

# Impact Of Global Warming on Tropical Cyclones in The Northwest Pacific Ocean

Jingtian Shi <sup>1,\*</sup>, Tunan Zhang <sup>2</sup>

<sup>1</sup> School of Atmospheric Sciences, Nanjing University of Information Science & Technology, Nanjing, China

<sup>2</sup> School of Ecology and Environment, Anhui Normal University, Wuhu, China

\* Corresponding Author Email: xyz01023zyx@gmail.com

**Abstract.** Tropical cyclones are meteorological phenomena that can affect mid to low latitudes around the world. This Paper systematically summarizes and reviews the main characteristics, potential influencing factors, and influencing mechanisms of tropical cyclones in Northwestern Pacific, and summarizes and analyzes their changing trends in the context of global change. Global warming will affect the generation and development of tropical cyclones from multiple dimensions, with the most intuitive being the surface temperature of seawater. Through the analysis of global surface temperature and tropical cyclones in the Northwest Pacific, it is shown that as global climate warms, the frequency of tropical cyclones in the Northwest Pacific decreases, the extreme central pressure decreases, and the extreme maximum central wind speed increases, there is no significant trend in the average minimum pressure and average maximum wind speed of tropical cyclones. In other words, the extreme intensity of tropical cyclones strengthens; In the 2010s, this relationship was particularly prominent.

**Keywords:** Global warming; northwestern pacific; tropical cyclone.

## 1. Introduction

In the past century, a large amount of greenhouse gas emissions, such as carbon dioxide and methane, have been caused by human activities. These gases accumulate in the atmosphere, causing global temperatures to continuously rise. It will have a significant impact on the ecological environment and socioeconomic development of the world and China. Currently, global climate change and its related issues have become a major concern for governments and the scientific community around the world.

The activity characteristics of tropical cyclones have also changed due to factors such as rising tropical sea surface temperatures caused by global warming. Tropical cyclones will become stronger and more destructive. The Northwest Pacific is the region with the most tropical cyclones in the world, and China is located on the west coast of the Pacific, which is one of the countries most affected by tropical cyclones. Studying the impact and characteristics of global warming on tropical cyclones in the Northwest Pacific is of great significance for China to understand, predict, and prevent catastrophic weather caused by tropical cyclones [1].

This article will review and summarize recent academic research on the impact of global warming on tropical cyclones in the Northwest Pacific, based on tropical cyclone data from the Joint Typhoon Warning Center (JTWC) in the United States and the Japan Meteorological Agency (JMA), explore the changing characteristics of tropical cyclones in the Northwest Pacific under the background of global warming, providing insights for future research in this field.

## **2. The Formation Mechanism of Tropical Cyclones in the Northwest Pacific and the Impact of Global Warming**

### **2.1. The Formation Mechanism of Tropical Cyclones**

Tropical cyclones develop from small disturbances on the sea surface, and the process may take several days. In tropical and subtropical regions, the sea surface intensifies seawater evaporation due to high temperatures, causing gas to rise and forming local low-pressure centers. Cold air from around converges towards the center and undergoes counterclockwise rotation under the influence of coriolis force; If the central pressure continues to decrease and the incoming air speed continues to increase, a typhoon is formed. According to statistics, less than 10% of the large disturbances on the sea surface can ultimately form typhoons. This is because the formation of typhoons involves some necessary dynamic, thermodynamic, and airflow structure conditions [2].

**Thermodynamic conditions:** The temperature of seawater within 60 meters of the surface is above 26 °C, which is used to ensure that the gas in the low-pressure center continues to heat up, which is also the origin of typhoons formed in tropical and subtropical regions [2].

**Dynamic conditions:** Convergent airflow appears in the lower atmosphere, causing rising air masses to condense and release heat (the latent heat of condensation) above the convective height, heating the atmosphere, resulting in continuous rise of air masses, continued decrease in ground pressure, further strengthening of converging airflow, and promoting the formation of typhoons; The Coriolis force is large enough to form a horizontal vortex with counterclockwise rotation in the converging airflow, generally requiring a latitude of 5 ° N or above [2].

**Troposphere structure:** The vertical shear of the tropospheric wind in the Taiwan wind source area is smaller, which means that the relative motion of the air above and below the troposphere is weaker, to ensure that the released latent heat of condensation heats the same gas column, accelerating the formation of a warm core structure and the decrease in central air pressure [2].

### **2.2. Impact of Global Climate Warming on the Intensity of Tropical Cyclones in the Northwest Pacific**

The most direct impact of global warming on typhoons is the creation of thermodynamic conditions favorable for their formation. During the process of global warming, the surface seawater temperature increases accordingly, with an average temperature growth rate of 0.11 °C/decade from 1971 to 2010. The increase in seawater temperature means that fuel can burn more vigorously and for longer. Therefore, once a typhoon forms, its intensity will inevitably intensify. The intensity of typhoons that have made landfall in East Asia and Southeast Asia over the past 40 years has increased with the warming of seawater, with the proportion of strong and super typhoons more than doubling.

However, solely relying on the thermodynamic conditions for the formation of typhoons does not necessarily mean that the number of typhoons generated will increase. This is because global warming can also affect the formation of typhoons from other perspectives. For example, some scholars have pointed out that global warming has led to an increase in the latitudinal temperature gradient between the Western Pacific and the Middle Eastern Pacific, strengthening the Walker circulation (latitudinal atmospheric circulation over the tropical Pacific), and thus intensifying the vertical shear of the Northwest Pacific winds, which is not conducive to the formation of typhoons [3]. Although global warming may not necessarily lead to an increase in the number of typhoons generated, it means that the intensity of typhoons will be greater in the future than it is now.

To verify the impact of climate change on the intensity of tropical cyclones, we analyzed the relationship between the average minimum pressure, average maximum center wind speed, extreme minimum pressure, and extreme maximum center wind speed over time based on tropical cyclone data from the Joint Typhoon Warning Center (JTWC) in the United States and the Japan Meteorological Agency (JMA).

### 2.2.1 Average intensity

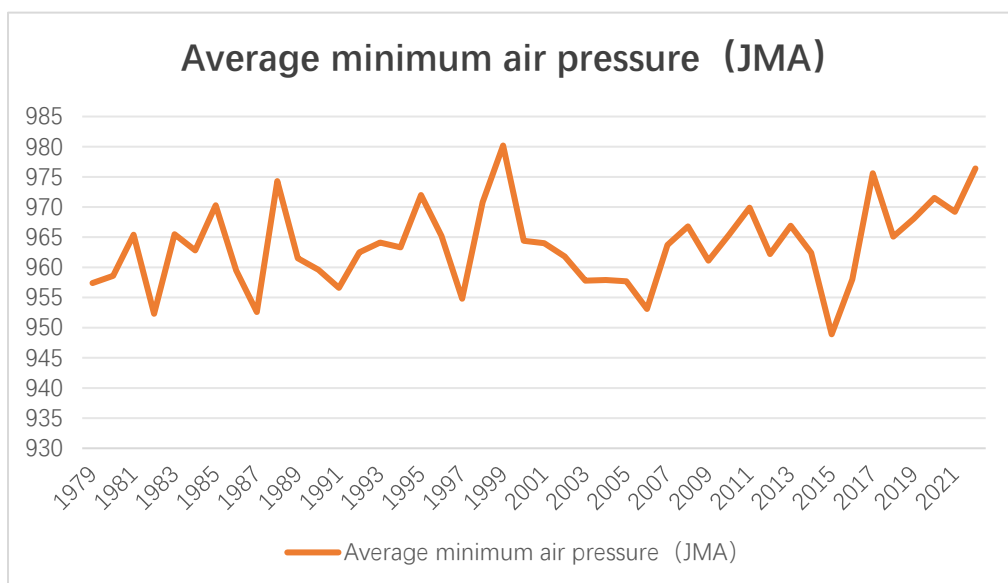


**Fig. 1** Average minimum pressure (JMA) of tropical cyclones in the northwest pacific from 1979 to 2021

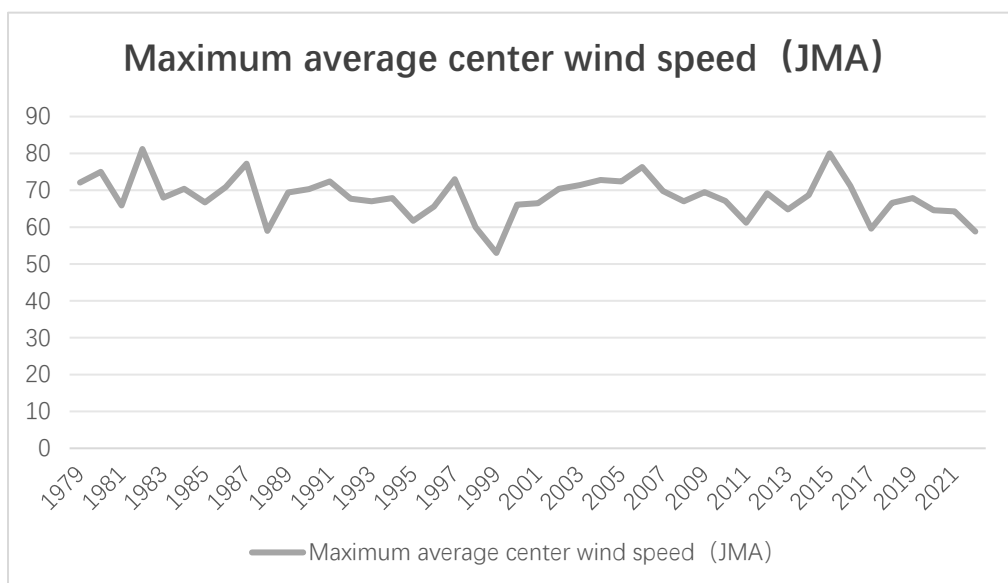


**Fig. 2** Maximum average center wind speed (JMA) of tropical cyclones in the northwest pacific from 1979 to 2021

As shown in figure 1 and figure 2, the average minimum pressure fluctuated from the late 1970s to the early 1990s and then began to show a significant upward trend. It reached its maximum in 1999 when the average intensity of typhoons reached its lowest value. In the early 2000s, the average minimum air pressure rapidly decreased. The average pressure in the 2010s fluctuated and increased compared to the 2000s. After reaching its lowest point in 2015, the average intensity of typhoons rapidly decreased. Overall, there is no significant correlation between global climate change and the average intensity of typhoons in the short term.

### 2.2.2 Extreme intensity

In terms of extreme intensity, JMA and JTWC have similar fixed strengths. After the Wind King Tip emerged in 1979 and won the throne of the Wind King of the last century, the extreme intensity of typhoons in the Northwest Pacific generally showed a fluctuating downward trend from the 1980s to the 1990s. After entering the new century, with the warming of the climate leading to a certain increase in seawater temperature and energy, the extreme intensity of typhoons gradually increased.

Especially in the 2010s and early 2020s, a total of four typhoons (1330, 1614, 2019, and 2102) received the evaluation of 170 knots, which was unprecedented since the satellite era. Meanwhile, Typhoon 1330 is also recognized by the meteorological community as the king of the century. So, with climate warming, the extreme intensity of typhoons is increasing, and the upper limit of typhoon development intensity is also constantly increasing, as shown in figure 3.

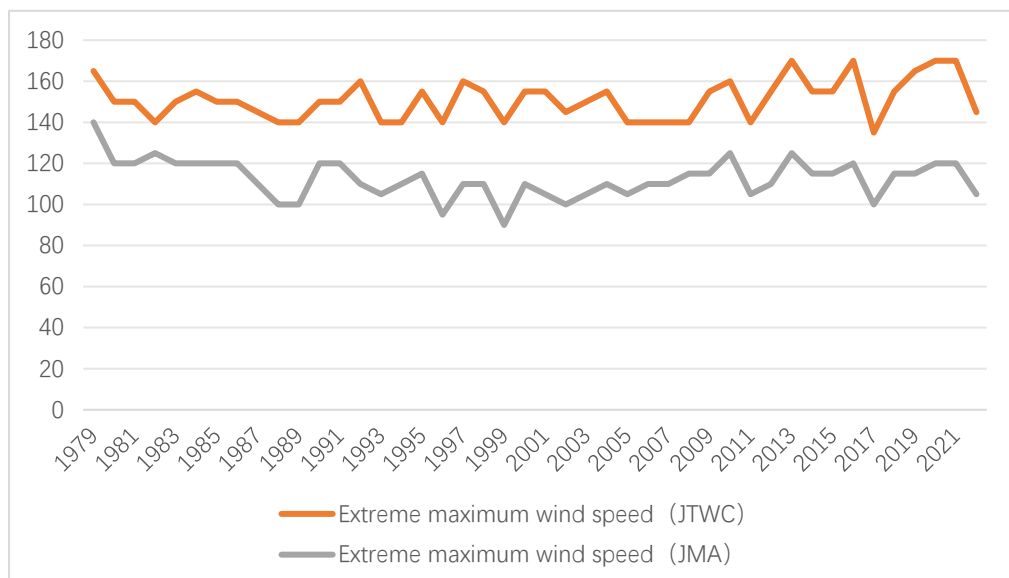


**Fig. 3** Extreme maximum wind speed of tropical cyclones in the northwest Pacific from 1979 to 2021

### 2.2.3 Changes in Typhoon Intensity in China

The actual measurements and model studies of the entire coastal and western Pacific regions of China indicate that global warming causes the equator to extend towards the poles and the subtropical high pressure to weaken. Therefore, the intensity of typhoons along the coast of China will continue to increase with the increase of tropical subtropical seawater temperature. The annual average landfall intensity and probability distribution skewness of tropical cyclones in China has shown an increasing trend, indicating an increase in the number of strong typhoons making landfall, and the difference in annual maximum landfall intensity of tropical cyclones has shown a long-term decreasing trend. In addition, typhoons that have made landfall in southern and eastern China have increased their intensity, with the former showing a more pronounced trend than the latter. However, Zhang and others compared the recent TC login intensity in Hainan Province, Fujian Province, Guangdong Province, and Zhejiang Province, and found that the increasing trend of TC login intensity in Zhejiang Province is more pronounced. The differences in viewpoints between the two may stem from differences in statistical methods and statistical years, and further research is needed [4].

### 2.3. Impact of Global Warming on the Paths and Landfall Positions of Tropical Cyclones in the Northwestern Pacific

Global warming may have two aspects of impact on the paths and landfall positions of tropical cyclones in the northwestern Pacific:

**Northward shift of generation position:** As the global temperature rises, the sea temperature will also rise accordingly. So, the 26 °C seawater isotherm will be pushed to the direction of high latitude, which may make the tropical cyclone generation range expand to the north. In addition, as the warming at high latitudes is more pronounced than at low latitudes, the temperature gradient in the direction of the meridional circle will be reduced, which will ultimately change the atmospheric circulation at low latitudes. According to climate simulations, a change of 15°C in the temperature gradient in the direction of the meridional circle can change the latitude of the subtropical high pressure by 10 degrees. The two are anti-correlated. It is also pointed out that the subtropical high

pressure and the equatorial convergence zone movement are positively correlated. That is, if the temperature gradient between the equator and high latitudes is reduced, the subtropical high pressure will move northward, and the equatorial convergence zone will move northward at the same time. As a result, the generation position of tropical cyclones will be farther north than the current climatic average position [5,6].

**Northward shift of the steering point and the landfall position:** The movement of tropical cyclones is manipulated by the outer guiding air flow of the subtropical high pressure. Global warming leads to a northward shift of the subtropical high pressure, which will cause the climatic average position of the steering point and the landfall position of the tropical cyclone to deviate to the north, and the movement speed of the tropical cyclone may also change.

In recent years, statistics by landfall position zones have revealed that the annual frequency of tropical depressions and (strong) tropical storms making landfall in southern China is mainly decreasing, while the annual frequency of tropical cyclones making landfall in eastern China is not changing significantly. However, the northernmost position of the landfall point (the southernmost position) tends to move southward (weakly northward), resulting in a gradual decrease in the maximum latitudinal difference between the north and south of the landfall point over the years, which suggests that the landfall area of tropical cyclones is more concentrated, increasing at 23°-35°N while mainly decreasing at the north of 35°N and south of 23°N. Zhang et al. compared the frequency of TC landfalls in Hainan, Fujian, Guangdong, and Zhejiang Provinces in recent years, and found that among these four provinces, the frequency of TC landfalls in Zhejiang Province, which is the northernmost province, increased the most, which is in agreement with the theoretical speculation [4].

## **2.4. Impact of Global Warming on the Frequency of Tropical Cyclones in the Northwestern Pacific**

In recent years, the annual frequency of tropical cyclones making landfall in China has shown a decreasing trend. Statistics by landfall position zones show that the annual frequency of tropical depressions and (strong) tropical storms making landfall in southern China is mainly decreasing, while the annual frequency of tropical cyclones making landfall in eastern China is not changing significantly. Similarly, as shown in the figure below, the change in the annual frequency of TCs in the northwestern Pacific is not significantly related to global warming.

The mere fact that thermodynamic conditions are favorable for typhoon formation does not mean that more typhoons will be generated because global warming can also affect typhoon formation at other levels. For example, global warming leads to an increase in the latitudinal temperature gradient between the western and central-eastern Pacific Ocean, which strengthens the Walker Circulation (the latitudinal atmospheric circulation over the tropical Pacific Ocean), which in turn increases the vertical shear of the winds in the northwestern Pacific, which is not conducive to typhoon formation.

## **3. Conclusion**

In recent decades, global warming has exerted a tremendous impact on the overall ecology of the Earth. In this study, the impacts of global warming on tropical cyclone activities in the northwestern Pacific are preliminarily explored. By reviewing the previous literature and analyzing the tropical cyclone data from the Joint Typhoon Warning Center (JTWC) and the Japan Meteorological Agency (JMA), it is concluded that the intensities and extreme intensities of tropical cyclones are increasing under the influence of global warming and the positions of their generation and landfall into China also have a tendency to move northward, while there is no significant change in the frequency. Tropical cyclone changes are affected by multiple factors, and researchers should closely and accurately track the trend of tropical cyclone changes and analyze the data trends from multiple perspectives in the future. In this study, the impacts of global warming on tropical cyclones in the

Northwest Pacific Ocean are summarized, which provides certain insights for China to understand, predict and prevent catastrophic weather caused by tropical cyclones.

### Authors Contribution

All the authors contributed equally, and their names were listed in alphabetical order.

### References

- [1] Tian Rongxiang. The Impact of Global Warming on Tropical Cyclones in the Northwestern Pacific. Journal of Zhejiang University, 2003, 30(4): 466-470
- [2] Wei Wen. The Exacerbation of Typhoons Due to Global Warming. Science, 2020, 72(4): 7-11
- [3] Han Yansong, Jiang Wei, Xiao Yuwen, et al. Characteristics of Major Changes in Tropical Cyclones and Influencing Factors under the Background of Global Warming. Progress in Earth Science, 2023, 38(5): 515-532
- [4] Zhang Jiaoyan, Wu Liguang, Zhang Qiang. The Trend Analysis of Tropical Cyclone Disasters in China under the Background of Global Warming. Journal of Tropical Meteorology, 2011, 27(4): 13.
- [5] Zhao Xiulan. A review of research on the spatial and temporal characteristics of Tropical Cyclones Making Landfall in China in the Past 50 Years and Their Impacts on Agriculture. Journal of Marine Meteorology, 2019, 39(4): 1-11.
- [6] Gu Chenglin, Kang Jiancheng, Yan Guodong, et al. Characterization of spatial and Temporal Variations of Tropical Cyclone Activities in the Northwestern Pacific under the Background of Global Warming and Analysis of Potential Risks. Disaster Science, 2019, 34(2): 89 - 96.