SAND2017-6658D

Exceptional service in the national interest

Sandia National Laboratories

Extreme Conditions Modeling for Wave Energy Converters

July 26, 2017

Interns:

Austin Berrier, Virginia Tech University, B.S. Engineering Science & Mechanics, May 2017
Jarred Canning, University of Texas at Austin, M.S. Ocean Engineering, est. December 2017
Sam Edwards, University of Michigan, M.S.E. Naval Architecture & Marine Engineering, est. April 2018
Tyler Esterly, University of New Mexico, B.S. Computer Science, est. May 2018
Bibiana Seng, University of New Mexico, B.S. Applied Math & B.S. Statistics, est. May 2019
Laura Smith, Virginia Tech University, B.S. Ocean Engineering, est. May 2018
Zach Stuart, University of New Mexico, PhD Statistics, est. May 2021

Mentors:

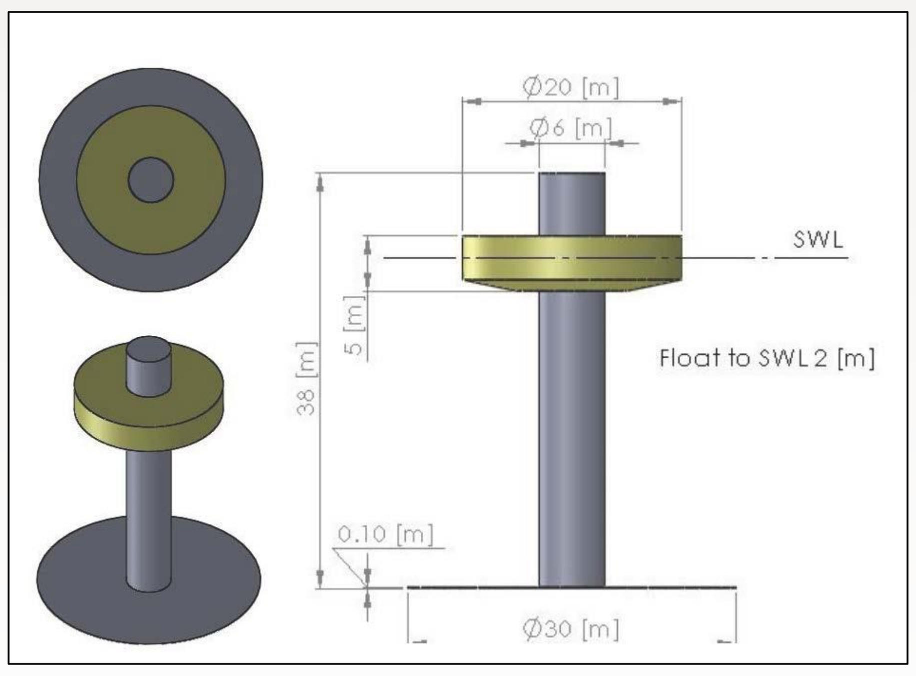
Ryan Coe, Org. 8822, Water Power Technologies
Aubrey Eckert-Gallup, Org. 8853, Structural & Thermal Analysis
Nevin Martin, Org. 9436, Statistical Sciences

Sandia National Labs, NM
U.S. Department of Energy

Abstract: This project aims to provide long-term responses and full sea state characterization for a specific WEC and its deployment site. We extract our site's metocean data to generate individual sea states and contours of different return periods. Using a numerical model and inverse reliability methods, the 50-year loads for our WEC model are determined and compared against direct integration of the sea states. From the results, there seems to be a large discrepancy between the methods that can be traced back to the procedural decisions of each process. Our current work deals with correcting the long-term response approach and studying the effect of different statistical methods with the environmental data.

Introduction:

- WEC devices seek to generate power using ocean waves to drive a Power Take-Off (PTO)
- Reference Model 3 (RM3): point absorber WEC comprising a floating body that oscillates along a spar cylinder with a submerged reaction plate (pictured on the right)
- Provide a long-term reliability analysis for this WEC.



Numerical Model:

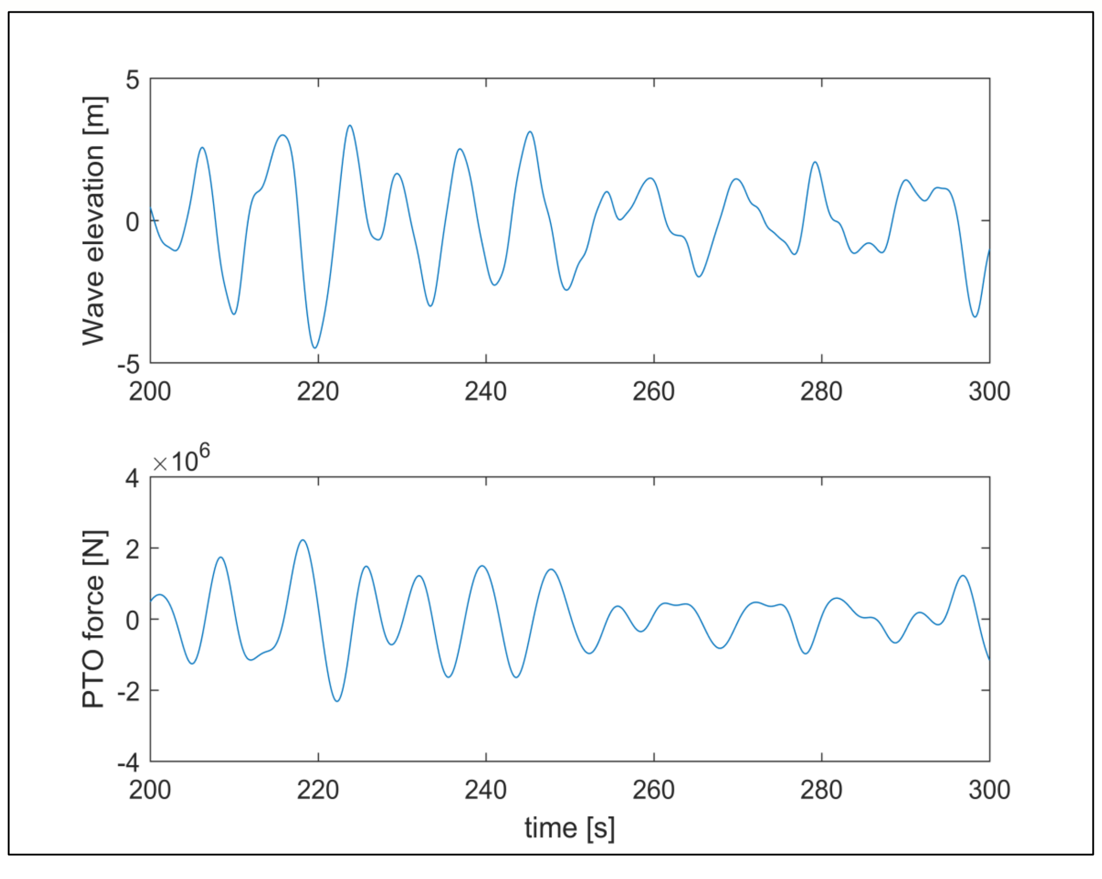
- WEC-Sim (WEC Simulation) used to simulate RM3 at various sea states

➔ http://wec-sim.github.io/WEC-Sim/

- WDRT (WEC Design Response Toolbox) used to pull NDBC data and generate environmental contours

➔ http://wec-sim.github.io/WDRT/

- Typical time-series plots are shown on the right



Comparison of Methods

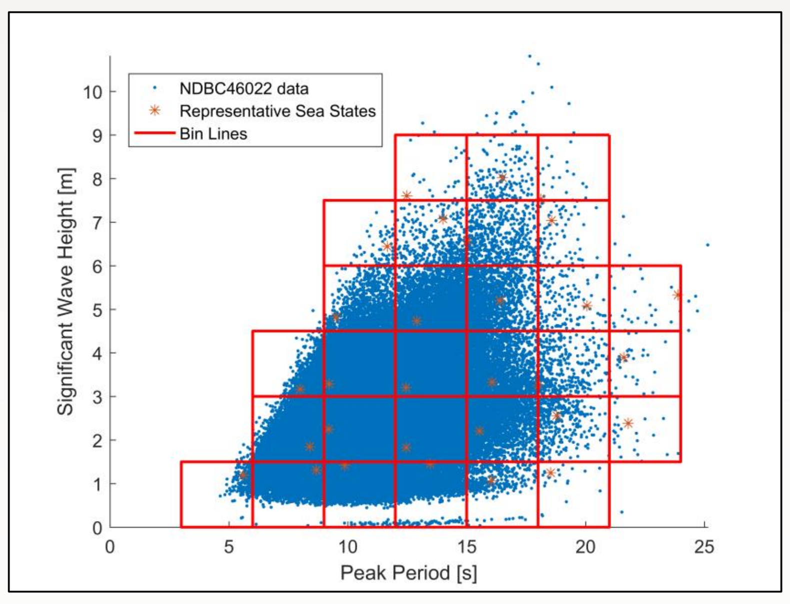
Direct Integration (DI):

- Split the H_s-T_p space into discrete bins (shown on the right)
- Generate short-term distributions for each bin using response block maxima
- Integrate over all bins using the following equation:

$$P_T = P[L > l_T] = \int P[L > l_T | X = x] f_X(x) dx$$

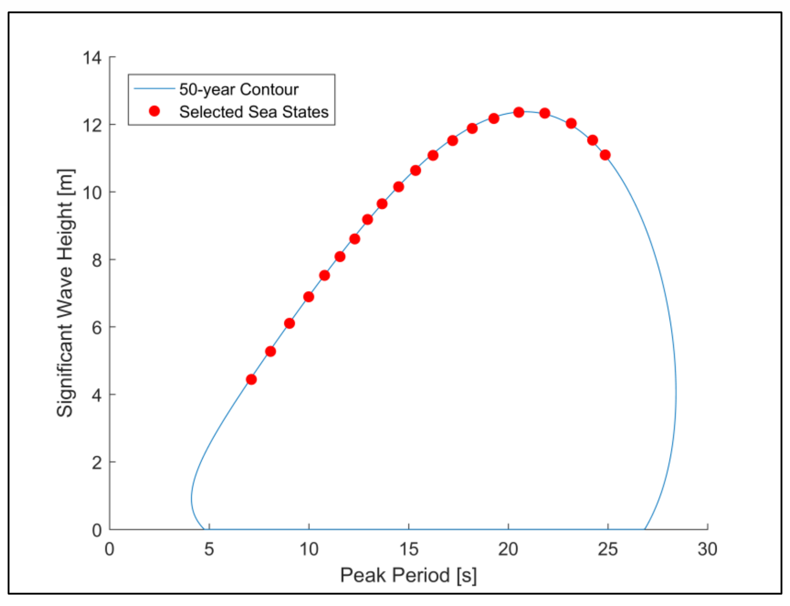
Short-term extreme — Sea state likelihood

- Find the design load l_T such that the target P_T is met



Environmental Contour (EC):

- Generate the 50-year contour using the Principal Component Analysis with inverse first order reliability methods (IFORM)
- Simulate sea states and extract extreme response values
- The largest of the median responses is the design load



Correction Factor:

- Correct the EC design load using:

$$R = \frac{l_T}{\hat{l_T}} = \exp[(\sigma_{\ln l} - \sigma_{\ln \hat{l}})\beta_T]$$

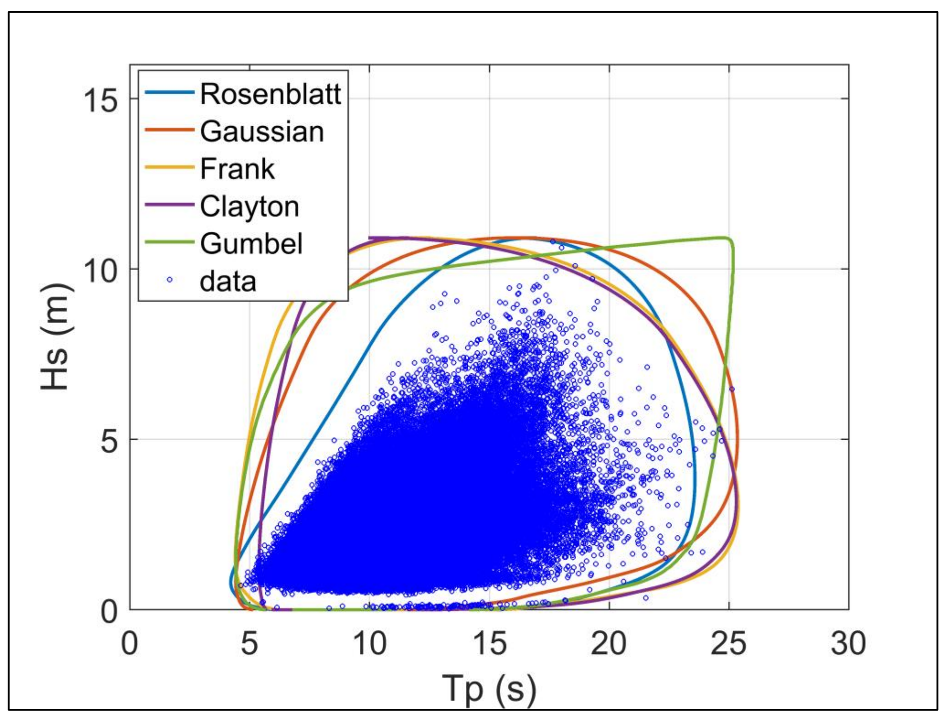
Results and Discussion:

- Table below shows results (controlling sea states for EC method are given)
- 13% - 25% difference between DI and EC values
- Large differences due to coarse binning of sea states and seemingly large contours
- More simulations should be run to reduce the variability in each response

Response	DI	EC	EC with correction
Heave Force [MN]	3.49	3.45 (8.6 m, 12.3 s)	4.47 (10.2 m, 14.5 s)
Surge Force [MN]	1.60	1.44 (6.1 m, 9.0 s)	1.82 (8.6 m, 12.3 s)
PTO Extension [m]	5.82	6.11 (11.1 m, 16.2 s)	6.67 (12.2 m, 19.3 s)

Future Work:

- Find ways to correct the direct integration answer
- Look at different approaches to generating contours
- Optimize the WEC software for quicker performance
- NDBC vs. SWIFT buoy data
- WEC geometry and power production
- Compare hurricane sea states to buoy data



U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.