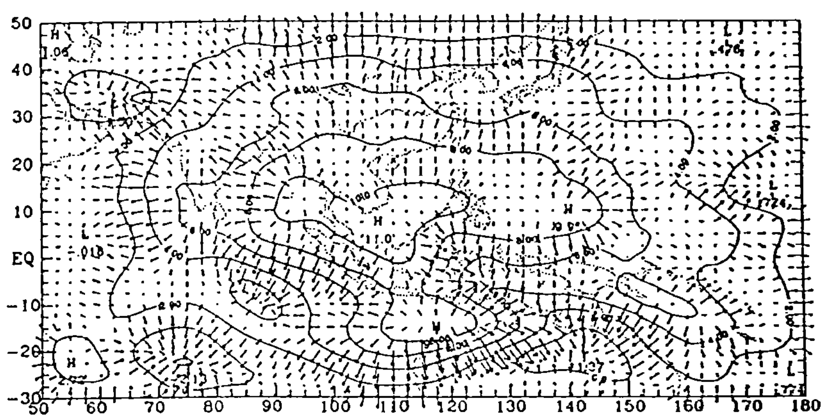

Fig. 7. 200 hPa divergent wind field associated with typhoon 8116 crossing 130 °E.

(3) The type of landing in the west of Guangdong Province

The west ends of divergence lines of 11 composite cases of this type in the subtropical high are located between 135°E and 145°E; the secondary divergence lines of 10 cases point to north to northwest and intersect the coastal line between 107. 5°E and 117. 5°E; one case intersects the coastal line at 105°E. According to the composite effect, we forecast that the 11 cases all land in the Pearl River Mouth (or the west of the Pearl River Mouth). Tropical cyclone 8303, for which the west end of convergence line in the subtropical high is at 142. 5°E and the secondary divergence line orientates south-north and intersects the coastal line at 112. 5 °E (Fig. 8), is a typical case.

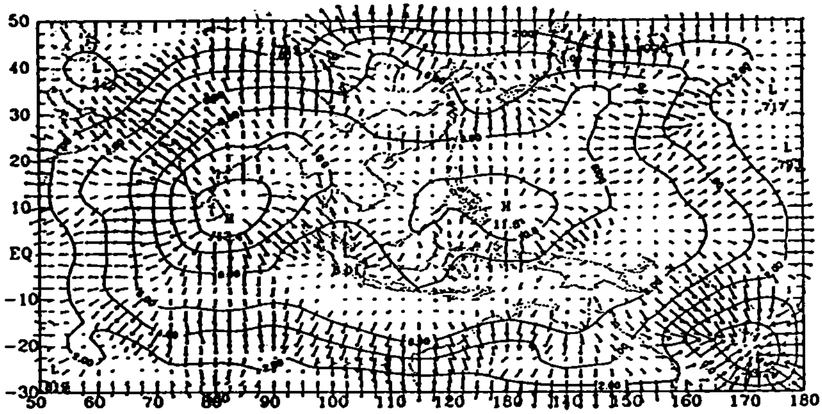

Fig. 8. 200 hPa divergent wind field associated with typhoon 8303 crossing 130 °E.

(4) The type of moving westward in the South China Sea

In the 6 cases of this type, five are in autumn, one in spring. Most tropical cyclones in the west Pacific move westward after entering into the South China Sea during the two seasons. The west ends of their convergence lines in the subtropical high are between 120°E and 140°E; and their secondary divergence lines all have quasi-west-east orientations and are located in the middle of South China Sea. According to the composite effect, we forecast that all cases move westward in the South China Sea. Tropical cyclone 8020, for which the west end of the convergence line in the subtropical high lies at 135°, is a typical case.

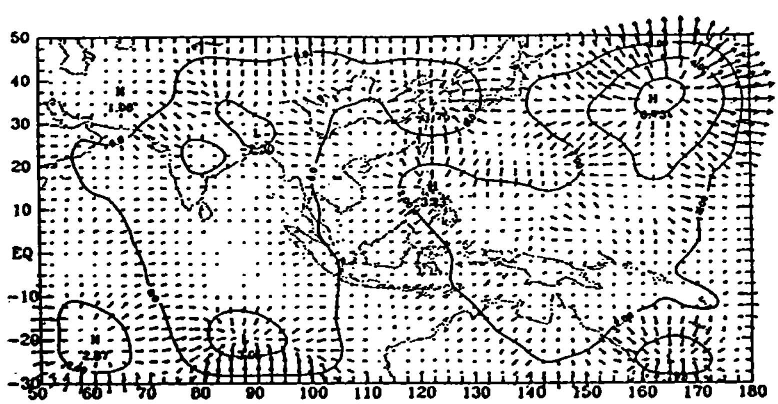

Fig. 9. 200 hPa divergent wind field associated with typhoon 8020 crossing 130 °E.

Ⅵ. THE CONCLUSION

The restraining effect of 200 hPa divergence circulation on tropical cyclone tracks is expressed as below.

a. East Asia monsoon and trade winds circulation characteristics stated by the divergence circulation determine the medium-range tendency of tropical cyclone tracks;

b. The direction and westward-stretching extent of the secondary convergence line of divergent winds for the west Pacific have impact on the coming tropical cyclone tracks.

c. The outward secondary divergence line in the divergence centre of tropical cyclones plays a certain indication role to the movement of tropical cyclones.

Despite that there are fewer cases to take part in composition for track types, the analysis through general cases investigation shows that two major characteristics of the 200 hPa divergence wind circulation of the most cases are consistent with tracks and conform to the law revealed by composite cases. Due to restricting conditions, it is of regret that this paper does not test and verify the conclusions or go through filtering with independent data. This problem is kept for further research in the future.

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