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ANALYSES OF THE ANNUAL FREQUENCY ANOMALIES OF TYPHOONS AND HURRICANES IN 1998

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ABSTRACT: In 1998, the annual frequency of typhoon (including tropical storms) genesis created a minimum value — 14, far lower than the minimum of 20 in 1950 over North-West Pacific, while in the Atlantic Ocean, the annual frequency of hurricanes (including the tropical storm) created a maximum value — 14, far higher than the average number — 9.2. In this paper, an analysis on the relationship between the generation of Typhoon, Hurricane and the Cross-Equatorial Flow was done by using the NCEP/NCAR reanalysis data for 1979 – 1995. It is pointed out that the anomalies of the CEF over the Pacific and Atlantic Ocean is the main cause for the 1998 annual frequency anomalies of Typhoon and Hurricane, respectively.

Key words: typhoons; hurricanes; anomalies of the cross-equatorial flow

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1 INTRODUCTION

An important bondage and channel for the exchanges of energy, momentum and water vapor between the Southern and Northern Hemispheres, the cross-equatorial flow contributes substantially to the general circulation across the globe. As shown in studies, most of the genesis of typhoon over the western Pacific and South China Sea are closely related with its sudden intensification[1 – 4]. As shown in statistics, an average of about 28 coded typhoons are generated every year in the northwestern Pacific and the South China Sea and about eight of them make landfall on the coast of China, being positively proportional to the number of genesis. In 1998, the number of typhoon genesis in the northwestern Pacific hit a record low since 1949 while that in the Atlantic a record high over recent years.

Studying the relationship between the activity of the cross-equatorial flow and typhoon generation, we find that the former was particularly weak in 1998 between 90°E and 180° in the western Pacific, which may be the main cause for exceptionally low number of genesis in that year. In the meantime, the unusually high frequency of hurricanes in the Atlantic in 1998 was attributed to specially strong cross-equatorial flow at 40°W and 75°W in the summer.

2 MAIN CHANNELS OF CROSS-EQUATORIAL FLOW

With 5°×5° long./lat. gridpoint datasets for 1979 – 1995 from the NCEP/NCAR reanalysis,

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channels of cross-equatorial flow at 850 hPa over the equator in the summer (June – September) of both the Eastern and Western Hemisphere are statistically worked out (Fig.1). Next are some analyses.

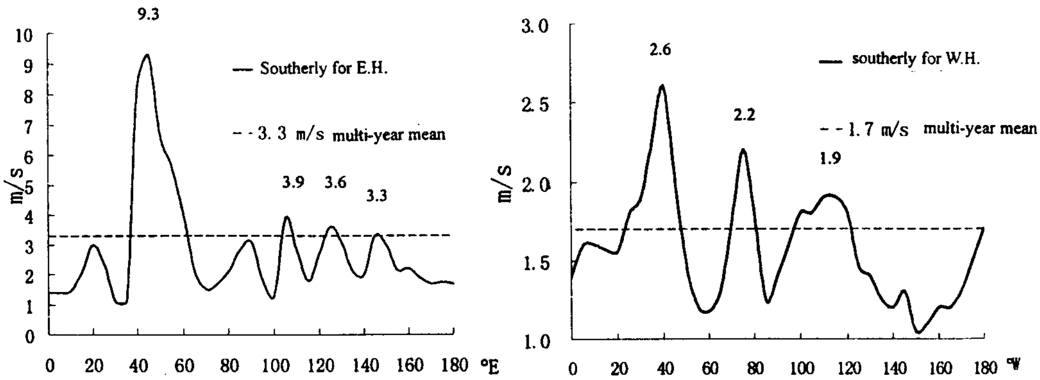

Fig.1 Channels of cross-equatorial (southerly) flows in the Eastern Hemisphere (left) and Western Hemispheres (right). (The mean of V^{+} at 850 hPa between June and September from 1979 to 1995)

2.1 *Cross-equatorial flow in Eastern Hemisphere*

There are mainly four climatologically meaningful channels in the Eastern Hemisphere for the cross-equatorial flow: (1) the 45°E channel with the daily mean southerly winds up to 9.3 m/s, (2) the 105°E channel with the same winds of 3.9 m/s, (3) the 125°E channel with the same winds of 3.6 m/s and (4) the 145°E channel with the same winds of 3.3 m/s, from June to September over the 17 years. They are climatologically significant because they are located in channels with daily southerly winds greater than or equal to the mean of 3.3 m/s across all longitudes of the Eastern Hemisphere. The above cases are useful in the sense of mean state. Any particular weather process may well be the result of one or more dominant channels of cross-equatorial flows. It should also be noted that the flow through the 45°E channel near the Somalia jet stream is more than twice as much as the rest.

2.2 *Cross-equatorial flow in Western Hemisphere*

There are three channels in the Western Hemisphere for the cross-equatorial flow: (1) the 40°W channel with the daily mean southerly winds of 2.6 m/s, (2) the 75°W channel with the same winds of 2.2 m/s, (3) the 115°W channel with the same winds of 1.9 m/s. They are climatologically significant because they are located in channels with daily southerly winds greater than or equal to the mean of 1.7 m/s across all longitudes of the Western Hemisphere.

2.3 *Comparisons of cross-equatorial flows between the Eastern and Western Hemispheres*

Comparing the cross-equatorial flow channels over the equator in the Eastern and Western Hemispheres in the summertime (June – September), we note that (1) peaks are more obvious in the channels of the Eastern Hemisphere, (2) there are more cross-equatorial flow channels in the Eastern Hemisphere that are climatologically meaningful, and (3) there are fewer channels in the Western Hemisphere and the flow at all longitudes is much smaller than in the Eastern Hemisphere. It is then concluded that the cross-equatorial flow is more active and intense in the Eastern than the Western Hemisphere, especially near the Somali jet stream on the east coast of

Africa where hemispheric exchange of momentum, energy and water vapor is more fierce.

3 CROSS-EQUATORIAL FLOW AND TYPHOON GENESIS

As shown in the analysis, the genesis of most typhoons in the northwestern Pacific is closely related with the sudden intensification and persistent maintenance of the cross-equatorial flow. Fig.2 gives the daily evolution of E value (where $E=\sum_{0^\circ}^{180^\circ} V_+$), the sum of the cross-equatorial flow at 850 hPa in the Eastern Hemisphere on the day of genesis and 10 days each before and after it for a total of 61 typhoons over the period from June to September in 1975 – 1979. The figure shows that the intensity of V_+ suddenly increases 2 days before (–2) and 5 days before (–5) the typhoon genesis; over the period 2 – 4 days after the genesis, powerful cross-equatorial flow keep forming and persist. It is particularly interesting that the intensity of the cross-equatorial flow near the Somali jet stream (45°E) is well related with the number of typhoon genesis in the typhoon season of that year, no matter whether it is the winter or summer.

Fig.3 gives the correlation between the sum of daily mean southerly wind for 850 hPa and 200 hPa at 45°E in June – September from 1975 to 1979 and the annual number of typhoon genesis in the northwestern Pacific. It shows that there are more geneses of typhoons in the northwestern Pacific in the years of stronger cross-equatorial flow and otherwise is true[3]. In the winter of 1980 – 1986 (December – February), the former (northerly wind) is similarly correlated with the genesis number in south Indian Ocean and south Pacific in the same period. No further discussions will be made here. It should be noted that Fig.2 and Fig.3 are mean statistics. Detailed analyses of each of the typhoons show that their geneses are all related with the sudden intensification of cross-equatorial flow near their respective longitudes, which are further proved by satellite images. Similar findings are found with analyses of typhoon geneses in the Southern and Northern Hemispheres[6].

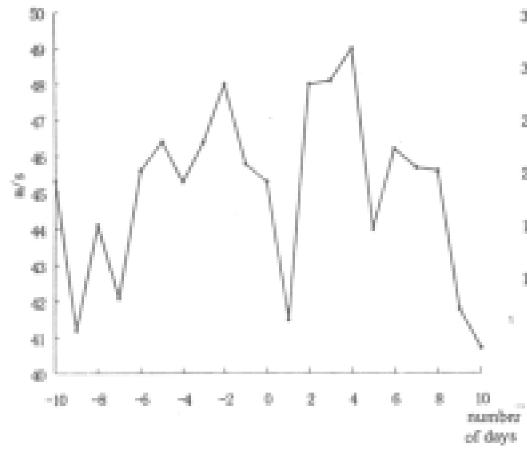

Fig.2 Daily distribution of the sum E for the cross-equatorial flows in the 10 days before and after the genesis of 61 typhoons between June and September from 1975 to 1979 (the sum of V^+ at 850 hPa from 0° to 180°). The genesis of a typhoon refers to the time when the eye acquires a wind force of 8 on the Beaufort scale.

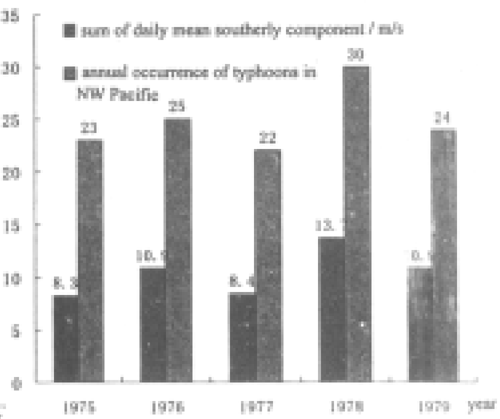

Fig.3 Correlation between the sum of daily mean southerly wind for 850 hPa and 200 hPa at 45°E in June – September from 1975 to 1979 and the annual number of typhoon genesis in the northwestern Pacific (excerpted from [2]).

4 MAIN CAUSES FOR EXTREMELY FEW GENESES OF TYPHOONS IN 1998

As shown in our study, there is an average of 28 typhoons (coded in China, same below) annually generating over the northwestern Pacific over the years from 1949 to 1995 (47 years) and the lowest annual genesis occurred in 1951, 20 typhoons. The year 1998 hit a record low by having 14 typhoons only. Studying the activity of the cross-equatorial flow for 1998, we note that in the months with the most frequent typhoon geneses (June – September), the cross-equatorial flow is especially weak in the western Pacific (90°E – 180°), with the daily mean value of the southerly wind ($\bar{V}_+$) about 2.0 m/s on individual longitudes while the multi-year mean is usually as high as 3.0 m/s. The difference is much more obvious in August, which plays an essential role in affecting the annual genesis number (Fig.4). Meanwhile, the cross-equatorial flow was especially strong from May to September over the region of the Somali jet stream (40°E – 45°E). From the map of mean wind field at 850 hPa covering rainy periods in China, we note that flows from the middle and higher latitudes of the Southern Hemisphere are travelling to the east coast of Africa, crossing the equator at the Somali jet stream and moving into the area of the Arabian Sea in northern Indian Ocean; it is then changed to a southwesterly monsoon under the condition of the Corialis force that passes over the Indian subcontinent, Bay of Bengal and Indochina Peninsula; some of the flows go into Yunnan, Guizhou and Sichuan by climbing over the Heng Duan Mountains while the others move into the south of China and Changjiang and Huaihe Rivers valleys via the northern part of the South China Sea, resulting in heavy rains over southern

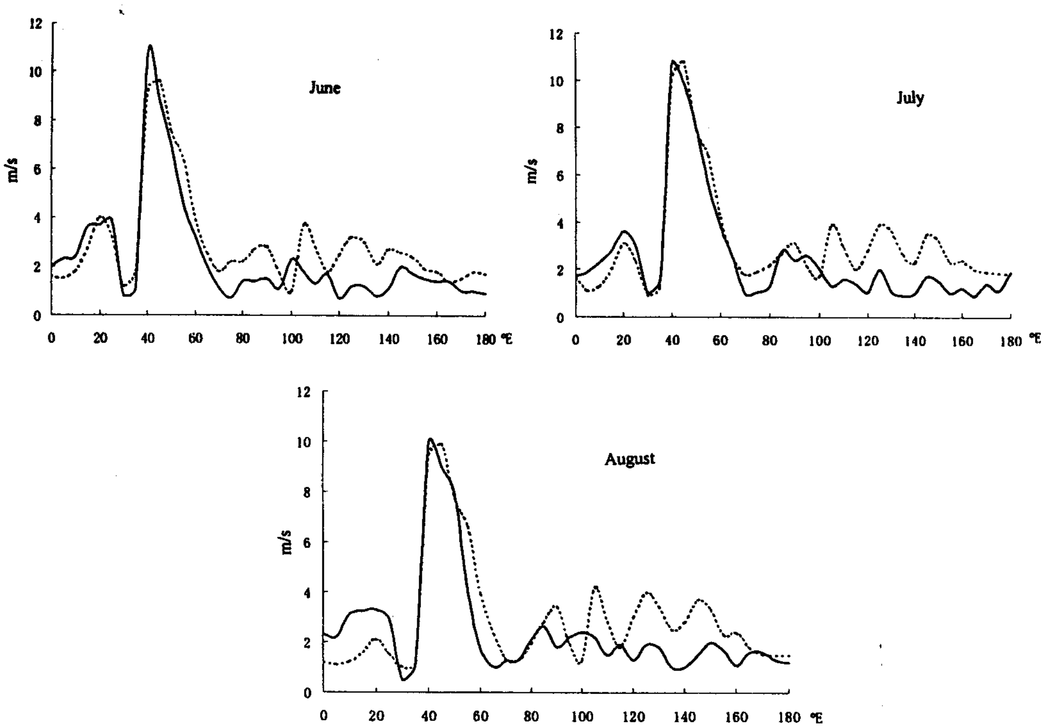

Fig.4 Comparisons between the V^+ value for daily mean cross-equatorial flows (southerly component) at 850 hPa in the Eastern Hemisphere in each month June through August in 1998 (solid line) and the multi-year mean for 1979 – 1995 (dashed line).

part of the middle and lower reaches of the Changjiang River and Changjiang and Huaihe Rivers valleys[7]. In our previous analysis, it is reported that in normal years the activity of cross-equatorial flows are “in phase” between the Indian Ocean (0° – 90°E) and western Pacific (90°E 180°). In other words, all components of the cross-equatorial flow can be strong or weak simultaneously in both regions. The year 1998 witnessed an El Niño episode that was the strongest over the past 100 years and caused anomalies in low-latitude general circulation so that the two parts of the cross-equatorial flow were no longer in phase — the component in the Indian Ocean region, especially over the Somali jet stream region, was particularly strong while the one in the western Pacific was particularly weak. The consequences: there were four tropical storms and four severe tropical storms generated in 1998 and only six typhoons with wind force above Level 12 on the Beaufort scale came into being (1/3 of the multi-year mean), making the lowest record of annual genesis of 14. In the meantime, the tropical cyclone source and active regions in 1998 are more westward than usual, which was closely related with the fact that the cross-equatorial flow was weaker in the east than in the west in the Eastern Hemisphere in the year.

5 ANALYSES OF EXCEPTIONALLY MORE HURRICANES IN ATLANTIC IN 1998

In the typhoon season of 1998, the number of western Pacific typhoons hit a record low since 1949 while the Atlantic number of hurricane genesis saw the highest record in recent years (14 hurricanes) in contrast to the annual mean of about 10. Fig.5 compares the distribution of cross-equatorial flow with longitude in the Western Hemisphere in 1998 with the multi-year mean over the period from 1979 to 1995. It shows the flow is much higher the multi-year climatological mean at 75°W and 40°W, about 2.5 times or 1.7 times as much as the latter, respectively. Furthermore, the first peak is not at 40°W where there is the first climatological mean peak but rather 75°W. Under such circumstances, the cross-equatorial flow, having crossing the equator at 75°W, comes to the Caribbean region where there are lots of shallow waters and islands, which favors the accumulation of latent heat energy[8] and is one of the regions with the highest frequency of hurricane genesis in the Atlantic as statistically calculated by Gray[9]. It is mainly why the Atlantic hit a record high over recent years of 14 hurricanes in 1998 and witnessed the formation of Hurricane Mitchell that caused huge amount of losses.

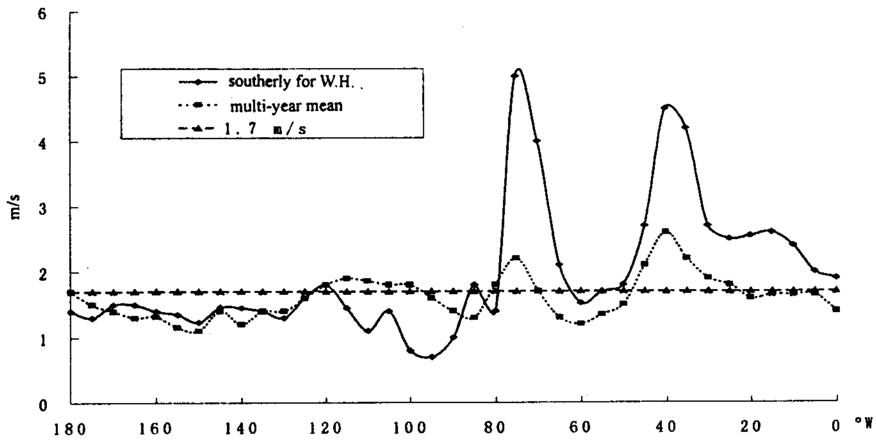

Fig.5 Comparisons between the distribution of the cross-equatorial flows with longitude in the summer (June – September) of 1998 (solid line) and the multi-year mean for 1979 – 1995 (dashed line).

6 CONCLUDING REMARKS

a. In the Eastern Hemisphere, the intensity of the cross-equatorial flow is very closely related with the genesis of typhoons over the northwestern Pacific. The flow is usually at its peak 2 days and 5 days before the genesis and 2 – 4 days after it.

b. The cross-equatorial flow at the Somali jet stream (40°E – 45°E) is more directly related with the genesis of tropical cyclones in the Northern and Southern Hemispheres. When the sum of the southerly winds at 850 hPa and 200 hPa for the region is large over the period from June to September, there are more typhoons over the northwestern Pacific; when the sum of the northerly winds at 850 hPa and 200 hPa for the region is large over the period from December to February, there are more typhoons over the south Indian Ocean and south Pacific. Vice versa.

c. The fact that there were extremely few geneses of typhoons over the northwestern Pacific in 1998 is mainly attributed to the extremely weak cross-equatorial flow between 90°E and 180° in the year.

d. The fact that the Atlantic had a record high for recent years frequency of annual hurricane genesis (14) in 1998 is made possible by exceptionally strong cross-equatorial flow at 40°W, especially at 75°W, in the year.

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