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Signature of the four-wave quasi-resonance on freak waves in the sea

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The aim of this study is to quantify the effects of the four-wave quasi-resonance to freak wave patterns in the deep water wave of the real ocean. Two freak waves were observed on the same day by a buoy moored in water over 5000 m deep in the Pacific Ocean near Japan. A third-generation wave model WAVEWATCH III was used to estimate the wave spectra during these two freak waves, and then a phase-resolved Monte Carlo simulation based on the Higher Order Spectral Method (HOSM) was used to simulate the evolution of the two wave fields initialized with estimated spectra. The estimated wave spectra by the wave model had distinct directional spreading of 30 degrees and 60 degrees and agreed with the spectra estimated from the buoy observation. The excess kurtoses of the narrower and broader spectral cases were 0.05 and 0.03, respectively. Despite small kurtosis, the comparison between second- and third-order HOSM simulations revealed that third-order wave interactions resulted in distortion of freak-wave shape. The distortion means front-to-rear asymmetry and crescent-shaped deformation of the crest, which was more pronounced in the narrow case. The distortion was more significant in the freak waves having a longer lifetime which indicates the existence of nonlinear wave groups. There were also less-distorted freak waves having a shorter lifetime. From the analysis of freak wave distortion and lifetime, this study concluded that two freak wave generation mechanism, the four-wave quasi-resonance, and dispersion focusing, coexisted in the narrow case. However, this study concluded that the four-wave quasi-resonance could deform freak waves in the real ocean. Owing to the phase-resolved simulation, this study revealed that the four-wave quasi-resonance influences not the statistics of the global wave field but the local kinematics of freak waves. According to a wave model hindcast, the wave fields when the two freak waves emerged were similar to that of some maritime accidents. The investigation on those two freak waves should have implications for maritime accident investigation.