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# The Shaping of the Long-term Meteorological Trend by the Changes in the Marine Dynamic Environment from the Perspective of Satellite Backtracking

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**Abstract:**

This paper, from the perspective of satellite backtracking, deeply explores the relationship between the changes in the marine dynamic environment and the long-term meteorological trend. By analyzing the marine dynamic environment data obtained by satellite remote sensing, it expounds the multifaceted impacts of the changes in elements such as ocean temperature, ocean currents, and ocean waves on the long-term meteorological trend, reveals the key role of the ocean in climate change, and emphasizes the importance and application prospects of using satellite backtracking technology to study the relationship between the ocean and meteorology.

**Keywords:**

satellite backtracking
marine dynamic environment
long-term meteorological trend

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## 1. Introduction

The climate system of the Earth is a complex whole, and there is a close connection between the marine dynamic environment and meteorological changes. The ocean covers about 70% of the Earth's surface and is the main driver of weather and climate. The development of satellite observation technology has provided us with an effective means to monitor the marine dynamic environment from space, enabling us to obtain long-term, large-scale, and high-resolution ocean data. With the help of satellite backtracking technology, we can deeply study the changes in the marine dynamic environment and its shaping effect on the long-term meteorological trend, which is of great significance for understanding the mechanism of climate change and improving the ability of meteorological forecasting and climate prediction.

## 2. The application of satellite backtracking technology in the study of marine dynamic environment

### 2.1. Overview of satellite backtracking technology

Satellite backtracking technology, as a key means in the field of marine dynamic environment research, its core essence lies in relying on the remote sensing data collected by satellites at different times in the past to conduct long-term, systematic in-depth analysis and exploration of the marine dynamic environment. Back in the 1970s, satellite observation technology first entered the field of marine research. Since then, a series of marine observation satellites with different functions have emerged and continued to evolve. These satellites are like a mobile "marine scientific research station", equipped with a variety of advanced sensors such as microwave radiometers, microwave altimeters, microwave scatterometers, and synthetic aperture radars. With these precise instruments, satellites can penetrate the numerous obstacles of the atmosphere and accurately capture the slight fluctuations in ocean surface temperature, the dynamic changes in sea surface height, the intensity and direction of the sea surface wind field, and various characteristic parameters of ocean waves, thus providing a high-confidence, high-precision data foundation for the comprehensive analysis of the marine dynamic environment.

### 2.2. Advantages and processing methods of satellite data

Satellite data has the advantages of wide coverage, high observation frequency, and good spatiotemporal continuity, and can provide synchronous observation information of the global ocean, making up for the limitations of traditional marine observation methods in space and time. However, satellite data also has some problems, such as noise interference and data missing, and requires a series of data processing and correction. Common satellite data processing methods include radiation correction, geometric correction, atmospheric correction, data fusion, etc. Through these methods, the quality and reliability of satellite data can be improved, and accurate data support can be provided for subsequent research. At present, China's marine satellite monitoring system has developed into a multi-satellite networking and multi-means collaborative observation mode. The number of marine satellites and satellites with the ocean as the main user launched by China has reached 12, including the HY-1 series satellites, the HY-2 series satellites, the GF-3 series satellites, and the China-France Oceanography Satellite. After the GF-3 03 satellite was put into operation, the networking of China's HY-1 series, HY-2 series, and GF-3 series satellites was completed, and the operational observation pattern of China's marine satellite networking has been fully formed [1].

## 3. Satellite backtracking analysis of the changes in the marine dynamic environment

### 3.1. Changes in ocean temperature

In the complex system of the marine dynamic environment, ocean temperature plays a pivotal role. As one of the key elements, it has extremely far-reaching and intricate internal connections with meteorological changes. Through in-depth analysis of the massive data obtained by satellite backtracking, it can be seen that under the macro background of global warming, since the middle of the 20th century, the global average sea surface temperature has shown a continuous upward trend. Specifically, in the 61-year time span from 1958 to 2018, through accurate measurement, the cumulative increase in the global average sea surface temperature is about 0.54 °C. This slight but significant temperature change actually contains a lot of information about the changes in the global climate system [2]. From a regional perspective, the offshore area of China shows more significant warming characteristics, and the increase in the average sea surface temperature has exceeded the global average level, which undoubtedly brings unique challenges and changes to the regional marine ecology and coastal meteorological conditions. At the same time, the dynamic changes of ocean temperature are not one-dimensional, but also have distinct seasonal change characteristics and interannual fluctuation characteristics. Especially, once the sea surface temperature in the central and eastern equatorial Pacific Ocean shows abnormal fluctuations, it is like throwing a huge stone into the "lake" of the global climate and can directly trigger two highly influential climate events, El Niño and La Niña. Specifically, when the sea surface temperature in this region is continuously higher than the average value by 0.5 °C for 6 months or more, the El Niño event will come quietly; conversely, if it is continuously lower than the average value by 0.5 °C for 6 months or more, the La Niña event will appear immediately. The two appear alternately and have a wide and profound impact on the global climate pattern [3].

### 3.2. Changes in ocean currents

In the vast and complex dynamic system of the ocean, ocean currents, as a key component of the large-scale directional movement of seawater, play an indispensable role in the process of heat transfer and material circulation and are an important link in maintaining the balance of the marine ecosystem and the stability of the global climate. With the high-precision data collected by satellite altimeters, researchers can accurately monitor the dynamic changes of ocean currents. Many in-depth studies have shown that in the past few decades, the flow velocity and flow path of many major ocean currents with global influence have changed obviously. Taking the North Atlantic Current as an example, in a specific historical period, its intensity showed a stage-wise weakening trend. This slight but far-reaching change is very likely to cause non-negligible disturbances to the climate pattern in the northwest of Europe, such as a decrease in winter temperature and an adjustment in precipitation distribution. In addition, with the continuous observation of satellites, a significant phenomenon has been revealed: during the occurrence of El Niño events, the sea area near the equator is like experiencing an "ocean current storm", and the ocean current pattern is rapidly reshaped. The equatorial countercurrent is like being injected with powerful power, and its flow velocity increases rapidly, while the trade wind current shows a weak state and its flow velocity decreases significantly [4]. Such a violent reversal of the ocean current situation further deeply interferes with the exchange flux of heat and water vapor between the ocean and the atmosphere, just like knocking down the first domino in the climate, triggering a series of subsequent meteorological chain reactions and exerting a subtle but crucial influence on the global climate trend.

### 3.3. Changes in ocean waves

In the complex structure of the marine dynamic system, ocean waves, as the most intuitive form of fluctuation on the ocean surface, have the energy and unique characteristic parameters that have a key influence on the shaping of the entire marine dynamic environment and even the atmospheric meteorological conditions that cannot be ignored. With the precise detection functions of satellite scatterometers and altimeters, researchers can accurately capture the core parameters such as the wave height and period of ocean waves, thus providing a solid data foundation for in-depth exploration of the dynamic change law of ocean waves. Through the systematic analysis of satellite backtracking data, it can be clearly seen that in the past few decades, the global average wave height of ocean waves has shown a relatively significant dynamic change trend. Specifically, in some specific sea areas, the wave height of ocean waves shows a steady upward trend. The driving factors behind this phenomenon are relatively complex and are very likely to be closely related to the fluctuation changes of the wind speed above the ocean. At the same time, the overall changes in the marine dynamic environment caused by climate change are also important incentives [5]. Taking the local sea areas of the North Pacific and the North Atlantic as examples, in recent years, due to the significant increase in the frequency of storm activities, more energy has been injected into the generation and development of ocean waves, resulting in the continuous rise of the wave height of ocean waves. The rise of the wave height of ocean waves is not an isolated event. It will directly lead to a significant increase in the roughness of the ocean surface and then deeply interfere with the sea surface wind stress. Like the butterfly effect, it will finally have a significant feedback and regulation effect on the operation mode of the atmospheric circulation and the regional meteorological conditions, further aggravating the complexity of the interaction between the ocean and the atmosphere.

## 4. The impact of the changes in the marine dynamic environment on the long-term meteorological trend

### 4.1. Impact on the atmospheric circulation

In the complex interactive network of the Earth's climate system, the dynamic changes in the marine dynamic environment are like a key "link", deeply connecting the heat and water vapor exchange process between the ocean and the atmosphere, and then exerting a decisive influence on the evolution of the pattern of the atmospheric circulation. Specifically, when the ocean temperature shows an upward trend, the direct consequence is that the evaporation rate of water vapor on the ocean surface is significantly accelerated, resulting in a significant increase in the water vapor content in the atmosphere. This is tantamount to injecting abundant "energy blood" and water vapor supply sources into the atmospheric circulation and driving the change of the atmospheric circulation mode. Moreover, the abnormal movement of ocean currents is also a key factor that cannot be ignored. The warm current, as the "porter" transporting low-latitude heat to high-latitude regions, heats and warms the atmosphere where it passes, and the distribution of temperature and pressure changes, forcing the original operation track of the atmospheric circulation to be adjusted; in contrast, the cold current is like a "refrigerator", cooling and cooling the atmosphere in the flowing area, prompting the atmospheric circulation to start the self-adjustment mechanism and re-layout the temperature and pressure fields to adapt to the new thermal environment and maintain the dynamic balance of the atmospheric system [7].

### 4.2. Impact on precipitation

In the complex and delicate system architecture of the Earth's climate, the changes in the marine dynamic environment are like an "invisible giant hand", exerting extremely significant regulatory power on the distribution pattern and intensity of global precipitation. During the occurrence of El Niño events, the sea surface temperature in the central and eastern equatorial Pacific Ocean shows an abnormal increase, and this thermal anomaly causes a sharp increase in the convective activity in the upper layers of the ocean, as if breaking the original balance of water vapor transport and precipitation. The direct consequence is that many places such as northern South America, Australia, and Southeast Asia are deeply trapped in severe drought, while the central and southern parts of South America have an abnormally high amount of rainfall, and the precipitation distribution is seriously unbalanced. In contrast, when the La Niña event comes, the sea surface temperature in the central and eastern equatorial Pacific Ocean is low, and the ocean convective activity is weak and decreases, making the central part of Africa, the southeastern part of the United States and other places frequently suffer from drought, while the northeastern part of Brazil, India and the southern part of Africa and other places have frequent heavy rain and flood disasters due to abnormal water vapor transport [8].

### 4.3. Impact on extreme meteorological events

The evolution of the marine dynamic environment is closely related to the frequent occurrence and intensity increase of extreme meteorological events. With the increase in the global ocean temperature, the intensity and frequency of tropical cyclones show an increasing trend. Since 1970, the intensity of strong tropical cyclones (including strong hurricanes and typhoons) has not only increased, but also the number of occurrences has gradually increased. Especially in the western North Pacific, the area west of the 140° east longitude, the proportion of strong tropical cyclones has increased by 16% to 20%, and the frequency of occurrence has almost doubled. The abnormally high ocean temperature may also trigger marine heatwaves, bringing far-reaching impacts on the marine ecosystem and the climate of coastal areas [9]. In addition, the abnormal changes in ocean currents and ocean waves may also lead to more frequent and violent occurrence of extreme marine disasters such as storm surges, thus causing serious damage to the meteorological environment and ecological environment of coastal areas.

## 5. Meteorological long-term trend prediction model based on satellite backtracking data

### 5.1. Model construction principle

In order to predict the long-term meteorological trend, it is necessary to construct a meteorological prediction model based on satellite backtracking data. Such models are usually based on physical processes and statistical relationships, taking the marine dynamic environment parameters obtained by satellites as input variables and combining with meteorological observation data to establish the quantitative relationship between the marine dynamic environment and meteorological elements. Common model construction methods include empirical statistical models, numerical models, and machine learning models. The empirical statistical model is a statistical relationship established based on historical data, and the parameters of the model are determined through the correlation analysis of satellite backtracking data and meteorological data. The numerical model is based on physical laws and fluid mechanics equations to simulate the interaction process between the ocean and the atmosphere and predict the changes of meteorological elements. Machine learning models such as artificial neural networks and random forests can automatically learn the complex nonlinear relationships in the data and improve the prediction accuracy.

### 5.2. Model verification and application

The constructed meteorological long-term trend prediction model needs to be strictly verified and evaluated. Usually, independent observation data is used to verify the model, and indicators such as the prediction error and correlation coefficient of the model are calculated to evaluate the accuracy and reliability of the model [10]. In practical applications, the meteorological prediction model based on satellite backtracking data can provide long-term meteorological forecast information for the meteorological department and provide a scientific basis for the decision-making of industries such as agriculture, transportation, and energy. For example, in agricultural production, the planting and irrigation plans of crops can be reasonably arranged according to the prediction results of the long-term meteorological trend, and the stability and disaster resistance ability of agricultural production can be improved.

## 6. Conclusion

This study uses satellite backtracking technology to deeply analyze the impact of the changes in the marine dynamic environment on the long-term meteorological trend and draws important conclusions. Satellite data reveals the significant impacts of the changes in ocean temperature, ocean currents, and ocean waves on the atmospheric circulation, precipitation distribution, and extreme weather events. The constructed prediction model provides reliable information for meteorological forecasting. Although there are limitations in understanding the ocean-atmosphere interaction and model accuracy in the study, future work will focus on improving the theoretical understanding and prediction ability to cope with climate change and support sustainable development.

**Disclosure statement**

The author declares no conflict of interest.

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