COUPLING SPECTRAL AND PHASE-RESOLVING WAVE MODEL FOR FORECASTING OF EXTREME WAVES IN WIND SEAS

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INTRODUCTION

''Freak'' or ''Rogue'' waves, when single individual wave height exceed two times of the significant wave height (Hi>2Hs), has been considered as one of the most dangerous sea states. Freak waves are believed to have caused many catastrophes, which result in ship damage and human casualties (Kharif and Pelinovsky, 2003). Occurrence of such waves are extremely unlikely according to Rayleigh distribution (Dean, 1990), however, in real ocean conditions occurrence of such events are higher than commonly used distributions.

The main objective of this study is the coupling of Spectral WaveWatch III (WW3) model and phase resolving wave models, which will advance the application of the third generation wave models one-step further and increase the precision of model outputs and forecasting of such "unlikely" extreme conditions.

METHODOLOGY

The present day wave forecasting system depends on the description of the ensemble-averaged sea states, for which wavenumber spectrum and its evolution plays a central role (Janssen, 2003). Spectral models are applicable and accurate globally, however information provided from those models are only spectral (averaged) results. On the other hand, phase-resolving models are able to create individual wave parameters. Nevertheless, they are not applicable in large scales, due to high computational cost. In this study, wind sea spectra is produced by WaveWatch III (WW3) model. Acquired discrete spectra partitioned in order to comb out noise and swell systems. Remaining wind sea spectra are analyzed for signs of possible extreme event such freak waves. Two phase-resolving models have been considered 1D fully nonlinear model (CS model) developed by Chalikov and Sheinin (1996) and high order spectral model (HOS-Ocean) developed by Ducrozet et.al (2016).

Freak waves are explained by many different mechanisms. However, many researches meet up at the idea that strong nonlinearity is present in event of freak waves. According to Janssen (2003) "Freak waves are likely to occur as long as the wave train is subject to nonlinear focusing." Therefore, indicators of nonlinear focusing which leads to evolution of an inhomogeneous and unstable random wave field should be present in shape of spectra. The present study investigates those nonlinearity using 2 different criteria. The first one is Benjamin Feir index (BFI) which is the ratio of steepness to spectral bandwidth, and introduced by Janssen (2003). BFI is based on and named after theory of Benjamin-Feir instability, which states that, if steepness is large and spectral bandwidth is small enough modulational instability is present for quasi-monochromatic wave trains (Benjamin and Feir, 1967). In order to apply BFI to the wind-sea, some modifications are considered since the theory only stands for monochromatic wave trains. Definition of the spectral bandwidth and BFI (Eq.1) has defined according the study of Gramstad (2017) who has recent founding that better representation of unstable growth rate due to modulational instability is possible when spectral bandwidth is measured close to the base of the spectrum.

$$\mathrm{BFI}_r = \frac{\varepsilon\omega_p}{\Delta r} \qquad \text{(Eq.1)}$$

where Δr is equal to r times the spectral width at r times the spectral maximum. Different values of r make it possible to adjust spectral width such as close to peak or base (heaviness of spectral tail) of the spectrum.

The second criteria has been selected as Π number proposed by Ribal, (2013). Π number (Eq.1) is an index based on steepness (ε), energy scale (α) and peak enhancement factor (γ) of the JONSWAP spectrum derived using the Alber equation for narrow-banded surface waves in deep water.

$$\Pi = \frac{\varepsilon}{\alpha\gamma} \qquad \text{(Eq.2)}$$

This study is also proposes is a fair comparison between commonly used and recently proposed criteria for occurrence of freak waves.

RESULTS

Total number of over 4840 test with different unidirectional JONSWAP spectra with varying α (0.001 to 0.020) and ϒ (1.00-7.00) values are completed for both models. Each test has been run for 100 realizations in order to obtain sufficient statistics to consider the effect of random initial phase. According to results, both criteria can be used as an indicator since occurrence of freak waves are increasing with increasing BFI and Π which represents the increase of nonlinearity. Certain threshold values for criteria are hard to determine, however probability of occurrence of freak waves significantly low when BFI<0.5 and $\Pi_1 < 0.2$ (figure1). It has also been observed that, height of freak waves decrease after certain point where breaking due to energetic nonlinear wave-wave interactions gets more active before freak wave reaches higher heights (Chalikov D., 2016).

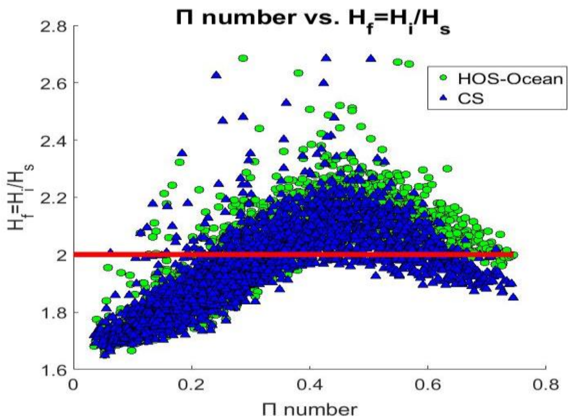

Figure 1. Hf vs. Π number

REFERENCES

Benjamin, T. B., & Feir, J. E. (1967). The disintegration of wave trains on deep water Part 1. Theory. Journal of Fluid Mechanics, 27(3), 417-430

Chalikov, D., & Sheinin, D. (1996). Numerical modeling of surface waves based on principal equations of potential wave dynamics. US Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, National Centers for Environmental Protection.

Dean, R. G. (1990). Freak waves: a possible explanation. Water wave kinematics, 178, 609-612.

Ducrozet, G., Bonnefoy, F., Le Touzé, D., & Ferrant, P. (2016). HOS-ocean: Open-source solver for nonlinear waves in open ocean based on High-Order Spectral method. Computer Physics Communications, 203, 245-254.

Gramstad(2017):Modulational Instability in JONSWAP Sea States Using the Alber Equation, OMAE (2017):61671

Janssen(2003):Nonlinear four-wave interactions and freak waves, Journal of Physical Oceanography 33.4 (2003): 863-884.

Kharif, C., & Pelinovsky, E. (2003). Physical mechanisms of the rogue wave phenomenon. European Journal of Mechanics-B/Fluids, 22(6), 603-634.

Ribal,(2013):Recurrent solutions of the Alber equation initialized by Joint North Sea Wave Project spectra, Journal of Fluid Mechanics 719 (2013): 314-344