LONG-TERM TRENDS OF EXTREME WAVES BASED ON 55 YEARS OF OBSERVATION DATA FROM THE COASTAL SEA AREA OF CHINA

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INTRODUCTION

On the background of global warming and sea level rise, the trend of extreme waves in the coastal sea area has been under sustained consideration (Sasaki, 2012. Young et al, 2011 and 2019. Liu et al, 2023). The First Scientific Assessment Report on Ocean and Climate Change of China and The Fourth Assessment Report on Climate Change of China were published in 2020 and 2022 respectively. However, there have been no concrete results on the long-term trends of wave changes in China. In this paper, using wave data from in situ observation sites along the coast of China, long-term trends in extreme wave elements over the past 55 years were investigated (Figure 1).

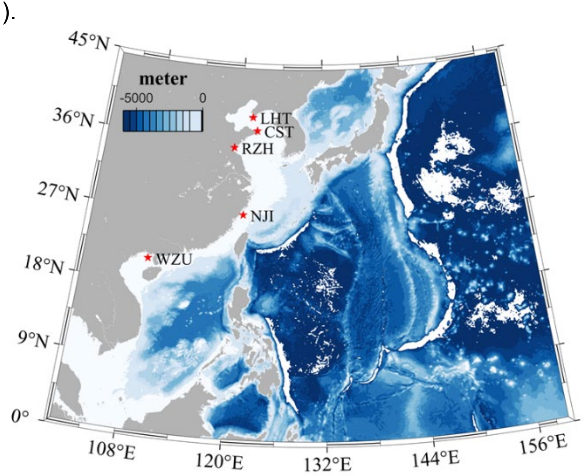
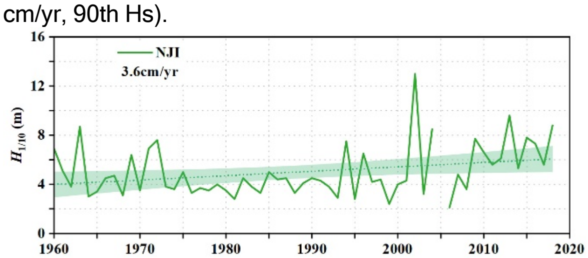


Figure 1 - Wave observation stations in China.

LONG-TERM TRENDS IN WAVE PARAMETERS

Figure 2 depicts the trend of annual maximum values of $H_{1/10}$ and H_{max} at NanJi Station (Hereafter NJI) in coastal China sea. The trend was assessed using the Mann-Kendall test. The $H_{1/10}$ yearly maximums of the NJI stations, typically vary from 2 m to 13 m. The trends of maximum of $H_{1/10}$ and H_{max} at NJI stations are 3.6 cm/yr and 5.3 cm/yr, respectively. In the China Sea, the results of Young et al. (2011) were slightly larger than those of Semedo et al. (2011) (0.5-1.5 cm/yr, Hs) and Wang et al. (2016) (0.5-1 cm/yr, 90th Hs).



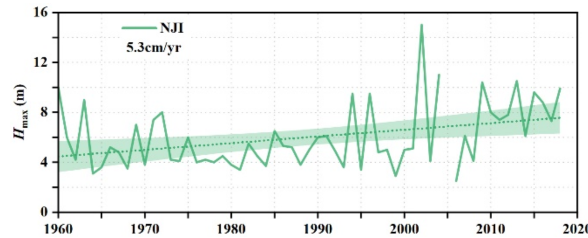


Figure 2 Time series of annual maximum $H_{1/10}$ (upper panel) and H_{max} (lower panel) from NJI observation stations. Trends (colored dashed lines) represent linear regressions of annual $H_{1/10}$ and H_{max}. Shaded areas are 95% confidence intervals.

CHARACTERISTIC INTER-MONTHLY DISTRIBUTION FOR WAVE HEIGHT

Monthly distribution for $H_{1/10} \geqslant 3$ m events at 5 stations over a cumulative period of 55 years are shown in Figure 3. NJI has the highest cumulative number of $H_{1/10} \geqslant 3$ m events of the five stations. The majority of events at this station occurred between July and October, with August having the highest number of occurrences at 622 over the 55-year period.

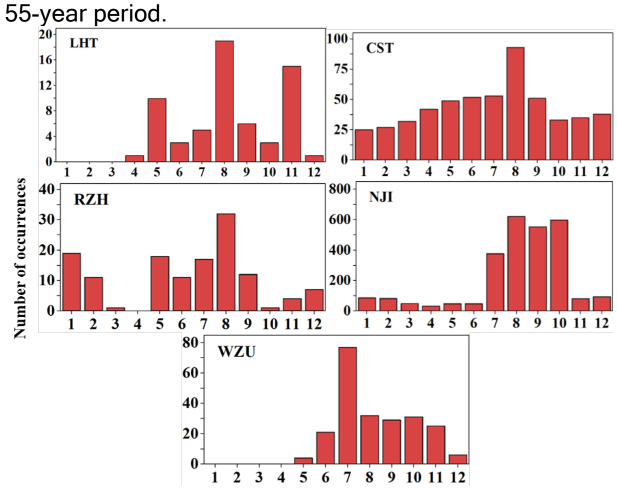


Figure 3 Monthly distribution for $H_{1/10} \geqslant 3$ m events at 5 stations over a cumulative period of 55 years (stations LHT, CST, RZH, NJI, and WZU in order)

ANALYSIS OF THE INTERANNUAL VARIABILITY AND DURATION OF ACTION OF WAVES

Furthermore, the sustained duration of $H_{1/10} \geqslant 3$ m may have negative effects on offshore structures, coastal shoreline topography, wave-induced urban flooding, and coastal aquaculture. Only events with a single duration greater than or equal to 3 days were taken into account when calculating the cumulative duration (Figure 4). RZH and NJI stations were more frequent and increased dramatically in frequency after 1990, with the NJI station recording the longest duration of a single event reaching 7 days.

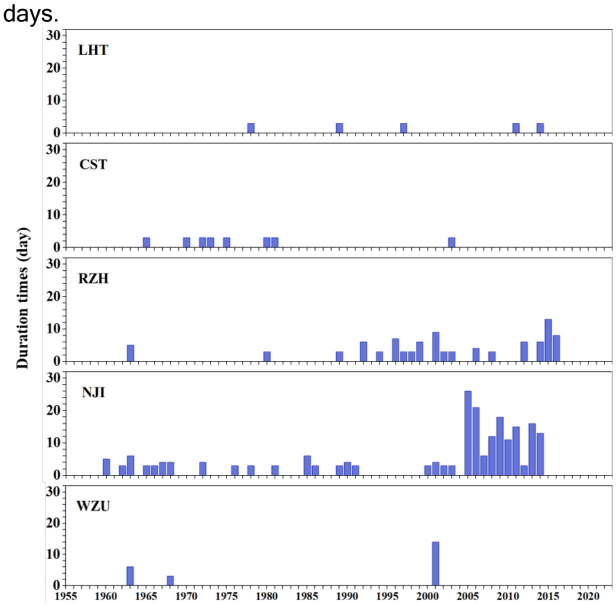


Figure 4 Inter-annual distribution of the cumulative duration for $H_{1/10} \geqslant 3$ m events at the 5 stations (only considered here for durations greater than or equal to 3 days)

TIME-DEPENDENT GEV DISTRIBUTION

The Gumbel curve method is applied to wave observation data from 5 stations, and the 50, 100, and 200-year return period values for H_{max} for the five stations are calculated (Figure 5). Compared to the three stations above, the NJI and WZU stations show a single peak pattern. The NJI station is the largest of the five stations, reaching 11.74 m (50-year return period).

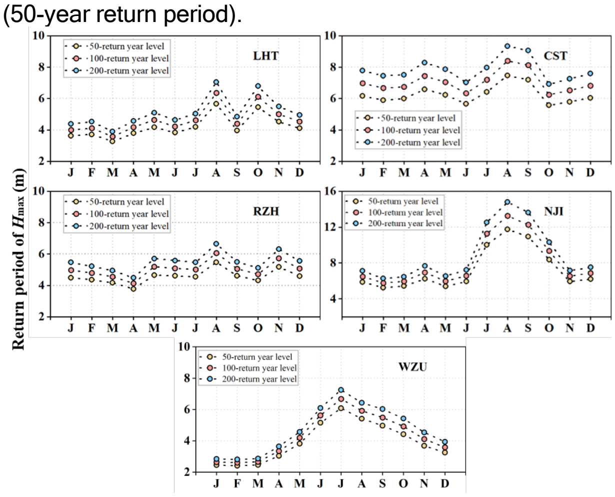


Figure 5 Hmax return period for 5 stations (LHT, CST, RZH, NJI, WZU in order of stations).

CONCLUSIONS AND PROSPECTS

The long-term wave trends over a 55-year time span for China with five in situ stations are investigated here. The features of monthly distribution of $H_{1/10} \geqslant 3$ m episodes were calculated. The NJI station had the most incidents in August with 622. The interannual variability and cumulative duration revealed an increase in NJI and RZH since 1990.

The inaccuracy of numerical simulations of nearshore waves and the inaccuracy of satellite inversions of nearshore waves make in situ observations essential. Future more observations could provide a more comprehensive understanding of the patterns of climate change impacts on coastal wave climate in China.

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