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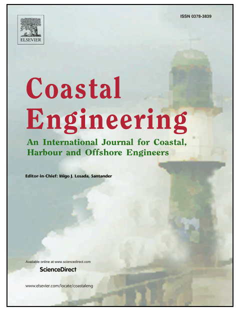

Statistical modelling of extreme storms using copulas: A comparison study

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Statistical modelling of extreme storms using copulas: A comparison study

Abstract:
Coastal risk assessment and structure design heavily rely on the statistical analysis of the extreme wave climate, such as the wave height, storm duration, wave period and surge height. Due to the dependence among these variables, the multivariate dependence structure should be taken into account for statistical simulation of the storm events. Here, three modelling framework are described and compared for probabilistic modelling of extreme storms, i.e. the Gaussian copula, conditional mixture method and entropy copula. This paper demonstrates the functionality of the approaches in simulating the sea storm while maintaining their statistical characteristics. None of the three methods can fit all the bivariate cases best, and the Gaussian copula gives the best overall fitting quality for the four dimensional data in the case study, while the conditional mixture method gives the lowest fitting quality. The entropy copula gives a comparable simulation results and shows its great potential to be universally applicable for modelling the multivariable joint distribution by avoiding the procedure of assigning any copula family before fitting data.
Keywords: Sea storm; Multivariate analysis; Statistical simulation; Copula; POME

1. Introduction

Sea storms is customarily characterized in terms of maximum significant wave height ($H_{s,max}$), storm duration (D), peak wave period (T_p) and surge height (h, total water levels with tides included), which are vital for offshore structures design and coastal dynamics assessment in the field of coastal and off-shore engineering[1,2]. Due to the mutual partial dependency between these variates, methods for simulation and analysis of multivariate sea storms have received more and more attention, however, establishing an accurate multivariate statistical model is quite a challenge task.

Copula method was widely used for multivariate simulations in hydrology [3–6] and coastal engineering since being firstly proposed by Sklar [7] for its efficiency in describing the dependency among multiple variates and its flexibility in marginal distribution selection. For the bivariate probability distribution modelling, the Archimedean copula, including the Frank copula, Clayton copula, Gumbel copula, and Ali-Mikhail-Haq copula et al., were used for some cases [8–11]. However, a storm event can not be sufficiently characterized by only two variables. Although, the Gaussian copula can be extended to higher dimensions directly, it has its limitations in application, a Gaussian copula will not be able to model asymptotical dependence structures properly [12,13]. Thus, attempts to building higher dimensional copula functions by using a cascade of lower dimensional copulas have been made. De Michele et al. [14] proposed a conditional mixture method to compute the multivariate CDF (cumulative density function) by linking the variables with conditional distribution functions, and a three-dimensional case and a four-dimensional case were illustrated to simulate the wave climate. Based on the bivariate Archimedean copula, Wahl et al. [15] and Lin-Ye et al. [16] applied the hierarchical Archimedean copula to model the storms. Li et al. [17] statistically simulated the four-dimensional wave climate variables by applying the Gaussian copula and the bivariate Archimedean copula coupling with the Gibbs sampling method, and the Gaussian copula was recommended for the study site according to the goodness-of-fit (GOF) analysis. For a detailed theoretical introduction to copulas, please refer to [18–22], while for a practical/engineering approach and guidelines, please refer to