PRELIMINARY ANALYSIS ON THE STRUCTURE AND INTENSITY OF CONCENTRIC DOUBLE-EYE TYPHOONS

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ABSTRACT

Typhoon eye, one of the most outstanding features in the evolution of typhoon, has various complex configurations: circular, elliptic, oval, square, polygonal, or irregular shapes. It is very interesting to note that some typhoons show the concentric double-eyes encircled with two concentric cloud towers.

The concentric double-eye structure and intensity of typhoons are investigated and discussed by using reconnaissance aircraft data, radar echo photos and satellite images. 76 double-eye typhoons were observed during 1949—1983. The results indicate that the concentric double-eye structure, generally appearing in intense typhoons over the northwestern Pacific Ocean, is closely related to typhoon's intensity. This kind of structure has apparent characteristics in geographical and seasonal distributions.

Based on the observational data, an idealized structure model for the concentric double-eye typhoons is proposed.

I. INTRODUCTION

During the SOE TTE-3(Second Operational Experiment, Typhoon Tracking Experiment-3) of TOPEX (Typhoon Operational Experiment), it is found that Typhoon Forrest (8310) had the structure of concentric double eyes through the satellite image of GMS at 1300 GMT 24 September 1983. The reconnaissance aircraft report of 2312 GMT 23 September also indicated such a structure.

In the past, some aspects of certain concentric double eyes of hurricanes were studied (Chen and Ding, 1979; Hoose and Colon, 1970; Bao, 1980; and Willough by et al., 1982, 1984) with the result that some interesting features of the double-eye configuration were shown. This paper investigates the historical data (1949—1983) for typhoons with concentric double-eye structures. It is found that this kind of typhoon accounts for 6.0% of the total over the northwestern Pacific Ocean. One fourth or more of them generated over the ocean east to the Philippines and Taiwan of China, and were often observed in September—November. It is also indicated that these concentric double-eye typhoons are closely related to their intensity.

Based on the observation data, an idealized model of the structure of concentric double-eye typhoons is proposed.

II. SOME MAJOR RESULTS

Hourly satellite pictures from GMS during the period of TOPEX were employed to investigate the fine changes of typhoon structure. At 1300 GMT 24 September 1983 (Fig. 1), the satellite picture (IR) shows a visible concentric double-eye structure of Typhoon Forrest

(8310). About ten hours before, the reconnaissance aircraft report indicated that the diameter of the inner eye had been about 9 km, while that of the outer eye 20 km. The concentric double-eye structures were also observed in radar echo. Fig. 2 drawn from the photograph of radar scope at 1300 GMT 13 October 1975 shows a well-defined concentric double-eye, which is Typhoon Elsie (7514), with the centre being about 200 km away from Shantou Radar Station in China.

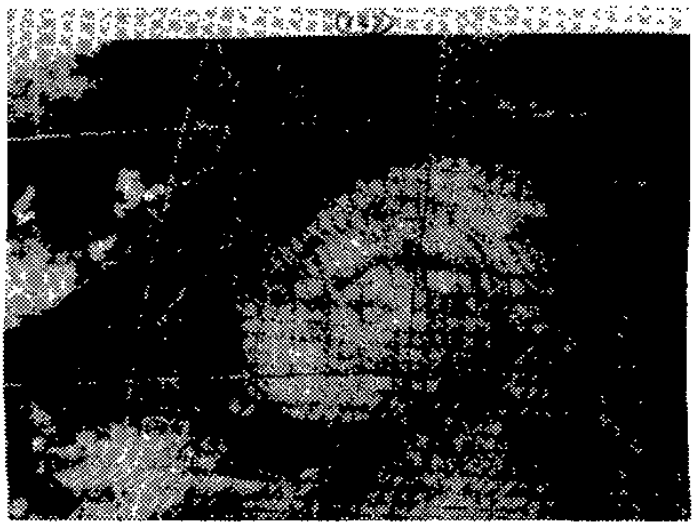

Fig. 1. GMS-2 IR image of the concentric double-eye Typhoon 8310 (Forrest), 1300 GMT 24 September 1983.

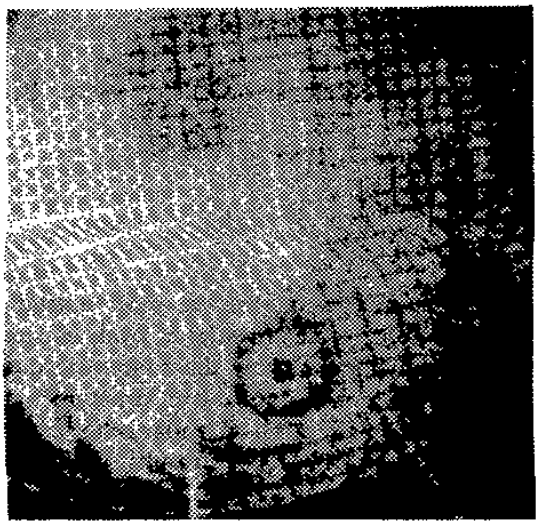

Fig. 2. Radar photography of the concentric double-eye Typhoon 7514 (Elsie) from Shantou Radar Station, 1300 GMT 13 October 1975.

Owing to the limitation of data obtained from radar and satellite, this paper mainly analyses aircraft observations on the typhoons during 1949—1983, and uses the satellite images and radar echo photos as reference material. There were 1268 typhoons over the northwestern Pacific Ocean during that thirty-five years, and 76 of them had concentric double-eye structures. A few of the 76 typhoons had two concentric cloud walls and a concentric circular cloud band and unclear eye areas. 59.2% of the 76 typhoons showed the double-eye structure only once during their life time. However, both Typhoons Karen (6221) and Billie (7008) showed the double-eye structure five times.

There were 134 reconaissance aircraft reports for the 76 typhoons. It is especially interesting that Typhoon 7519 (June) showed three closed concentric cloud walls, the diameters of these eyes being 9 km, 50 km and 75 km respectively.

(1) *The relationship between the concentric double-eye and typhoon intensity*

The concentric double-eye phenomena occurred in intense typhoons, the central pressure of which was always lower than 970 hPa and the maximum surface wind speed was larger than 45 m/s. Typhoons with their central pressure higher than 970 hPa do not have such structure. The analysis shows that the frequency of occurrence of concentric double-eye structure increases with the increase of typhoon intensity. Fig. 3 shows that the double-eye typhoons account for 76.9% of the intense typhoons with central pressure lower than 890 hPa. Among them there were six especially intense typhoons with central pressure lower than 880 hPa, namely, Ida in 1958, Nora (7315), June (7519), Rita (7822), Tip (7919) and Forrest (8310).

The lowest central pressure of Forrest (8310) was 876 hPa during the TOPEX. The double-eye structure was observed in Typhoon Forrest (8310). However before the 1960s, just a few double-eye structures, only accounting for 3.2% of the total, were observed because of the limitation of sounding technique.

(2) *The geographical distribution of the concentric double-eye typhoon*

Fig. 4 shows the geographical distribution of this kind of typhoon. It is found that one fourth or more of these typhoons mainly occurred over the ocean east of the Philippines and Taiwan of China (15°N—25°N, 120°E—130°E), where intense typhoons often occur and the tropical upper-tropospheric trough (TUTT) and an anticyclone outflow in upper level (200 hPa) frequently remain.

These facts indicate that the occurrence of the concentric double-eye typhoons is closely related to the developing regions of intense typhoons.

The other two regions where the concentric double-eye typhoon is likely to occur are to the south of Mariana Islands and near Ogasawara Islands, which may be related to the fact that some typhoons would intensify near the recurving point.

(3) *The monthly distribution of the concentric double-eye typhoons*

Fig. 5 shows the monthly distribution of this kind of typhoon. There were 42 times in September, that is to say, the concentric double-eye typhoons most frequently occur in this month. There were 25 times in November, next to September. It is further found that the concentric double-eye typhoons occurring in September-November account for 63.4% of the total.

These facts correspond to the fact that most intensive typhoons usually occur in autumn (Li and Wang, 1983).

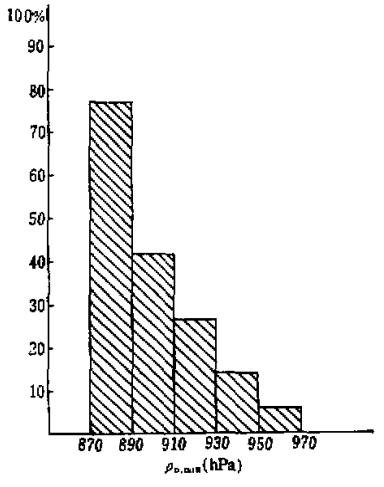

Fig. 3. The frequency of concentric double-eye typhoons as a function of typhoon intensity.

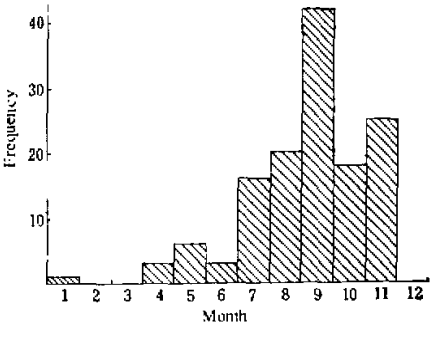

Fig. 5. The monthly distribution of the concentric double-eye typhoons.

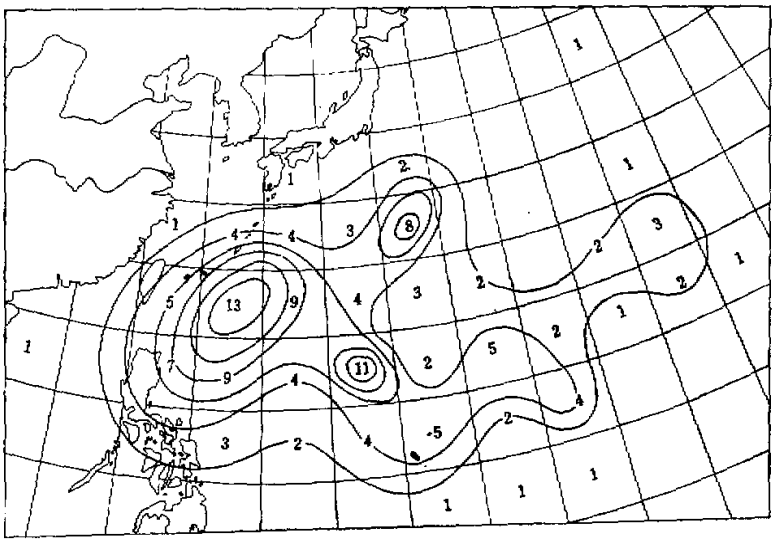

Fig. 4. The geographical distribution of concentric double-eye typhoons.

(4) *Model of the concentric double-eye configuration of typhoons*

The analysis on the 134 observations shows that the diameter of the inner eye (d_1) is between 5 km and 65 km with the average of 24.5 km, and that of the outer eye (d_2) is between 20 km and 165 km with the average of 75.1 km. The limited available data about the height and thickness of double cloud walls show that the height of the outer cloud wall is twice of the height of the inner cloud wall. The averaged height of the inner cloud wall (H_1) is 4.2 km, and that of the outer cloud wall (H_2) is 8.3 km. In general, the outer cloud wall is wider than the inner one. The averaged width of the latter (W_1) is 8.7 km, and that of the former (W_2) is 12.6 km. This indicates that the outer cloud wall of the concentric double-eye typhoon can develop more intensely than the inner cloud wall, and so does the convection in the outer cloud wall.

Fig. 6 shows the idealized model of the concentric double-eye typhoons. In the upper part of Fig. 6, the three-dimensional cloud pattern of the concentric double-eyes is depicted. In the lower part of Fig. 6, the vertical cross section of the cloud pattern is depicted. The heavy and light vectors indicate the strong and weak vertical circulations respectively. The convergence at the low level of typhoons is concentrated near the outer cloud wall, where the ascending flow is strong. On the other hand, the divergence outflow at the upper level is also strong, which is usually accompanied with cirrus divergence as seen in the satellite picture. The descending currents are dominant in the big-eye area. For some intense typhoons, the well-developed convergence currents at the low level will not only maintain the convective development of the outer cloud wall, but will also flow into the eye area and join in the descending flow. It will generate another ascending flow to develop the convective cumulus in the eye. Under the effect of this cyclonic vortex circulation, the inner eye gradually forms and the inner cloud wall is organized. The convectional circulation of

the inner cloud wall can not develop very intensely due to the restraint by the descending flow in the big-eye area. The divergence currents at the top of the inner cloud wall flow outwards with the descending flows in the inner and outer eyes. Thus it can be seen that the vertical circulation of the concentric double-eye is much more complex than that of a single eye.

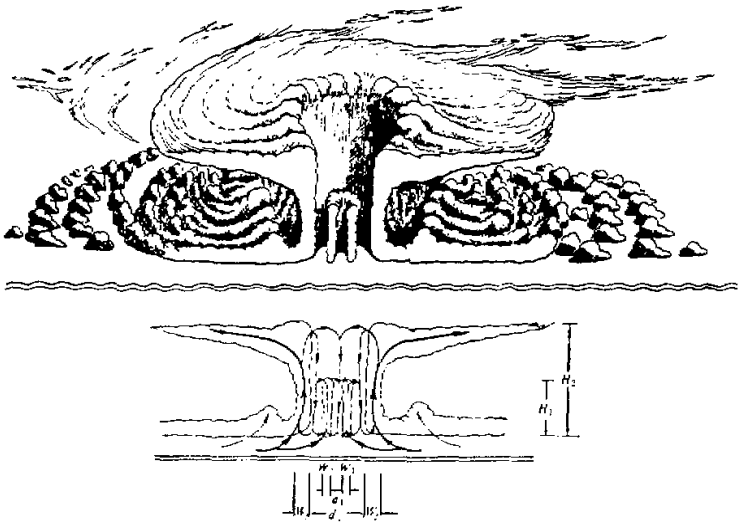

Fig. 6. An idealized model of the concentric double-eye typhoon.

III. DISCUSSION

(1) The concentric double-eye typhoon is closely related to the intensity of typhoon. It is useful for us to forecast the change of the intensity of typhoon.

It is especially interesting that among the 134 observations with such concentric double-eyes some showed the double-eye structures before or after typhoons reached their maximum intensity. In general, when the structure of typhoon eye changes from double to single typhoon appears to be intensifying.

(2) The formation process of the double eyes is quite complex. Sometimes, double eyes are formed as the inner eye region gradually extends and convective cumulus in the eye develops. Sometimes, as a result of development of spiral cloud band outside the eye wall, a well-closed outer eye is organized. Sometimes, the formation of the outer eye wall is accompanied by the shrinking in the diameter of the original eye. So far, no data are available for the investigation of the process of their formation.

(3) It is possible to reveal the complex and fine changes of the concentric double-eye structure through the enhanced observations by radars and satellites. For instance, Shantou Radar Station has observed the complex changes of Viola's concentric double eye (Typhoon 6903).

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