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A STATISTICAL ANALYSIS ON INTENSITY CHANGE OF TROPICAL CYCLONES OVER THE WESTERN NORTH PACIFIC

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Abstract: 55-year (1949 – 2003) data sets are used to study the statistical characteristics in intensity change of the tropical cyclones (TC) over the western North Pacific. According to the mathematical meaning of average value and standard deviation, the abruptly intensifying, gradually intensifying, stable intensity, gradually weakening and abruptly weakening of TC intensity are defined and the statistical characteristics, such as inter-decadal variation, inter-annual variation, inter-monthly variation, and regional distribution, etc. are analyzed. Main results are as follows: (1) From 1949 to 2003, there were 1886 TCs, averaging at 34.29 TCs per year. After 1995, the number of TCs dropped dramatically with less than 30 per year. 3.56% of the total were abruptly intensifying samples, and 3.31% were weakening samples. (2) For the annual mean, all but the stable group tend to decrease with the shift of decades as far as the overall change of the 6-h isallobaric process is concerned. (3) The abruptly intensifying TC seldom occurs over mid- and high-latitude area (north of 30°N) and low-latitude area and sometimes occurs around the islands and continent. Basically there is no gradually intensifying of TC over mid- and high- latitude area (north of 30°N and west of 125°E), in offshore Chinese waters. The gradually weakening and abruptly weakening TCs usually occur offshore China, west of 125 °E, but seldom over low-latitude area (0 — 5°N).

Key words: tropical cyclones; intensity; statistics

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1 INTRODUCTION

The theory of TC intensity abrupt change was studied as a specific subject from 1991 to 1995 in China. Yan et al.[1, 2] put forward a standard for the rapid intensification of TCs in the western North Pacific and offshore China and analyzed the climatological characteristics of rapidly intensifying offshore TCs. With data from 1949 to 1990, Wu[3] studied the distribution of TCs in the western North Pacfic that intensified abruptly. Liang et al.[4] made diagnostic study of TC "Vongfong" that increased its intensity off the coast.

Based on the data from the *Yearbook on Typhoons* and *Yearbook on Tropical Cyclones* from 1949 to 2003 (55 years in all) compiled by the China Meteorological Administration, this work analyzes the statistical pattern of the variation of the lowest pressure near the eye of TCs to reveal how they change in intensity. No intensity change in the secondary center of TCs is taken into account during the study. The basic data from the yearbooks are presented four times per day at 02:00, 08:00, 14:00 and 20:00 L.T., respectively. For each of the above times, the TC intensity change is depicted using the isallobaric process of Δp every 6 hours. For instance, the Δp for 08:00 is the difference of minimum lowest pressure between the time and 02:00, six hours earlier. If $\Delta p<0$ hPa/6h, the sample is one of intensification; otherwise it is one of weakening. When $\Delta p=0$ hPa/6h, the sample is one of unchanged intensity.

With 35 years of TC data from 1953 to 1987, Yu et al.[5] analyzed the statistical characteristics of intensity change of TCs in the western North Pacific from a total of 18258 samples. This paper will use a

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total of 53412 samples for 1949 – 2003 to define the intensity change of TCs with a more generalized standard.

2 STATISTIC CHARACTERISTICS OF INTENSITY CHANGE OF TCS

For the years 1949 – 2003, there are all together 15778 intensifying samples, taking up 29.5% of the total. The mean rate of intensification is –4.14 hPa / 6h and the standard deviation for the 6-h isallobaric process is 3.64 hPa / 6h. There are 12633 weakening samples in all, taking up 23.7% of the total. The mean rate of weakening is 4.57 hPa / 6h and the standard deviation for the 6-h isallobaric process is 3.73 hPa / 6h.

Over the course of the 55 years, there were 1886 TCs, averaging at 34.29 TCs per year. There were 53 TCs in 1967, the most in the period but only 21 TCs in 1998, the least. After 1995, the number of TCs dropped dramatically with less than 30 per year.

3 VARIOUS TYPES OF DEVELOPING TCS

There are five types of development in the life cycle of TCs, with intensity either increasing abruptly or gradually, or remaining unchanged, or weakening gradually or abruptly. For a certain period of time, the TC is said to be stable if the intensity does not change or changes little; it is defined as gradually intensifying if the intensity increases significantly but at a moderate rate; it is classified as abruptly intensifying if the intensity increases rapidly at rates larger than those of gradually intensifying TCs. Likewise, the patterns of gradually or abruptly weakening TCs can also be defined. Following the mathematical meaning of mean and standard deviation, TCs are defined in terms of stable, gradually changing or abruptly changing intensity. Specific standards, sample size and frequency for the five developing patterns of TCs are presented in Tab.1.

Tab.1 Standards of five developing patterns of TCs (unit of Δp : hPa / 6h)

	Abruptly intensifying	Gradually intensifying	Stable intensity	Gradually weakening	Abruptly weakening
standards	$\Delta p < \overline{\Delta p_-} - s_-$ $\Delta p < -7.78$	$\overline{\Delta p_-} - s_- \le \Delta p \le \overline{\Delta p_-}$ $-7.78 \le \Delta p \le -4.14$	$\overline{\Delta p_-} < \Delta p < \overline{\Delta p_+}$ $-4.14 < \Delta p < 4.57$	$\overline{\Delta p_+} \le \Delta p \le \overline{\Delta p_+} + s_+$ $4.57 \le \Delta p \le 8.30$	$\Delta p > \overline{\Delta p_+} + s_+$ $\Delta p > 8.30$
Sample size	1904	3978	41911	3853	1766
frequency	3.56%	7.45%	78.47%	7.21%	3.31%

3.1 Interannual and interdecadal variations of frequency and intensity

The five types of TCs have similar trends of interdecadal variation (figure omitted). For the annual mean, all but the stable group tends to decrease with the shift of decades as far as the overall change of the 6-h isallobaric process is concerned. For the gradually intensifying and weakening TCs, the mean of the 6-h isallobaric process was larger from the end of 1950's – 1960's and early 1980's than the rest of the years (figure omitted).

For the type of abruptly intensification, the increasing rate of 6-h isallobaric process was the most in 1983 (-14.14 hPa / 6h), followed by 1975 (-14.48 hPa / 6h); it was the least in 1949 (-9.85 hPa / 6h), followed by 1992 and 1999 (-10 hPa / 6h). The amplitude of variation has been mild since mid-1980's for the type of abruptly intensifying TCs.

For the type of abruptly weakening, the increasing rate of 6-h isallobaric process was the most in 1975 (14.96 hPa / 6h), followed by 1973 (14 hPa / 6h); it was the least in 1992 and 1997 (about 10 hPa / 6h).

3.2 Monthly variations of frequency and intensity

Fig.1 gives the size of samples for all five types of TCs on a monthly basis. Being in unimodal distribution, the monthly trends of cyclogenesis do not vary much from each other with all but the stable type in consistence with that of monthly variation. The active period of frequency variation take place in July – November but tend to drop in January and February. From February to September, cyclogenesis keeps going up for the four types and reaches the maximum in September before decreasing till December. The stable type of TCs is different; it has the most frequency of cyclogenesis in August. In addition, it is shown that approaching curves of cyclogenesis for the types of abruptly and gradually intensification and similar curves for the gradually and abruptly weakening (figure omitted).

There is not much change in the monthly variation of the monthly mean and the trend of variation is moderate for the 6-h isallobaric process (figure omitted). The gradually intensifying type has a relatively large amplitude of increase in February and the gradually weakening type has a relatively large amplitude of decrease in March.

For the type of abrupt intensification, the

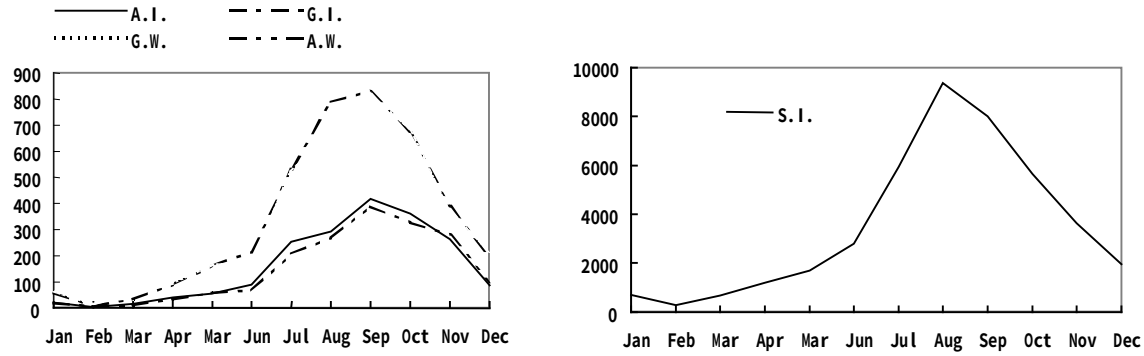

Fig.1 Monthly variations of the size of samples for all five types of TCs. "A.I." stands for those TCs that abruptly intensify; "G.W." for those that gradually weaken; "G.I." for those that gradually intensify; "A.W." for those that abruptly weaken; "S.I." for those that have stable intensity.

maximum rate of intensification for the 6-h isallobaric process occurs in May (-13.49 hPa / 6h), followed by November (-11.96 hPa / 6h); the minimum rate appears in March (-9.88 hPa / 6h), followed by February and April; the amplitude is more ore less the same in the remaining months of the year.

For the type of abrupt weakening, the maximum rate of intensification for the 6-h isallobaric process occurs in September (12.51 hPa / 6h), followed by November and August; the minimum rate appears in April (10.65 hPa / 6h), followed by March (10.7 hPa / 6h); the amplitude is more ore less the same in the remaining months of the year.

3.3 Regional distribution of frequency

In determining the regional distribution of TC cyclogenesis, the area of 0° – 50°N, 100° – 180° E in the western North Pacific is divided into 160 blocks of 5°lat.×5°long., which consists of 10 latitudinal boxes and 16 longitudinal boxes. It is known from the regional distribution of cyclogenesis (figure omitted) that the abruptly intensifying type appears most frequently in the area of 10°N – 20°N, 125°E – 140°E, taking up 35.51% of the total; the gradually weakening type occurs most frequently in the area of 10°N – 20°N, 110°E – 140°E, taking up 41.08% of the total; the stable type is most active in the area of 10°N – 20°N, 110°E – 145°E, taking up 32.97% of the total; the gradually weakening type is mostly occurred in the area of 15°N - 25°N, 105°E - 125°E, taking up 24.84% of the total; the gradually weakening type is mostly seen in the area of 10°N – 30°N, 110°E – 125°E, taking up 35.87% of the total. In addition, TCs usually do not intensify abruptly in middle and higher latitudes north of 30°N or lower latitudes between 0° and 5°N, or near land or islands. TCs usually do not intensify gradually in offshore area in the middle and higher latitudes north of 30°N and west of 125°E; they usually do not weaken gradually in low-latitude area between 0° and 5°N; they usually do not weaken abruptly in low-latitude area between 0° and 5°N. For analyses of other aspects, refer to the Chinese edition of the journal.

4 DISCUSSIONS

The intensity change of TCs is dependent on multiple factors, such as cold air, jet streams, westerly troughs, mesoscale systems, topographic effect, sea surface temperature and sprays [6]. Instead of thorough discussion of its possible causes and physical mechanisms, only the basic statistics about TC intensity change are given here, which are to be addressed on the basis of the current work.

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