A310

Extreme Sea Levels and Freak Waves along Global Coast in Response to Climate Change

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Introduction

As the observed positive trends in temperature and sea level rise become clear, several climate change projections have been conducted for historical reanalysis and future hindcast, such as ERA-5 and d4PDf database.

In this project, we focus on global sea level rise, especially extreme events (freak waves) caused by high-order non-linear instability and their evolution in long-term climate simulations with circulation models.

Theoretical Model

Based on the contribution from B-F instability, Lyu et al. (2021) and Lyu et al. (2023) developed a numerical model through non-linear Schrödinger equation to estimate the occurrence of freak waves.

In this model, the probability of freak waves depends on two components: the initial condition, which includes the bandwidth of the frequency spectrum and directional spreading, and the boundary condition of bottom topography. Through a large number of Monte Carlo simulations, we parameterize and formulate the occurrence probability of freak waves considering multiple contributing factors.

Global Wave Model

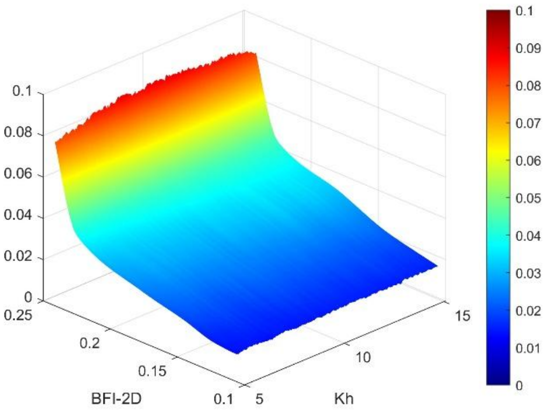
Global wave model WaveWatch III (WW3) is applied to provide the wave data for reanalysis process. WW3 model estimates the wave information through the construction of spectral from different contributions. However, it considers extreme sea levels only in traditional way and the maximum wave height is simply assumed to be linearly related with significant wave height.

In this study, we use WW3 to provide high-precision information corresponding to the required initial condition and boundary conditions for the freak wave estimation model.

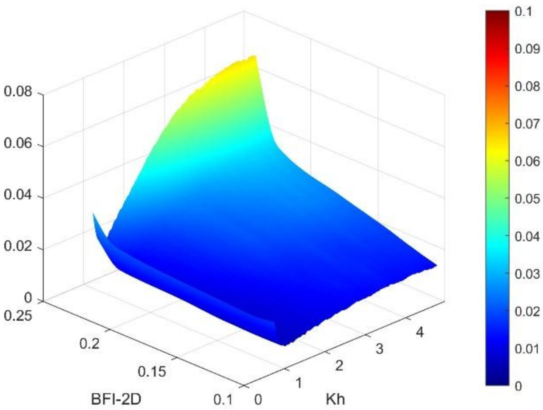
Result and Discussion

In Fig.1, we present the interpolation fitting of the occurrence probability of the freak wave $P(f)$ from Monte Carlo database (we take the most widely definition that freak wave is more than 2 times of significant wave). At different bottom topography types, $P(f)$ is fitted from dimensionless water depth kh and $BFI-2D$, which is an index to describe B-F instability in a 2D directional wavefield (Mori et al., 2011). In deep and medium water, $P(f)$ will significantly increase as $BFI-2D$ increases. At shallow water area ($kh<2$), steep slope will lead to a rebound process due to the second-order effect.

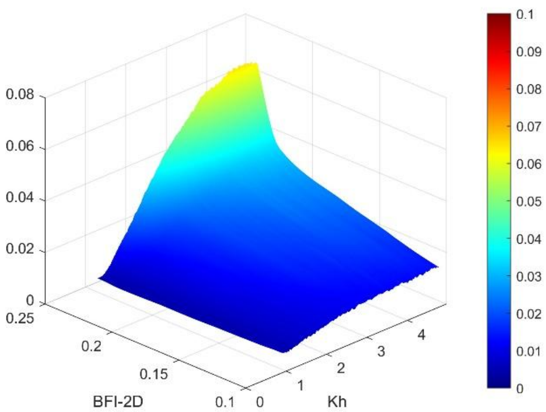
In WW3 model, we calculated the spectral width excluding wind sea contribution, and generated corresponding $BFI-2D$ in reanalysis process. As an example, we calculate the global wave condition in 2021.6 and 2021.12 with jra3Q wind and ice forcing. Fig.2 gives the spatial distribution of significant wave height Hs from WW3 and corresponding reanalyzed $P(f)$. In 2021.6, wave heights are significantly higher in the Southern Hemisphere, and freak risk is also higher in corresponding area. In 2021.12, wave heights and freak risk in North Pacific and Atlantic Ocean increase because of Typhoon effect. Mediterranean district also gives high risk for freak waves.



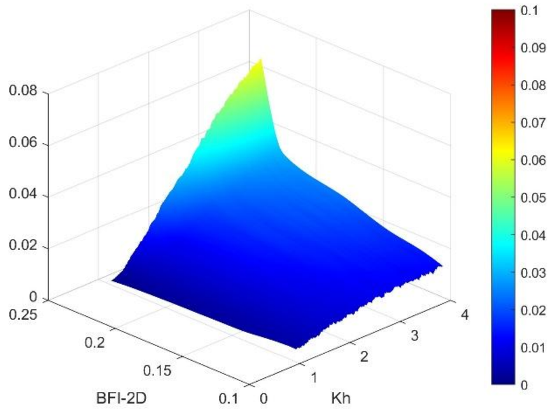
a. Deep water



b. Bottom slope = 0.05



c. Bottom slope = 0.02



d. Bottom slope = 0.01

Fig. 1 Interpolation fitting of $P(f)$ with $BFI-2D$ and kh

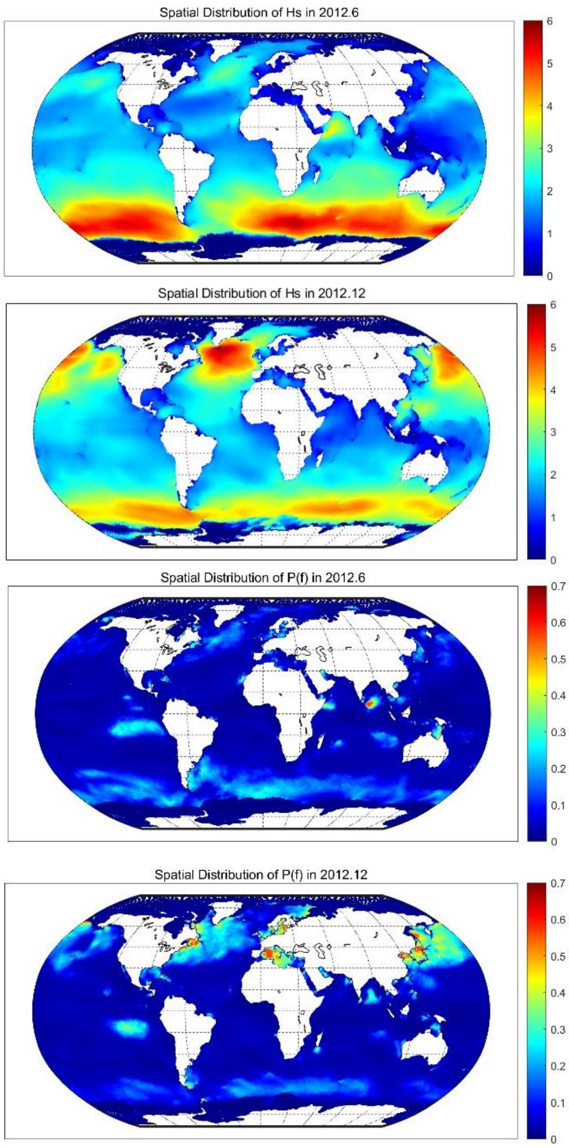


Fig. 2 Spatial distribution of Hs and $P(f)$ in 2021.6 and 2021.12