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Editorial: Advances in sea state modeling and climate change impacts

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Editorial on the Research Topic
Advances in sea state modeling and climate change impacts

1 Introduction

Research on generating accurate wind and wave hindcasts and investigating climate change effects on marine environments and conditions have become popular in recent decades. The wind and wave modeling communities have made significant developments in physical and numerical parameterizations and model performance in sea state modeling. Knowledge of the marine environment has been understood better with modeled wind and wave datasets, supplemented by *in-situ* and remotely sensed data. The quality of wind data is being improved, which leads to generating the wave climate with higher accuracy. Therefore, improvements in wind predictions are of prime interest. This Editorial on Frontiers in Marine Science aims to bring together a diverse group of experts to discuss the latest advancements in wind and wave hindcasts and climate models. The focus is on understanding the most recent developments in wave hindcasts in various marine environments, as well as identifying the potential impacts of climate change on ocean climate. The research articles included in this collection showcase the most recent findings on topics such as sea state modeling, wind and wave climate, wave and sea level projections, and more.

2 Sea state modeling

This thematic section focuses on some papers about sea state modeling in different sea areas. This summary covers the impact of various wave-ice parameterization models on wave model hindcast performance, the role of non-linear tide-surge-river interactions in exacerbating flooding, the effects of binary typhoons on ocean surface waves, the evaluation of WRF and WAVEWATCH-III® (WWIII) models during a meteotsunami event, and introduces a two-scale approximation as a new method for estimating transfer rates in wind-wave spectra.

Iwasaki and Otsuka conducted an evaluation of the wave-ice parameterization models in WWIII along the coastal region of the Sea of Okhotsk during winter. They discovered that the accuracy was lower in ice-covered areas compared to open-water areas, with a noticeable discrepancy between the six sea ice models. The simulations that incorporated sea ice greatly improved the wave field bias in coastal areas as compared to the simulations without sea ice. Xiao et al. characterized the non-linear interactions between tide, storm surge, and river flow using the unstructured-grid Finite Volume Community Ocean Model in the Delaware Bay Estuary, United States. The authors indicated that the tide-surge interactions mainly influenced diurnal tides, and semidiurnal tides were damped due to tide-river interactions. The effect of binary typhoons on ocean surface waves was numerically analyzed by Chang et al. in waters surrounding Taiwan. These effects were elucidated near the tracks of the three super typhoons. The results of the analysis indicate that binary typhoons not only lead to an increase in significant wave height (H_s), but also result in an enhancement of one-dimensional wave energy and two-dimensional directional wave spectra. Rahimian et al. conducted a reliability assessment of the WRF and WWIII models during a recent meteotsunami event in the Persian Gulf. They determined that the Mellor-Yamada-Nakanishi-Niino (the Mellor-Yamada-Janjic) scheme produced the best performance for stations over the water (land) for planetary boundary and surface layer (Eta similarity). Additionally, the results of the study revealed that the calibrated ST6 formulation with the Gaussian Quadrature Method produced a more accurate prediction of the wave spectrum. Perrie et al. proposed a generalized two-scale approximation for estimating transfer rates in wind-wave spectra. They introduced a generalized formulation of the two-scale approximation into the WAVEWATCHIII^{TM} model, which can handle multiple peaked spectra, sheared spectra, and sea-swell combinations. The new methodology has been shown to significantly improve the accuracy of the results and was validated through application to real test cases.

3 Wind and wave climates

This thematic section presents six studies on the examination of wind and wave climates in various regions. These studies explore into the topics of wave climate variability and mudbank formation, a comprehensive analysis of wave climatology, the long-term and seasonal variations of wind and wave extremes, the impact of internal climate variability on historical ocean wave height trends, the spatial and temporal variability and climate teleconnections of global ocean wave power, and the use of innovative polygon trend analysis for detecting trends in winds and waves. Saprykina et al. analyzed the relationship between wave climate variability and the formation of mudbanks along the southwestern coast of India. They employed the wavelet correlation method to find significant correlations between the height of wind waves and swell and various climatic indices, including both positive and negative phases, on different time scales. The study also identified the time lags between these fluctuations. Barbariol et al. conducted a study of the wind waves in the Mediterranean Sea and presented their findings in the form of a 40-year wave hindcast. The authors investigated the relationship between the wind waves and atmospheric parameter anomalies, as well as with teleconnection patterns. They discovered that the Scandinavian index variability had the strongest correlation with the variability of the Mediterranean Sea wind waves, particularly in the case of typical winter sea states. Additionally, the authors found that the typical and extreme significant and maximum individual wave heights in the Mediterranean Sea tend to decrease in the summer and increase in the winter. Cabral et al. conducted a study of the historical trends of extreme waves in the Arctic Ocean using a 28-year wave hindcast and a non-stationary approach to analyze the time-varying statistical properties. They found substantial seasonal differences and robust positive trends in extreme wave height, particularly in the East Siberian seas and Beaufort, with increasing rates of up to 60% for the 100-year return period, despite a marginal increase in wind speed of up to 5%. Casas-Prat et al. evaluated the trends in the annual mean and maximum H_s using a 100-member ensemble with a single model initial-condition for the period 1951 to 2010. They discovered that relying on a single member was insufficient in identifying the statistically significant positive trend present in the ensemble in some regions of the Southern Ocean. Cao et al. analyzed the ERA5 reanalysis data from 1979 to 2020 and quantified the global distribution and variability of wave power. According to their findings, the regions with the highest potential for wave energy were located in the westerlies of both hemispheres. Furthermore, they observed a trend of increasing wave power in the Southern Ocean, which dominated the overall pattern of global wave power. Akçay et al. compared the effectiveness of innovative trend methods and traditional methods in identifying the trends of monthly mean and maximum wind speed and H_s in the Black Sea coast using 42 years of SWAN wave simulations forced by CFSR winds. The results of the Mann-Kendall test indicated a low occurance of trends for both parameters, while the IPTA method identified stronger trends.

4 Wave and sea level projections

In this thematic section, sea level and wave climate projections are studied, in the context of the mean and extreme wave climate, directional spectra, and regional wave climate.

Li et al. examined the projected changes in the average and extreme wave climate in the East China Sea, Yellow Sea, and Bohai Sea for two future time frames (2021-2050 and 2071-2100) under the RCP2.6 and RCP8.5 scenarios. They discovered that the average annual and seasonal H_s is expected to decline during both future periods and under both scenarios. However, in contrast, the annual and summer/winter 99th percentile H_s is likely to increase in a significant portion of the study area. Lobeto et al. analyzed the projections of directional wave spectra to understand how wind waves will behave in the future using a seven-member wave climate projection ensemble under a high-emissions scenario. They pointed out that relying solely on integrated wave parameters such as H_s and mean wave period can conceal important information about the direction, magnitude, and reliability of wave climate changes. This is because positive and negative variations within the spectrum can cancel each other out, leading to an underestimated change for certain wave systems. Su et al. analyzed the impact of climate change on the water level caused by storm surges and wind waves in Køge Bay, near the entrance of the Baltic Sea, which has a low tidal range. The authors found that the change in wave height and period during stormy conditions is negligible. However, when taking into account sea level rise, the simulation showed that under storm surge conditions, the wave height is expected to double in the near future (mid-century), and the wave period may also increase by around 1.5 seconds. Jackson et al. used a dynamical downscaling approach, consisting of a series of nested two-dimensional hydrodynamic models, to calculate the anticipated changes in the total sea level climate and its components along the Uruguayan coast. The authors found that the primary contributor to the projected changes in the area is the rising regional mean sea level, followed by the impact of increased water depth on the tidal component amplitudes.

5 Other topics

Finally, the Research Topic includes three papers aiming to investigate inter-annual to multi-decadal sea surface temperature (SST) variability, freshwater transport by the Labrador Current, and the long-term variability of intermediate water thickness.

Al Senafi utilized an empirical orthogonal function (EOF) decomposition analysis to study the interannual to multi-decadal variability of sea surface temperatures (SST) in the Persian Gulf from 1982 to 2020. The author found that the warming rate from 1982 to 2020 was as high as 0.59°C per decade and concluded that despite the overall warming trend of SST, there was a cooling period, which then shifted back to warming and has been increasing since 2003. Ma et al. analyzed the freshwater transport by the Labrador Current around the Grand Banks of Newfoundland using 26 years of data from the Global Ocean Physical Reanalysis (GLORYS12v1). The study found that the seasonal and inter-annual variations of the freshwater transport in the eastern area of the Grand Banks of Newfoundland are primarily driven by variations in the horizontal velocity of the Labrador Current, while changes in salinity play a significant role in the variation of the freshwater transport north of 45°N. Park studied the fluctuations of the East Sea intermediate water (ESIW) thickness over a long period and the change in the intermediate layer that took place in the mid-1990s. The author proposed that the shift in the regime of the East Sea meridional overturning circulation was behind this change. Before the mid-1990s, the variability of the ESIW layer was largely influenced by active deep-water formation, but after the mid-1990s, the formation rate of the ESIW became the primary factor in determining its thickness variability.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

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