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IMPACT OF LARGE-SCALE CIRCULATION ON THE INTERDECADAL VARIATIONS OF THE WESTERN NORTH PACIFIC TROPICAL CYCLONE

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Abstract: Based on the annual frequency data of tropical cyclones from 1960 to 2005 and by the polynomial fit and statistical analysis, this work has discovered that TC activity in the 46a exhibits significant decadal-scale variability. It has two high frequency periods (HFP) and two low frequency periods (LFP). Significant differences in the number of TCs between HFP and LFP are found in active TC seasons from July to October. Differences of large-scale circulation during HFP and LFP have been investigated with NCEP/NOAA data for the season. In HFP, the condition includes not only higher sea surface temperature, lower sea level pressure, larger divergence of upper air, larger relative vorticity at low levels and smaller vertical shear, but also 500-hPa wind vector being more available for TC activity and moving to western North Pacific, the position of the subtropical anticyclone over the western Pacific shifting more northward, and South Asian Anticyclone at 100-hPa being much smaller than that in LFP. The precipitation of western North Pacific has no clear influence on TC activity.

Key words: western North Pacific; TC; frequency; interdecadal variation; large scale circulation

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1 INTRODUCTION

The tropical cyclone (TC) is one of the most destructive natural disasters that cause loss of lives and enormous property damages around the world. The western North Pacific (WNP) is an area where typhoon activity is the most frequent and strongest and China is one of the countries that seriously suffered from typhoons in this area. It is then necessary to do some research on the TCs in WNP. Many domestic and foreign researchers [1-5] have already made detailed analyses of associated climatic conditions, which show that the activity of these TCs has remarkable features of interdecadal variation. Interdecadal variation of the TCs is related with a number of large-scale circulation factors, like tropospheric vertical wind shear, ENSO, sea level pressure, sea surface temperature, total precipitation amount (Gray [6] and Landersea [7]). Inevitably these factors have an influence on Pacific TCs too. Large-scale circulation factors affecting the central Pacific interdecadal TC activities have been analyzed by Chu et al.[8]. WNP TC frequency data from 1951 to 1999 are used to analyze the interdecadal variation of TCs in relation with sea surface temperature, relative vorticity of low level, divergence of upper air, long-wave radiation (Yumoto et al.)[9]. Before the 1960s, meteorological satellites were not used to detect the TC and no other means of surveillance data were able to provide reliable estimates of TCs [10]. The research by Yumoto includes data prior to 1960, but the selected factors are not comprehensive enough and the sea surface pressure, vertical wind shear and other factors may have important impacts on the interdecadal variations of TCs. The Chinese scholars have also made a great deal of analysis of the circulation factors affecting the activities of TCs [11-13], but not from the point of interdecadal variation. This paper will select the latest TC data to analyze the interdecadal variation of WNP TC and the large-scale circulation factors affecting the

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interdecadal variations of TCs.

2 DATA AND METHODS

The data used are those in the yearbooks of TC [14, 15] of the WNP from 1960 to 2005 (including the South China Sea, the same below) about the TC (whose wind are at least 17.2m/s) frequency and the generation locations. Monthly mean sea level pressure (SLP), wind data at the 850-, 500-, and 200-hPa levels, relative vorticity data at the 850-hPa level, divergence at the 200-hPa, geopotential height at 500 hPa and 100 hPa, and total rainfall are derived from the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis dataset from January 1, 1960 to September 1, 2005. The methods of polynomial fitting and statistical analysis are used to analyze large-scale circulation factors affecting TC interdecadal variations.

3 INTERDECADAL VARIATIONS OF TC FREQUENCY

Based on the latitude and longitude of the 1960 – 2005 WNP TC generation locations to count the TC occurrence frequency within every 2.5 lat.×2.5 long. (Fig.1a), it is shown that TCs tend to focus their generation on an area of 110°E – 165°E, 5°N – 25°N. From the seasonal characteristics of 46a TC occurrence frequency, the time from July to October is called the TC active season.

Using 5-order polynomial fitting and 5-year moving average comprehensive analysis (Fig.1b), it is found that there is a significant interdecadal variation in the 46a TC activities, with the fitting curve presenting the changes of cosine wavetrain and the existence of two high-frequency and two low-frequency periods: high-frequency period being from 1960 to 1974 and from 1987 to 1995, low-frequency periods from 1975 to 1986 and from 1996 to 2005. And an increase in the trend of positive TC activities after 2002 indicates that the TC tends to move towards a new high-frequency phase.

4 LARGE-SCALE CIRCULATION FACTORS AFFECTING TC INTERDECADAL VARIATION

Since July to October is the most active season, which accounts for more than 70% of the TCs throughout the year, high frequency and low frequency phases of the season in the active season of TCs should

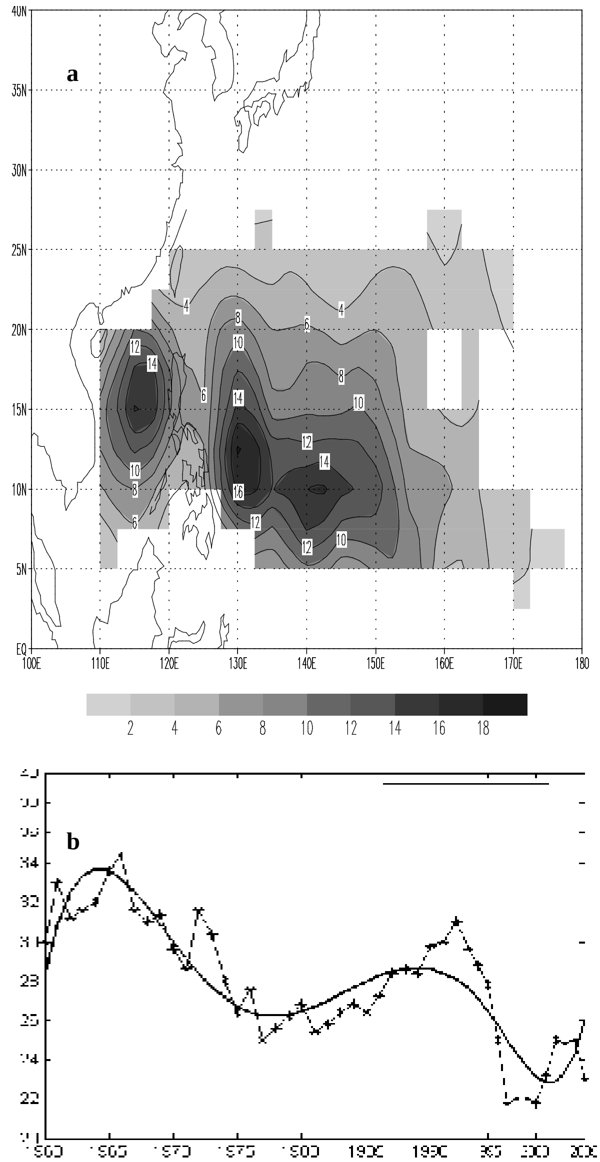

Fig.1 Temporal variation of TC source location and total frequency of occurrence from 1960 – 2005. (a) Frequency of occurrence within every box of 2.5 lat. × 2.5 long.; (b) fifth-order polynomial fitting curve (the bold, solid line) and 5-year running mean curve (the line with *) for TC frequency.

be the most significant if the circulation differences in different periods have an impact on the generation of TCs. So the difference of the large-scale circulation can be analyzed for different periods of this season. To note the difference of circulation, the mean circulation in the high frequency phase is subtracted from the mean circulation in the low frequency phase (LFP-HFP), defined as DIF.

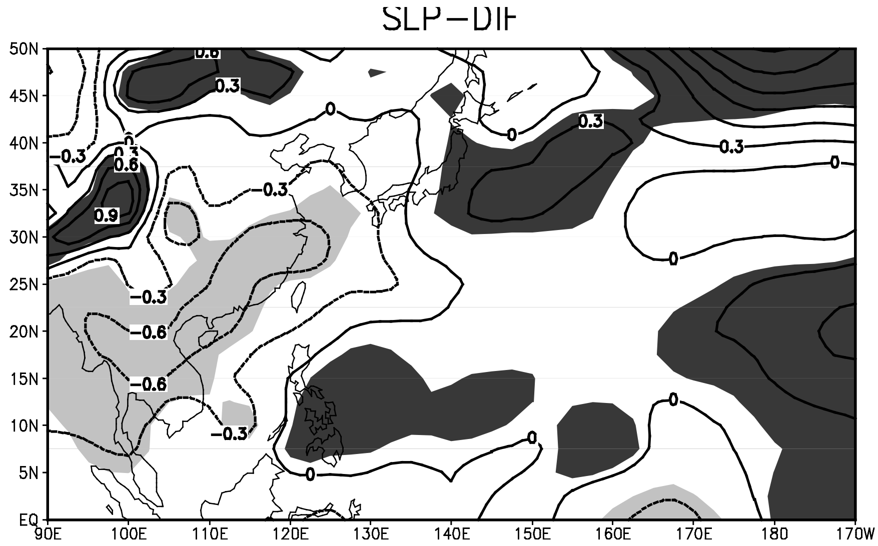

Fig.2 SLP difference between LFP and HFP. Negative values are dashed. Shading indicates regions where the difference in the mean between the two periods is statistically significant at the 5% level.

4.1 *Sea level pressure*

The average difference of high and low frequency periods of sea level pressure (Fig.2) shows that low sea level pressure is available for TC generation but otherwise not conducive to TC generation. It is worth noting that the opposite relationship appears in the waters near the eastern and southern parts of the Chinese mainland, which may be due to the impact of a southern Asia anticyclone on the sea level pressure field.

4.2 *Tropospheric vertical wind shear*

Strong vertical wind shear will inhibit the formation of initial disturbance of TC. The tropospheric vertical wind shear is defined as:

$$vws = \left[\left(u_{200hpa} - u_{850hpa}\right)^2 + \left(v_{200hpa} - v_{850hpa}\right)^2\right]^{\frac{1}{2}}$$

where u and v denote the zonal and meridional wind components, respectively.

The distribution diagram of vertical wind shear variation difference (figure omitted) shows that weak vertical wind shear is conducive to TC generation, but strong vertical wind shear TC inhibits it.

4.3 *Steering current*

500-hPa wind field is the steering current of TC. 500-hPa wind vector differences (figure omitted) show that the wind field with low TY generating frequency phase does not help the TC generating over the central Pacific move to the western Pacific, and it is neither favorable for the TC in the major formation area over the western Pacific to develop westward and intensify after generation.

4.4 *Subtropical anticyclone over the Western Pacific*

500-hPa western Pacific subtropical anticyclone has a steering effect on the TC movement, and via it has impacts on TC frequency [16]. By comparing 500-hPa geopotential height difference (figure omitted), it is shown that a southward subtropical anticyclone over the western Pacific is not conducive to TC generation, but a northward location is favorable for it.

4.5 *Southern Asia anticyclone*

The circulation character of Southern Asia anticyclone is quite significant in July, August and September, so we only analyze it in terms of 100hPa geopotential height difference for these months. Analysis shows that a deep strong southern Asia anticyclone is not conducive to TC development, and a weak one is favorable for it.

4.6 *Total precipitation*

Tropospheric water vapor directly affects TC formation. According to an analysis of total precipitation difference in the WNP basin, the precipitation in the high-frequency phase reduces as compared with the low frequency phase, and TC will bring rich precipitation wherever it goes, showing that the precipitation of the WNP basin is caused by a variety of factors. TC precipitation is only part of the total precipitation, so it cannot be used to analyze the interdecadal variations of TC frequency.

For analyses of other aspects, refer to the Chinese edition of the journal.

5 DISCUSSIONS AND CONCLUSIONS

Through studying the TC generation influenced by large scale environmental conditions in low frequency and high frequency phases in the active season of TCs, it is indicated that there exists a good correlation between the interdecadal variation of TC activities and that of sea level pressure, vertical wind shear, 500 -hPa subtropical anticyclone over the western Pacific and 100 -hPa southern Asia anticyclone, though the interdecadal variation of the total precipitation is not significant or even contrary to the relationship with that of TC activities.

Although Chu [8] points out that a thicker layer of atmospheric moisture is conducive to TC activities in a study on TC interdecadal variation over the central Pacific, the relationship between the WNP basin precipitation and the interdecadal variations of TC activities is not significant.

Specific conclusions are as follows.

(1) TC frequency of 46a has exhibited significant decadal variability and the time from 1960 to 2005 has two high frequency periods (HFP) and two low frequency periods (LFP).

(2) In HFP, the conditions include higher sea surface temperature, lower sea level pressure, larger divergence of upper air, larger relative vorticity of low level and smaller vertical shear. When they become significant, they are conducive to the generation and development of TCs in the WNP basin. It is otherwise true with the LFP.

(3) A southward-located subtropical anticyclone over the western Pacific is not conducive to the TC generation while it is otherwise; a weak South Asia high is favorable for TC activity and it is otherwise true when it is strong.

(4) The total precipitation of western North Pacific has no clear influence on TC activity.

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