Short - Term Wave Statistics in the Greek Seas

Takvor H. Soukissian(1), Dafni E. Sifnioti(2), Aristides Prospathopoulos(1), Danai Kastriti(2)

(1) Hellenic Centre of Marine Research, Athens, Greece
(2) Dept. of Geology and Geoenvironment, National and Kapodistrian University of Athens, Zografou, Athens, Greece

ABSTRACT

Short-term analysis of wind waves is often based on the assumption that the sea surface elevation is a stationary and Gaussian process. In this work, measured sea surface elevation data obtained from a deep water wave buoy were analyzed. The work focuses on obtaining the best fit for normalized wave height data using Weibull, Rayleigh and Kumaraswamy distributions. For each sea-state, down-crossing wave heights were identified and the aforementioned theoretical distributions were fitted and assessed. The fit of the Kumaraswamy distribution to the wave height data was found to be much better than that of Weibull and Rayleigh distributions.

KEY WORDS: wave height; short-term analysis; Rayleigh distribution; Weibull distribution; Kumaraswamy distribution; Greek seas;

INTRODUCTION

According to Pierson (1952) and Longuet-Higgins (1952), free sea-surface elevation $\eta(t)$ at a fixed position of the free sea surface, can be modeled as a zero-mean, stationary, ergodic and Gaussian linear process. Considering that, the stochastic representation of $\eta(t)$ is the following:

$$\eta(t, \beta) = \sum_{i=1}^{\infty} A_i \cos(2\pi f_i t + \varphi_i(\beta)),$$

where $A_i$ denotes the amplitude, $\varphi_i(\beta)$ is phase, modeled as a random variable uniformly distributed in $(0, 2\pi)$, $f_i$ is the frequency of small amplitude components of (1), i.e., $f_i = 1/T_i$, where $T_i$ stands for wave period and $\beta$ is a choice variable. The spectral density function of $\eta(t)$ is defined as follows:

$$S_{\eta\eta}(f) = \int C_{\eta\eta}(\tau) \cos(2\pi f \tau) d\tau,$$

where $C_{\eta\eta}(\tau) = C_{\eta\eta}(-\tau)$ is the auto-covariance function of $\eta(t)$.

The probability density function $f_h(h)$ of wave height $H$ for the general case (i.e., for a spectrum of arbitrary bandwidth) is not readily derived. For an ideally narrow band spectrum, this function is of Rayleigh type and is expressed as follows:

$$f_h(h) = \frac{h}{4m_0} \exp\left(-\frac{h^2}{8m_0}\right),$$

where $m_0$ is the zero-th order spectral moment.

For the short-term statistical analysis of wind waves, the Pierson (1952) and Longuet-Higgins (1952) model is often assumed. In the relevant literature, a number of theoretical distributions for modeling of wave height has been discussed; specifically, Rayleigh distribution and its modifications are the most used, even though they all overestimate the probability of the higher waves in a sea state (Sobey, 1992). As noted in (Tayfun and Fedele, 2007), nonlinear effects are small for wave heights though they may be large for wave crests. From this point of view the linear model suggested in Boccotti (1989, 2000), describe wave heights accurately by using a 2-parameter Rayleigh-like distribution. Additionally, in a quite recent review of short-term wave statistics (Casas-Prat and Holthuijsen, 2010) various distributions of wave height data collected from buoys and laser altimeters are presented and discussed. The authors compared: a) the conventional Rayleigh distribution (with the scale parameter equal to the standard deviation), b) Rayleigh-like distributions (with two parameters $a$ and $b$), of the following form:

$$p(\bar{H}) = \frac{b\bar{H}}{4\alpha^2} \exp\left(-\frac{\bar{H}^2}{8\alpha^2}\right) f(\bar{H}),$$