Geophysical Research Abstracts
Vol. 16, EGU2014-11771, 2014
EGU General Assembly 2014

Estimation of freak wave occurrence in shallow water regions

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In the last two decades, freak waves have become an important topic in engineering and science and are sometimes featured by a single and steep crest causing severe damage to offshore structures and vessels. An accurate estimation of maximum wave height and prediction of freak wave occurrence frequency is important for marine safety and ocean developments. According to several studies on freak waves, the deep-water third-order nonlinearity (quasi-resonant four-wave interactions) can lead to a significant enhancement of freak wave occurrence from normality. However, it is not clear the behavior of offshore generated freak waves shoaling to shallow water regions. In general, a numerical simulation based on Boussinesq model has been frequently and widely used to estimate wave transformation in shallow water regions and has high-level performance in the design of coast and harbor structures in Japan. However, it is difficult to describe the freak wave occurrence from deep to shallow water regions by the Boussinesq model because it can express only up to the second-order nonlinear interactions. There is a gap of governing equation between deep and shallow water regions from the extreme wave modeling point of view. It is necessary to investigate the aftereffects of generated freak waves by the third-order nonlinear interactions in deep water regions and their propagation to shallow water regions using the Boussinesq model. In this study, the model experiments in a wave tank and numerical simulations based on the Boussinesq model were conducted to estimate the freak wave occurrence from deep to shallow water regions. In the model experiments, the maximum wave height increases with an increase in kurtosis by the third-order nonlinear interactions in deep water regions. The dependence of kurtosis on freak wave occurrence weakens by the second-order nonlinear interactions associated with wave shoaling if dimensionless water depth kph becomes shallower than 1.363, which kp and h indicate the wave number for deep water waves and water depth respectively, but its amplified extreme wave still remains until the surf zone. The aftereffects of third-order nonlinearity in deep water regions remain even in shallow water regions depending on the bathymetry and give remarkable influences on random wave height distribution. Finally, it is possible to understand the characteristics of freak wave occurrence in shallow water regions using the Boussinesq model data, if appropriate higher-order nonlinear correction to the development process of both skewness and kurtosis from deep to shallow water regions is considered analytically.