

# Environmental Measurements at the U.S. Navy's Wave Energy Test Site

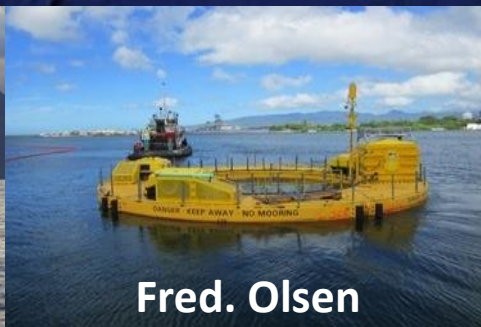
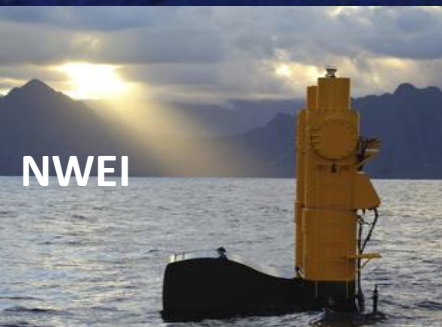


## Environmental Interactions of Marine Renewables Kirkwall, Orkney 24 April 2018

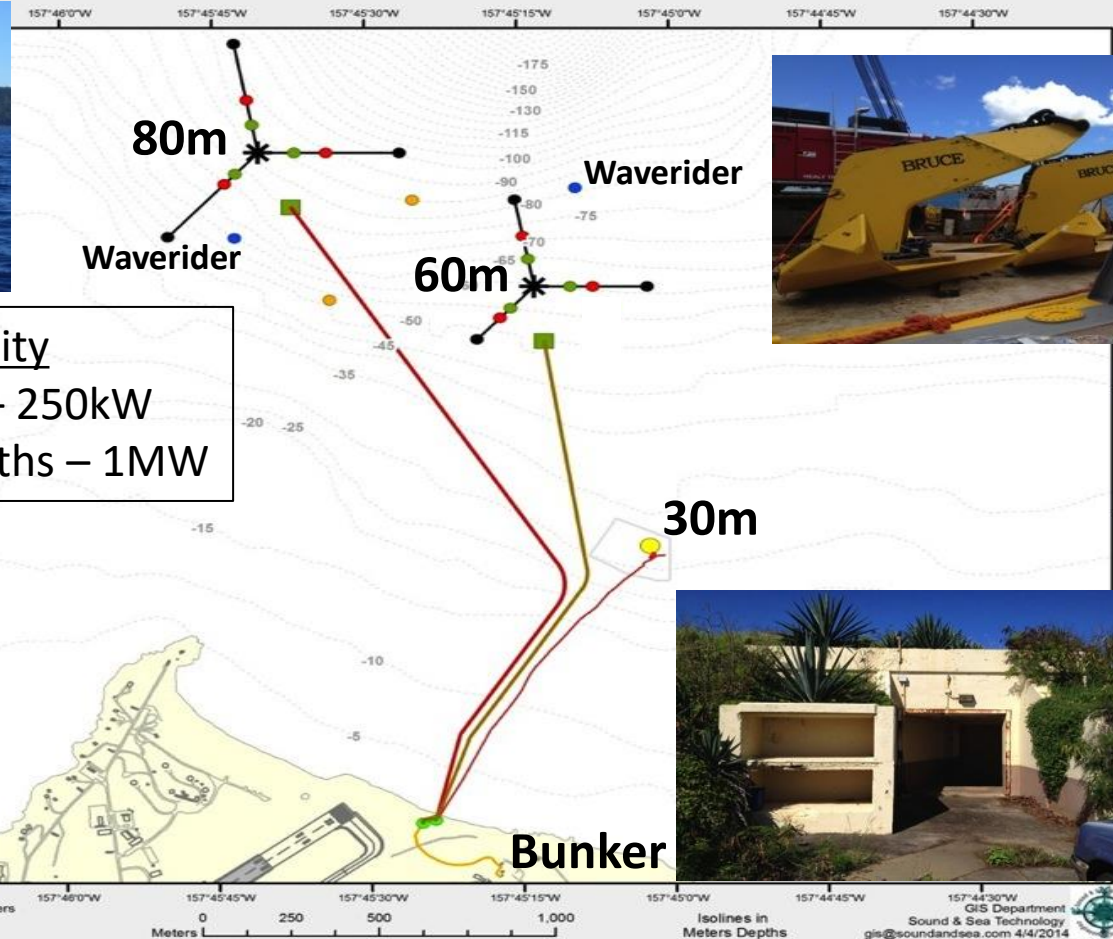
Patrick Cross, Hawaii Natural Energy Institute  
University of Hawaii



**APPLIED RESEARCH LABORATORY**  
UNIVERSITY OF HAWAII



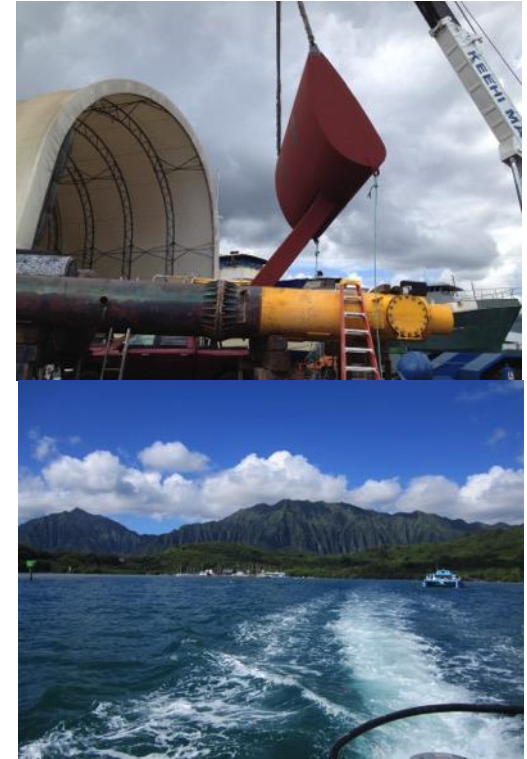
# WETS Layout



# Testing Expected at WETS

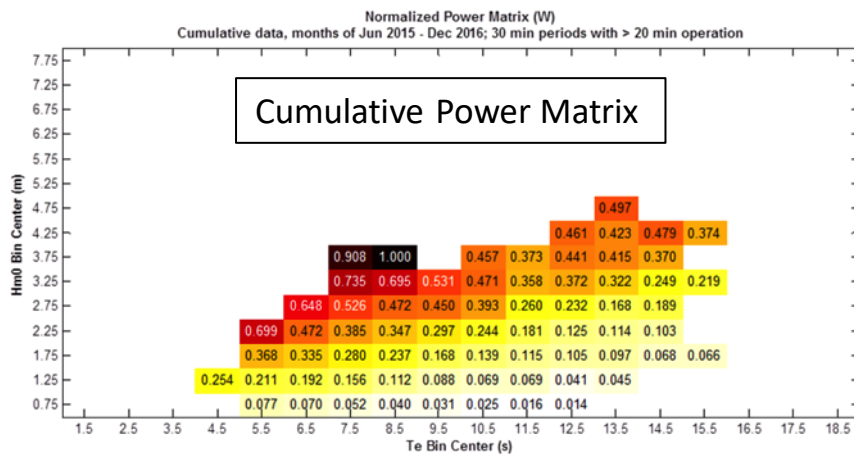
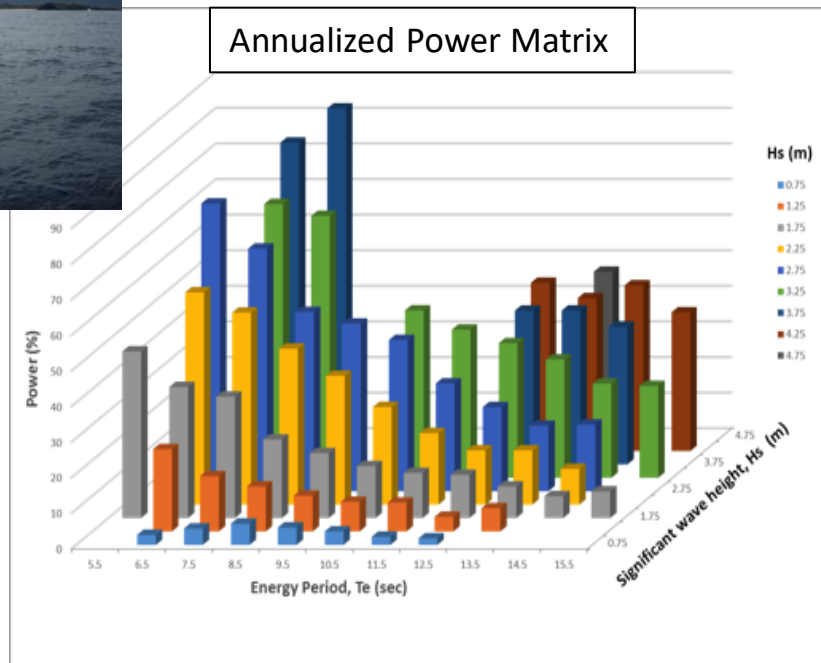
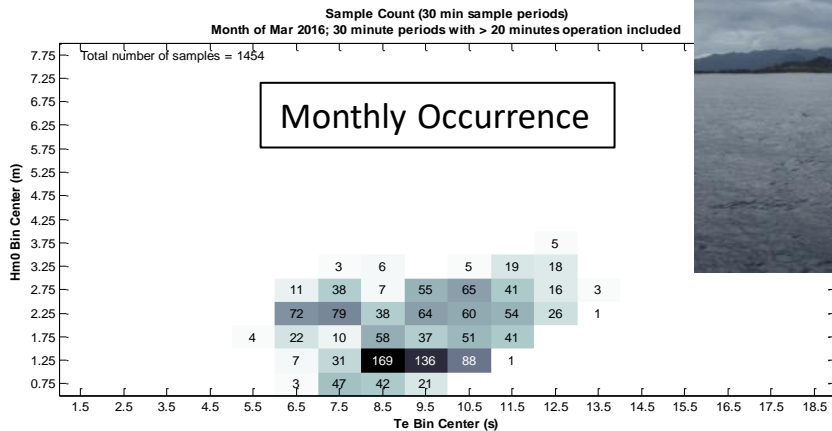
- Northwest Energy Innovations (NWEI) Azura, Jun 2015 – Dec 2016
- Fred. Olsen Bolt Lifesaver, Mar 2016 – Apr 2017
- NWEI Modified Azura, Feb – May 2018
- Bolt Lifesaver Redeployment, May – Nov 2018
- Ocean Energy USA, LLC, Nov 2018 – Nov 2019?
- Columbia Power Technologies, Apr 2019 – Apr 2020?
- NWEI (grid-scale device), 2019/2020?
- Oscilla Power, Fall 2019 – fall 2020?
- California Wave Power Technologies, 2020/2021?
- AquaHarmonics, 2020/2021?

Projects receive support funding  
from Navy and/or DOE



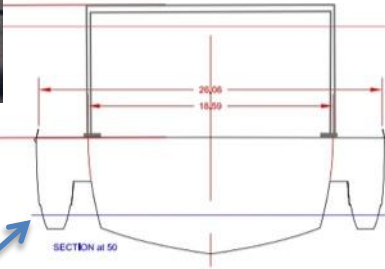


# Power Performance Assessment



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
- Reconfiguring w/added beam
- To be kept at boat harbor ~ 1hr away

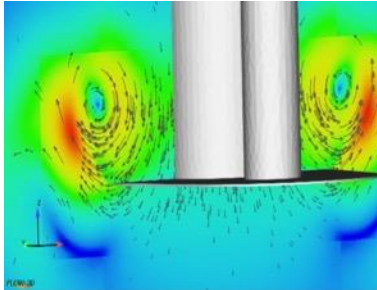


# Numerical Modeling Efforts

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

## Hydrodynamic Motion Analysis

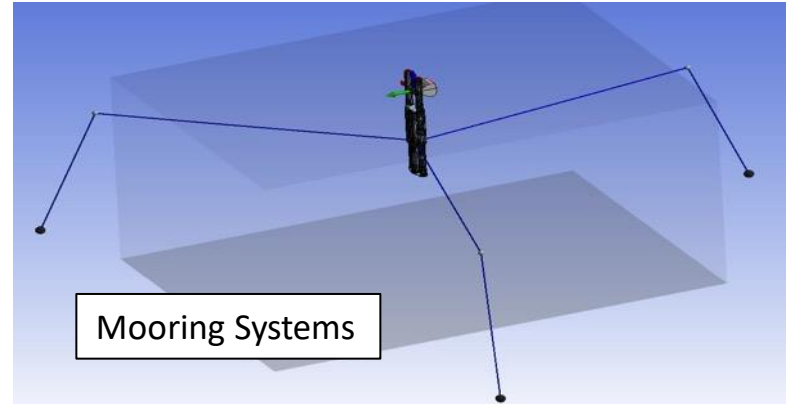
- WEC-Sim (Primary) & In-house code (Selected cases)
- Solution of equations of motion in time domain
- BEM: Estimation of hydrodynamic coefficients (Added mass, Wave damping)
- CFD : Estimation of viscous drag
- Predicted electric power, body motions
- Numerical model tuned with prototype trial data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



Dr. Kumar Rajagopalan

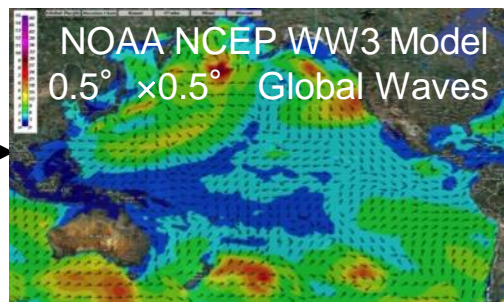
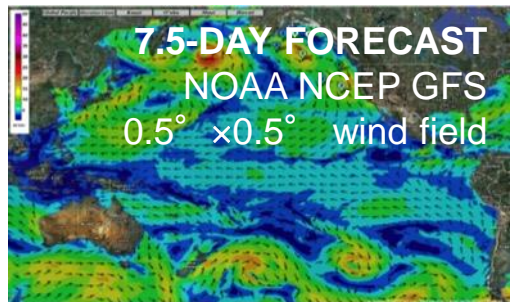
## Modeling tools employed

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



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

# Daily 7.5-day Wave Forecast (oceanforecast.org)



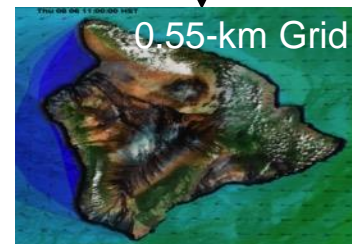
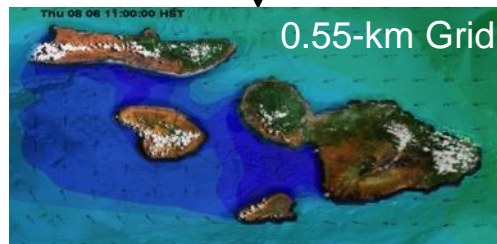
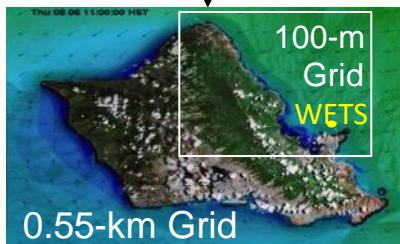
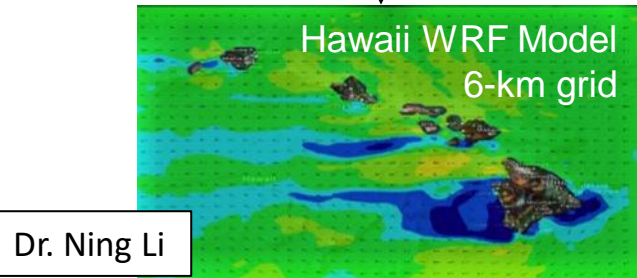
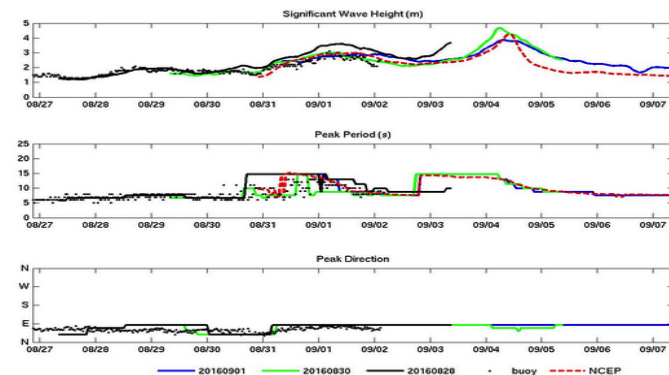
Real-time validation with measurements

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

Hawaii Region, 51207\_Kaneohe\_Bay UH Forecast Buoy 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](#)

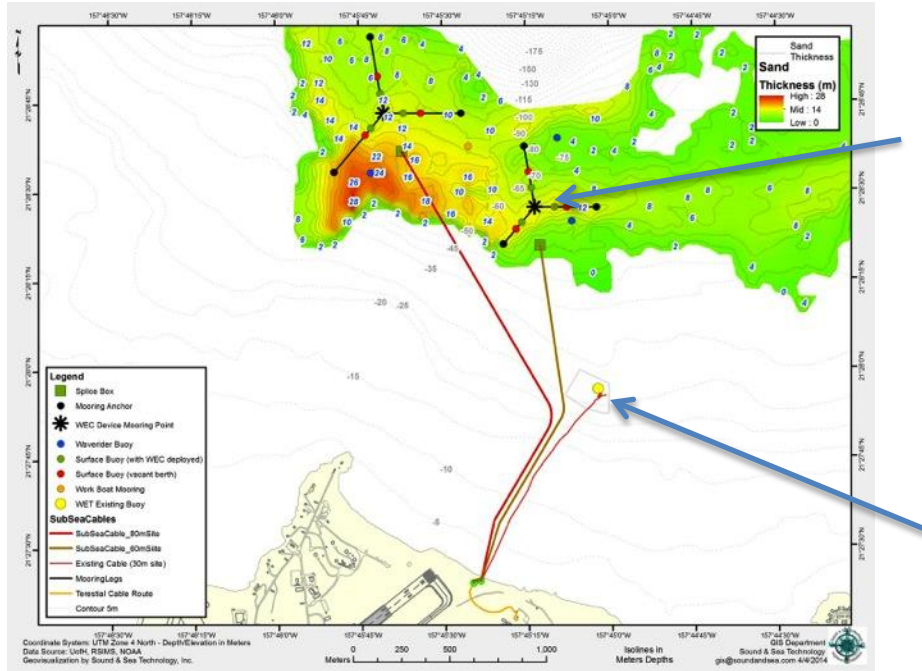


34-year Hindcast paper – N. Li, et al, *Ocean Modelling*, vol. 100, pp. 78-95, Feb. 2016.

Dr. Ning Li



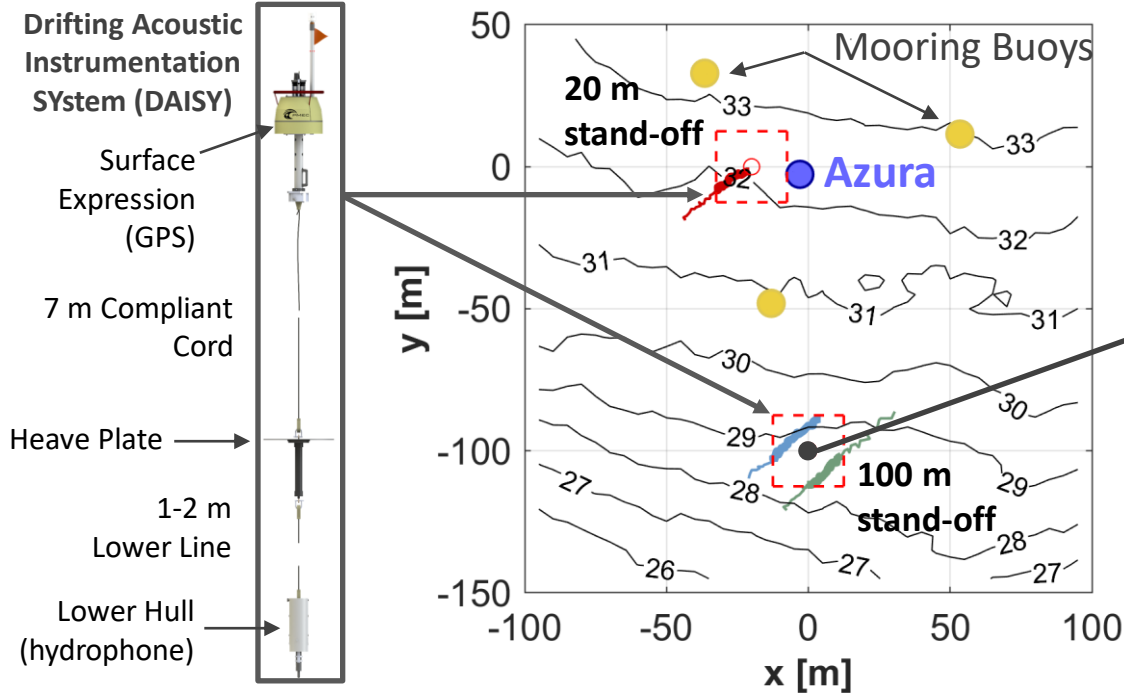
# Devices Under Test to Date



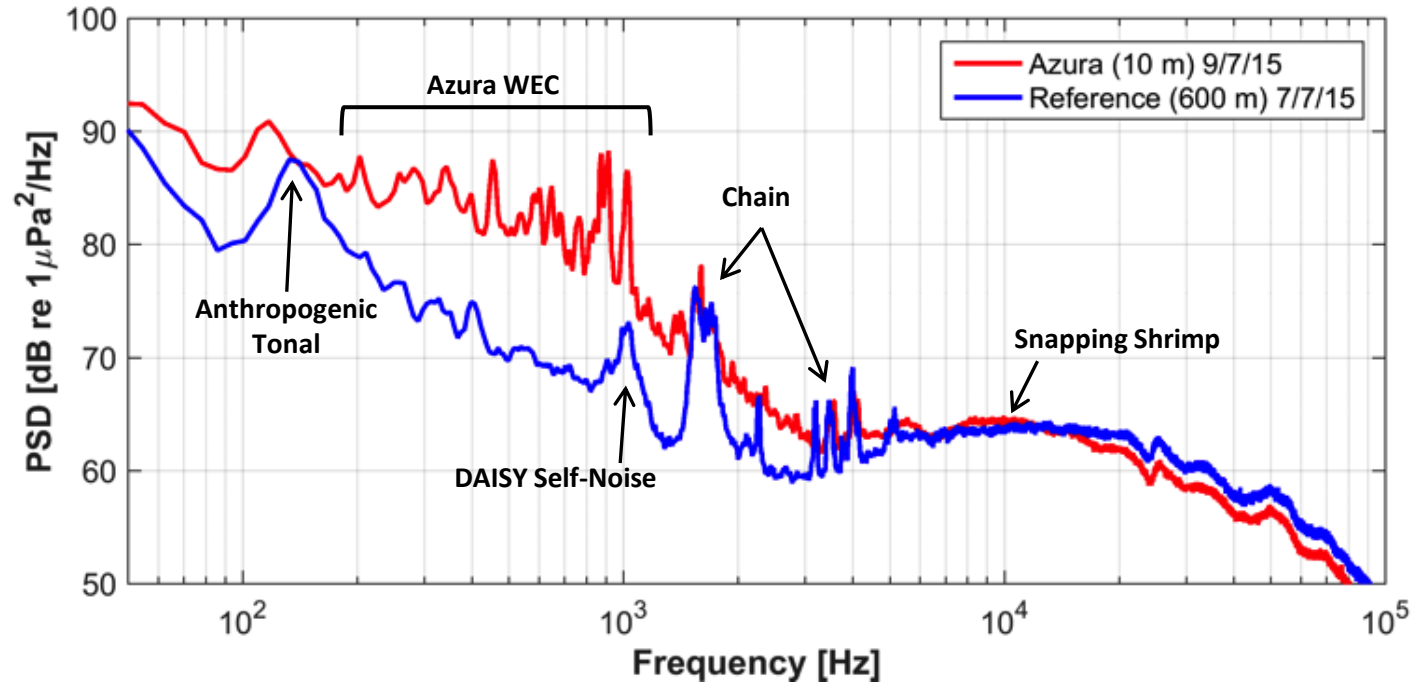


# Acoustic Measurements

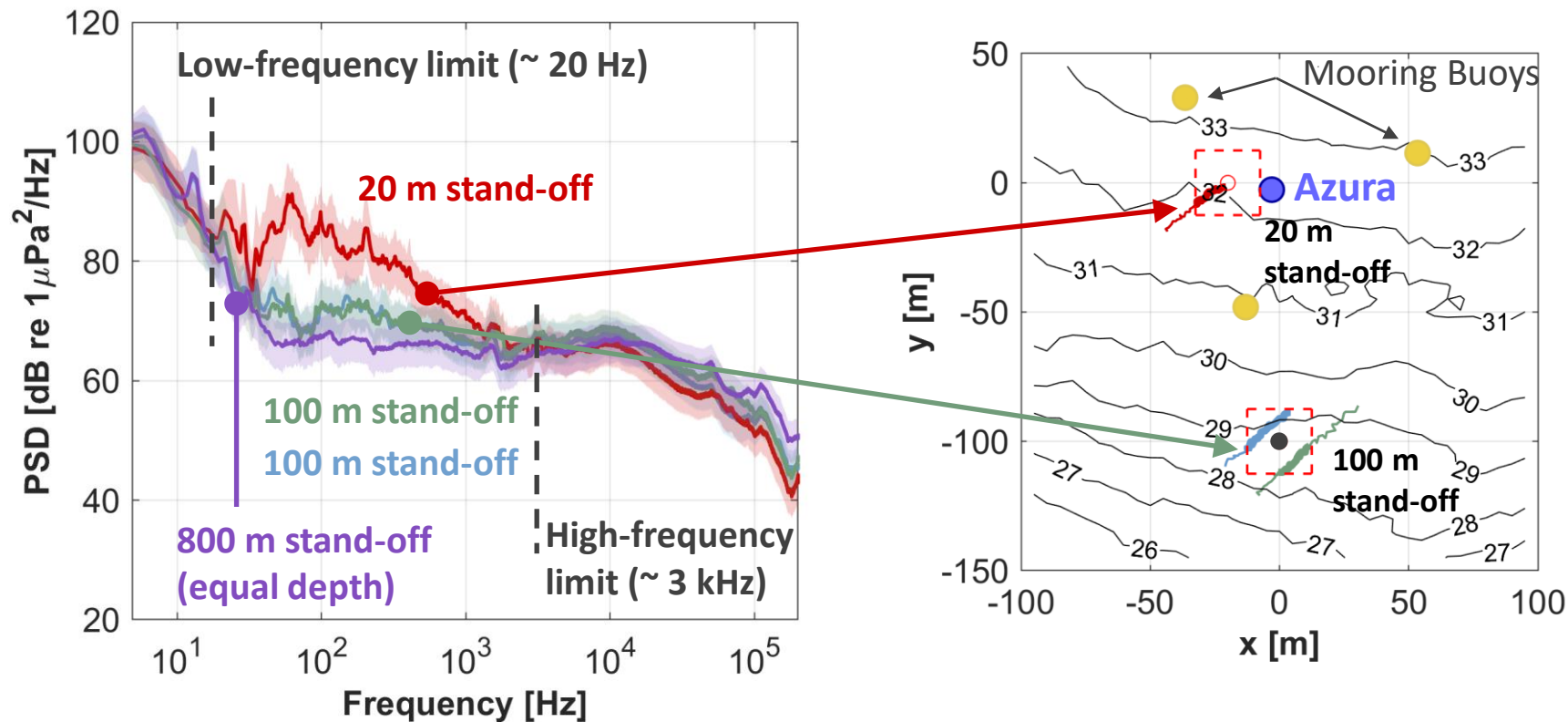
Assessment combines drifting and stationary observations



# Drift Data from UW DAISY



# Identification of WEC Sound

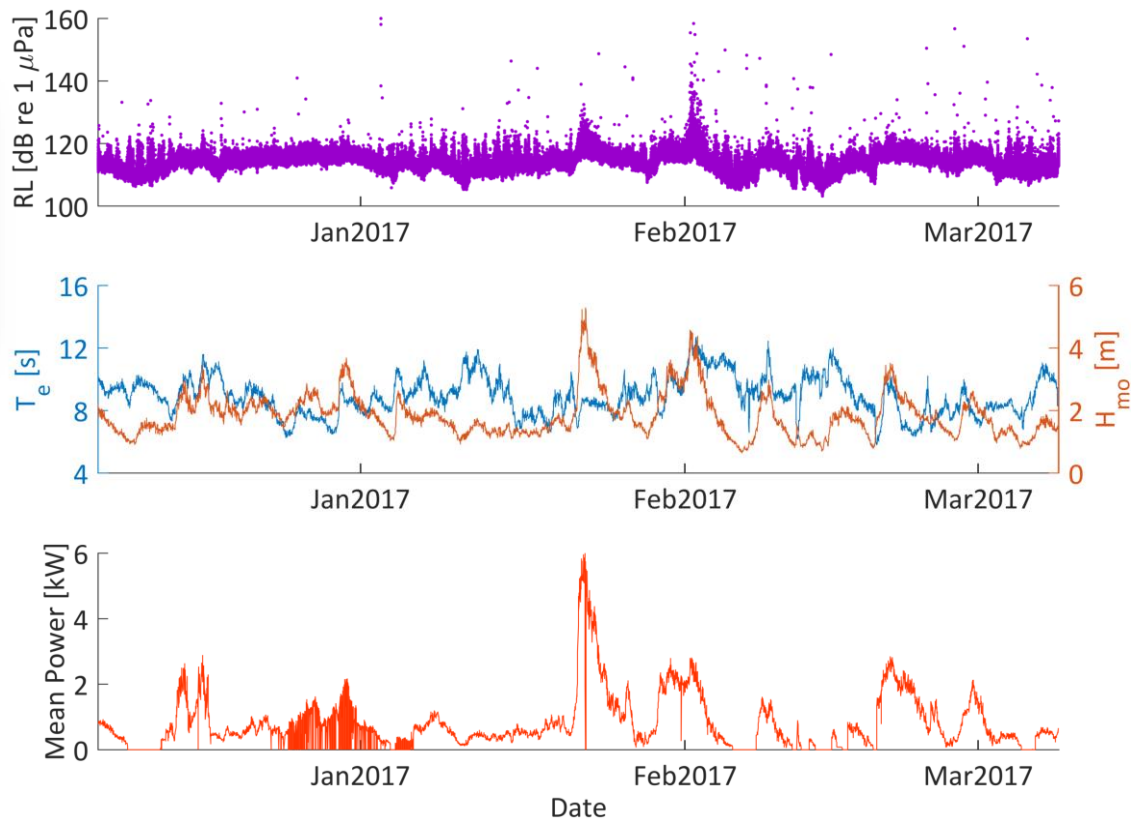




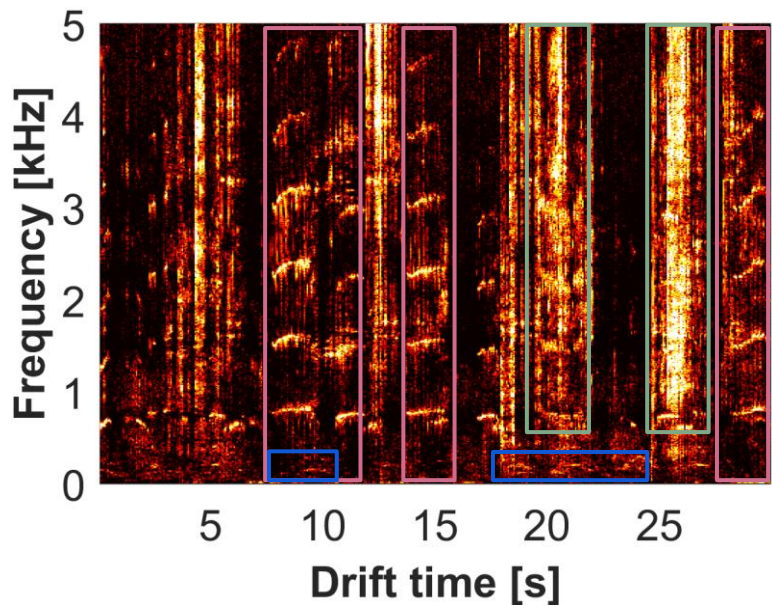
# Temporal Variability



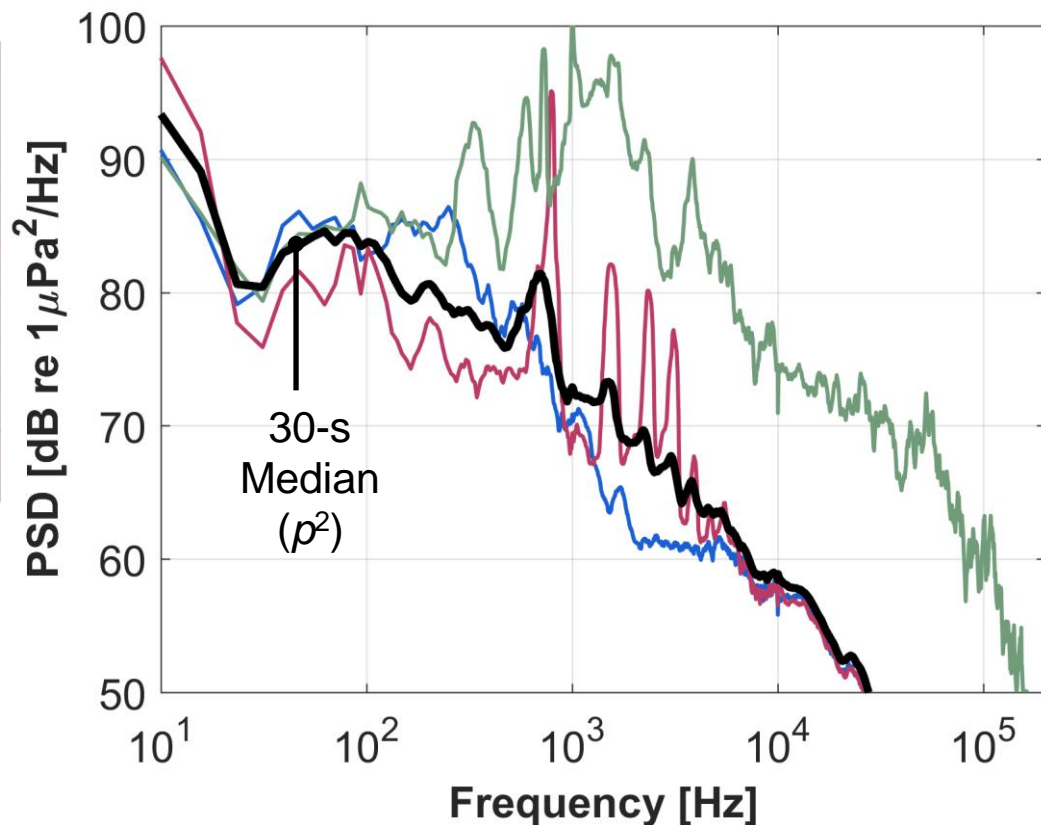
Some correlation observed  
between received levels  
(broadband), sea state, and  
power output



# Heterogeneous Soundscape



Multiple, overlapping sounds



# Other Environmental Monitoring

- **Sediment transport measurements/observations at WEC moorings.**
- **Protected marine species monitoring (ongoing from late 2014 through all WETS hardware installations and WEC device testing), water chemistry measurements.**
- **Periodic ecological dives/ROV surveys to monitor marine biology (since 2003 at 30m berth).**



Blue-striped snapper, one of the most common fishes at 30m berth.

## Protected species:

Humpback whales, Hawaiian monk seals, Green sea turtles, Hawksbill turtles, Hawaiian Insular False Killer Whale, Giant manta rays



# Environmental Findings to Date

- Acoustics
  - Azura produces sound primarily between 20 Hz and 3 kHz and is barely detectable at a range of 100 m
  - Lifesaver produces sound in a similar frequency range, but detectable beyond 1000 m (damaged PTO and mooring)
  - WEC acoustic emissions vary in time
  - Soundscape is heterogeneous mix of WEC PTO, moorings, and biological contributions

*No WEC sound recorded to date has approached prescribed NMFS thresholds that would require immediate reporting.*

# Environmental Findings to Date

- Sediment Transport

- *Note: scour areas observed at both deep berths (sand bottom), from mooring chains and sinker weights in prevailing WSW current. No effects seen at 30m berth (rock bottom).*



- Protected Marine Species Monitoring

- Routine observations recorded during all at-sea operations.
- Dedicated and trained observers monitor during WEC deployment operations and periodically from shore.
- *Note: periodic sightings of humpback whales (all winter) and sea turtles (no apparent impacts).*



# Environmental Findings to Date

- Ecological Surveys
  - 8 dives completed to date to augment NAVFAC efforts begun during Ocean Power Technologies deployments at 30m berth.
  - *Note: no detectable negative impacts noted in fish populations, coral growth, or other impacts. Infrastructure fosters aggregation.*
- Water Chemistries
  - *Note: no detectable impacts/changes.*
- EMF
  - *Note: no measurements made to date (studies elsewhere indicate no impacts at much higher transmission levels; levels at WETS will be relatively quite low).*



# Questions?

