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Comparing Extreme Wave Height Estimation Techniques for Classifying Energy Resources and Conditions

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Introduction

Significant wave heights occurring at 50-year return periods, $H_{s(50)}$, are important metrics used to evaluate and classify the extreme environmental wave loads to design wave energy converters [IEC/TS 62600-2]. They are also used to evaluate and classify risks at wave energy project sites with respect to opportunities for wave energy extraction, $H_{s(50)}$ /$H_{s(mean)}$, [Neary et. al., 2017]. This ratio represents the expected extreme conditions in a wave energy converter's lifespan relative to the expected average conditions.

Methods Used

The 2 methods used are the Annual Maxima (AM) method and the Peak Over Threshold (POT) Method. The AM method fits yearly maxima (Fig. 1.) of H_s time series to a Gumbel distribution [Coles, 2001]. While this method is simple, it is recommended to have at least 20 years of data [DNV, 2014].

The POT Method fits *independent* samples, obtained from an H_s time series, above a chosen threshold (Fig. 2.) to an exponential distribution. [Ferreira and Guedes-Soares, 1998] The POT method can be used with less than 20 years of data, but it requires a manual threshold choice. The threshold needs to be chosen carefully – too low of a threshold violates statistical assumptions, and too high of a threshold results in too few samples to fit.

There are many ways to choose the threshold, though none are recommended by design standards yet. 2 different methods discussed in literature [e.g. ibid] were used to identify proper threshold choices, denoted as MQQR and MGoFEx. MQQR uses quantile-quantile plots and Wald-Wolfowitz Runs test values, and the MGoFEx uses traditional goodness of fit tests and mean excess plots [Seng and Neary, 2018]. There is a level of subjectivity in choosing the threshold, because these tests often rely on visually identifying certain occurrences, such as a change in slope. This is compared in Table 1 (right).

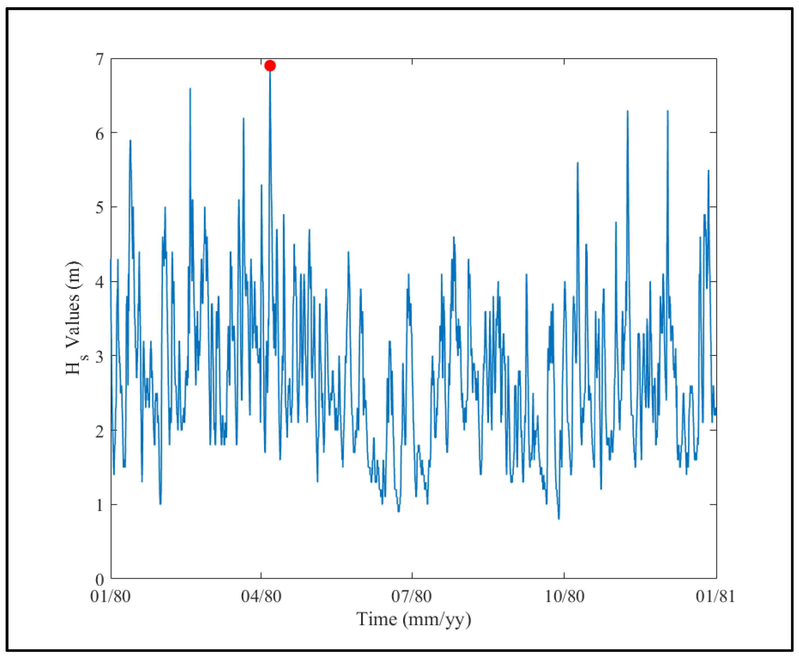

Fig. 1. An example of the Annual Maxima method for the year 1981.

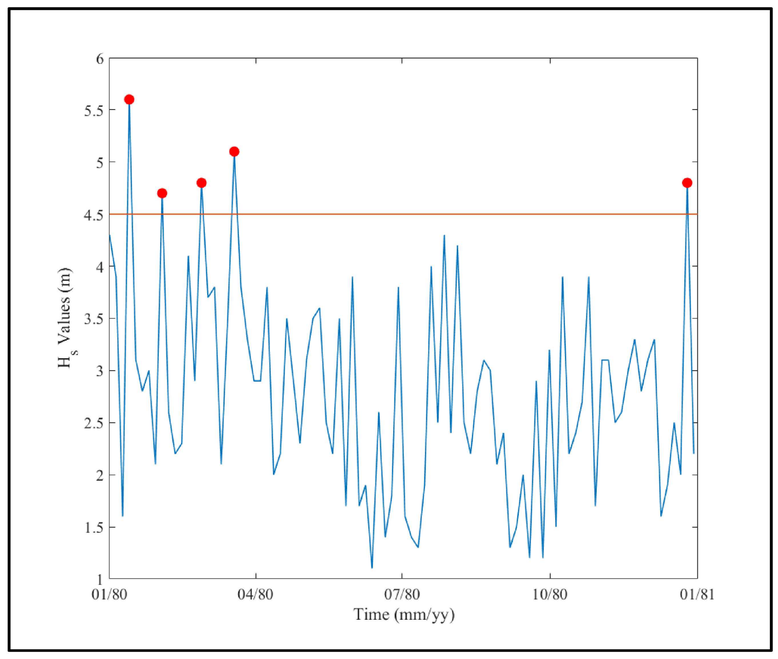

Fig. 2. An example of the POT Method for the year 1981. Note the coarseness of the time series compared to the time series in Fig 1.

Method	1 (Objective)	2 (Mixed)	3 (Subjective)
MQQR (West)	39 (45.88%)	30 (35.29%)	16 (18.82%)
MGoFEx (West)	37 (43.53%)	36 (14.12%)	12 (14.12%)
MQQR (East)	29 (31.52%)	43 (46.74%)	20 (21.74%)
MGoFEx (East)	27 (29.35%)	45 (48.91%)	20 (21.74%)

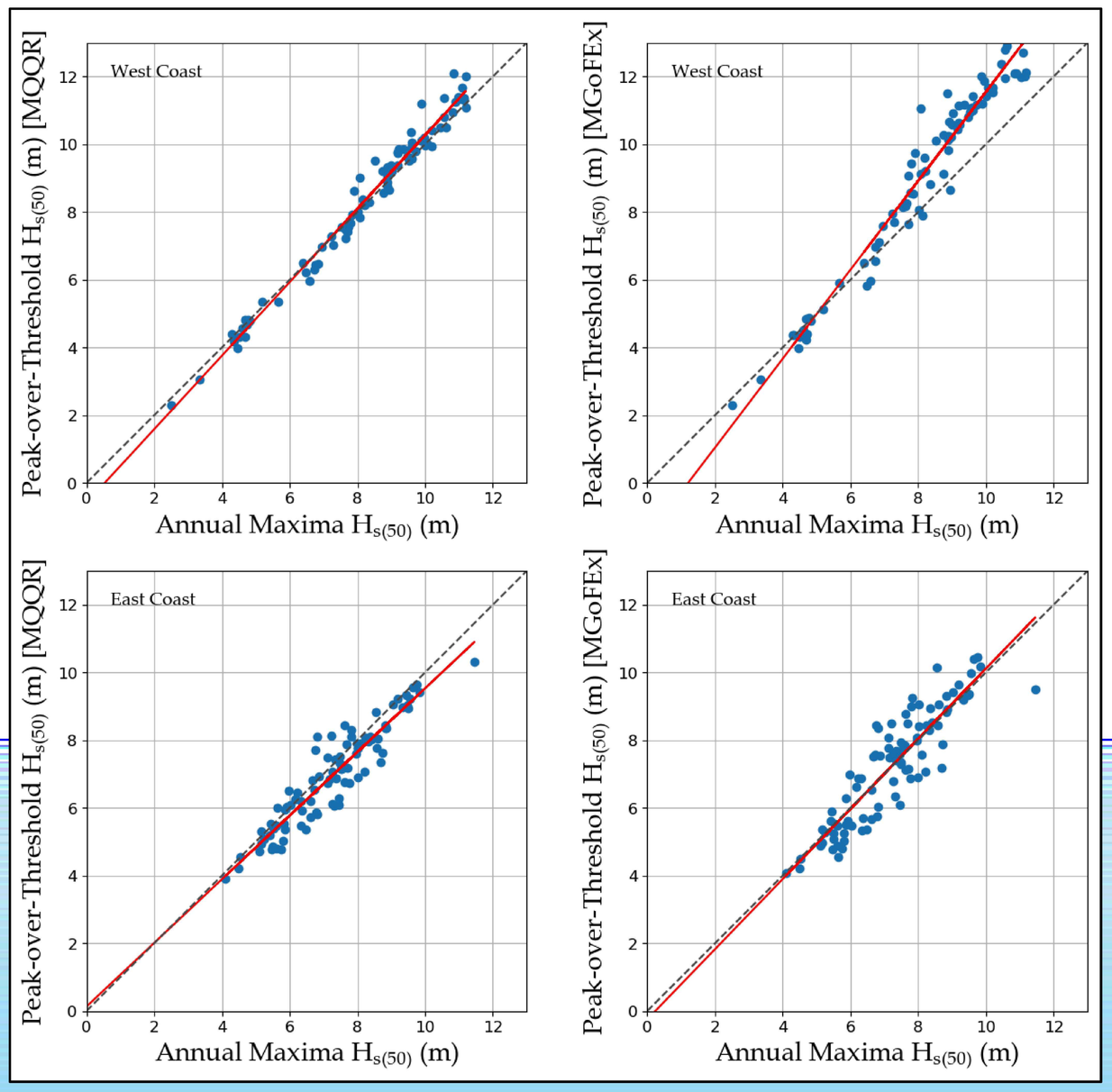

Fig. 4. Scatterplots showing the differences in value between the Annual Maxima estimated $H_{s(50)}$ and the 2 different POT $H_{s(50)}$ values for the West and East Coasts. The red line is a regression line of best linear fit.

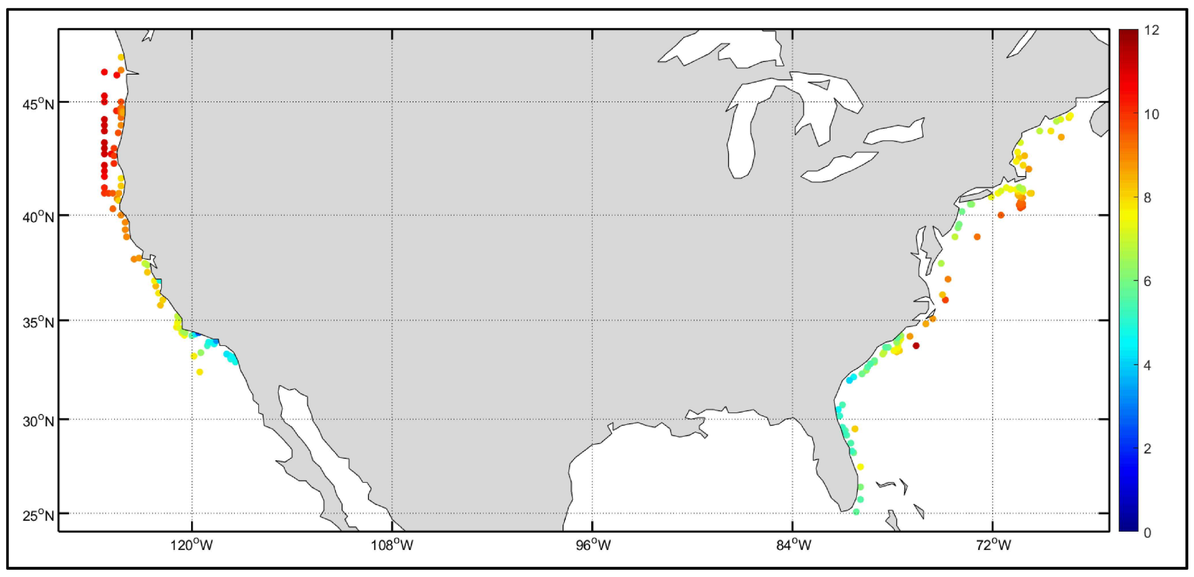

Fig. 3. A heatmap of $H_{s(50)}$ values (in meters) obtained using the Annual Maxima method for the West Coast and East Coast.

Results and Conclusions

Data was taken from a WAVEWATCH III hindcast [NOAA], where 85 West Coast and 92 East Coast sites were sampled. These sites span the entire length of each coast, as shown in (Fig. 3.). The results (Fig. 4) show reasonable agreement across both threshold selection methods. The MQQR method's results align well with the Annual Maxima results for the West Coast, but this method results in smaller values for the East Coast relative to the AM method. By contrast, the MGoFEx method has less bias in its results for the East Coast, but results in more conservative values for the West Coast relative to the AM method .

Current device standards (e.g. DNV 2014) do not require using POT methods when sufficient historical record exists. Because the AM method does not require choosing a threshold, it is an attractive choice for estimating $H_{s(50)}$ when there is enough data. However, a case can be made for using the MGoFEx method as it returns higher values. This would need to be supported by results showing that its statistical tests are better than the MQQR's tests, as this would make for a sound basis for its use.

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