PO.ID 161

New proposal for extreme data management for offshore wind applications

Fernando del Jesus, Raúl Guanche and Íñigo J. Losada
Environmental Hydraulics Institute (IH Cantabria) – University of Cantabria (Spain)

IH cantabria
INSTITUTO DE HIDRÁULICA AMBIENTAL
UNIVERSIDAD DE CANTABRIA

Abstract

- **Offshore wind** design requires the estimation of **return levels** for design parameters determination.
- **Standards & Guidelines** propose different methodologies for **several and extreme cases**, commonly based on **50-yr return period** values for design loads.
- **Instrumental and Reanalysis** data **combination** becomes crucial in order to improve the accuracy based on the characterization of the location.
- Reducing the uncertainty is possible by improving the methods and the quality of data. Taking into account the common short length of instrumental time series (2-3 years) mixed extreme models should be developed.
- In this work, the mixed extreme model presented in **Mínguez and del Jesus (2014)** is applied to a location in the North of Spain.

Objectives

- Develop an **extreme model** for offshore wind applications & Evaluate the **instrumental records length** that is necessary for the correct application of the method.
- Apply the extreme model to **IFORM** method to real case and & Evaluate the changes in the design parameters determination.

Location & Data

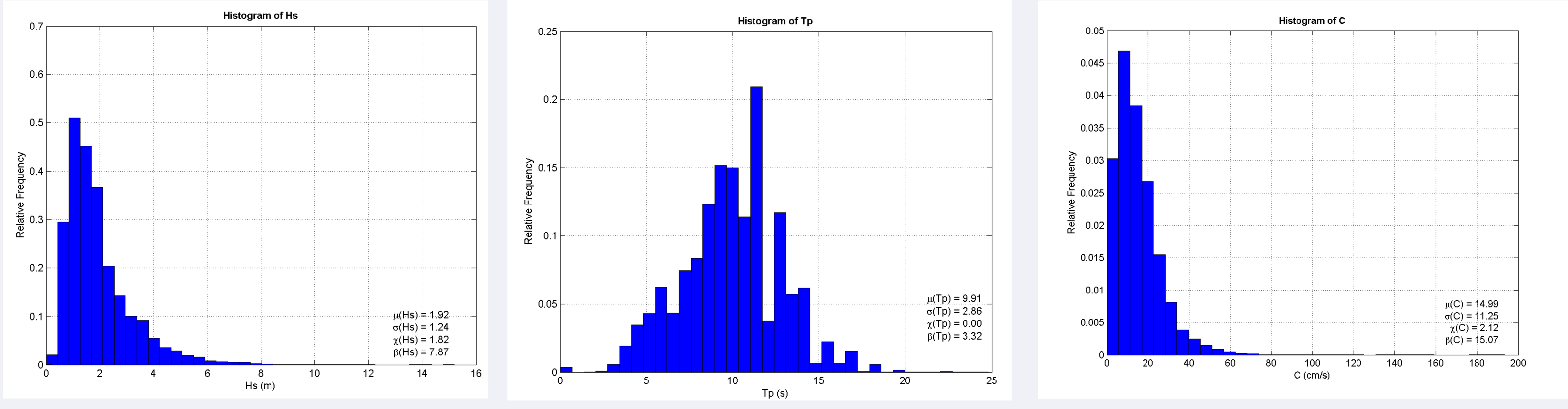

Figure 1. Histograms of (a) significant wave height, (b) peak period and (c) currents.

As it can be seen in figure 1, the mean significant wave height at the location is lower than 2 meters. In the case of peak period its mean is around 10 seconds. The man value of current speed is 15 cm/s.

Figure 2 (right) shows the correlation between the reanalysis wave height and the instrumental wave height. It can be noticed that the reanalysis database used in this work has a correlation higher than 0.9. In fact, it is simulating correctly the extreme, reducing the impact of applying the mixed extreme model.

In figure 2 (left) the density histogram of Hs and Tp can be seen.

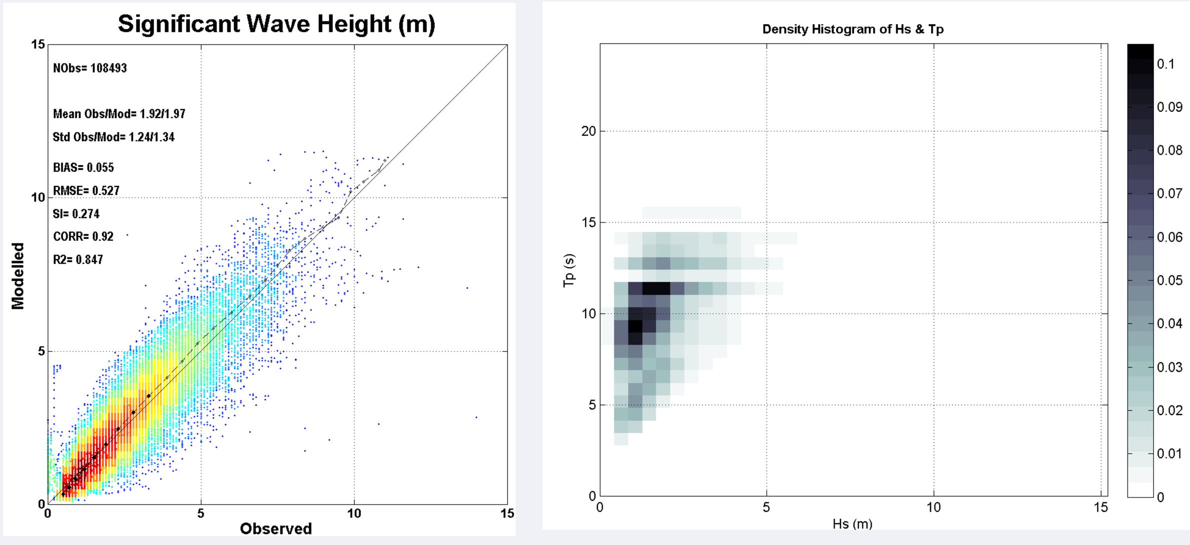

Figure 2. (left) Scatter of Reanalysis and Instrumental Hs. (right) Significant wave height and peak period combined probability

Methods

Mixed Extreme Model

The model assumptions are based on Mínguez et al. (2013):

1. Independent peaks over threshold follow a Poisson distribution.
2. Annual Maximum Reanalysis (X) distribution is known: Pareto (Davidson and Smith (1990)).
3. Difference (Y) between Instrumental and Reanalysis conditioned to X follows a normal distribution.

Random variable related to storm peaks are: Z = X + Y and its CDF:

$$F_Z(z) = Prob(Z \le z) = \int_{x+y\le z} f_{X,Y}(x,y)\,dy\,dx$$

Considering that the distribution of Y|X is normal and the distribution of X is known:

$$F_Z(z) = \int_u^{\infty} f_X(x,\theta_x)\,\phi\left[\frac{z - x - \mu_{Y|X}}{\sigma_{Y|X}}\right]dx$$

The data used in this method is not annual maxima. Due to this, an expression for representing the return level should be developed:

$$Prob\left(\max_{1\le i\le N} Z_i \le z\right) =$$

$$Prob(N=0) + \sum_{n=1}^{\infty} Prob(N=n)F_Z(z)^n = e^{-\lambda}\left[\sum_{n=1}^{\infty}\frac{e^{-\lambda}\lambda^n}{n!}F_Z(z)^n\right] = e^{-\lambda(1-F_Z(z))}$$

And quantile associated with given return period T is obtained by solving:

$$F_Z(z_T) = 1 - \frac{1}{\lambda T}$$

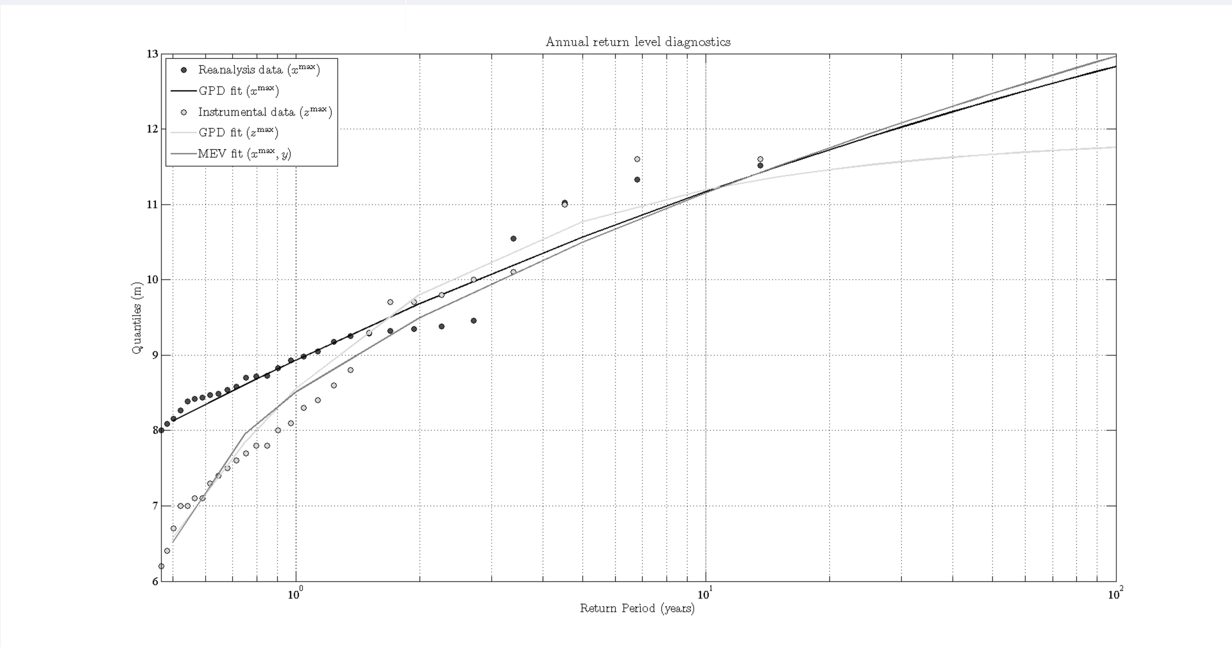

Figure 4. Annual return level.

Time Series Length

The model is based on instrumental time series. The length of the time series available influences considerably the final result. In order to evaluate this influence in an easy way, the method was applied using 1,2,…,25 years. In figure 3, red line is the 50-yr return level of the reanalysis data and black color line is the 50-yr return level for the mixed model.

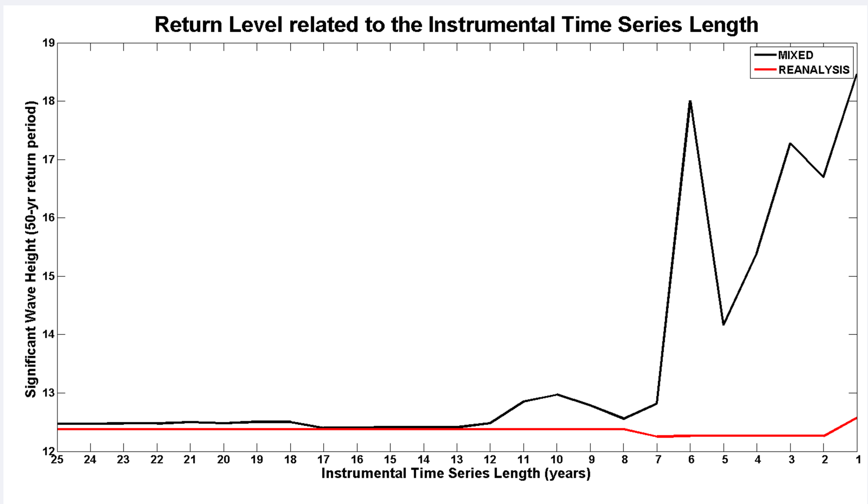

Figure 3. 50-yr return level of significant wave height.

Red line is not horizontal due to the change of threshold. This threshold should be adapted to each case because of the minimum number of storm peaks required for the distribution fitting process

IFORM

Mínguez et al. (2014), proposed the following expression to combine more accurately the point-in-time and right tail of the distribution:

$$\begin{cases} F^{PT}(x) & if\ x \le x_{lim} \\ p^{PT}_{lim} + \dfrac{F^{EV}(x) - p^{EV}_{lim}}{1 - p^{EV}_{lim}}(1 - p^{PT}_{lim}) & if\ x > x_{lim}\end{cases}$$

IFORM method (IEC61400-3) extrapolates met-ocean data. It is used to evaluate the return level of sea and wind states, considering the combined distribution.

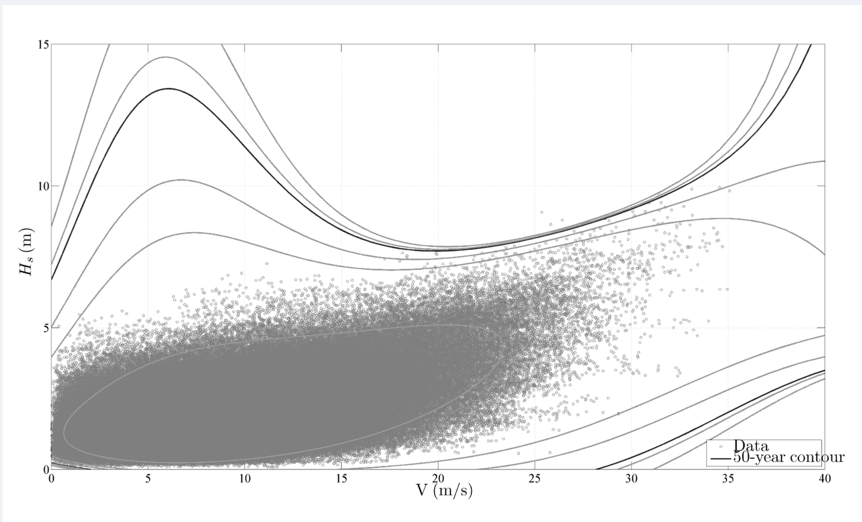

Figure 5. IFORM

IFORM as proposed in some guidelines gives place to inaccurate results as shown in figure 5, where the low tail of the distribution and the right tail are not well simulated, giving wrong results.

Changing the distribution, using a GEV or PARETO the right tail is well simulated and the results are shown in figure 6.

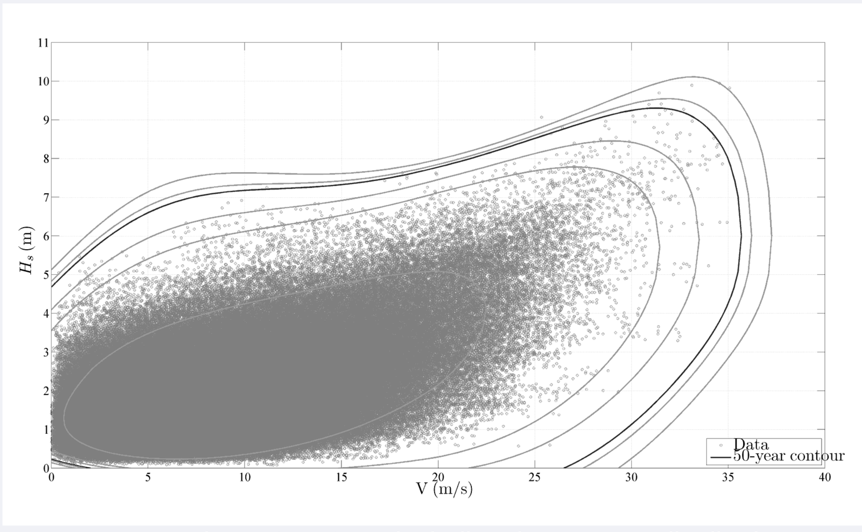

Figure 6. IFORM including the extreme distribution

Conclusions

- The mixed extreme method is a good solution in order to combine reanalysis and instrumental data, improving the return level design parameters estimation.
- The method is very sensitive to the length of instrumental time series. More work should be developed in order to evaluate this sensitivity.
- The distribution used is crucial to improve the estimation of return levels.

References

1. Mínguez R. and del Jesus F.(2014) Revisited mixed extreme wave climate model for reanalysis data bases. *Stochastic Environmental Research and Risk Assessment*.
2. Mínguez R., Guanche Y., Méndez FJ., Medina R.(2013) Mixed extreme wave climate model for reanalysis databases. *Stoch. Environ. Research and Risk Assess.*
3. Davidson SC., Smith RL.(1990) Models for exceedances over high thresholds. *Journal of the Royal Statistical Society Series B (Methodological)*
4. Minguez R., Guanche Y., Jaime F.F., Méndez F.J.; Tomás A. (2014) Filling the cap between point-in-time and extreme value distributions. *Safety, Reliability, Risk and Life-Cycle Performance of Structures and Infrastructures*

Acknowledgments

Fundación IBERDROLA
maren2 MARINE RENEWABLE ENERGIES