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Characterizing freak waves with wavelet transform analysis

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A freak wave is a wave of unusually large size known to have observed in the coastal and open oceans and hazardous to mariners. As the occurrence of freak waves has been mostly during unknown and unexpected conditions, available measurement and analysis are extremely rare. Because of its rareness and lack of measurement, neither the cause of the occurrence nor a specific definition of freak waves have been sufficiently established. Conjectured mechanisms account for the occurrence of freak waves include caustic formation in an area of strong current such as the Agulhas (Lavrenov, 1998), nonlinear superposition of waves leading to larger instability and wave heights (Dean, 1990), and third order resonant interactions (Yasuda *et al., 1992).* The difficulty has been the differentiation between freak waves and maximum waves from extreme value statistics.

In this paper we present an analysis of available wave measurements made in the Sea of Japan during 1986 to 1990 where freak waves are known to be observed. (Yasuda *et al.*, 1997) The measurements were made with ultrasonic type wave gages in water depth of 43 m. Five data sets at 1 Hz sampling frequency each with over 20 to 40 hours of continuous measurements are used. Since freak waves are primarily transient events, wavelet transform analysis is used to analyze the time series and examine the freak wave characteristics in the time-frequency domain.

Figure 1 in the next page presents an example of 10 minutes time series that contains the occurrence of a freak wave. Its corresponding wavelet spectrum is shown in the bottom panel. It appears that this well-defined freak wave can be readily identified from the wavelet spectrum where strong energy density in the spectrum is instantly surged and seemingly carried over to the high frequency components at the instant the freak wave occurs. Therefore, for a given freak wave, there appears a clear corresponding signature shown in the time-frequency wavelet spectrum. This is an ideal freak wave case, similar to the available cases of North Sea measurement. (Sand *et al.*, 1990) There are other cases that showing freak wave in the time series, however, do not always provide corresponding wavelet spectrum that displays a clear signature. (*e. g.* Figure 2.) Clearly there are different kinds of freak waves. Since the mechanism of freak wave formation can be diverse, it should not be surprising that different freak waves exhibit different qualitative features. Wavelet transform analysis is the ideally suited approach to study freak wave time series that may serve to clarify the occurrence of the freak waves as well as their general characteristics and statistical properties.

References:

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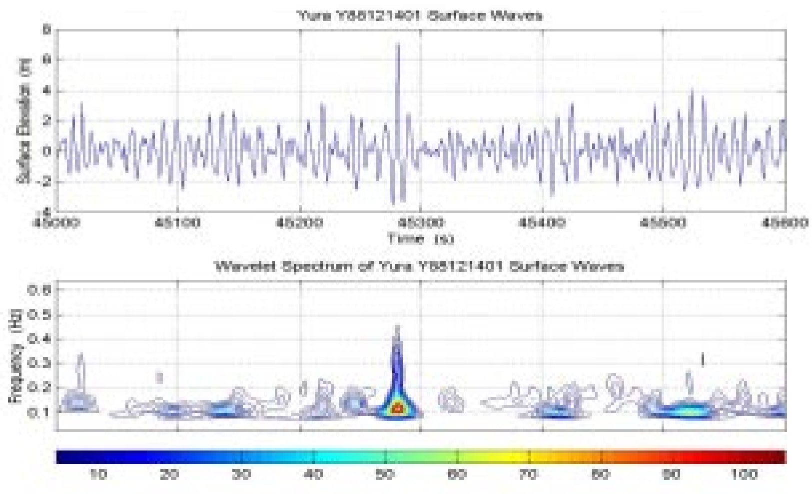

Figure 1. Freak wave time series and its time-frequency wavelet spectrum.

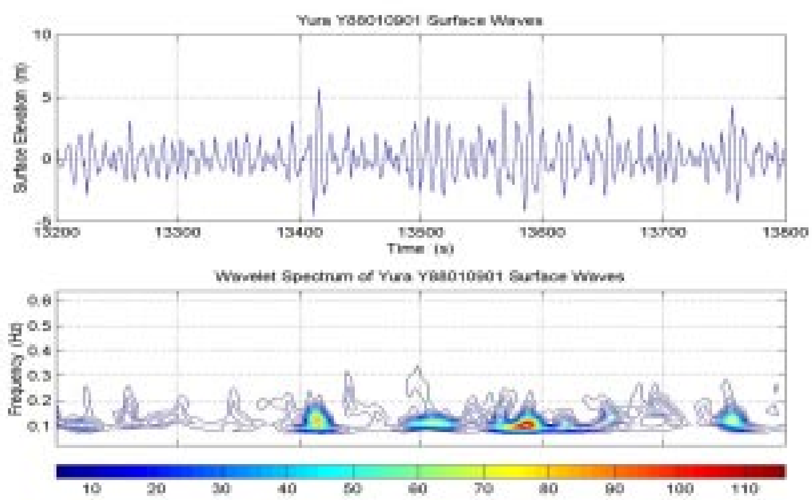

Figure 2. Another freak wave time series and its time-frequency wavelet spectrum.