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Variation Tendency of TC activity in the NWP

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Abstract

Based on the tropical cyclone dataset during 1945~2013 by Joint Typhoon Warning Center (JTWC), this study has systematically analyzed the long-term variation of tropical cyclone (TC) in the Northwest Pacific (NWP). People recorded annual variations of Typhoon's maximal wind speed, power dissipation index (PDI) and frequency in this period. The results showed that these meteorology parameters display a rising trend, implying that the TC activity presents a feature of non-stationary stochastic processes. Geographically, we give spatial distribution of their historical maximal wind speed by combining database with parametric TC model. The results indicate that spatial distribution of TC intensity in the NWP is uneven and the sea area east to the Philippines is the most severely affected region by typhoon.

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Keywords: TC activity; non-stationary stochastic process; climate change

1. Introduction

Assessment Reports issued by IPCC have further confirmed the conclusion that the anthropogenic emission of carbon dioxide is the major factor leading to continuous global warming since 1860 [1]. With this consideration, a growing number of researchers shift their attention to the challenging topic whether the TC activity has varied with climate change. However, the answers are often conflictive [2]. For instance, Webster [3] believed that a remarkable increase in the proportion and number of strong hurricanes of category 4-5 was observed. In particular, the largest increment occurred in the Pacific and Indian Oceans. However, Klotzbach [4] concluded that although sea surface temperatures were rising since 1980s, the hurricane number of category 4 and 5 only exhibits minor growth.

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To clarify this kind of inconsistency, we use the best-track database from JTWC in the period 1945-2013 to examine the variation of TC activity in the NWP by statistical analysis in this paper.

2. Interannual variation of TC activity

2.1. Interannual variation of TC intensity

TC intensity usually could be divided into 5 or 6 grades for hurricane or typhoon, respectively based on the maximal average wind speed nearby TC bottom center [5]. Then we counted TC's annual maximal wind speed recorded in a certain year to analyze interannual variation of the maximal wind speed in the NWP.

We can see in Fig.1 that the annual maximal wind speed in the NWP basically ranges from 60 to 90 m/s. Nevertheless, none of them was under 70 m/s since the eighties of the last century. More specially, the characteristic parameter of tropical cyclone reaches 87 m/s in 2013, which is assumed the highest one in the past 69 years. Applying the least square method fitting these data, we acquire the red solid line. The result indicates that annual maximal wind speed presents an evident upward trend.

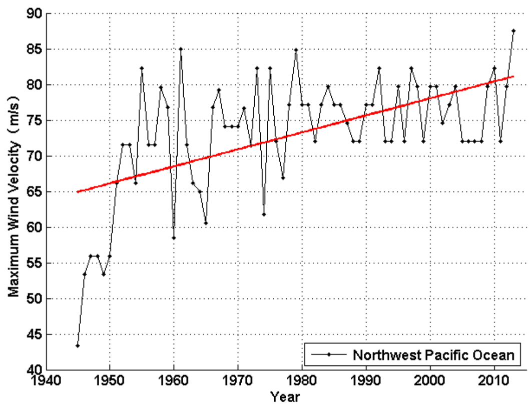

Fig. 1 Annual variations of TC maximal wind speed.

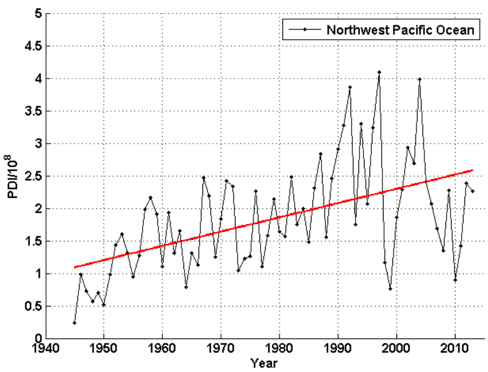

Fig. 2 Annual variations of TC power dissipation index.

In order to overall describe TC intensity, it is obvious that the maximal wind speed at a certain moment as a measurement of TC intensity is insufficient. Emanuel [6] defined the power dissipation index (PDI) as a major factor, which seems to be closely related to actual monetary loss in a tropical cyclone process. So PDI is a useful characteristic parameter to well describe TC intensity. PDI's definition can be given by:

$$PDI=\int_0^{\tau} V_{\max}{}^3 dt \quad (1)$$

where $V_{\max}$ is the maximal sustained wind speed, and τ is the life time of the tropical cyclones.

As shown in Fig. 2, the growth of the PDI in the NWP is tremendous since 1950s. In particular, the PDI in the early years of the 21th century even reached almost 2.5 times of those in 1950s. We still apply the least square method to fit these data and then acquired the red solid line, exhibiting that the PDI has also increased tremendously from 1945 to 2013.

2.2. Interannual variation of Tropical Cyclone Frequency

Apart from TC intensity, tropical cyclone frequency is an aditional crucial indicator to characterize TC activity as well. Generally speaking, annual frequency of tropical cyclone could be described by the number of tropical cyclone occurring in a year. If the occurring number of tropical cyclone is increasing to a certain extent in a certain sea area, we could infer that the TC activity in this region is becoming stronger.

The red solid line in the diagram represents long-term trends extracted by the least square method, as shown in Fig. 3. Hence, the numbers of tropical cyclone occurring in the NWP display an apparent rising trend from 1945 to 2013 as well. For example, none of them was more than 35 prior to 1980, while the numbers of tropical cyclone even reached a peak of 44 in 1996.

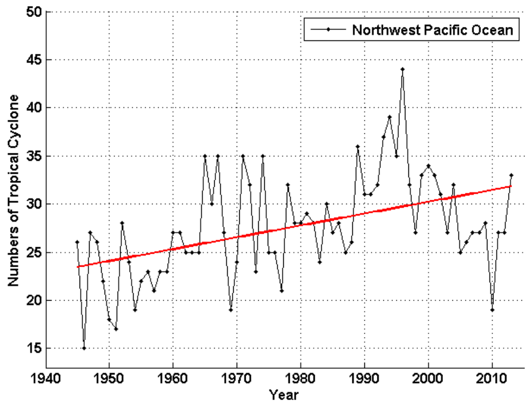

Fig. 3 Annual variations of TC frequency.

3. Spatial Variation Characteristics of Tropical Cyclone Maximal wind speed

We recorded the maximal wind speed occurring in 69 years in each 1°×1° subarea of the NWP area (0°-60°N, 80°-180°E). Specifically, we use parametric tropical cyclone model presented by Jelesnianki [7] to estimate wind speed and select the maximum value among the result of computation as the maximal wind speed in each subarea, by processing the TC location and wind speed dataset recorded every six hours. The wind speed in each subarea is calculated in the following way:

$$V(r)=\begin{cases} V_0\cdot(\dfrac{r}{R_m})^{1.5}, & r\le R_m \\ V_0\cdot(\dfrac{R_m}{r})^{0.5}, & r>R_m \end{cases} \quad (2)$$

,where r is the distance between a certain point in the nearby subatrea and the tropical cyclone center recorded, V_0 is the maximal wind speed, R_m , the radius of maximal wind speed. In this case, R_m was set as 40 km according to experience. The calculated result is shown in the following diagram.

From Fig. 4, we can see that the spatial distribution of historical maximal wind speed is primarily dependent on the track of strong tropical cyclones. The sea area east to the Philippines is found to be the most severely affected region by typhoon. At the same time, the area north of 48° N and nearby the equator has scarcely been hit by tropical cyclone in this period as we could expect. In other words, spatial distribution of TC activity is extremely inhomogeneous in the NWP.

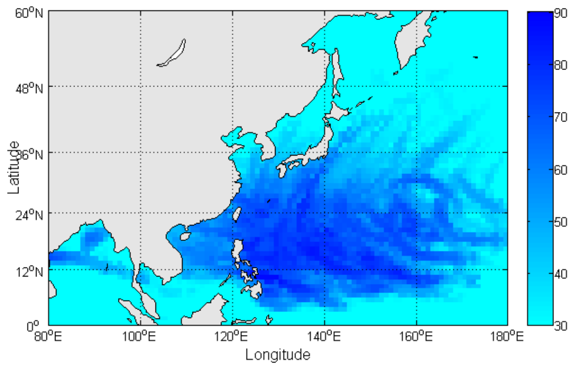

Fig. 4 Historical maximal wind speeds of TC occurrence.

4. Conclusions

Based on tropical cyclone database, we have acquired interannual variation of TC activity and spatial distribution characteristics of tropical cyclone in the NWP during 1945-2013. The following conclusions can be finally drawn by this study: (1) An upward trend in the annual maximal wind speed over the past 69 years can be found; (2) PDI as a proper measurement of TC intensity has exhibited a sharp rising trend since 1950s; (3) tropical cyclone frequency of occurrence was increasing year by year; (4) spatial distribution of historical maximal wind speed of tropical cyclones in NWP is uneven. .. In summary, these characteristic parameters are obviously rising in the context of climate change, which means that the variation of TC activity turns out a non-stationary stochastic process.

Acknowledgements

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