Analysis Wave Characteristics in the Southeastern Bengal Bay Based on Different Data Sources

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Abstract. The research uses the wave parameters of OWI and ECMWF including wave height, period and direction, and analysis the wave characteristics of the sea area throughout the year and the wave characteristics of the NW wave. For the analysis of wave characteristics of waves biased to NW, OWI analysis biased towards NW waves in which wind and waves accounted for 62.6% and swells accounted for 37.4%, showing mixed wave characteristics dominated by wind and waves; while ECMWF analysis was biased towards NW waves. Wind and waves accounted for 24.5%, and swells accounted for 75.4%. There are big differences between the two data sources in the wave pattern analysis of NW direction. The research further uses the model to calculate and analyze the wave conditions of the Bay of Bengal waters affected by the monsoon (without considering the introduction of ocean waves). The results also show that the NW wave is characterized by a mixed wave feature dominated by wind and waves. The proportion of wind and waves is 76.1%, the proportion of swell is 23.6%, the average period is about 4.7s, and the maximum average period is less than 9s. From the analysis of the calculated directional spectrum, the biased NW wave caused by the monsoon also shows the characteristics of a bimodal spectrum, in which the wave energy is mainly reflected in the average period of about 5s. The research results show that the NW wave is a mixed wave feature dominated by wind and waves. There are long peak wave swells in the wave train, and the wave height and periodic characteristic values are relatively small.

1. Introduction
Scholars have carried out a series of research work on the characteristics of waves and wind fields in the Bay of Bengal based on measured data and reanalysed data. Cui Kaifu[1] et al. used the NCEP/NCAR wind field data from 1958 to 2010 to analyze the temporal and spatial characteristics of the sea level wind field in the North Indian Ocean. The analysis found that the wind speed distribution in the North Indian Ocean has the characteristics of small wind speed at the north and south ends, large in the middle, and smaller in the east than in the west. At the same time, there is a feature that the wind speed in the Arabian Sea is greater than the wind speed in the Bay of Bengal during the same period. Huang Meiling et al. [2] analyzed the double-peak characteristics of waves on Java Island, Indonesia, using actual engineering data. Li Pei et al. [3] used the meteorological ship data of the North Indian Ocean from 1950 to 1995 to analyze the meteorological characteristics of the North Indian Ocean, and found the distribution characteristics and inter-annual variation characteristics of the wind field. Mei Yong et al. [4] used ECMWF’s wind field data from 1957 to 2002 to analyze the characteristics of the interannual
variation of the wave field and wind field in the North Indian Ocean-South China Sea. The analysis showed that the temporal and spatial distribution of the effective wave height of the Indian Ocean and the temporal and spatial distribution of the wind field exist good correspondence. Liu Jinfang\cite{5} et al. used the meteorological ship data in the North Indian Ocean from 1980 to 1990 to analyze the characteristics of wind and wave fields in the North Indian Ocean. The analysis showed that the wind direction and wave direction were basically the same during the monsoon. Li Ting et al. \cite{6} used NCEP/NCAR wind field data to analyze the climatic characteristics of the southwest monsoon in the Bay of Bengal and the South China Sea tropical monsoon. The results showed that the southwest monsoon prevailed in the Bay of Bengal longer than the South China Sea prevailed, and the intensity of the southwest monsoon in the Bay of Bengal was much greater than the South China Sea monsoon. Strength of. Fu Chen\cite{7} et al. used the wave data and wind field data in ECMWF from 1979 to 2016 to analyze the distribution and change characteristics of extreme waves in the South China Sea and the North Indian Ocean, and the results showed that the characteristics of the extreme effective wave height and the extreme wind speed in the South China Sea and the North Indian Ocean Consistent. Xu Yanan\cite{8} used ECMWF to analyze the characteristics of waves on the east and west coasts of the Bay of Bengal. The sea area of the Bay of Bengal is significantly affected by the monsoon, and the regional differences in the wave climate of the entire Bay of Bengal are obvious. At present, most studies focus on the global waters, the Indian Ocean and the entire waters of the Bay of Bengal. In this study, the characteristics of wind and waves in the southeast of the Bay of Bengal are discussed in detail, and the characteristics of the waves in the southeast of the Bay of Bengal in different seasons are analyzed based on different source data. The sea area is affected by the SW monsoon and the SW swell of the Indian Ocean. The SW sea wave is the main wave direction in this sea area. However, the sea area has waves that are biased toward NW and different source data have different descriptions of waves biased toward NW. The study adopts SWAN The model further analyzes the characteristics of NW waves in the sea area.

2. Data source
This paper analyzes the wave characteristics of the eastern coast of the Bay of Bengal based on the used Ocean Weather wave and 10m wind field on the sea surface. OWI is a data released by the United States that includes all reanalyzed data and wave data of wind fields 10m above the global sea level. Its spatial resolution includes 0.75°×0.75°, 0.50°×0.50°, 0.25°×0.25°, 0.125°×0.125°, the highest accuracy currently achievable is 0.125°×0.125°. ECMWF uses UTC time with a time resolution of 6 hours, which are 4 times of 0 o'clock, 6 o'clock, 12 o'clock, and 18 o'clock each day. Use different source data to focus on analysis.

3. Analysis of sea wave characteristics based on multi-source data
3.1. Analysis the characteristics of ocean waves based on OWI data
OWI data analysis results show that the wave directions along the southeast coast of Bangladesh are distributed between SW and NW directions, with WSW and SW direction waves being the main ones. The normal wave direction is represented by the WSW direction with a frequency of 32.8%, the second normal wave direction is represented by the SW direction with a frequency of 30.5%, followed by the influence of the NW monsoon, the frequency of WNW waves is 15.2%. The research based on the criteria established by wave conditions\cite{9} judged the proportion of wind and swell components in the sea area, and the results showed that wind and waves accounted for 32.4% and swells accounted for 67.6%. The sea area appeared as a mixed wave dominated by swells feature. The average effective wave height in the sea is 1.29m, and the average period is 9s. Among them, the frequency of cycles of 8s or more accounted for 57.4%, the frequency of average cycles of 10s or more accounted for 42%, and the frequency of cycles of 12s or more accounted for 15%.
Statistical analysis of the characteristics of north-westward waves shows that WNW-NW-NNW-N waves accounted for 23.5% of all wave directions. Based on the criteria established by wave elements, the analysis of NW waves accounted for 62.6% of wind waves, and swells. It accounts for 37.4%, showing the characteristics of mixed waves dominated by wind and waves. The frequency of WNW and NW waves in the north-westward waves exceeds 98%, the frequency of waves below 1m exceeds 76%, and the probability of wave heights above 1.5m is 0.6%. The statistical maximum significant wave height is 4.04 m, and the average wave height is 0.87 m. According to statistics, the average period of this sea area is 7.26s, the probability of waves with an average period of less than 8s is more than 55%, and the probability of waves with an average period of more than 8s is nearly 45%. Among the waves with an average period of 8s or more, the proportion of the wave height less than 1 is 85%.

3.2. Wave characteristics analysis based on ECMWF
ECMWF data analysis results show that the wave directions along the southeast coast of Bangladesh are distributed between SW and NW directions, with SW direction waves being the main wave. The normal wave direction is represented by the SW direction with a frequency of 39.1%, and the secondary wave direction is represented by the WSW direction with 22.5%. The frequency of wind and waves is 13.4%, and the frequency of swells is 86.6%, which is characterized by mixed waves dominated by swells. Affected by the NW monsoon, the frequency of WNW waves is 8.4%. The average effective wave height in the sea area is 1.06m, the average period is 7.9s, and the wave characteristics are mixed waves dominated by swells. Among them, cycles below 8s account for 55.5% of the frequency, and cycles above 12s account for 0.7% of the frequency. The waves show seasonal changes. The waves affected by the NW monsoon from January to March in the first quarter are mainly WNW waves, with an average effective wave height of about 0.87m and an average period of 9.06s; the second and third quarters are all affected by SW Directional waves are dominant, the average effective wave height is about 1.93m, and the average period is 7.76s;

The research analyzes the WNW~NW~NNW-N meteorological wave data supplementary analysis of the wave type and wave height period distribution characteristics of the north-westward waves in the sea area. WNW-NW-NNW-N waves accounted for 15.37% of all wave directions. Based on the criteria
established by wave elements, analysis of NW waves accounted for 24.5% of wind waves and 75.4% of swells. The frequency of waves below 1m exceeds 82%, and the probability of waves above 1.5m is 0.23%. The statistical maximum significant wave height is 2.5 m, and the average wave height is 0.83 m. According to statistics, the average period of this sea area is 5.6s, the probability of waves with an average period of less than 8s is over 99%, and the frequency of waves with an average period of over 8s is 0.1%.

In summary, when using different data sources to analyze wave characteristics in this sea area, there are differences in three aspects: main wave direction, wave pattern characteristics and wave parameter characteristic values. ECMWF analysis results show that the main wave direction is SW direction, the frequency of waves biased to NW is 15.37%, and the frequency of waves biased to SW is 81.4%. OWI analysis results show that the main wave direction is the WSW direction, the frequency of waves biased to the NW direction is 23.5%, and the frequency of waves biased to the SW direction is 75.6%. There is a 22.5 degree difference in the main wave direction between the two data sources, and the OWI data shows that the NW wave component is slightly higher. From the wave type analysis, the research based on the criteria established by the wave elements to determine the proportion of wind and surge components in the sea area. OWI results show that wind and waves account for 32.4%, and swells account for 67.6%. ECMWF results show that the frequency of wind waves is 13.4 %, the frequency of swells is 86.6%, although they are all characterized by a mixed wave feature dominated by swells, and the frequency of wind waves in OWI data is higher than that in ECMWF. For the analysis of wave characteristics of waves biased to NW, OWI analysis biased towards NW waves in which wind and waves accounted for 62.6% and swells accounted for 37.4%, showing mixed wave characteristics dominated by wind and waves; while ECMWF analysis was biased towards NW waves. Wind and waves accounted for 24.5%, and swells accounted for 75.4%. There are big differences between the two data sources in the wave pattern analysis of NW Xianglang. From the analysis of the eigenvalues of the overall wave elements, the average effective wave height in the sea area analyzed by OWI is 1.29m and the average period is 9s; while the average effective wave height in the sea area analyzed by OWI is 1.06m and the average period is 7.9s. Analysis of the eigenvalues of the wave elements in the NW direction, OWI shows that the average effective wave height is 0.85m, and the average period is 7.26s; ECMWF shows that the average effective wave height is 0.83m, and the average period is 5.6s. The results show that the average effective wave height of OWI is greater than the average effective wave height of ECMWF, and the magnitude of the wave height for the partial NW direction is similar, but the wave period is different.

Therefore, the study found that for waves that are biased toward NW, there are large differences in wave type judgment and wave period analysis based on OWI data sources and ECMWF data sources. In order to further study the characteristics of waves biased toward NW in this sea area, the study uses the SWAN model for this area Model analysis of wind and waves.
3.3. Analysis of Wave Characteristic Spectrum Based on SWAN Model

The bay of the Bay of Bengal has wide open seas. The length of the wind zone in the NW direction is nearly 900km. The bay is directly connected to the North Indian Ocean, and the sea conditions in the Bay are affected by the SW wave from the Indian Ocean. In order to further analyze the characteristics of the waves in the NW direction in this sea area, using ECMWF's 2019 wind field data (time resolution is 1 hour) for one consecutive year as the driving force, the SWAN model was used to simulate the wave conditions caused by the wind field in 2019 analysis. The simulation analysis will not consider the impact of the SW wave entering the Bay of Bengal from the Indian Ocean boundary. From the analysis of the simulation results, the main wave direction throughout the year under the influence of the SW monsoon appears to be the SW direction, and the probability of occurrence of the NW direction is 35.98%, and the average wave period is within 8s. The frequency of wind and waves is 76.1%, and the frequency of swells is 23.9%. The wave height rose diagram of the sea area is as shown in the figure from the analysis of the direction spectrum on January 14, 2019. The wind and waves in the sea area show the characteristics of double-peak spectrum. At this moment, the internal wave energy is mainly concentrated in the NW direction, and part of the energy is shown in the SW direction. The peak
frequency of the wave is about 0.2hz, that is, the main energy is concentrated in the wave period of about 5s.

Figure 5. SWAN modelled wave rose in seasonal wind period

4. Conclusion
The research uses the wave parameters of OWI and ECMWF including wave height, period and direction, and analyzes the wave characteristics of the sea area throughout the year and the wave characteristics of the NW wave. From the analysis of the NW wave, the northwest wave in OWI accounts for 62.6% of the wind wave and 37.4% of the swell wave, which is characterized by a mixed wave characterized by wind and waves. When the wave height is greater than 1m, the frequency of occurrence of sea conditions with a period of less than 8s is more than 85%. In order to further analyze the characteristics of the wind surge component of the NW wave, the design institute provided the direction spectrum in January 2013. The wave in the sea area has the characteristics of a double peak spectrum. At the same time, the research unit used the model to calculate and analyze the wave condition characteristics of the Bay of Bengal waters affected by the monsoon (without considering the introduction of ocean waves). The results also show that the NW wave is a mixed wave feature dominated by wind and waves, of which the proportion of wind waves It is 76.1%, the proportion of surge is 23.6%, the average period is about 4.7s, and the maximum average period is less than 9s. From the analysis of the calculated directional spectrum, the biased NW wave caused by the monsoon also shows the characteristics of a bimodal spectrum, in which the wave energy is mainly reflected in the average period of about 5s. The calculation results show that the NW wave is a mixed wave feature dominated by wind and waves. There are long-peak swells in the wave train, and the wave height and periodic characteristic values are relatively small.

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