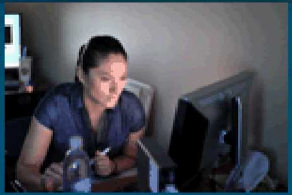
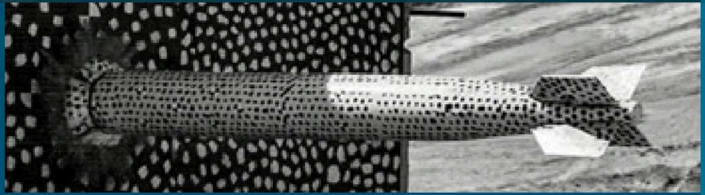
SAND2019-4187C

Extreme Wave Height Estimation Methods for Energy Resource Classification





PRESENTED BY

Bibiana E. Seng

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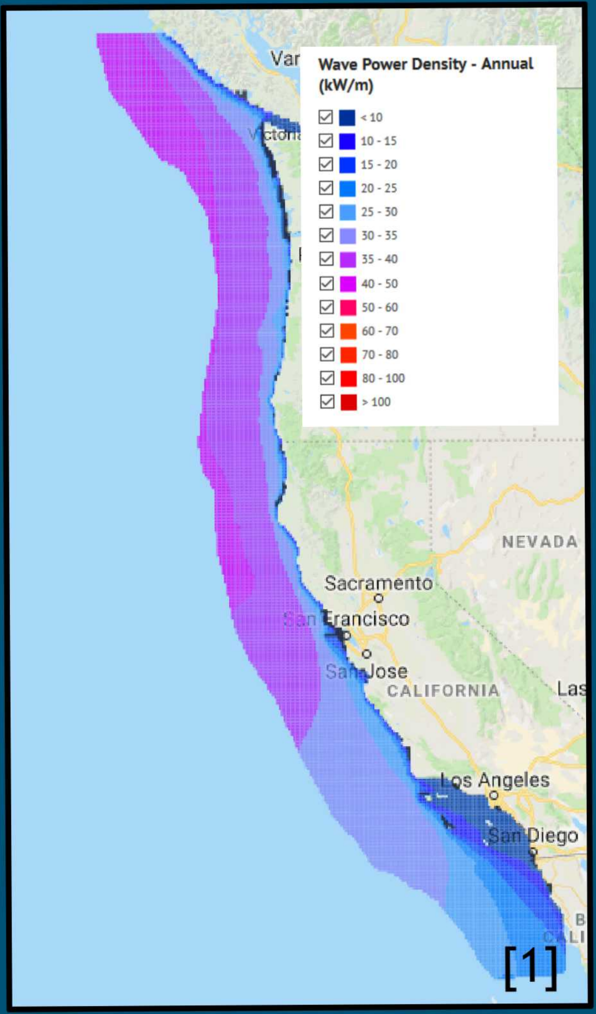
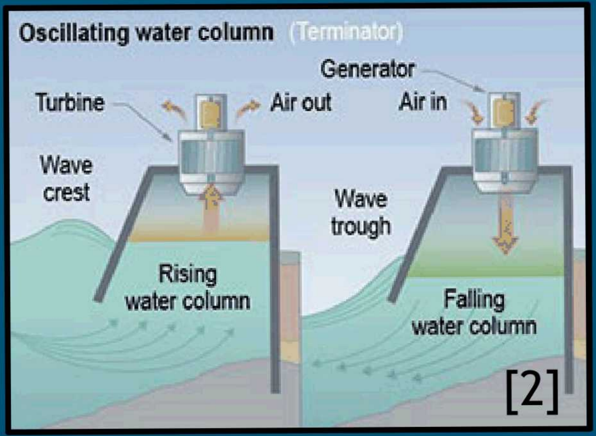
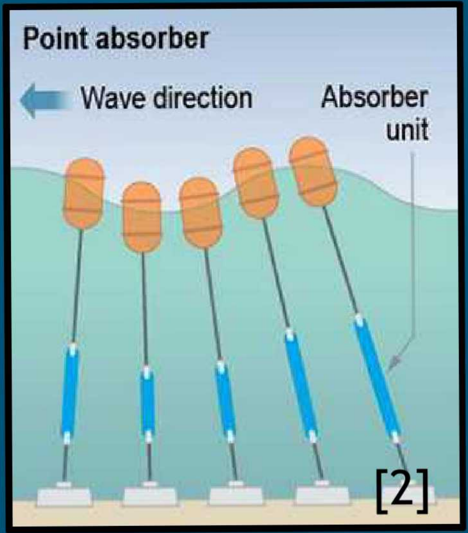
Introduction

- The US Coastline has the potential to generate 898 – 1229 TWh/yr. [1]
- Sites on the coastline need to be characterized for siting Wave Energy Converter (WEC) projects. [6]
- How do we know if project risks are acceptable relative to opportunities for wave energy generation?
  - Relative Risk Ratio: $H_{s(50)}/H_{s(mean)}$
- **How do we calculate $H_{s(50)}$?**







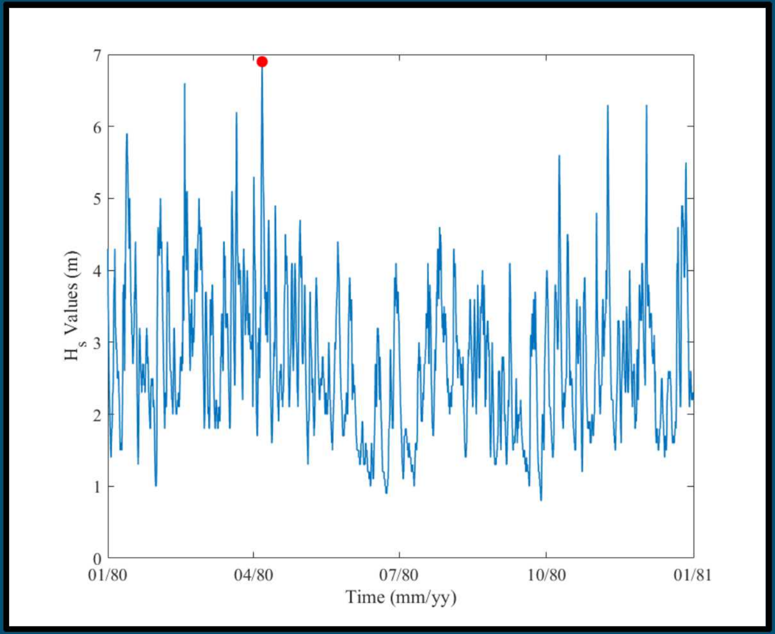
Annual Maxima Method

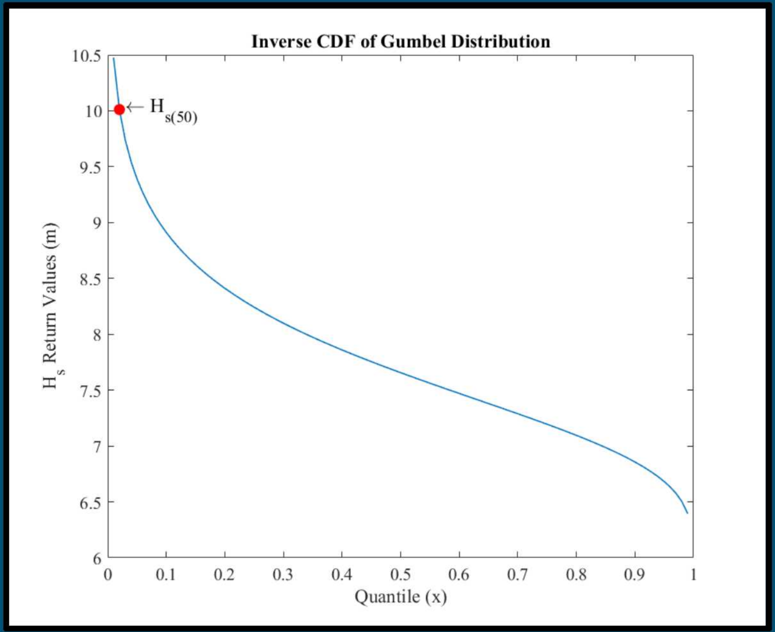
1. Find a yearly maxima H_s from a time series of H_s values.
2. Repeat this for the entire period of record.
3. Fit the yearly maxima values to a Gumbel Distribution:

$$F(x) = e^{-e^{-\frac{(x-\mu)}{\sigma}}}$$

4. Find the 0.02 quantile of the inverse CDF to get $H_{s(50)}$ [3]

- Requires a minimum of 20 years to satisfy statistical fit requirements. [4]
- No user input requirements, computationally fast.

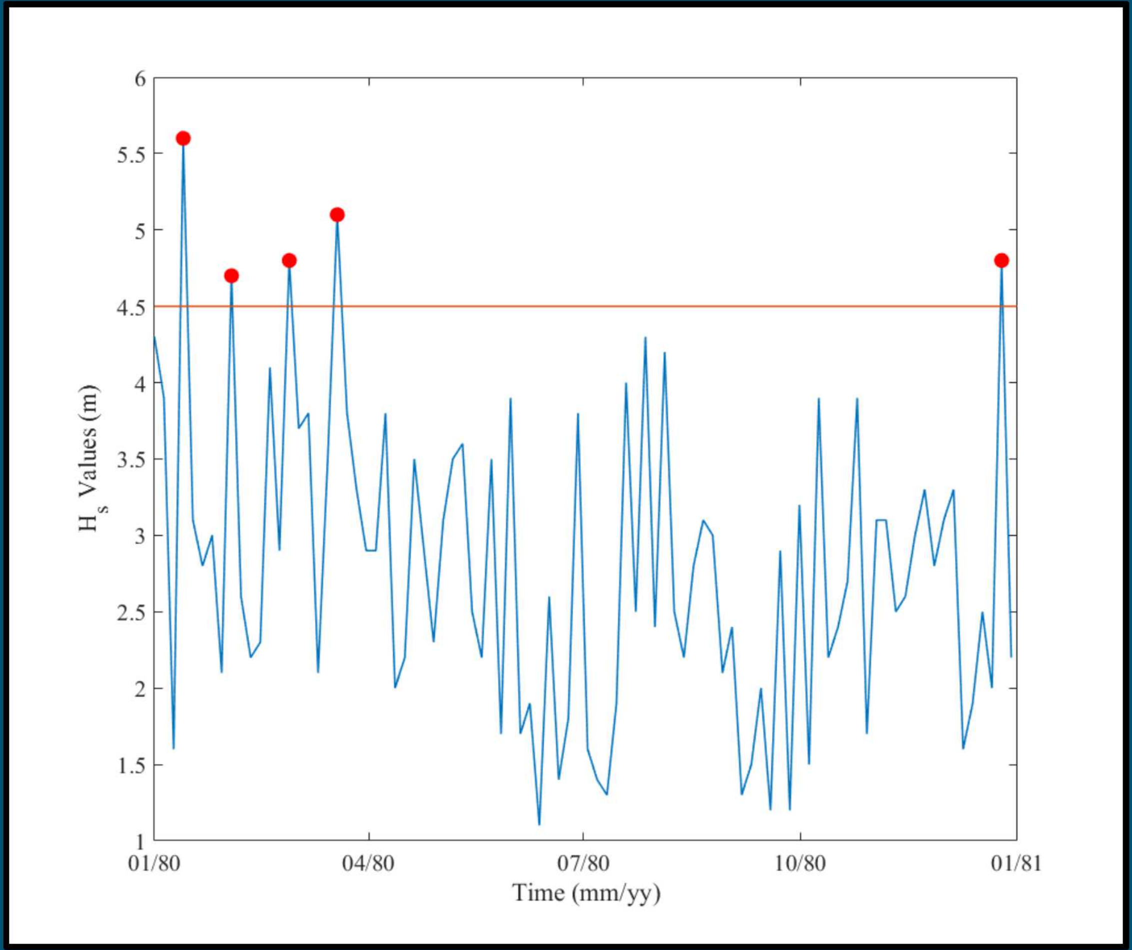




Peak over Threshold Method

1. Ensure all H_s values are independent from one another.
   - For example, the wave heights shouldn't all be associated with storm events.
2. Find all H_s values above a certain threshold v
3. Fit to a Generalized Extreme Value distribution.
   - A common choice is the exponential distribution: [5]

$$F(x) = e^{-\frac{(x-\mu)}{\sigma}}$$



How to Choose the Threshold

- Threshold choice is critical!
  - Very small thresholds violate statistical assumptions.
  - Very large thresholds remove too many samples.

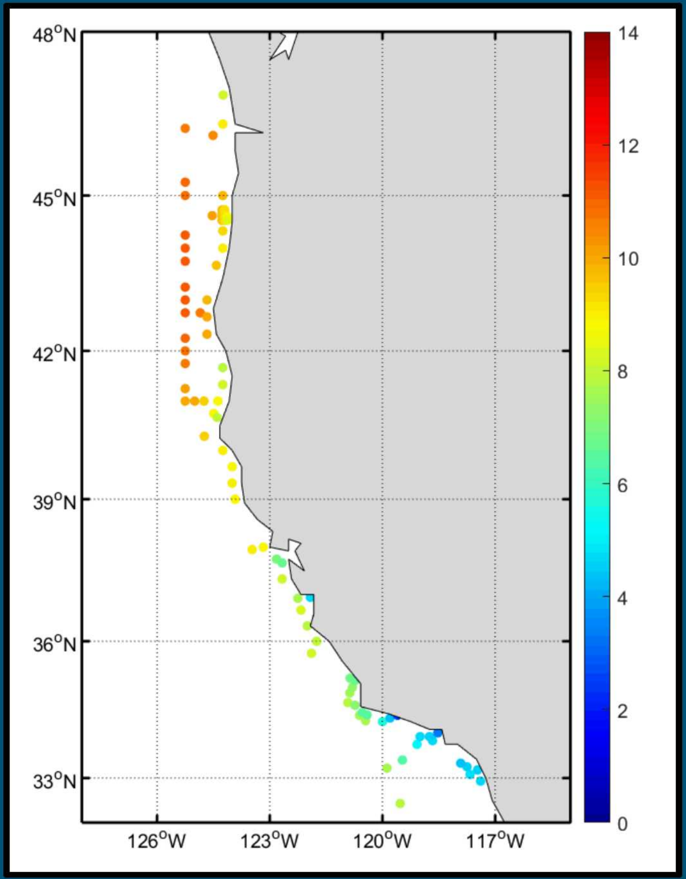
- Thresholds can be chosen by a variety of methods:
  - Automating the POT method. [e.g. 7]
  - Checking GoF tests [5] and Mean Excess values (MGoFEx). [10]
  - Checking the Wald-Wolfowitz Runs tests [9] and visually evaluating the Quantile-Quantile plots (MQQR). [5]

  - No industry standard recommended practices for POT. [4]

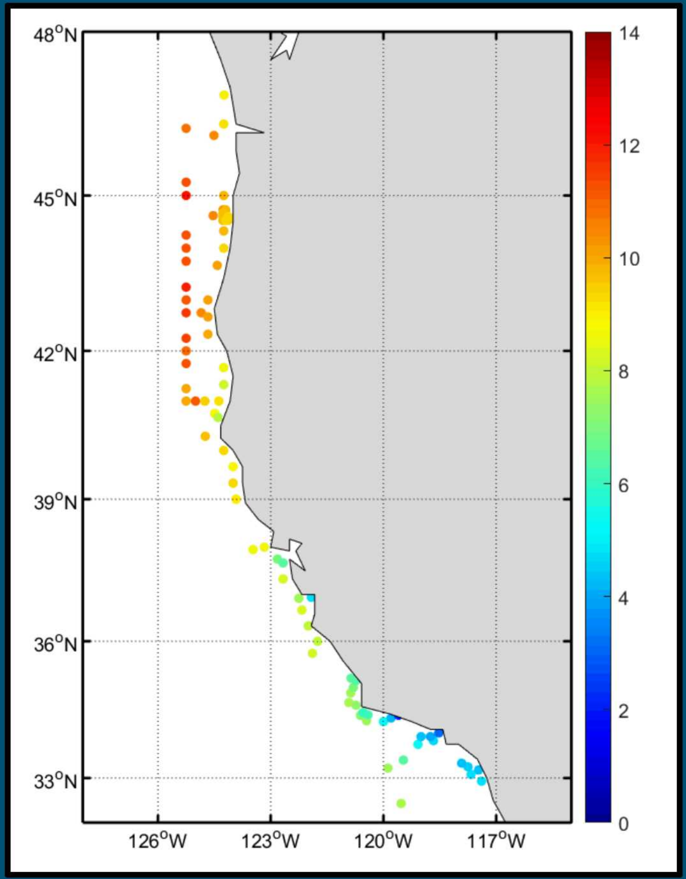
Data

- Simulated hourly H_s time series from WAVEWATCH III [8] hindcasts at 85 sites along the West Coast.

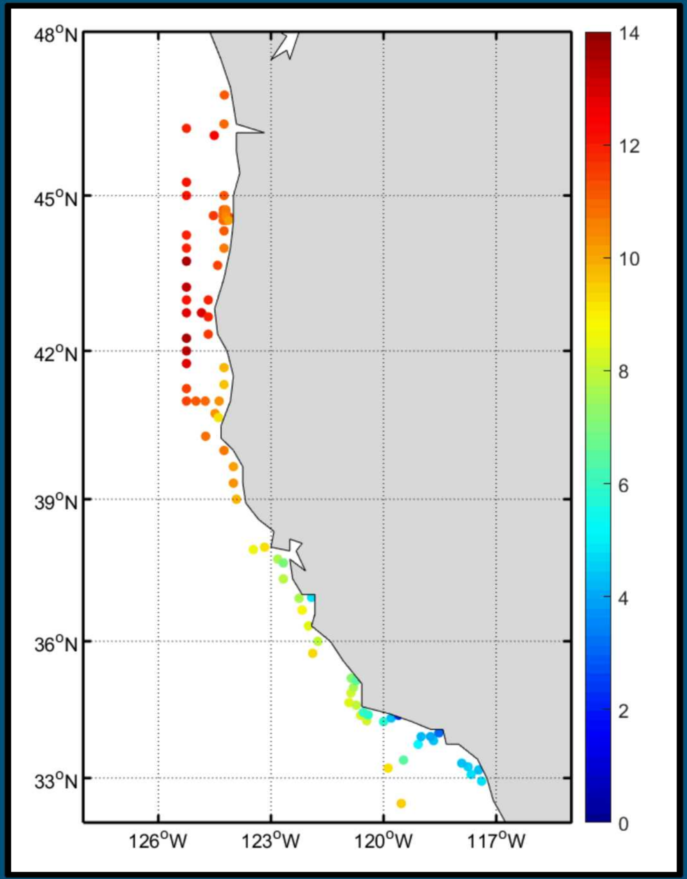
AM $H_{s(50)}$



POT (MQQR) $H_{s(50)}$

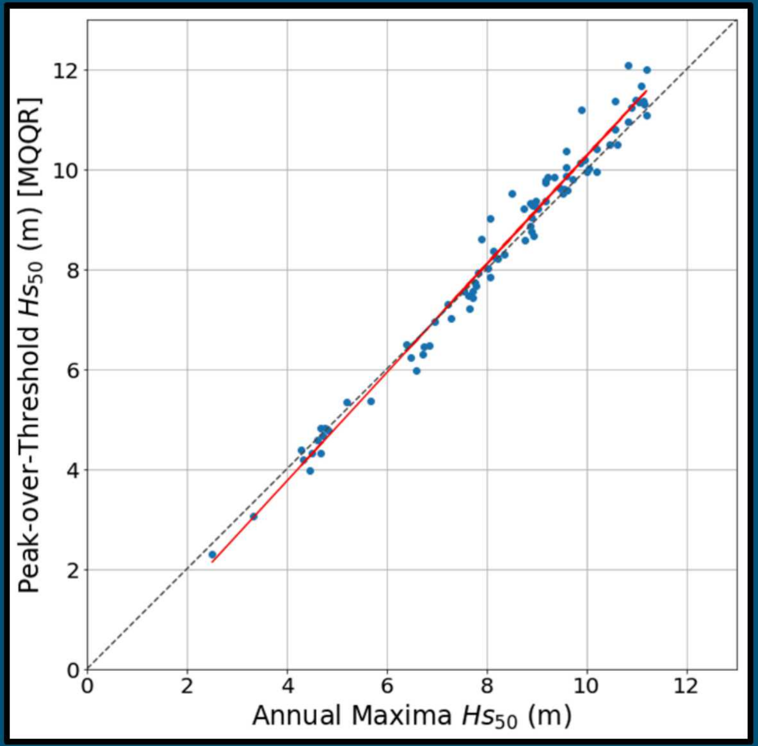


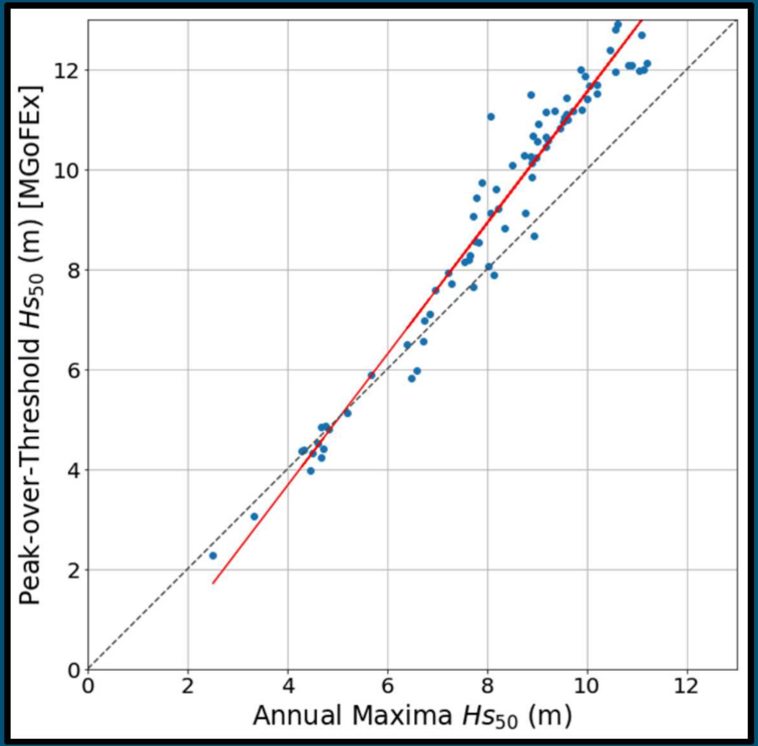
POT (MGoFEx) $H_{s(50)}$

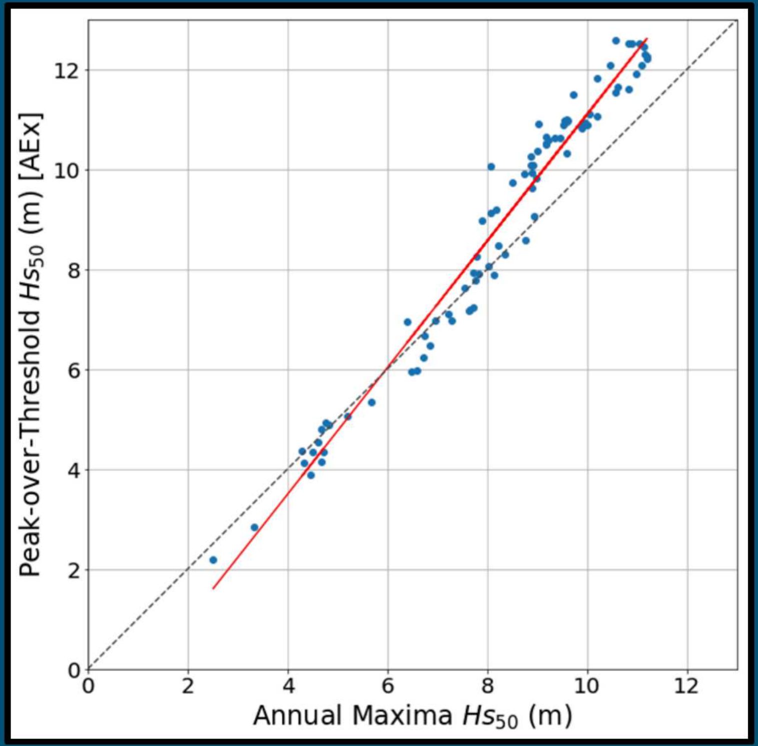


Results

- $H_{s(50)}$ values are sensitive to the threshold choice for any POT method.
  - User bias needs to be addressed when using POT methods.
- The AM method tends to return smaller $H_{s(50)}$ values than the POT method above approx. 6m.







Conclusions

- The AM method is an attractive choice to calculate $H_{s(50)}$ for sites with a lengthy historic record.
  - Current design standards do not require POT methods *if the historic record is large enough, and the event return period is greater than 5-years.*
  - They generally agree with manual POT methods but tend to under-predict.
- Manual POT methods should be applied for sites with a less than sufficient historic record and/or for return periods of less than 5 years.
  - They should also be applied if a more conservative estimate is desired.

Acknowledgments

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Questions?

References

1. Office of Energy Efficiency & Renewable Energy. "Marine and Hydrokinetic Technology Glossary". url: https://energy.gov/eere/water/marine-and-hydrokinetic-technology-glossary
2. "Mapping and Assessment of the United States Ocean Wave Energy Resource". EPRI, Palo Alto, CA: 2011. 1024637. Technical Report.
3. Coles, S. "An Introduction to Statistical Modeling of Extreme Values." 2001. Springer
4. DNV, 2014. Recommended Practice – DNV-RP-C205 Environmental Conditions and Environmental Loads. Technical Report. Det Norske Veritas
5. Ferreira J.A., Guedes Soares C. "An Application of the Peaks Over Threshold Method to Predict Extremes of Significant Wave Height." ASME. J. Offshore Mech. Arct. Eng. 1998, vol 120, no.3, pp. 165-176
6. Neary, V. et. al. "Classification systems for Wave Energy Resources and WEC Technologies." European Wave and Tidal Energy Conference, 2017.
7. Thompson, P. et. al. "Automated Threshold Selection Methods for Extreme Wave Analysis." Coastal Engineering, 2009, vol. 59, pp. 1012-1021
8. WAVEWATCH III® Hindcast and Reanalysis Archives. Natl. Ocean Atmos. Adm. n.d. http://polar.ncep.noaa.gov/waves/hindcasts/.
9. Bradley, J. "Distribution-free Statistical Tests." 1968. Prentice-Hall.
10. Mendez et. al. "Estimation of the Long-Term Variability of Extreme Significant Wave Height Using a Time-Dependent Peak Over Threshold (POT) Model." Journal of Geophysical Research, 2006, Vol. 111.