

HNEI Role at US Navy Wave Energy Test Site

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NAVFAC
Naval Facilities Engineering Command



Testing Expected at WETS

- Northwest Energy Innovations (NWEI) Azura
- Fred. Olsen Bolt Lifesaver

Jun 2015 – Dec 2016

Mar 2016 – Apr 2017

- NWEI Modified Azura
- Bolt Lifesaver Redeployment
- Ocean Energy USA, LLC
- Columbia Power Technologies
- NWEI (grid-scale device)
- Oscilla Power
- California Wave Power Technologies
- AquaHarmonics

Sep 2017 – Jan 2018

Jan – Jul 2018

June 2018 – June 2019

Early 2019 – early 2020

2019/2020

Fall 2019 – fall 2020

2020/2021

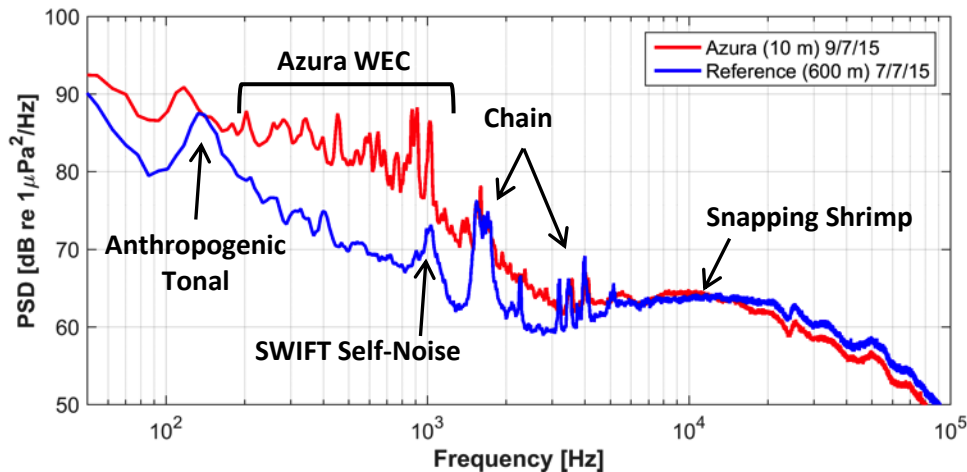
2020/2021



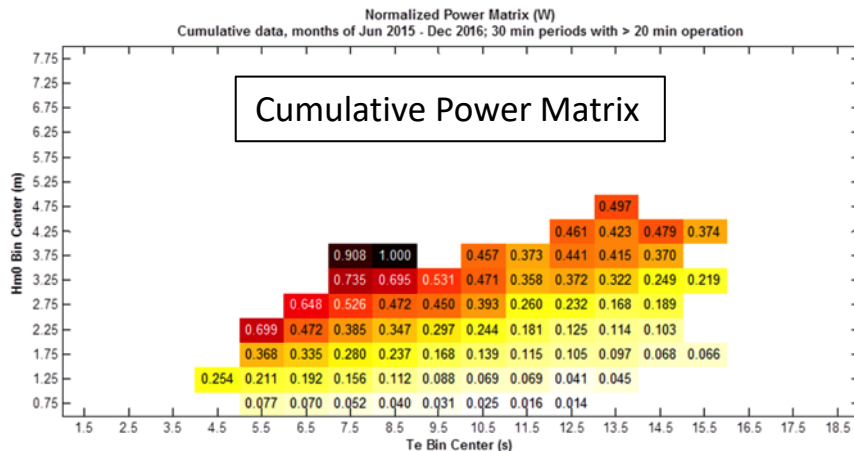
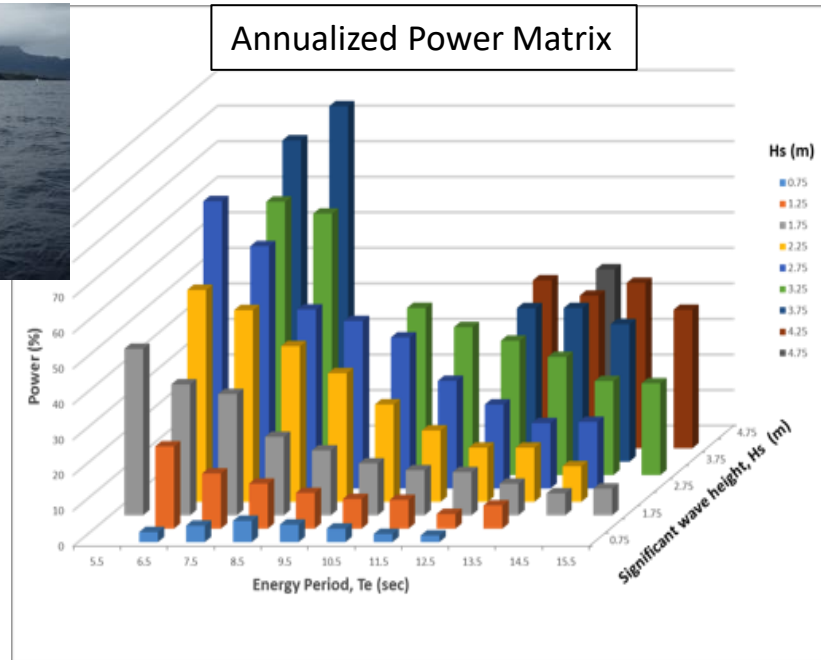
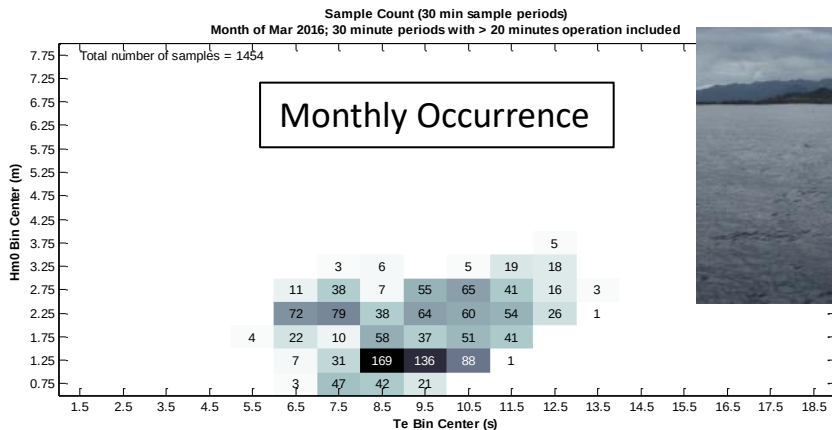
Projects receive support funding
from Navy and/or DOE

Environmental Data Collection

- Device acoustic signatures
 - Bottom-mounted and drifting hydrophone systems
 - Regular deployments to build database
- Sediment transport
- Ecological surveys
- Protected marine species monitoring



Power Performance Assessment

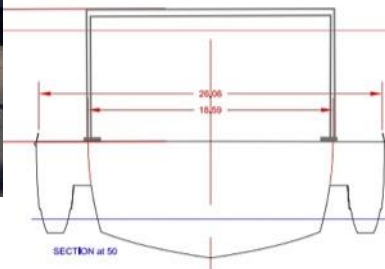


Performance assessed in accordance with
IEC Technical Specification 62600-100

WETS Site-Dedicated Support Vessel – Sea Engineering, Inc.



- 85 foot LOA
- 4-point mooring capability
- 10-ton A-frame lift capacity
- Knuckle-boom crane
- Deepwater dive spread
- ROV enclosure
- Reconfigured w/added beam
- To be kept at boat harbor ~ 1hr away



Numerical Modeling Efforts

- Develop numerical models to enhance independent assessment of WEC performance
- Model comparison with ocean test data

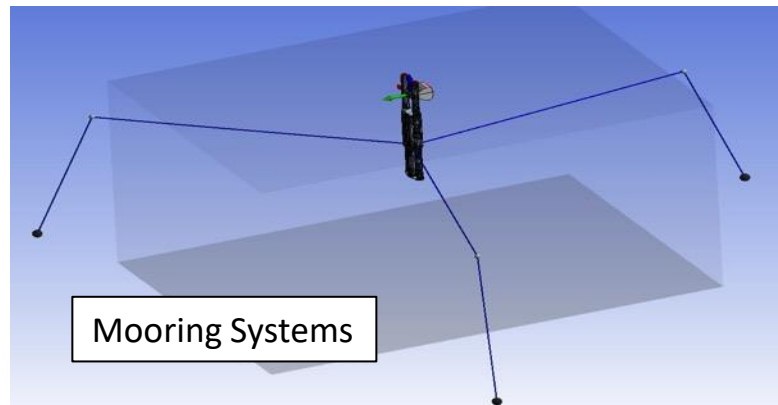
HNEI In-house WEC Concepts

- Study to design a WEC device that is tuned to evolving wave regimes
- BEM used to compare hydrodynamic characteristics of a wide range of geometries
- Ongoing study shows importance of device wave drag on maximizing power performance

Dr. Kumar Rajagopalan

Modeling tools employed

- WEC-Sim
- Flow3D
- OpenFOAM
- ANSYS SUITE
- In-house codes



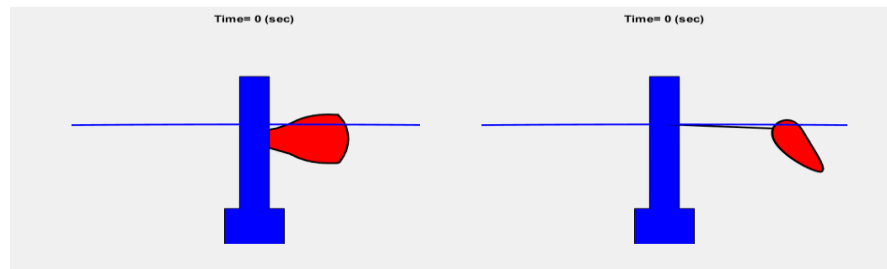
Mooring Systems

- Azura moored at 30m berth
- Mooring modeled in ANSYS AQWA

Northwest Energy Innovations Azura

Hydrodynamic Motion Analysis

- WEC-Sim (Primary) & In-house code (Selected cases)
- Solution of equations of motion in time domain
- BEM: Estimation of hydrodynamic coefficients (Added mass, Wave damping)
- CFD : Estimation of viscous drag
- Predicted electric power, body motions
- Numerical model tuned with prototype trial data
- (Tuned) Num. model applied for comparative evaluation of versions 1 & 2 of Azura

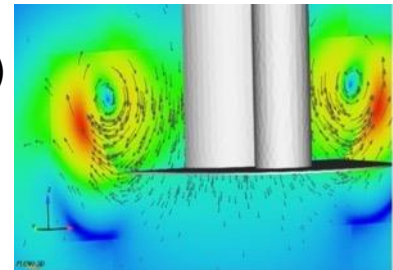


Development of In-house Code

- To improve confidence in predictions
- Similar in approach to WEC-Sim (hydrodynamic coefficients & viscous drag)
- Difference
 - WEC-Sim: MATLAB toolbox for connection between WEC bodies
 - In-house code: Linear and non-linear constraints
- Good agreement between WEC-Sim and In-house

CFD Solver for Viscous Drag Estimation

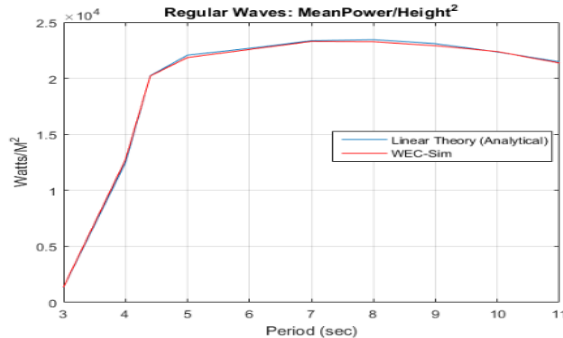
- Oscillation tests for float and spar in Flow3D Numerical Wave Tank (NWT)
- Solve Navier Stokes Equations with RNG turbulence model
- Morison equation to estimate Drag Coefficient as input to WEC-Sim/In-house code



Additional Modeling

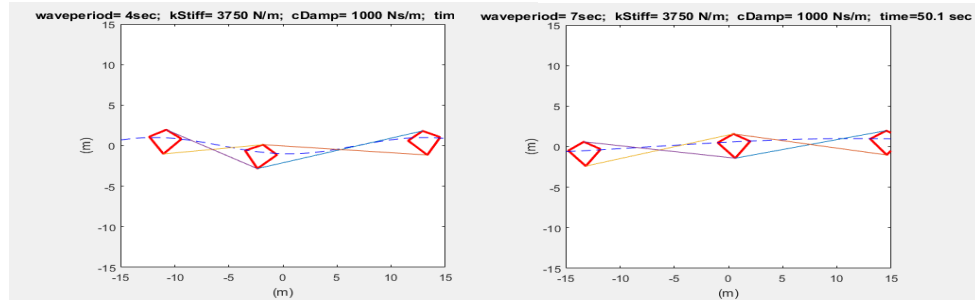
IEA OES Task 10 WEC Modeling

- HNEI participated in task 10 for validation of WEC modeling software
- Discussion of results, methodology through webinars/meetings
- Device: Heaving sphere
- Results from WEC-Sim compared with linear theory for selected cases

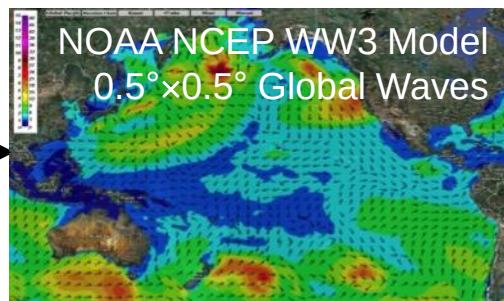
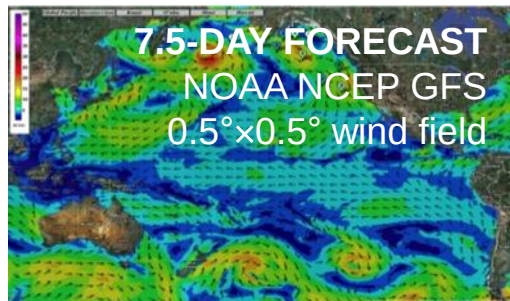


Natural Power Concepts

- Hawaii-based WEC developer
- Subset of buoy system modeled with in-house code
- Able to model optimal buoy spacing, conceptual PTO spring stiffness and damping



Daily 7.5-day Wave Forecast (oceanforecast.org)



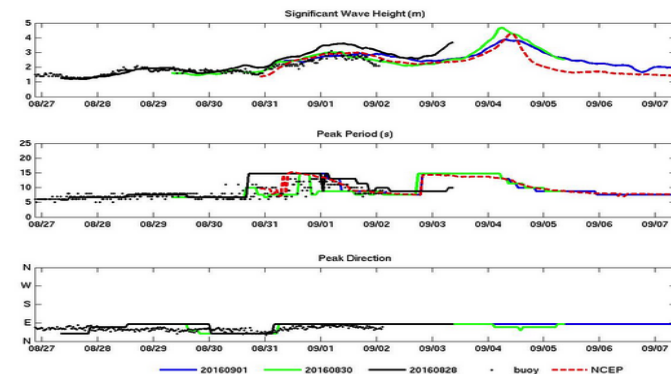
Real-time validation with measurements

- 30 buoys in the Pacific Basin
- Example on-line display for WETS

Hawaii Region, 51207_Kaneohe_Bay UH Forecast Bouy lat = 21.477 N, lon = 157.752 W

Waves are 2.8 meters/ 9.2 feet 8.7 sec. 82° dir. on Thu Sep 01 2016 6 PM HST

[7.5 Day forecast plot](#) [3D spectral animation](#) [7.5 Day forecast table](#) [Performance history](#)
[51207_Kaneohe_Bay Webpage](#)



Hawaii WRF Model
6-km grid

Hawaii WW3 Model
5.5-km grid

Dr. Ning Li

0.55-km Grid
SWAN

0.55-km Grid

100-m
Grid
WETS

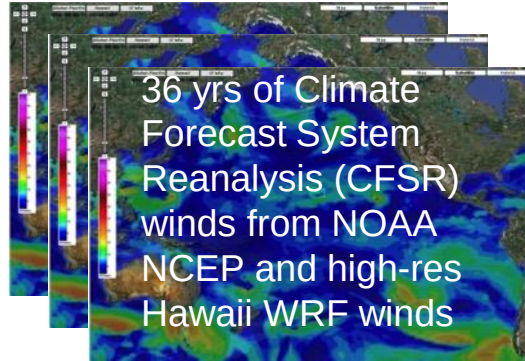
0.55-km Grid

0.55-km Grid

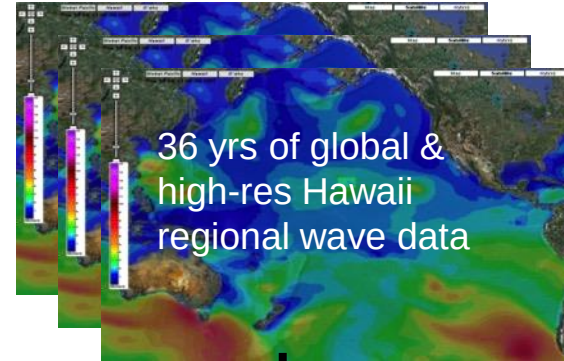
Long-term Wave Hindcast

Hindcasting of global and Hawaii regional wave data from 1979 – 2015

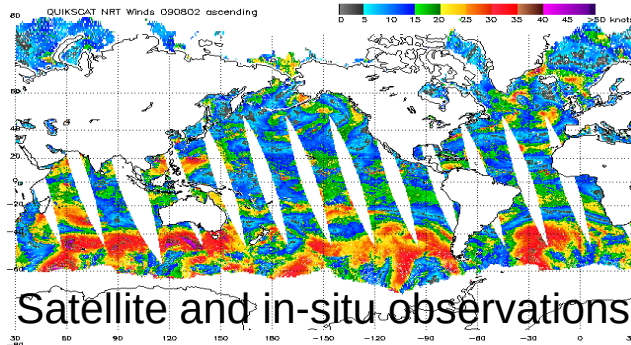
- Validation with satellite and buoy wave measurements, hourly hindcast for entire period



Wave
→
Models



Data assimilation ↑ reforecasting



Validation ↓ measurements



N. Li, et al, *Ocean Modelling*, vol. 100, pp. 78-95, Feb. 2016.

WEC Survival Analysis

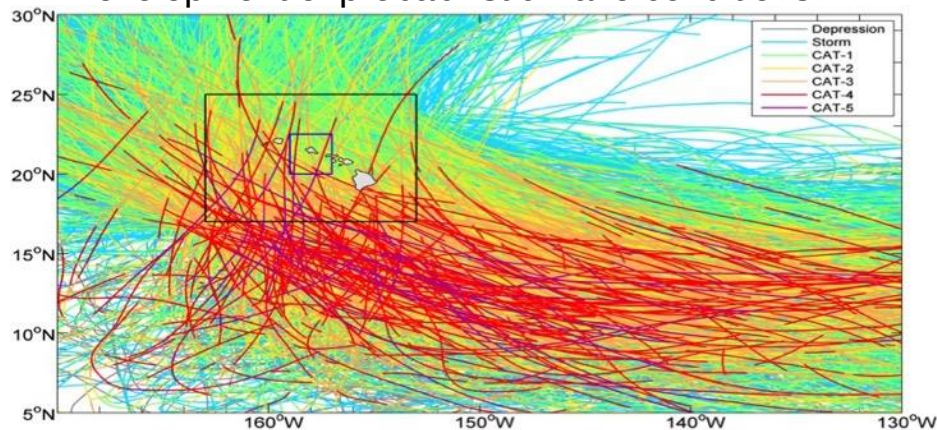
Climate Model Downscaling

Global Climate Model w/1950-2100 greenhouse gases

- Synoptic weather output for stochastic-deterministic simulation of hurricanes

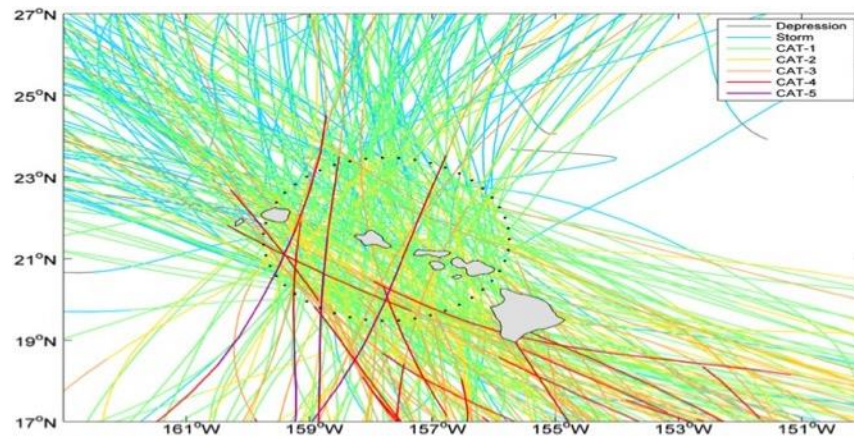
Climate Model Downscaling by Emanuel (2013 PNAS)

- 50 simulations, 1980-99, using NCAR CCSM4 model
- 2436 hurricanes in equivalent 1000-year period
- Development of probabilistic wave conditions



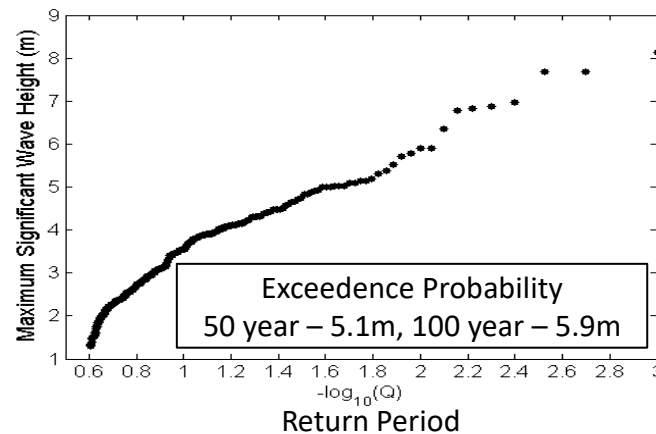
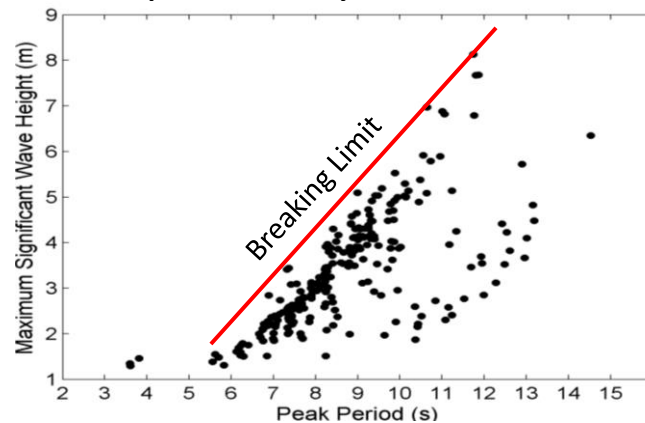
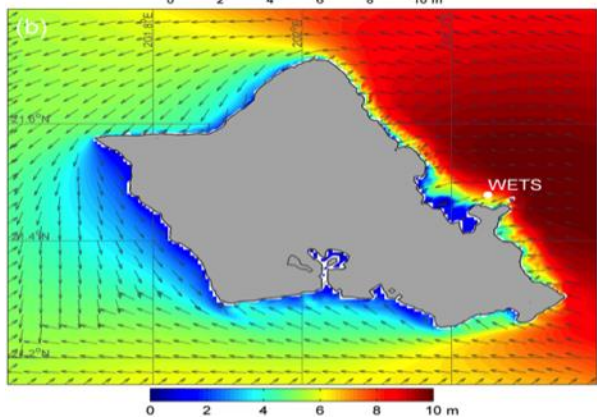
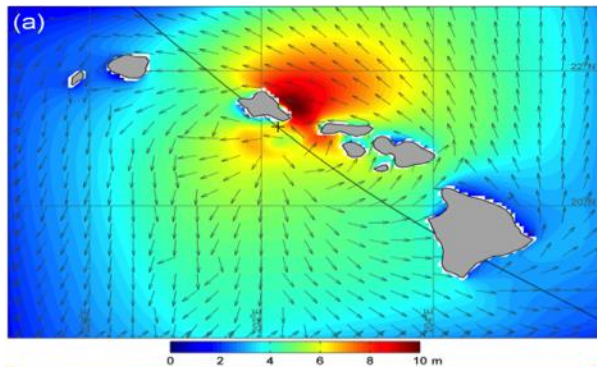
Hurricane Wave Modeling

- 2436 simulated hurricanes, 252 w/in 200 km of WETS
- 3rd generation spectral wave model WaveWatch III
- Nested grids for the Hawaiian islands and Oahu with ~5.5 km and 500m resolution
- Parametric hurricane model for wind forcing from hurricane track, central pressure, and radius of maximum winds



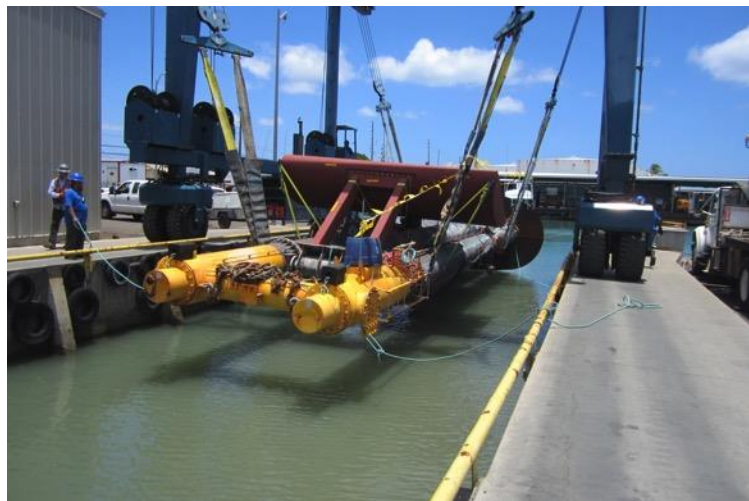
Hurricane Wave Modeling

- 252 sets of H_s and T_p over the 1000-year period
- H_s as a function of return period or annual exceedance probability



Navy-funded Follow-on Projects

- Modify and Redeploy NWEI Azura
 - Wider/extended float
 - Heave plate
 - Better adaptation to WETS wave regime – validate models
- Redeploy Fred. Olsen BOLT Lifesaver w/Relevant Power Loads
 - UW AMP Sensors
 - WiBotic subsea charging/data transfer capability
- Improve PTO moorings for better power performance



Questions

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