

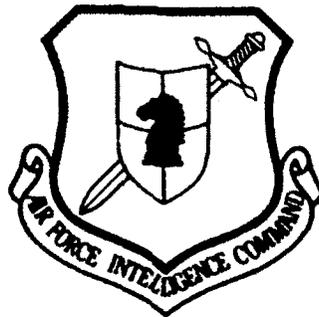
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by

Cheng-lan Bao, Rong-mao Wei, Chang-hua Huang



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THE ACTIVITIES OF EQUATORIAL ANTICYCLONES OF WESTERN PACIFIC
AND SOUTH CHINA SEA AND THEIR EFFECTS ON THE TRACKS OF
TYPHOON MOVEMENT¹

By Cheng-lan BAO, Rong-mao WEI and Chang-hua HUANG
(Tropic Weather Advance Class, Department of Meteorology,
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ABSTRACT

This paper carries out a preliminary investigation and analysis of the activities of equatorial anticyclones over the Western Pacific and South China Sea. They occur on average 8 times a year and are mostly concentrated during the months of June-September. An equatorial anticyclone is a tropical weather system of meteorological magnitude of 1,000 - 2,000 km. It can continue on for a few days. It is a kind of a warm and high pressure system, and is often related to a fair weather system. The equatorial anticyclone clearly has an effect on the development of the typhoon genesis and the track of its movement. Once a deep, thick and strong equatorial anticyclone appears to the South of a typhoon, the typhoon often seems to search for its path. However, the actual track of the typhoon is determined by the high pressure cooperative activities of the equatorial anticyclone and subtropics. This paper also presents several typhoon tracks for analyses.

ONE

Equatorial anticyclones show up in the equatorial region of low latitudes, south of 15 - 10°N, being developed and activated to make counterclockwise rotations (in the northern hemisphere, clockwise), forming a closed

* Numbers in margins indicate foreign pagination. Commas in numbers indicate decimals.

¹ Received August 24, 1977

circulation in the region of low latitudes of the Western Pacific and South China Sea. Usually one can observe the activities of equatorial anticyclones because they have such a strong influence on the genesis and development of typhoons, and even their tracks [1][2]. The South China Weather Forecast Station of our country predicted the saddle shape in the middle of 3 heights; that is, there were 3 high pressure anticyclonic circulations around the South Sea, in the middle of the Pacific, Central Indian Peninsula, and Indonesia-Kalimantan Island, because the South Sea is located in the saddle shaped region among the 3 heights. The 2 former high pressures were 2 circular subtropic heights, while the high pressure of the Indonesia-Kalimantan Island is an equatorial anticyclone. Such an environment is most susceptible for low elevation disturbances in the region to develop a typhoon out of it [3]. In the middle and later parts of August of 1960, a typhoon environ was created (Fig.1) to allow 3 typhoons, namely Nos. 6014, 6015, and 6017, to circulate at the Western Pacific moving northward, while typhoon No. 6016 was created in the South China Sea, reversing itself from the northern track to turn eastward into Bass Strait and then moving northward to cut into the westward direction ending up at China's 2 provinces of Taiwan and Fukien. The cause of this was that, except that there was a subtropic height in the Western Pacific which tilted either east or north, there was a strong equatorial anticyclone in the Western Pacific with a northward action. Thus, it pushed the whole tropic typhoon group northward, to cause the early eastward movement of Typhoon No. 6016 in pushing it out of the South Sea.

This paper makes a preliminary investigative analysis by use of the equatorial meteorological data collected during the months of May-October in 1973-1976 and then studies their effects on the typhoon tracks.

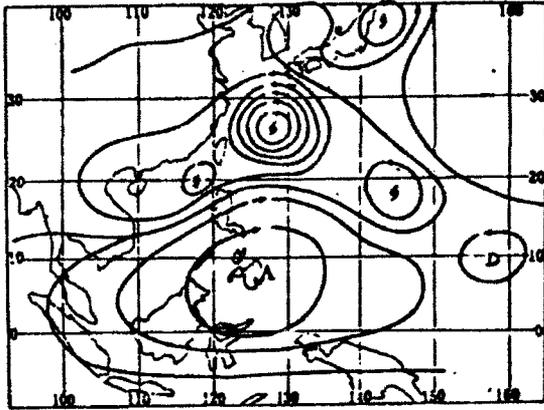


Fig. 1. The shape of 850 mb current fields on August 21, 1960 at 08 0'clock.

TWO

In this investigative analysis, we determined that the center of the clockwise circulation was at the equatorial region (or at the time it could also be the center of the high pressure zone) staying there for 3 days, during which at least for 1 day the high pressure center had reached northward to 3 - 5°N in completing one activity cycle of the equatorial anticyclone. In general, equatorial anticyclones seem to be different from their appearance on land, and they become very distinctive at 850, 700 and 500 mb; especially at 500 mb they are very sharply defined. Thus 850 mb could be taken as the main investigative point, while 500 mb was taken as the secondary point. However, when a study of the effect of the equatorial anticyclone on the typhoon tracks was to be carried out, especially in calculating the spatial average of the air current induced by the rotation of the earth, 500 mb was taken as the principal point.

TABLE 1.

	5 月 ^②	6 月	7 月	8 月	9 月	10 月
1973 年 ^①		6.12-6.16 6.23-6.26	7.12-7.20 7.22-7.25	8.7-8.17 8.30-9.5	9.8-9.11	10.5-10.11 10.11-10.18
1974 年		6.5-6.12 6.13-6.18	7.2-7.10 7.15-7.22	8.14-8.18 8.23-8.30		10.20-10.25
1975 年			7.3-7.8 7.11-7.15	7.31-8.11 8.15-8.18 8.20-8.23	9.3-9.9 9.20-9.26	
1976 年	5.3-5.11 5.17-5.26	6.1-6.13 6.22-7.4	7.12-7.17 7.20-7.26	7.29-8.13 8.16-8.22	9.18-9.30	

Key: (1) Year; (2) Month - 5 = May, 6 = June, etc.

Based on the above decision, during the months of May-October in 1973-1976, 32 equatorial anticyclones appeared in the region of the Western Pacific and South China Sea, 8 times a year on average (see Table 1). Equatorial anticyclones appeared most frequently in the northern hemisphere during the heat of Summer in June-September, and the early appearance occurred in the early part of May, while the latest one was in the latter part of October. From one calculation a day, the positions of total 208 equatorial anticyclones were obtained. 71.6 % of them appeared in the region of 0 - 10°N and 108 - 130°E, which is known as the end of the equatorial air circulation [4] passing from Australia through Indonesia. Every time when a strong equatorial anticyclone was generated and developed, usually Australia went through a process of rising high pressure and then a cold high pressure activity for one time. We analyzed the change of the maximum wind velocity in the second half of June, 1976 and found that the maximum east-southward wind velocity started from 10 - 15°S and 120 - 135°E to spread directly into 5 - 10°N and 105 - 120°E, then after crossing the equator it turned into a southwest wind. At the same time in the second half of June, a corresponding strong equatorial anticyclone developed. Based on

this fact there seemed to exist a relationship between the generation and development of equatorial anticyclones in the northern hemisphere and the east-south storm of cold high pressure in the southern hemisphere which passed through the equator. However, due to a lack of data from the vicinity of the equator for an investigative analysis, a definitive and affirmative conclusion cannot be yet made at this time.

The life-cycle of an equatorial anticyclone was in general 4 - 9 days (which took up 78.2 %) but the largest one reached 16 days, and the altitude for the most frequent occurrence of equatorial anticyclones was usually below 1,000 - 2,000 km, although a few of them reached above 3,000 km, but a few stayed within a few hundreds of miles. Some of the equatorial anticyclones could develop into the upper layers of the convection current, but most of them were present in the lower and middle layers of the convection current, and some of them could exclusively show up only in one of the layers. At the same time one can see from the source of genesis that a predominantly large number of the equatorial anticyclones were generated and developed in the warm equatorial region and then moved northward. A small number of them were formed as independent small circulations at the subtropic region in the ridge area which stretched out in the southward direction, and then as a rule they moved southwest close to the low latitude region of the equator. Between them and the main subtropic region there was a tropical propagation band, and there were 4 equatorial anticyclones which were formed in this manner. Quite a few equatorial anticyclones reached the subtropic region.

From all these data, one can see that an equatorial anticyclone cannot be compared with a subtropical high pressure as observed on the spatial scale at sea level, nor by the vertical degree of thickness during its exist-ence.

An equatorial anticyclone is a kind of tropical weather system on a meteorological scale, which can persist for several days in the region of 1,000 - 2,000 km. However, it has a relation with a subtropical region due to the fact that they can change into each other.

THREE

We selected 3 northward equatorial anticyclones in the vicinity of 10°N, which had become strong and thick, for analysis in order to reach some conclusion on their characteristics. These 3 examples are as follows: June 28, 1976, August 2, 1976 and October 9, 1973. Fig. 2 shows one of them, an especially prominent one. It was an equatorial anticyclone of June 28, 1976, starting out at 850 mb, developed directly to 200 mb (the other two also stretched above 400 mb); the class of development was extremely thick. The center of the high pressure tilted in the northeastern direction a high altitude, and the distance between the high and low layer was more than 6 - 8° in latitude. The altitudes (at 151, 317, 592, 765, 976, and 1252 potential equivalent meters) of the isobaric surfaces around the center of the 98645-station were higher than those of the nearby 91413-station (149, 313, 586, 758, 969 and 1243 potential equivalent meters). The height of the equatorial anticyclone center was comparable to that of the center of the subtropical height. Furthermore, the center of an equatorial anticyclone joined up with the warm center of the temperature field or with the warm tongue shape, which was most obvious in the middle and lower layer of the convection current layer. At 500 mb, the equatorial anticyclone and the center of No. 7607 Typhoon to its north by about a distance of 15° latitude were both the warm temperature centers of -1°C and 0°C, respectively, but

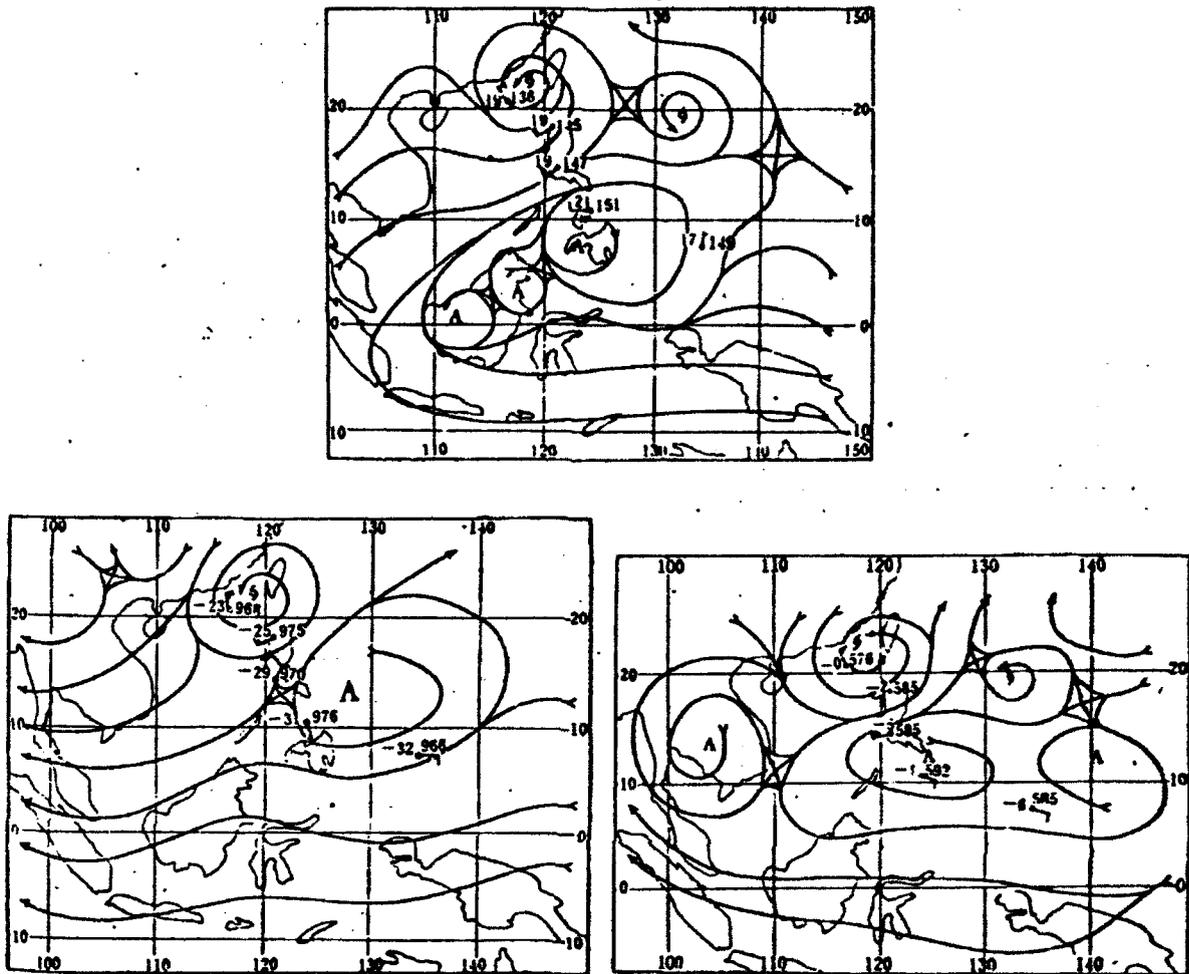


Fig. 2 The weather diagrams of various layers at 08 o'clock on June 28, 1976

between them there was a -5°C cold temperature cutoff zone. However, at 400 mb, the equatorial anticyclone rotated faster to produce a cold region and thus the temperature difference with respect to the warm center region of the typhoon was quite large. Furthermore, in the middle and lower layer below 500 mb, the equatorial anticyclone was separated out from the bottom part of the typhoon, but above 400 mb, these 2 slowly merged together to form one system. Below 500 mb, the 98327-station at the north of the equatorial anticyclone was under a strong southwest wind of 16 - 20 m/s, but above 400 mb there was no strong west-south

wind. One can see that an equatorial anticyclone could extend vertically up to the 200 mb surface, yet as viewed from the structural characteristics there should be some difference between the upper and lower layer. It was even possible that the middle and lower layer could be independent equatorial anticyclone systems, but at the higher layer it combined with the subtropical region. On this point, one needs more data to substantiate it.



Fig. 3 The satellite cloud picture on June 28, 1976.

An equatorial anticyclone is always related to a fair weather system. Fig. 3 is a satellite cloud picture on June 28, 1976. It was the area of an equatorial anticyclone between the cloud system of No. 7607 - 08 Typhoons and the cloud system of the southern hemisphere; it was indeed a wide south-north sweep covering more than 10° in latitude, forming a large ellipsoid, in which there was a cloud free zone shown by a deeply darkened color region with a few places of convection cloud systems. This explains that when an equatorial anticyclone had completely developed, it looked very similar to a subtropical region according to the characteristics shown by the satellite picture. Sometimes,

when an equatorial anticyclone (a warm storm track) was pushing northward, it could create intermittent fair, warm and dry weather which could last more than half a month during the regular rainy west-south storm season in the central India Peninsula [5].

FOUR

The activities of equatorial anticyclones very definitely can affect the genesis and development of typhoons, and also their tracks, but here stress is given only to the effect on the typhoon tracks. During the activities of a total of 32 equatorial anticyclones, in 22 active periods either there was no typhoon in the Western Pacific and South Sea, or equatorial anticyclones were so weak that they could occur only in a certain localized surface; or equatorial anticyclones in all of the layers did not reach to the north further than 5°N; as a result no effect was created on the tracks of typhoons. In other 10 equatorial anticyclones which were relatively deep, thick and strong, all layers between 850 - 500 mb were affected; the upper and lower mixing was good, and furthermore the center moved to the north of 5°N, and such equatorial anticyclones had an important influence on the genesis of typhoons of the Western Pacific and South Seas as to open the tracks for them. In these 10 cases, one was exceptional; that is, the equatorial anticyclone of July 15 - 22 of 1974 was quite deep and thick, and furthermore it moved to the north of 5°N, but it did not affect the tracks of typhoons No. 7410 - 7411. The reason was that even though the equatorial anticyclone was sufficiently well defined in all the layers, its southwest wind at the northern side did not exceed 7 - 8 m/s even at its maximum. This fact showed that its power was not enough to guide the air currents of the

typhoons. Among the well defined equatorial anticyclones (whose maximum speed of southwest wind all exceeded 12 - 16 m/s), this was uniquely an exception.

We selected several examples to explain the effects of equatorial anticyclones on the typhoon tracks. To determine the controlling behavior of a circulation field over typhoons, we used the Tong-Ke-Jin method [6] to calculate the spatial average of air currents induced by the earth's rotation. First the main body of the typhoon current field is to be eliminated from the 500 mb altitude field; then with the maximum radius of the typhoon taken as the radius, a circle is drawn and the altitude values inside this circle are to be discarded. The average value from 4 points of east, west, south and north is taken as the value at the center; by use of these 5 points as well as the altitude values outside the circle, interpolations are made to obtain the altitude values of various lattice points inside the circle. Afterwards, the values from the 6 corners of a regular hexagon are taken in working out the average as the spatial average of the lattice points. Lastly, the average equal altitude lines are to be analyzed. In this way, one can filter out small turbulence and obtain the spatial average of air currents which are induced by the rotation of the earth without including the circulation field of the equatorial anticyclone circulations. The typhoon will move along the induced air currents.

(1) TYPHOON NO. 7607 - 7608

Typhoon No. 7607 possessed a uniquely rarely seen track. It moved west-northly from the Western Pacific, passing Luzon Island of the Philippines, to enter the east-northern section of the South Sea, and on June 27 it

reached the west-southern end of Pratas Islands about 100 km from sea level. From the force picked up along the track, it could make a straight run in the west-northly direction, to hit the land from the west at the Pearl River entrance. However, just on June 27, Typhoon No. 7607 suddenly turned eastward from the west-northly path, and in half a day it swept 120-150°. Finally on June 29 via Bass Strait it left the South Sea. Typhoon No. 7608 also showed similar characteristics in making a sudden directional turn toward the east-northly passage, but the only thing was that the whole path veered eastward by 15°, and a day later it cut into the Pacific. The main reason for Typhoon Nos. 7607 and 7608 changing direction is as follows: From the 26th to the 28th of June, there was clearly a strong equatorial anti-cyclone present to the North of the Philippines' southern Mindanao Island, where the northernmost point it reached was 12 - 14°N (Fig. 4). Along with this, the western shoulder

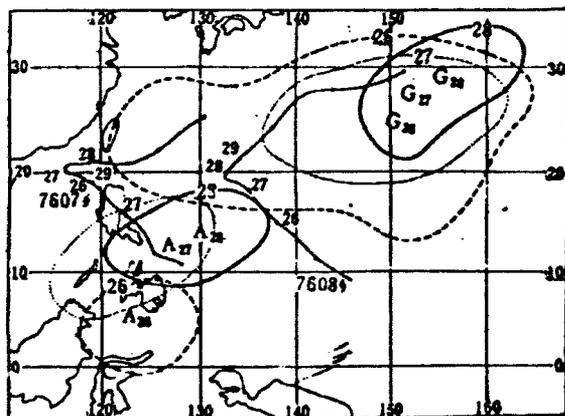


Fig. 4 The diagram of the overall situation of the 588 lines during the period when Typhoons Nos. 7607 and 7608 were making sudden turns.

of the 588-subtropical high pressure lines started out from Taiwan Province at 120°E to reach the ocean surface directly at 147°. The high elevation air current of the Western Pacific - South Sea started from the south side of the sub-tropical region as an east-east south wind, but made a rapid change into west-west south wind at the north side of the

equatorial anticyclone, and thus eventually guided Typhoon No. 7607 on June 27 and Typhoon No. 7608 on 28th to make another sudden turns in the east-east northly direction.

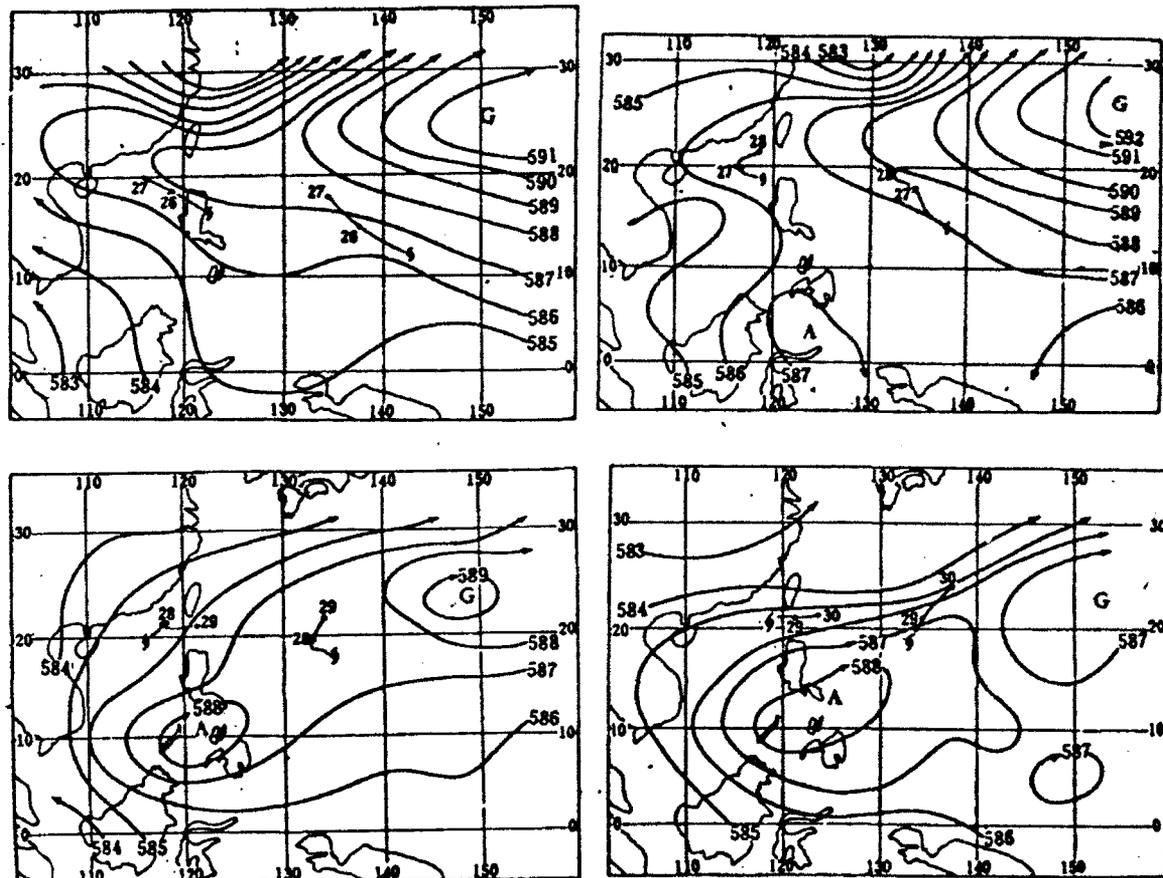


Fig. 5 The induced air currents due to Typhoons Nos. 7607 and 7608.

The change (Fig. 5) of the air current induced by the earth's rotation can be seen clearly by spatial averaging. Before June 25, the equatorial anticyclone was to the south of 5°N, its force was not strong, Typhoons Nos. 7607 - 08 were completely under control by the east-south air flow at the south side of the subtropical region, and moved in the west-northly direction. On 26th, the equatorial anticyclone started to get strength, which was being felt at Mindanao Island as well as at its southern current field, but the

influence did not spread further than 10°N. On reaching June 27, the situation suddenly changed. The secondary current field spread east to reach 140°E, but Typhoon No. 7608 continued west-northward even under this influence. Then in the vicinity of the Philippines, the equatorial anticyclone current field was further strengthened to make a northly move, the induced air current at the east-northern section of South Sea had already changed to west-west south. At this time, Typhoon No. 7607 made a sudden turn to move to the east, on June 28 the subtropical region also made a move to spread eastward, and the whole low latitude region of the Western Pacific was under the control of the equatorial anticyclone which had grown huge. Typhoon Nos. 7607 and 7608 were controlled by the west-west southwest air current from the north side to make them move in the east-east northward direction. One can see that the tracks taken by Typhoon Nos. 7607 and 7608 with the sudden turns were clearly due to the eastward motion of the subtropical region as well as the northly movement of the equatorial anticyclone.

(2) TYPHOON NO. 7315

Typhoon No. 7315 has become famous lately. Its central air pressure on October 6 reached 875 mb even at the lowest point which certainly is a record. Before October 7, the typhoon moved basically westward to hit the east shore of Luzon Island, but on the 7th it made a sudden turn to north-north west to reach the east-northern section of the South Sea, making a landing at Macao on October 10 and wrecking havoc there. The track of Typhoon No. 7315, according to the forecast, made a sudden important turn at 60 - 70° around the 7th. The causes were the equatorial anticyclone

which was moving northward, and the effect of the subtropical region.

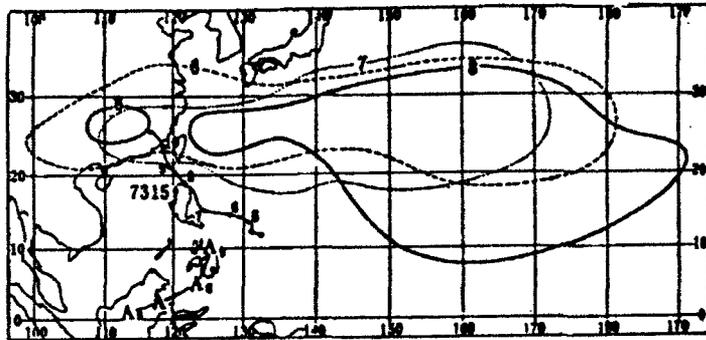


Fig. 6 The overall situation diagram of the 588 lines at the time when Typhoon No. 7315 was making turn.

Around the time that Typhoon No. 7315 was making a turn, the subtropical region was roughly eastward but was staying as a whole within 25 - 30°, and the 588 lines were spreading out in bands toward the east. Typhoon No. 7315 was directly to the south of the subtropical region (Fig. 6). Before the 7th, the equatorial anticyclone was around the equator and thus the typhoon was only guided by the subtropical region toward the west. During the 48 hrs of the 7th - 9th, the equatorial anticyclone was located to the south of the typhoon moving from 2°N east-northly to 10°N. It gained strength, the area it covered extended, it started to act in cooperation with the subtropical region, to raise the altitude of the eastern side of the typhoon higher, and the induced air current became a south-east south air current. As a result, during these 48 hours, Typhoon No. 7315 was pushed north by northwest to move from 15°N to 20°N and to enter the east-northernmost section of the South Sea.

(3) TYPHOON NO. 7610

On the whole, Typhoon No. 7610 took a very ordinary track moving west-northly to make a landing. The special points were that on July 23 after it landed at Zhing-hai County of Hainando Island, passing the east-northern tip of Hainando, on the early morning of the 24th it suddenly turned east leaving Wen-Chong County for the sea; on the 25th it returned west-northly, and on the 26th it made a landing at Yang-Zhiang County to disappear inland. Basically, an equatorial anticyclone was there at Kalimantan Island moving northly to reach 8 - 10°N to receive an induced air current at the west-northern section of the South Sea starting out as a weak air current on the 23rd south by southeast but suddenly turned into a west by southwest air current on the 24th, to push the track of Typhoon No. 7610 making a short eastern trip out to the sea. Subsequently, on the 25th, although the air current of the equatorial anticyclone basically did not change, yet the subtropic height of the Pacific pushed the backside of Typhoon Nos. 7611 and 7612 making strong western stretches, and consequently, Typhoon No. 7610 received control of the southly air current, and finally turned west-north in making the landing at the west of Macao.

(4) TYPHOON NO. 7308

At the time when Typhoon No. 7308 was being formed (10 - 13th of August), it stayed at 500 km above sea level east-south of Okinawa, turning around and around for 2 times. This was due to the strong northern subtropic region which was moving eastward to be weakened, the equatorial anticyclone at the south increased its strength slowly moving eastward, and these 2 high pressure systems were

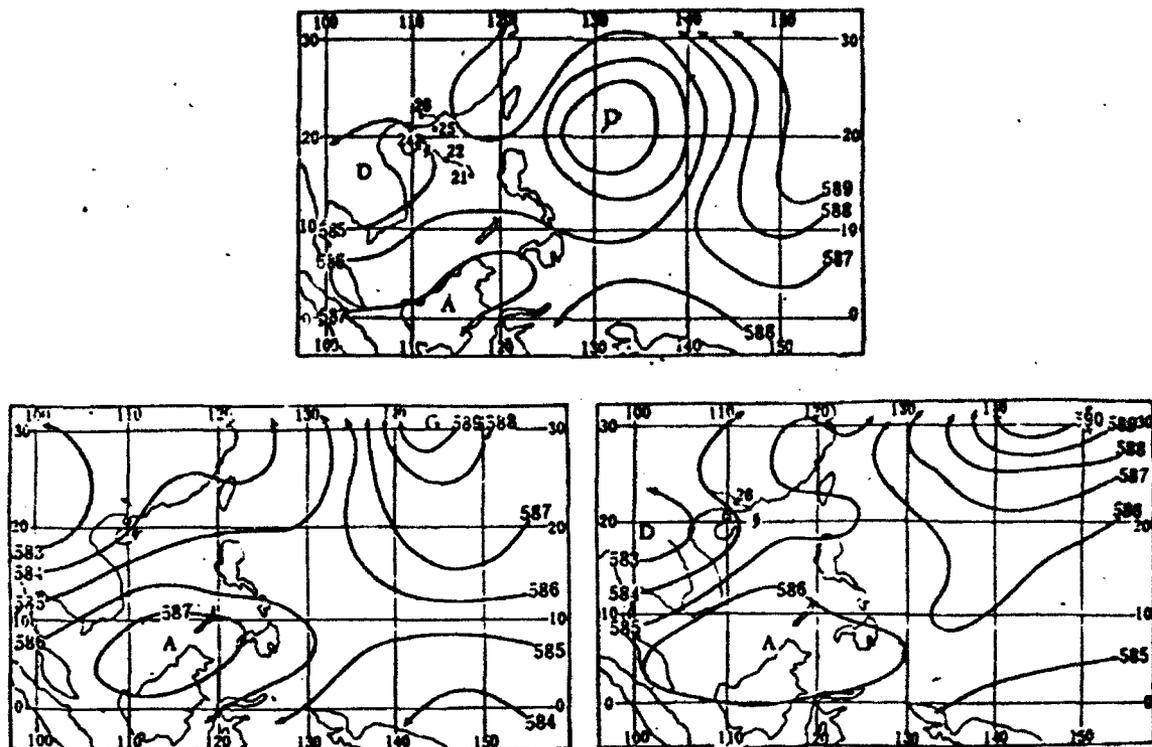


Fig. 7. The induced air current of Typhoon No. 7610.

comparable in strength. The typhoon was located between these 2 high pressures at the isobaric area, to allow the external forces canceling each other out to disappear, while the induced air current weakened. As a result, Typhoon No. 7308 stayed at the isobaric spot turning around and around, as shown in Fig. 8.

(5) TYPHOON NO. 7414

Typhoon No. 7414 was a relatively weak typhoon. To its north there was strong Typhoon No. 7413, and to its south there was an equatorial anticyclone. Under the control of both these 2 systems, Typhoon No. 7414 turned east as soon as it was formed, then it turned north to be weakened to disappear in the southern Japanese Sea, as shown in Fig. 9.

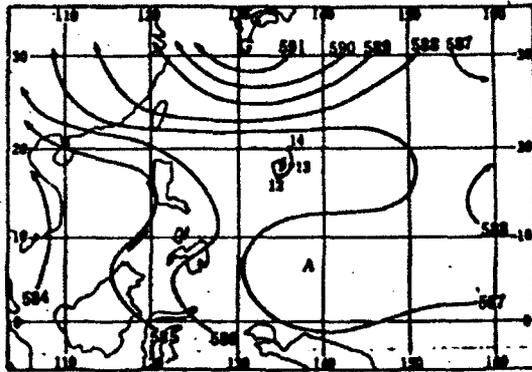


Fig. 8 The induced air current while Typhoon No. 7308 was turning around and around.

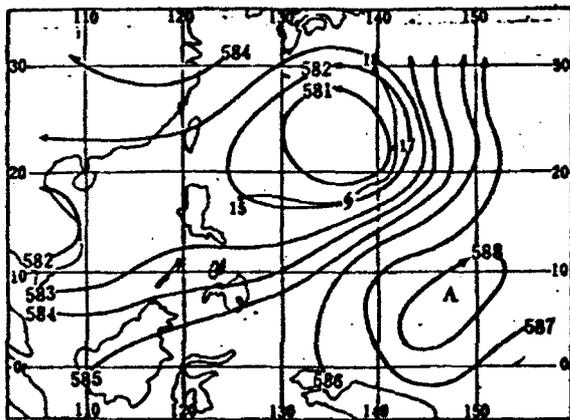


Fig. 9 The induced air current of Typhoon 7414.

Typhoon No. 7413, however, was not affected, because Typhoon No. 7414 was blocking the equatorial anticyclone, but it received control from the strong northern subtropical region to make a westward landing at Zhejiang Province.

In summary, once the activities of a strong equatorial anticyclone appears to the south of a typhoon, often it makes the track of the typhoon turn its direction, and a westward movement can turn into a east-east northly direction, thus some unusual tracks could appear. However, actual tracks of typhoons are really determined by the

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