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DEVELOPING AND NON-DEVELOPING TROPICAL CYCLONES AS REVEALED BY HIGH DENSITY CLOUD MOTION WINDS

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ABSTRACT: An algorithm for computation of cloud motion winds has been developed at the National Satellite Meteorological Center in China. Since 1997, it has been applied to calculate the cloud motion winds for a 1.25 lat. ×1.25 long. mesh over the northwest Pacific region with the satellite data from GMS-5. The development of the tropical cyclones is studied. It shows that the tropical cyclone is usually intrigued by the westerly jet streams at the upper levels of the troposphere, which may be caused by mid-latitude troughs well extending into the tropics. During the prime season of summer, the westerly flowing equatorward of the TUTT may also be a cause for the generation of typhoons.

Key words: cloud motion winds; tropical cyclones; developing westerly jets; middle latitude troughs; TUTT

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1 INTRODUCTION

Predicting the development of the tropical cyclone is a major task of the forecaster in the regions where the storm is active. It is also one of the challenging work for scientists involving with the research. Much work has been done in this aspect. The CISK theory[1], for example, holds that one of the fundamental conditions for the development of tropical cyclones is that there are cyclonic inflows on the synoptic scale in the lower levels of the troposphere. Making comprehensive analyses of the rawinsonde data, Gray[2] indicates that the pattern of circulation in the upper troposphere decides whether the tropical cyclone develops or not. Prevailing in the upper troposphere of non-developing tropical cyclones are airflows that travel in a homogeneous direction, which increases the vertical shear in the troposphere by which relevant cloud clusters are present. On the other hand, multi-directional outflows are usually found in the upper tropospheric layers of developing tropical cyclones, which favor not only the weakening of vertical shear in the cyclone but also the inflow of cyclonic angular momentum[3]. On the basis of aircraft reports and cloud motion winds measurements, Sadler[4] points out that developing tropical cyclones are associated with outflows going in a number of directions around the tropopause.

There is a point that much of the previous work has all agreed on and it is that the multi-directional outflows are a prerequisite condition in the upper troposphere right above a developing tropical cyclone. Two problems, however, remain to be solved:

(1) Are the outflows resulted from low-level inflows as argued in the CISK theory or are they supplied by the environmental field?

(2) Are the observations dense enough to enable the forecaster for tropical weather to diagnose the circulation situation of the upper levels of the troposphere needed in studying the devel-

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opment of the tropical cyclone?

There has not been sufficient amount of data up till the present to cope with these questions as far as the low latitudes of the northwest Pacific are concerned. The rawinsonde stations are scarcely distributed and unconventional aircraft reports and satellite cloud motion winds are available only with low intensity.

Recently, an algorithm for cloud motion winds has been developed at the National Satellite Meteorological Center (NSMC) of China, which performs superbly in the reduction of computation[5]. With the algorithm, the NSMC is successful in deriving high-density cloud motion winds on a mesh of 1.25 lat. × 1.25 long. in the northwest Pacific with the aid of GMS - 5 satellite imagery. It is with this dataset that the viewpoint about tropical cyclones developing in the region has been justified. The paper describes the result of our study. The second part of the work gives an account of the abnormal activity of tropical cyclones in the summer of 1998. The third part probes into the upper-tropospheric environmental flow field associated with the potential for a tropical cyclone to develop. The fourth part offers a number of observed cases, which clearly indicates that the multi-directional outflows above the storm are powered by the environmental flow field. The fifth part discusses and summarizes what we have worked on.

2 ANOMALOUSLY FEW TROPICAL CYCLONES IN NORTHWEST PACIFIC IN SUMMER 1998

Tropical cyclones are very inactive in the northwest Pacific in the summer of 1998. By the end of August, only 3 tropical cyclones have been coded, being contrast to 6 in normal years. What causes such limited appearance of tropical cyclones within the region in this period? Let's see if the SST and circulation are normal at the time. Fig.1 is the distribution (a) and anomalies (b) of SST in July 1998 as published by NOAA. As clearly shown in Fig.1a, the values of SST in July 1998 all go above 26°C in the northwest Pacific region that is south of 28°N and west of 180°. Such temperatures are higher than the critical SST required in the generation of tropical cyclones. In Fig.1b, we can find that the SST anomalies are positive in most of the northwest Pacific and so are the cases in June and August of the year. It is, however, hard to explain the observed fact that tropical cyclones were very inactive in the northwest Pacific in the summer of 1998 if only the SST and its anomalies are used.

Fig.2 gives the monthly mean vectors of cloud motion winds in the upper layers of the troposphere as computed at NSMC for July 1998. It shows that the easterly winds prevailed in the

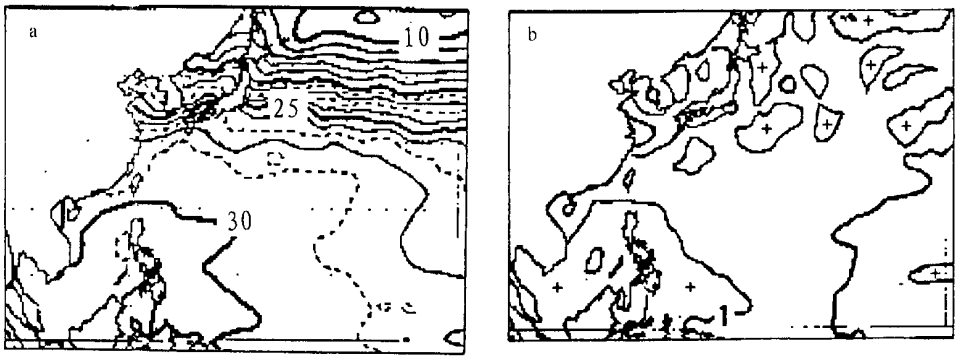

Fig.1 Distribution of SST (a) and anomalies relative to multi-year mean (b) in July 1998

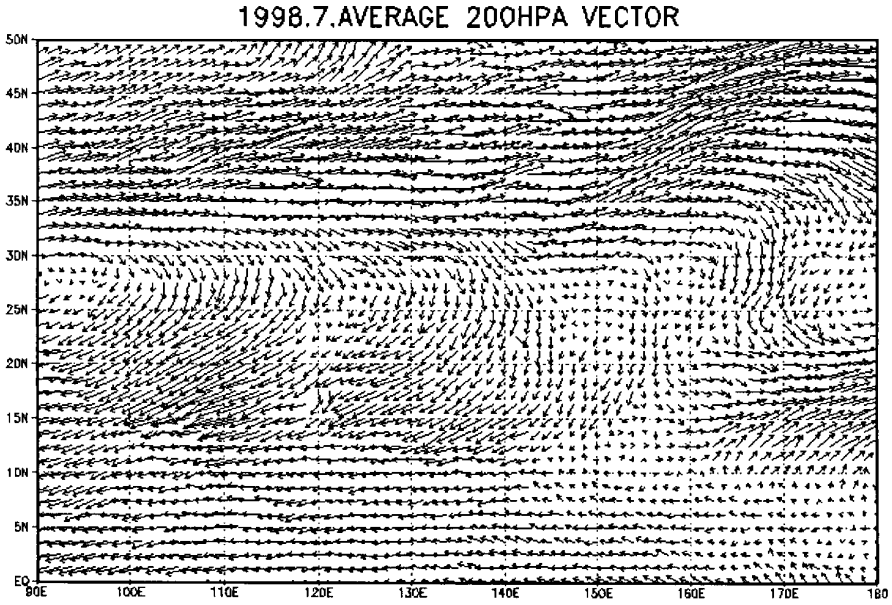

Fig.2 Monthly mean cloud motion winds in upper troposphere of northwest Pacific in July 1998

month in the low latitude area south of 28°N and west of 160°E; the monthly mean SST is higher than 30°C near the Philippines; monthly mean easterly surpasses 20 m/s. Similar cases are found in June and August 1998. The anomalies of the general circulation can be explained by low frequency of tropical cyclones in the northwest Pacific in the summer of 1998.

3 ENVIRONMENTAL FLOW FIELD OF UPPER TROPOSPHERE ASSOCIATED WITH DEVELOPING & NON-DEVELOPING TROPICAL CYCLONES

Fig.3a, 3b & 3c are the cloud motion winds in the upper levels of the troposphere at 00:00 GMT August 25, 1998, as derived from the NSMC. For this level of time, the tropical storm Rex is officially named. Lying in the middle of Fig.3c is the cyclonic center of Rex, which develops rapidly the following day. Fig.3c clearly shows the multi-directional outflows above Rex and a westerly trough north of it.

Fig.3d is the cloud motion winds in the upper levels of the troposphere at 00:00 GMT August 10, 1997. It was at the time that the tropical cyclone was named Winne. On the following day, it also rapidly developed. As shown in Fig.3d, multi-directional outflows were also present above Winne. Fig.3d differs from Fig.3a, 3b & 3c in that for the former the westerly winds north of the tropical cyclone was supplied by the westerly on the southern side of TUTT rather than the westerly troughs in middle latitudes; TUTT was along 28°N, as shown by Fig.3d, about 13 latitudes more northward than Winne.

Fig.3a, 3b, 3c & 3d are the typical flow fields of upper tropospheric layers of a developing tropical cyclone in the summer of 1997 and 1998. Fig.3d represents what looks like when there is a TUTT in the northwest part of the Pacific Ocean in summer. The figure (a, b, c) depicts the situation when there is no TUTT north of the tropical cycle, which is quite a common environmental flow field in any seasons. Fig.4 composes high-level wind fields of 6 tropical storms from March to June in 1997 at the of formation, which is in effect a summary of what has been described above

with respect to upper-tropospheric multi-directional outflows above developing tropical cyclones. It clearly shows the presence of a westerly trough northwest of such storms.

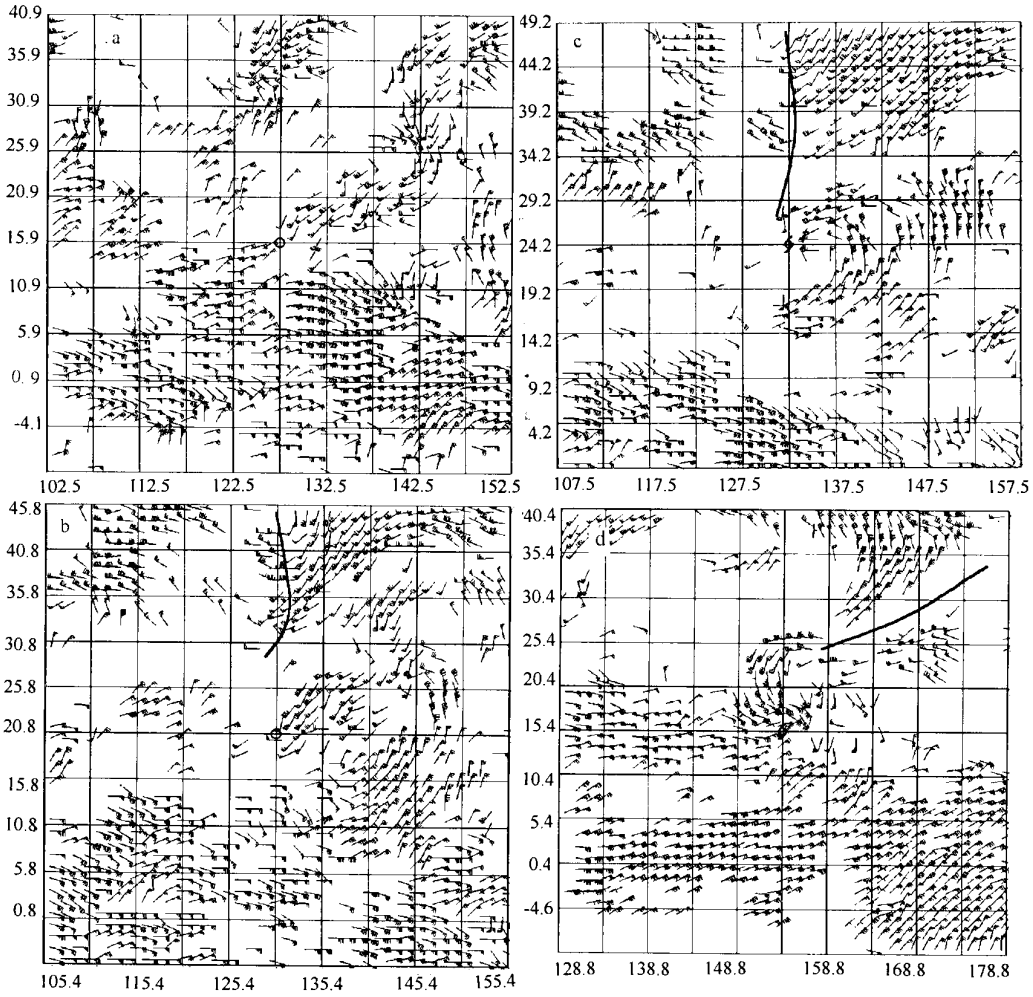

Fig.3 Cloud motion winds around Rex in the upper troposphere 48 h (a), 24 h (b), and 0 h (c) before it reached the intensity of tropical storm; Cloud motion winds around Winne in the upper troposphere when it reached the intensity of tropical storm (d)

Fig.5 is the cloud motion winds at 00:00 GMT August 18, 1998. A tropical depression is shown to exist around the point 15.7°N, 132.3°E. It did not develop on the day followed. As shown in the figure, winds are blowing in consistent directions in upper troposphere over the non-developing tropical cyclone, i.e. there is no such phenomenon as multi-directional outflows as in the cases above. Fig.6 gives the cloud motion winds at 06:00 GMT May 29, 1997. For the middle portion of the figure at 25.3°N, 128.5°E, Levi, a tropical storm, was dissipating. The westerly trough apparently powers the consistent westerly over this storm.

Non-developing and dissipating tropical systems have similar environmental flow fields in the

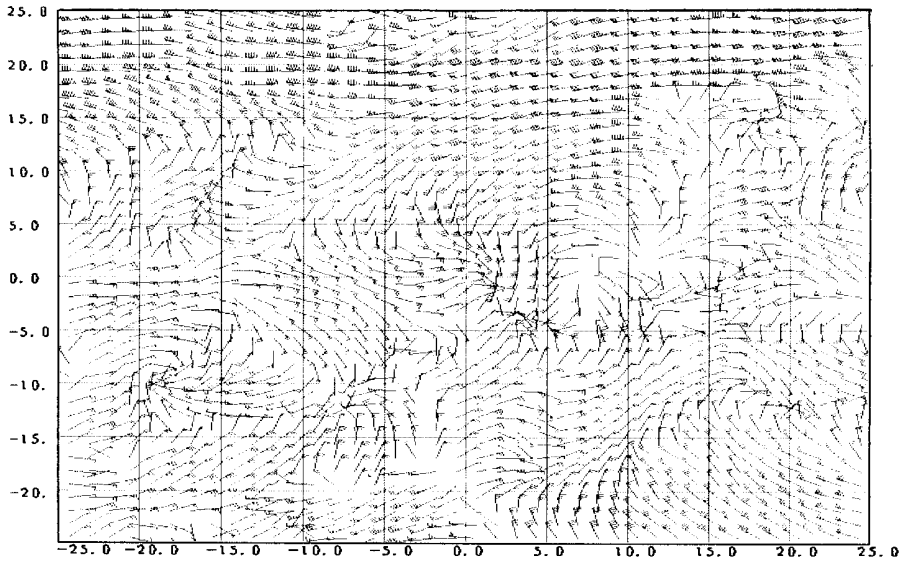

Fig.4 Composition of cloud motion winds in upper troposphere as 6 tropical storms acquire the named intensity in May ~ July 1997

upper levels of the troposphere, as shown in Figs.5 & 6. Usually consistent easterly winds prevail above non-developing tropical depressions while consistent westerly winds are in control above dissipating tropical storms or typhoons. Examining all tropical cyclones since 1997, we have selected the aforementioned cases for discussion, which both observe the rules presented above and are representative.

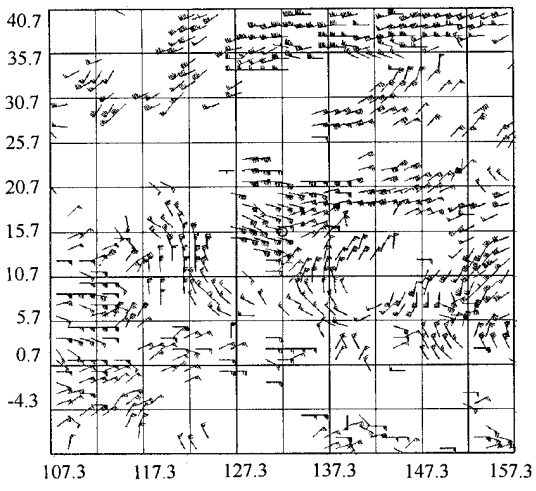

Fig.5 Cloud motion winds of upper troposphere Near a non-developing tropical cyclone

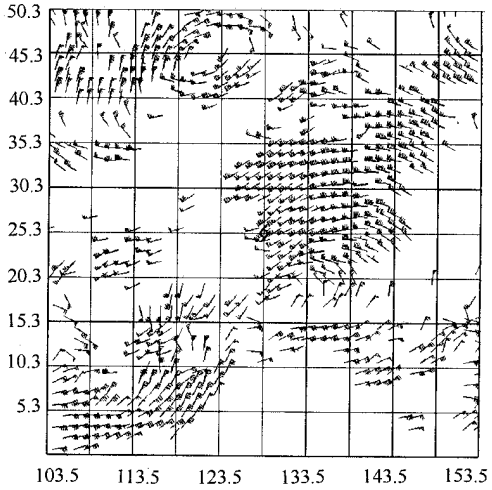

Fig.6 Cloud motion winds of upper troposphere near the dissipating tropical storm Levi

4 MIGRATING WESTERLY TROUGHS ASSOCIATED WITH THE FORMATION OF TROPICAL CYCLONE

To evaluate the original source of the westerly north of a developing tropical cyclone, a thorough examination is conducted of all cases since 1997. It is found that it is difficult to determine whether it is resulted from the development of the tropical cyclone itself or the environmental flow field. One thing is clear: the westerly north of the developing system is generally powered by the environmental flow field in the absence of TUTT. Fig.3a, 3b & 3c offer one of such cases. They respectively represent the cloud motion winds near the tropical cyclone 48 h, 24 h, and 0 h before it acquires the intensity of tropical storm. The figure shows a well-outlined westerly trough that is approaching a tropical cyclone. Other cases in 1997 and 1998 also indicate similar situations. When a westerly trough comes within 12 ~ 15 latitudes of a tropical cyclone from the northwest, the westerly winds it carries through would become a source for the multi-directional outflows needed in the development of the storm. For the northwest Pacific in 1997 and 1998, most of the tropical storms, as shown in high-density cloud motion winds, are intrigued by multi-directional outflows that are supplied by the westerly trough advancing well into the tropics.

5 CONCLUDING REMARKS

a. There are multi-directional outflows in the upper levels of the troposphere just above the developing tropical cyclone.

b. For the northwest Pacific Ocean, the westerly in the upper troposphere north of the cloud cluster is usually powered by the mid-latitude westerly trough well advancing into the tropics.

c. For the northwest Pacific in the prime season of summer, the westerly in the upper troposphere north of the cloud cluster is usually powered by the westerly south of the TUTT.

d. There is usually a consistent easterly airflow in the upper levels of the troposphere above a non-developing tropical cyclone.

e. Consistent westerly airflow usually prevails in the upper part of the troposphere over a dissipating tropical storm or typhoon.

f. High-density data of cloud motion winds are powerful tools for diagnosing the development potential of the tropical cyclone.

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