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A New Method for Applying r-Largest Maxima Model for Design Sea-State Prediction

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A frequent problem in design sea-state prediction is the limited amount of available extreme wave data. Thus, several methods to characterize extreme values have been developed, in order to allow the modeling of a sequence of maxima rather than the block maximum itself. Such a model is the *r*-largest maxima model, postulating independency among the *r*-largest maxima within a block. Independency is approached through semi-empirical techniques, but hardly any of them consider the physical behavior of the examined phenomenon. In this work, a de-clustering method is applied in order to locate sequences of independent maxima from among native H_S time-series. Significantly large wave energy reductions of local maxima to following minima were used to partition the time-series into approximately independent sea-state systems, and the maxima of each system is in the sequence used as an input to the *r*-largest maxima model.

INTRODUCTION

Extreme value theory deals with the probabilistic description of the maximum random variable of a stochastic sequence. To this end, appropriate conditions regarding the stochastic structure of the sequence—e.g. independency conditions, mixing conditions etc.—should be adopted. The most elegant and fundamental results of the extreme value theory refer to sequences of independent and identically distributed (iid) random variables. The case of iid sequences is actually the cornerstone of the entire extreme value theory and of particular interest in the extreme value prediction of environmental parameters, such as wave height, wind speed, sea level, river discharge, rainfall accumulation, etc. Extreme value analysis has always been a field of main concern for engineers and environmental scientists, while the extremes of wave characteristics are of major interest in offshore and marine structure design, optimal ship routing and navigation, coastal management, naval architecture, etc.

Taking into consideration the pluralism of wave processes and associated models existing in both the short- and long-term time scales, various extreme value models can be utilized depending on the specific application, relevant time scale, variable of interest and data availability. However, the assumptions which the existing extreme value models dictate are rarely confirmed in practical applications, and they do not always account for the particular physical characteristics and features of the examined wave phenomenon. In addition, various types of physical, statistical and modelling uncertainties are always present, rendering extreme value analysis of sea waves a difficult yet challenging task; see e.g. Winterstein and Haver (1991), Labeyrie (1991), Guedes Soares and Scotto (2001) and Winterstein et al. (2001).

The fundamental results of Fisher and Tippet (1928) and Gnedenko (1943) form the well-known Asymptotic Extreme Value Theory (AEVT). For applying AEVT in practice, it is assumed that successive block maxima of the examined sequence are realizations of the maximum random variable of the same sequence; this maximum, under very general conditions, follows one of the 3 possible asymptotic distributions or equivalently, the Generalized Extreme Value (GEV) distribution. For the prediction of design values of spectral wave parameters, the block size is usually one year and the method is known as the Annual Maxima Method (AMM). In ocean engineering applications, however, restrictions such as low data availability and loss of valuable extreme-like information from the original data sets are frequently met. Thus, various alternative methods considering several of the higher values observed in a specific block have been developed, such as the *r*-largest maxima method and methods concerning excesses over a threshold (e.g., the widely used Peaks-Over-Threshold method).

The key result of the *r*-largest maxima method is a closed form for the joint probability density function of the *r*-largest maxima $r = 1, 2, \ldots$ within a year. These maxima are required to be independent, and their joint density function shares the same parameters with the GEV distribution of the maximum. The main advantage of this method compared to the AMM is the expansion of the available extreme-type data, since not only the annual maxima but the *r*-largest annual maxima are taken into consideration. However, when it comes to design sea-state prediction, intense H_S sea states are actually highly correlated due to the appearance of clustering (i.e., strong dependence between neighboring extreme values). The main difficulty, then, is to secure the statistical independence of the selected *r*-largest ($r = 1, 2, \ldots$) H_S maxima. Safeguarding of independency is very crucial for environmental parameters prone to clustering, yet it is often misvalued. In principle, de-clustering can be achieved through various techniques, which are discussed below. It should be noted beforehand that, as the authors are aware, there is no existing de-clustering technique regarding time-series of wave parameters which take into consideration the inherent physical characteristics of the examined variable extracted from the sample. (This is not the case with hydrological applications dealing with floods, where several approaches based on physical criteria are also used—Lang et al., 1999.) Discussions on this issue can be found in Muir and El-Shaarawi (1986), Palutikof et al. (1999), Winterstein et al. (2001),

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