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Wave extremes off the Catalan coast: time and space-time domains analyses

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The occurrence of extreme wave conditions at sea represents a frequent and severe hazard for human activities in the marine environment (e.g. ships in navigation and coastal or off-shore structures). Therefore, it is of crucial importance to accurately predict extremes of sea states. In this context, wave observations represent at the same time the starting point of the analysis and the sea truth to validate theoretical prediction models. Extreme waves are usually searched for by looking at the sea surface elevation recorded by point instruments in time domain (e.g. buoys, wave gauges). Alternatively, the likelihood of extremes occurrence within a sea state can be controlled through nonlinear wave parameters. Recently, measuring systems capable of observing the wave field in the space-time domain, i.e. over an area and during a certain period, offered a novel perspective for extreme value analysis. In fact, it was proved that the maximum sea surface elevation gathered in time over an area, i.e. the space-time extreme, is larger than that one measured in time at a point, i.e. the time extreme. Lately, theoretical stochastic models for the evaluation of maxima of multidimensional Gaussian random fields (i.e. Piterbarg's theorem or the Adler and Taylor's Euler Characteristics approach, further developed by Fedele) have been applied to ocean wave statistics. Using such models, the space-time extreme of a sea state can be estimated from the directional wave variance density spectrum, which collects space-time features of the sea state.
In this context, measurements gathered by a directional buoy (XIOM network of the Catalan Government) were analyzed by searching for extremes of sea states, during 25 days of March 2012. Since this study relied on a relatively small sample (1195 30-minutes sea states), the aim was to propose a methodology rather than to characterize the buoy location. The buoy was deployed in the North-West Mediterranean Sea, off the Catalan coast, at 50 meters water depth. After a quality control on the data, extreme value analysis was firstly performed in time domain by looking at nonlinear parameters of the sea states (e.g. skewness, kurtosis, BFI index, Ursell parameter). Then, we performed the extreme value analysis in the space-time domain, resorting to Piterbarg's and Fedele's models. To this aim, we reconstructed the directional wave spectra exploiting the vertical and horizontal displacements recorded by the buoy. To investigate and model the dependence of the space-time extremes from the size of the area at a sea location, a sensitivity analysis on the size of the space domain (i.e. the area) was performed. Besides this, we obtained dimensionless relationships that allow predicting the space-time extremes at a given location by using only two synthetic wave parameters (i.e. significant wave height and mean wave period).