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Generation of multivariate near shore extreme wave conditions based on an extreme value copula for offshore boundary conditions.

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Near shore extreme wave conditions, used as input for numerical wave agitation simulations and for the dimensioning of coastal defense structures, need to be determined at a harbour entrance situated at the French North Sea coast. To obtain significant wave heights, the numerical wave model SWAN has been used. A multivariate approach was used to account for the joint probabilities.

Considered variables are: wind velocity and direction, water level and significant offshore wave height and wave period. In a first step a univariate extreme value distribution has been determined for the main variables. By means of a technique based on the mean excess function, an appropriate member of the GPD is selected. An optimal threshold for peak over threshold selection is determined by maximum likelihood optimization. Next, the joint dependency structure for the primary random variables is modeled by an extreme value copula. Eventually the multivariate domain of variables was stratified in different classes, each of which representing a combination of variable quantiles with a joint probability, which are used for model simulation.

The main variable is the wind velocity, as in the area of concern extreme wave conditions are wind driven. The analysis is repeated for 9 different wind directions. The secondary variable is water level. In shallow waters extreme waves will be directly affected by water depth. Hence the joint probability of occurrence for water level and wave height is of major importance for design of coastal defense structures. Wind velocity and water levels are only dependent for some wind directions (wind induced setup). Dependent directions are detected using a Kendall and Spearman test and appeared to be those with the longest fetch. For these directions, wind velocity and water level extreme value distributions are multivariately linked through a Gumbel Copula. These distributions are stratified into classes of which the frequency of occurrence can be calculated. For the remaining directions the univariate extreme wind velocity distribution is stratified, each class combined with 5 high water levels.

The wave height at the model boundaries was taken into account by a regression with the extreme wind velocity at the offshore location. The regression line and the 95% confidence limits where combined with each class. Eventually the wave period is computed by a new regression with the significant wave height.

This way 1103 synthetic events were selected and simulated with the SWAN wave model, each of which a frequency of occurrence is calculated for. Hence near shore significant wave heights are obtained with corresponding frequencies. The statistical distribution of the near shore wave heights is determined by sorting the model results in a descending order and accumulating the corresponding frequencies. This approach allows determination of conditional return periods. For example, for the imposed univariate design return periods of 100 years for significant wave height and 30 years for water level, the joint return period for a simultaneous exceedance of both conditions can be computed as 4000 years. Hence, this methodology allows for a probabilistic design of coastal defense structures.