Facets of uncertainty 2013

Kos Island, Greece,
17-19 October 2013

Session: Stahy '13/P28

Stochastic modelling of sea waves for simulation of wave energy

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1. ABSTRACT

Wave energy is regarded a promising renewable source of energy. Many companies have introduced devices that are installed in the sea, move with the waves and convert the wave energy into electrical energy. The wave energy in regions of large depth (> 50 m) is not affected by the sea bottom and depends on the wave height and its frequency. Therefore, the energy produced by these devices is directly related to these two wave characteristics. In this study we explore the distribution of one of these two wave characteristics, the distribution of the significant wave height *H*s. We assume that such a model might be also helpful in simulating also the wave-energy production.

2. Motivation

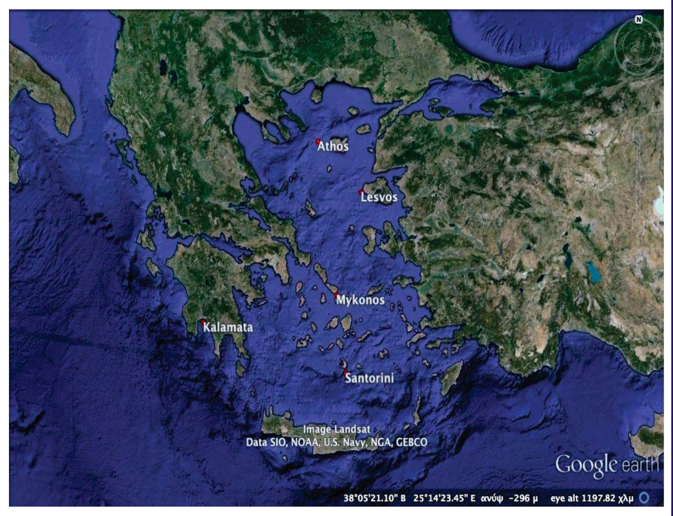
- The distribution of the significant wave height *H*s is very important in describing the sea severity and designing marine systems.
- Additionally, the significant wave height is also important in predicting the wave-energy and, consequently, the wave-power in order to produce electrical energy from the waves.
- Is there a distribution that describes better the statistical characteristics of the wave heights than the Rayleigh?
- The results could be extended also in freak waves and provide the ocean engineers with a more precise distribution than Rayleigh in order to better describe the extremes.
- We try to infer also about the autocorrelation structure of the significant wave height as it may be also important for the afore-mentioned purposes.

3. Definitions-Significant wave height

The significant wave height, denoted by *H*s, was introduced by Sverdrop and Munk (1947) and is the most commonly used definition for representing the severity of sea conditions. It is defined as the average crest-to-trough height of the one-third of the highest of the zero-upcross waves, and was chosen as being as near as possible to the waveheight reported by visual observers. However, it is rarely evaluated following the definition, as even now, no exact relationship between this parameter and other more fundamental wave height parameters has been found. So its use has been largely abandoned. Instead, it is commonly evaluated by using the variance computed from a spectrum, or by applying a statistical analysis of amplitude and height from wave records. The parameter generally used now is also called the "significant waveheight" but the symbol used is H_s or, preferably, H_{m0} and sometimes $H_s(m0)$ to avoid any confusion with the earlier definition. It is defined by $H_{m0}=\sqrt{m_0}$, where m_0 is the variance of the sea surface elevation.

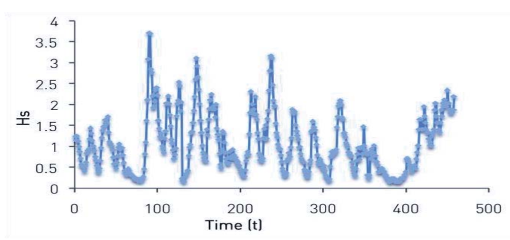
4. Data

The historical data used here, are daily wave records obtained from Poseidon Database, Hellenic Centre for Marine Research-Poseidon System web site (http://www.poseidon.hcmr.gr/). Among the records comprising the Poseidon Database the data selected for the analysis were records with length greater or equal than 10 years. Only five stations were fulfilling these criteria. The map above depicts the locations of the five stations used in the analysis. In the poster only the analysis from Santorini station is displayed.



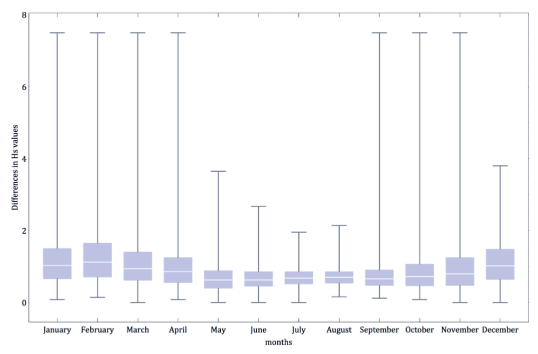
The wave data being measured in Poseidon stations are essentially "spectral" values computed with the help of spectral moments (m_n). The measurements are performed by Poseidon's oceanographic buoys and they take place every 3 hours while the duration of every recording is 1024 seconds. The recordings take place, daily, at 00:00, 03:00, 06:00, 09:00, 12:00, 15:00, 18:00 and 21:00 UTC.

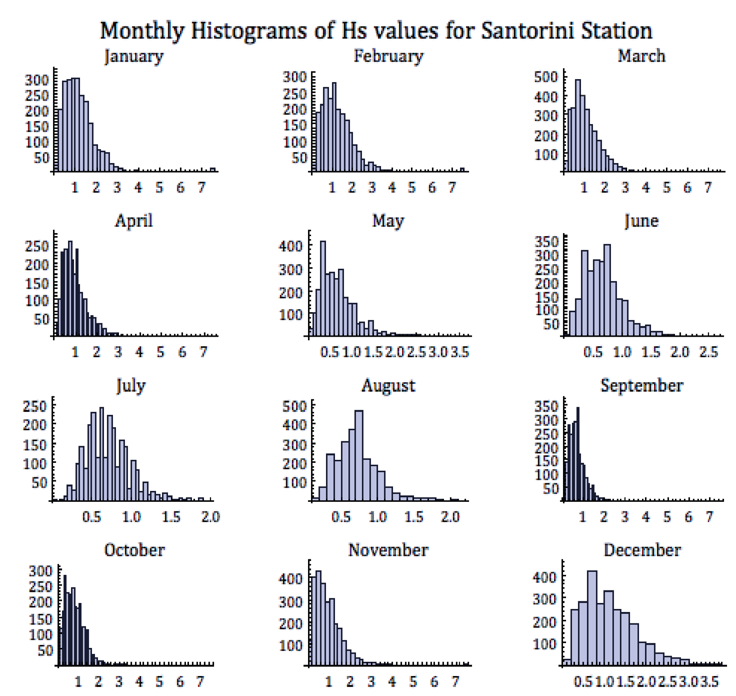
The figure depicts the Time Series Plot of the significant wave height of the Santorini station for the month February for a specific period of time.



5. Seasonal Analysis

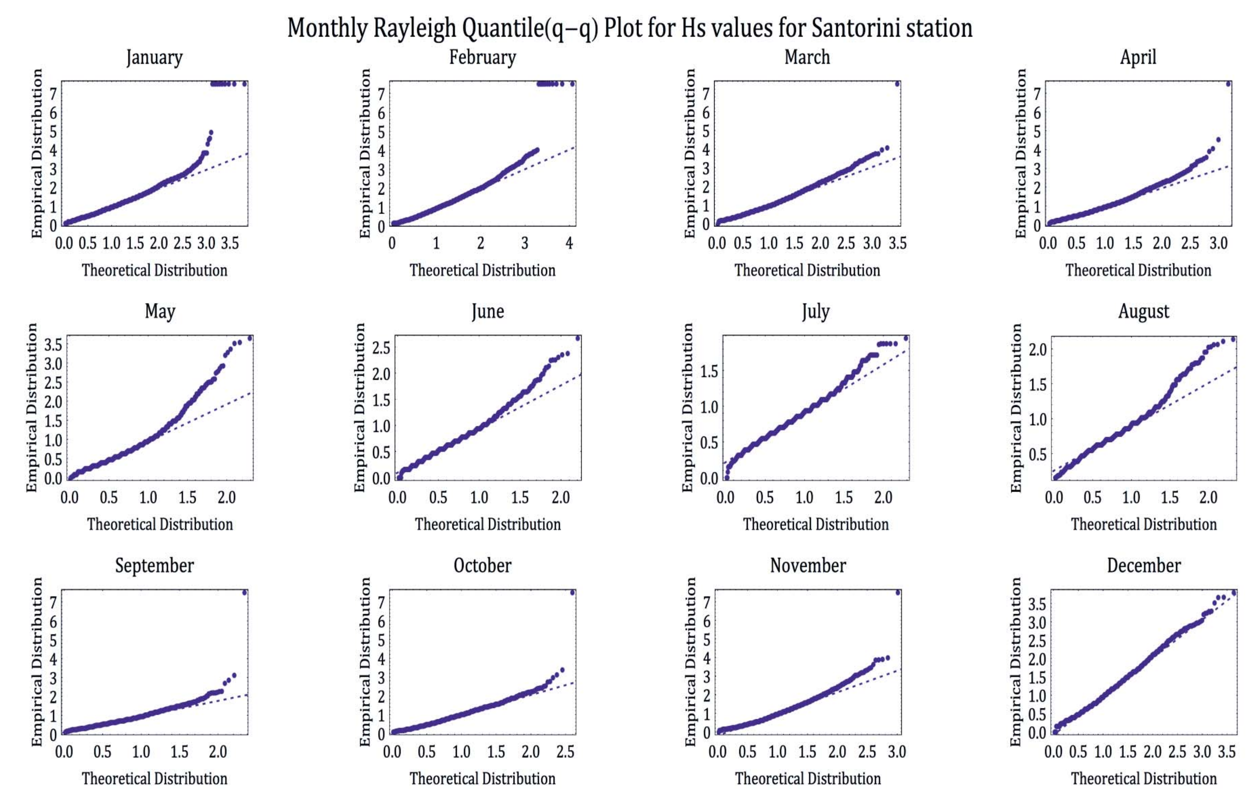
The box plots depict the monthly empirical data of *H*s. And we observe a clear seasonal variation.





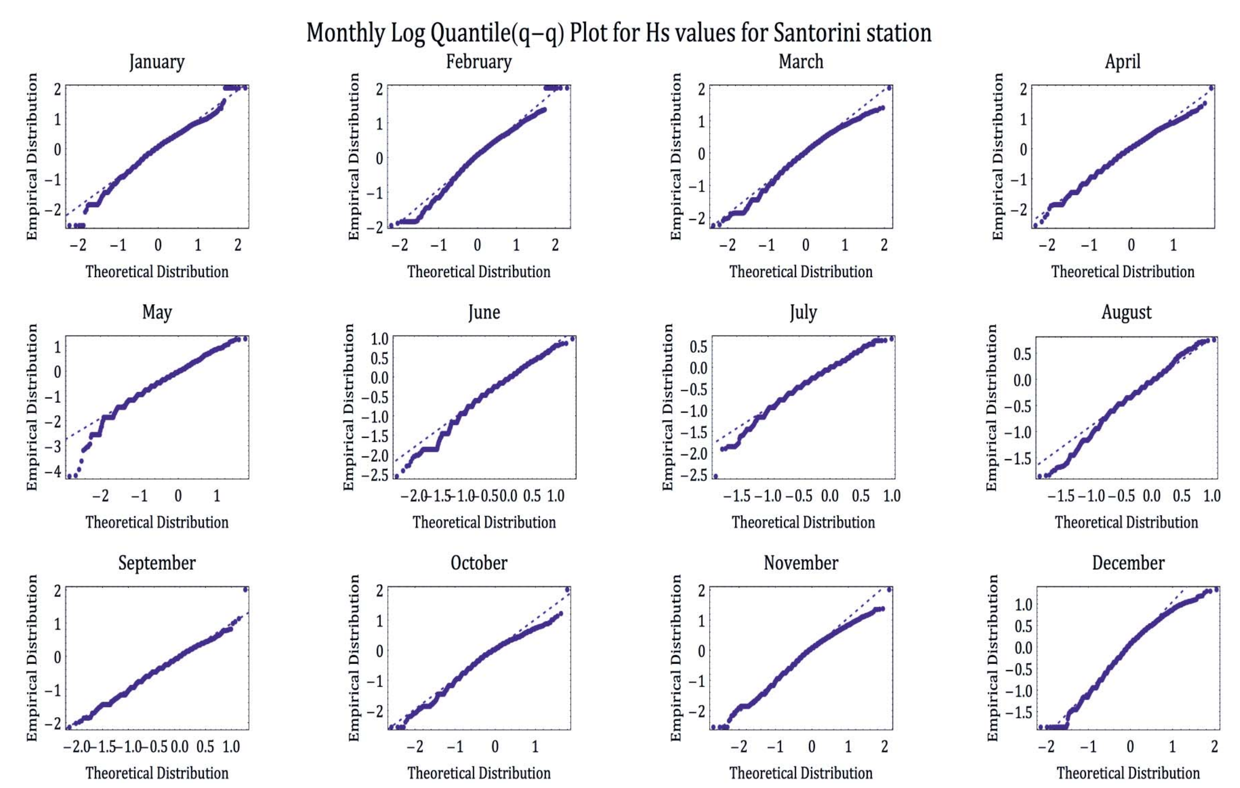
The histograms depict the empirical distribution of the significant wave height for every month. In the literature this random variable is usually probabilistically described by the Rayleigh distribution.

6. Fitting the Rayleigh Distribution



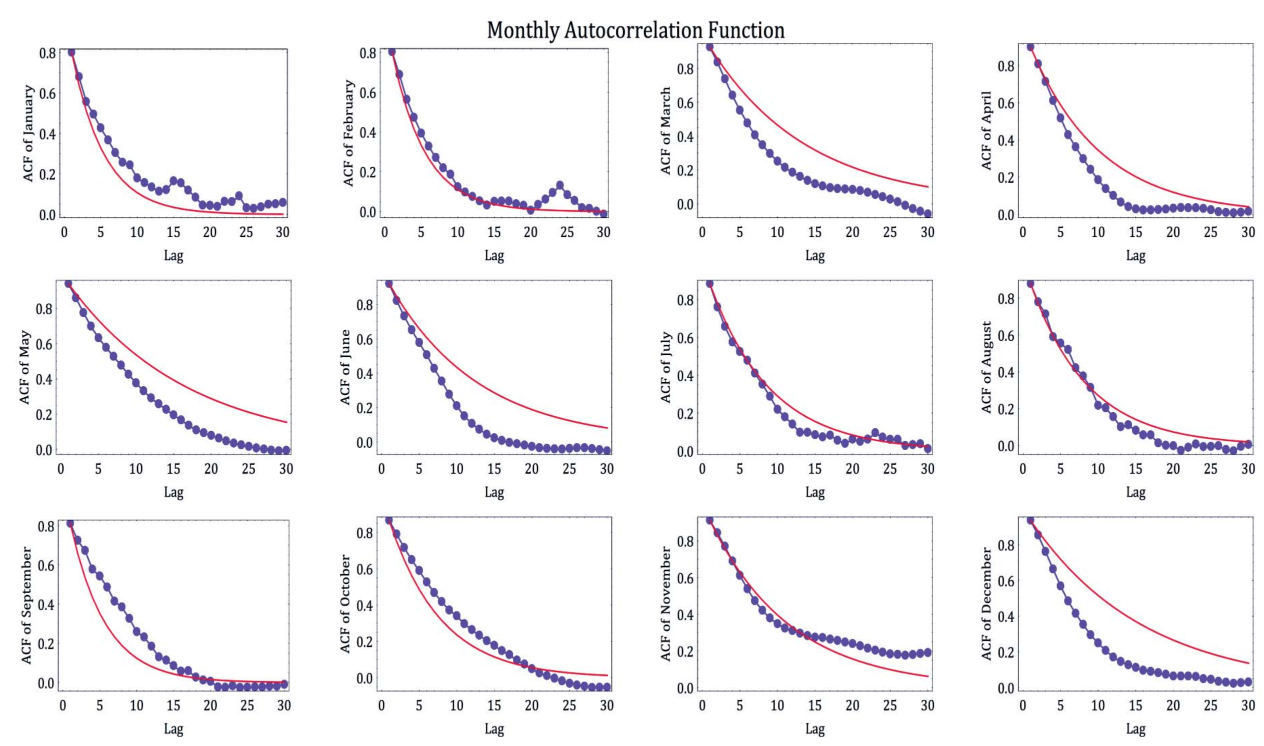
Comparison of the empirical distribution with the fitted Rayleigh distribution. The quantile plot shows that the Rayleigh distribution which has a light tail cannot express adequately the extreme waves.

7. Fitting Log-Normal Distribution



Comparison of the empirical distribution with Log-Normal distribution. Log-Normal distribution which has heavier tail than the Rayleigh distribution seems to describe better the extreme events and offer a better fit.

8. Autocorrelation Function



The figure depicts the empirical autocorrelation function, in a monthly basis, of the Santorini station and compares it with the Markov autocorrelation structure. As we see in some months the empirical autocorrelation decreases more slowly than the Markov structure while in other cases it decreases more rapidly.

9. Conclusions

- Rayleigh distribution which is the most commonly used distribution to describe the significant wave height *Hs* , seems to be inadequate to describe extreme values of significant wave height.
- Here we tested the performance of the Log-Normal distribution which has a heavier tail than the Rayleigh and it seems that it can better describe extreme values.
- As a future perspective a joint distribution of significant height and period would be helpful in estimating the wave-energy and power that could be extracted from the waves.

References

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