Effects of wave energy converters on wave and sediment circulation

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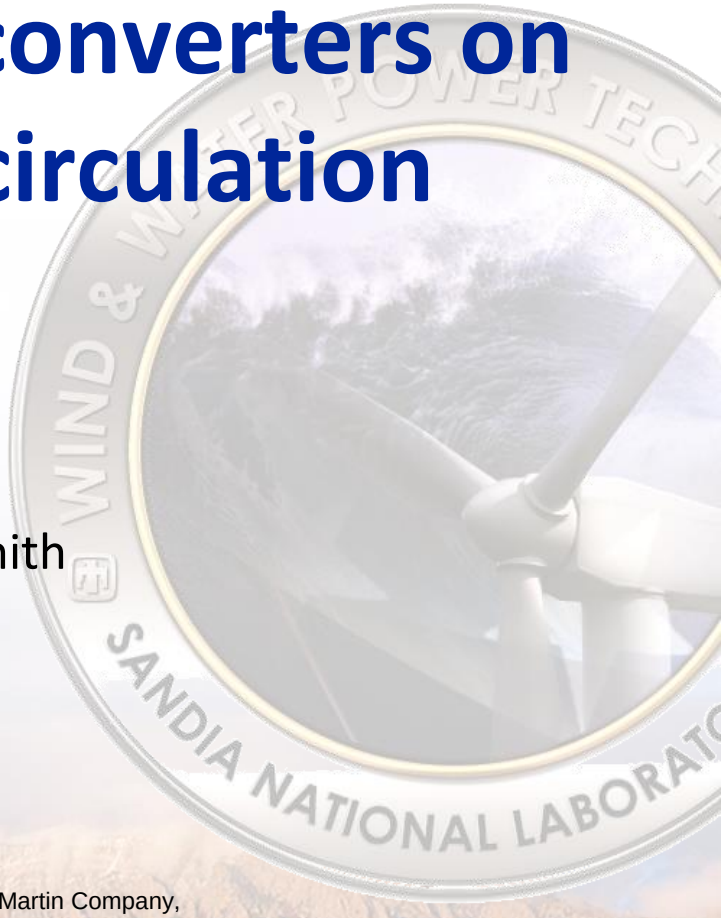

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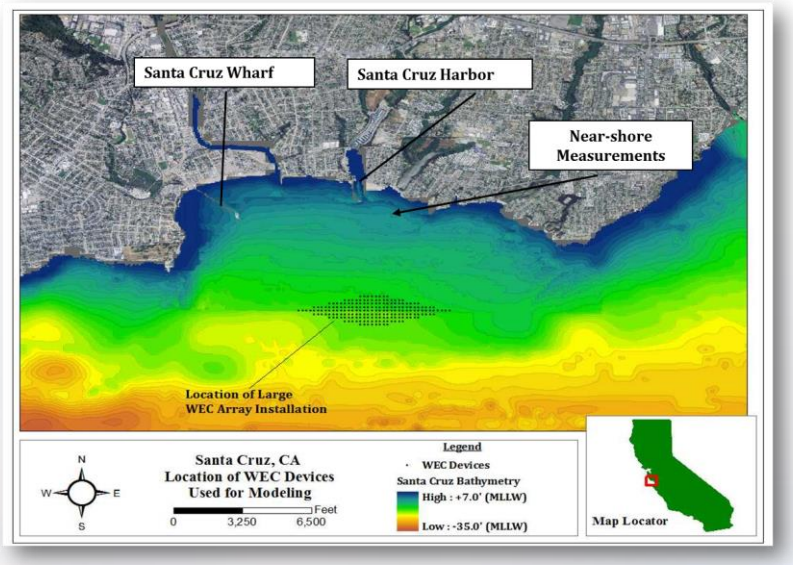
Introduction

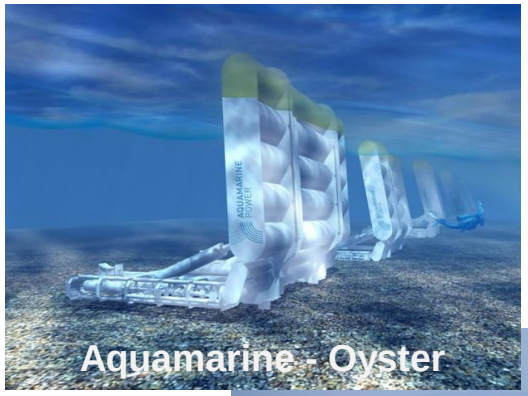
- **Wave energy converter (WEC) arrays have the potential to alter nearshore wave propagation and circulation patterns**
  - Sediment transport
  - Ecological processes
  - Socioeconomic services

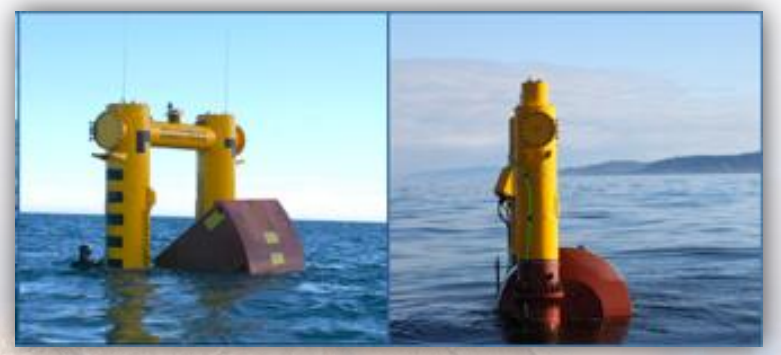


- **Wave and circulation model simulations can provide environmental assessments of WEC arrays**

Objectives

- Develop and evaluate the wave modeling tool, SNL-SWAN
- Simulate wave propagation through hypothetical WEC arrays
- Perform model sensitivity analysis to examine effects of WEC characteristics on near-field and far-field wave conditions
- Evaluate changes in sediment transport patterns





Pacific Energy Ventures (WET-NZ)

Code Modifications

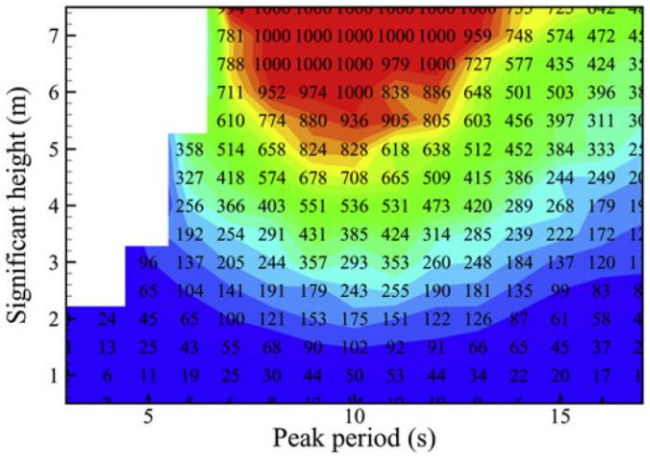
- **SWAN (Simulating WAves Nearshore)**
  - Open source spectral wave model by TU Delft
  - Models WECs as obstacles with a constant transmission coefficient, K_t

$$K_t = \frac{H_{lee}}{H_{incident}}$$

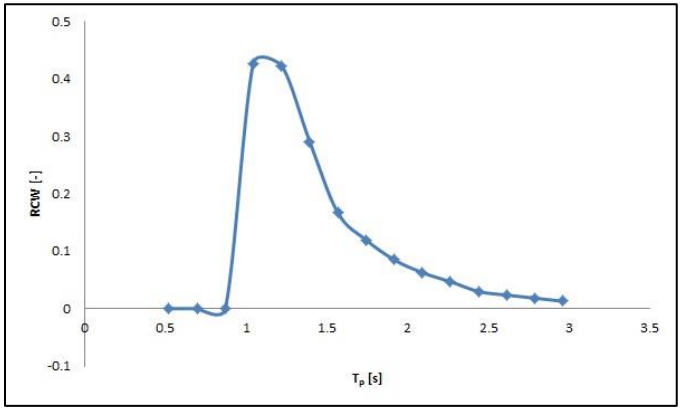
$$K_t{}^2 = 1 - RCW$$

- **SNL-SWAN is a modified version SWAN**
  - Includes a *WEC Module* to better model WECs
  - Defines WEC power performance as *WEC Power Matrix* or *Relative Capture Width (RCW)* curve
  - Accounts for period and wave height dependent power extraction

Sample Power Matrix

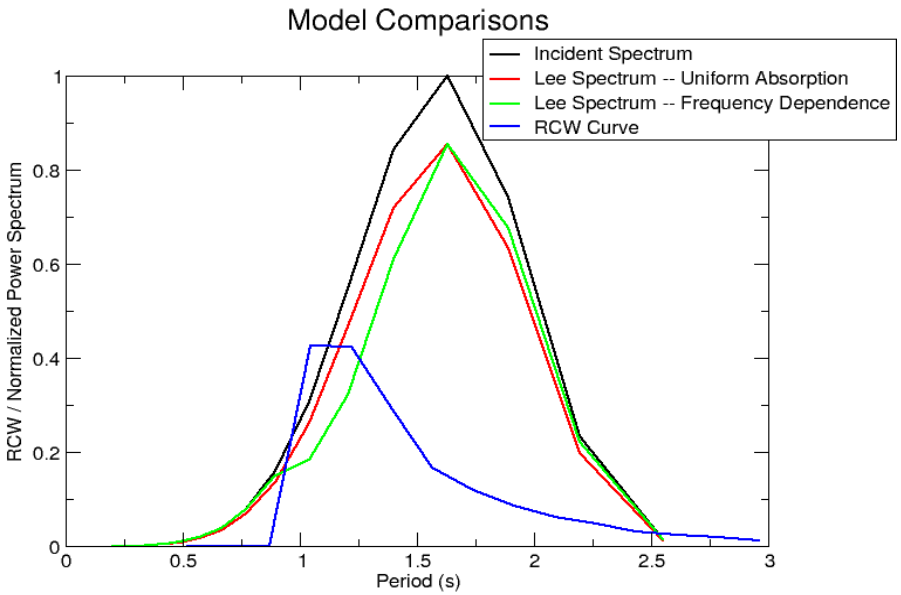


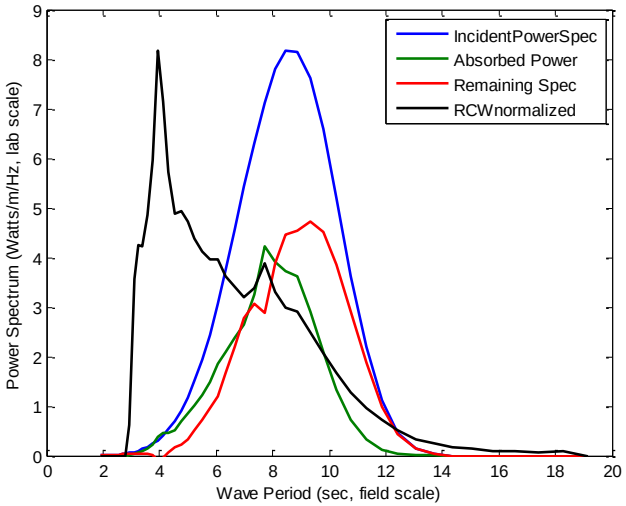
Sample RCW Curve

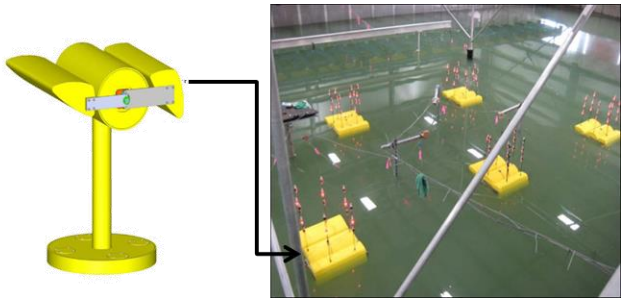


Code Verification & Validation

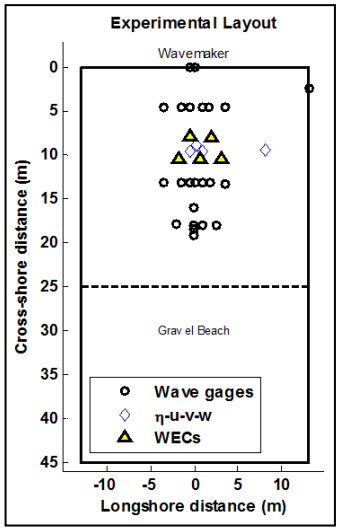
- **Verification by comparison to:**
  - Total power extracted by WEC Module
  - University of Exeter SWAN modifications by Helen Smith
  - Oregon State University (OSU) SWAN modifications by Aaron Porter
- **Preliminary validation by comparison to:**
  - WEC array experimental data set of Columbia Power Technologies (CPT) 1:33 scale Manta 3.1 device at OSU





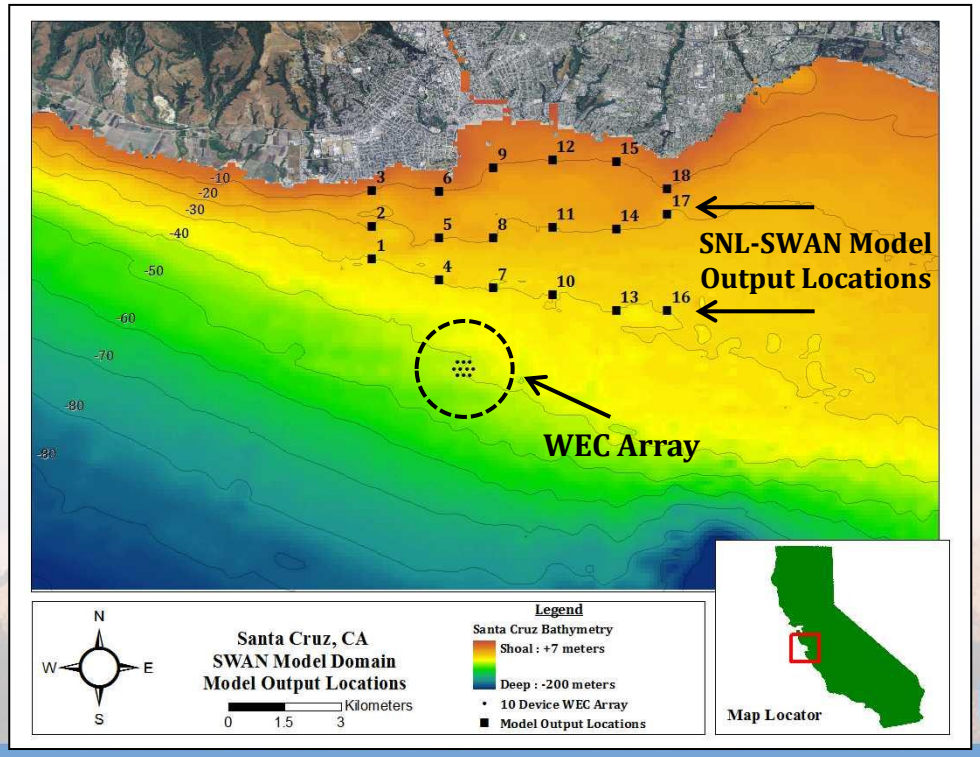


CPT Array Tests @OSU

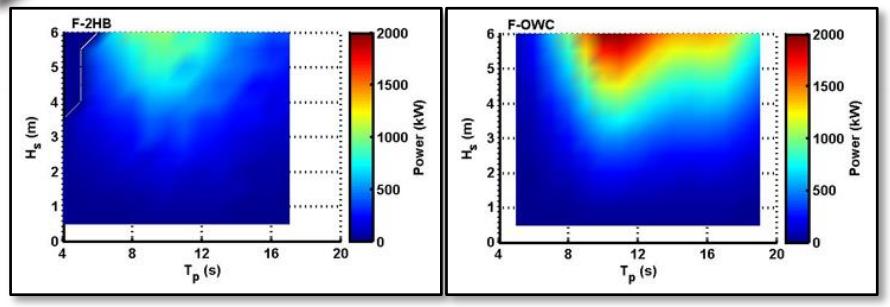


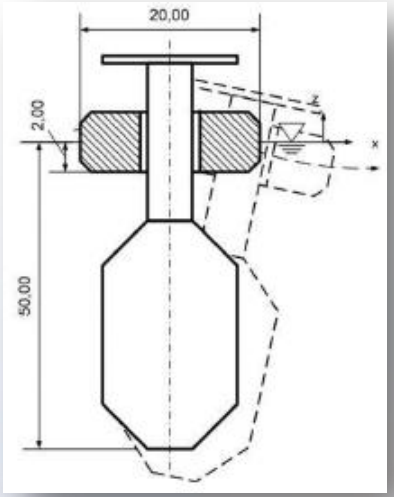
SNL-SWAN Investigation

- Results evaluated near-shore Santa Cruz
- Deep-water waves propagated from offshore Monterey Bay to Santa Cruz, California
- Model simulations with WECs compared to simulations without WECs (baseline)

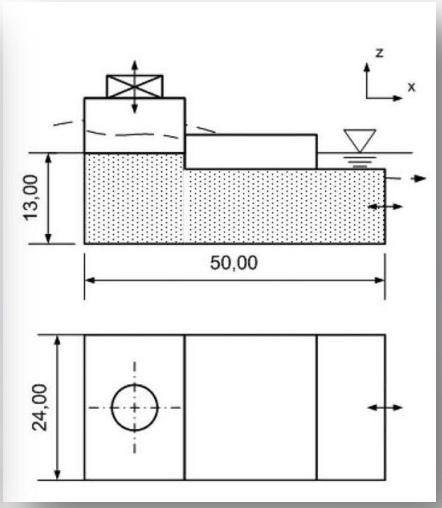


SNL-SWAN Technical Approach





Heaving Buoy
F-2HB

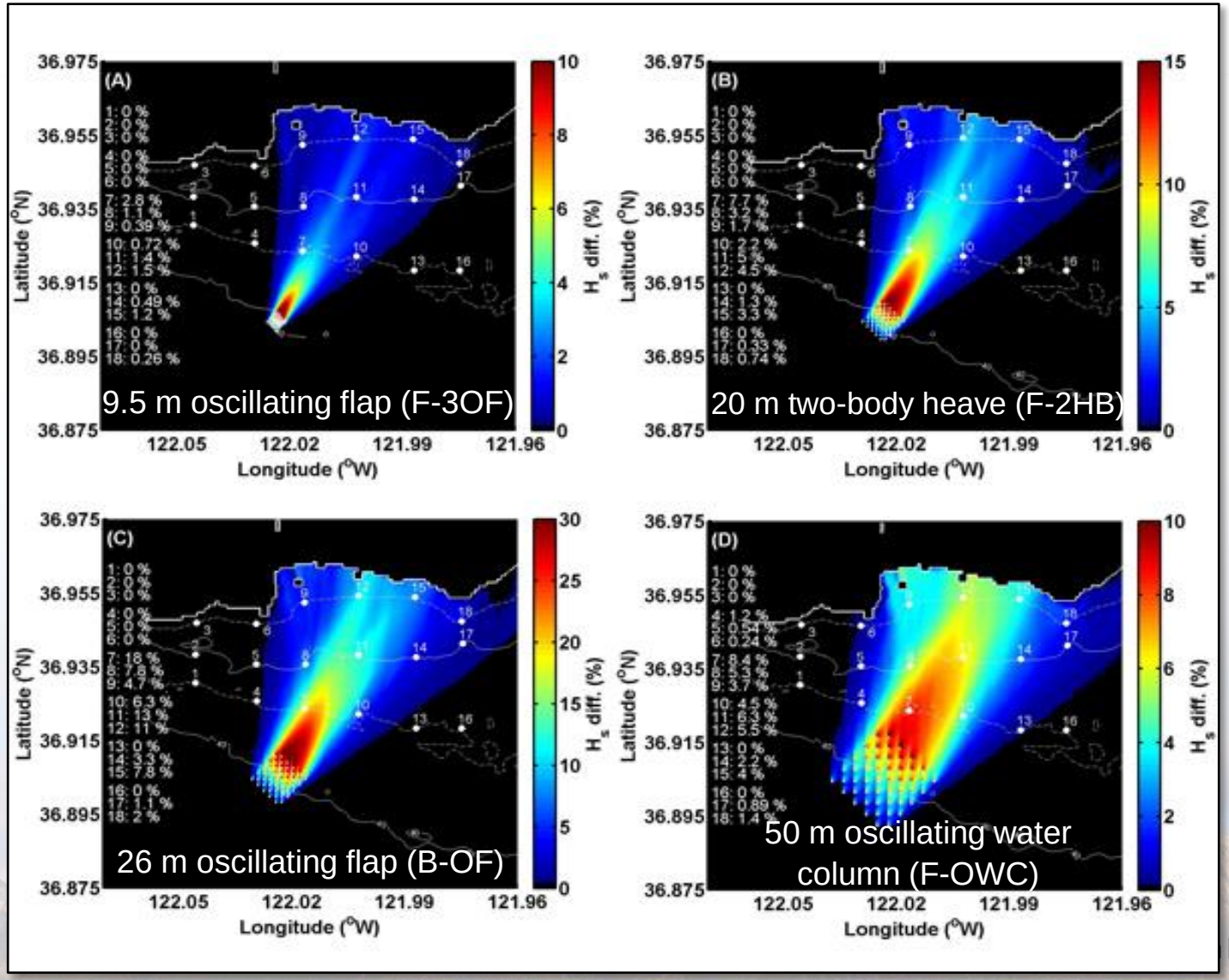


Oscillating Water Column
F-OWC

- **User-specified WEC power matrix**
- **8 different WEC types**
  - Widely varying dimensions and power ratings
- **Size of Array**
  - 10, 50, or 100 WECs
- **Distance Offshore**
  - 40m, 50m, 60m contour lines
- **WEC spacing**
  - 4, 6, or 8 diameter spacing (center-to-center)

Babarit, A., J. Hals, M.J. Muliawan, A. Kurniawan, T. Moan, and J. Krokstad (2012) Numerical benchmarking study of a selection of wave energy converters, Renew. Energ., 41, 44-63.

SNL-SWAN Results



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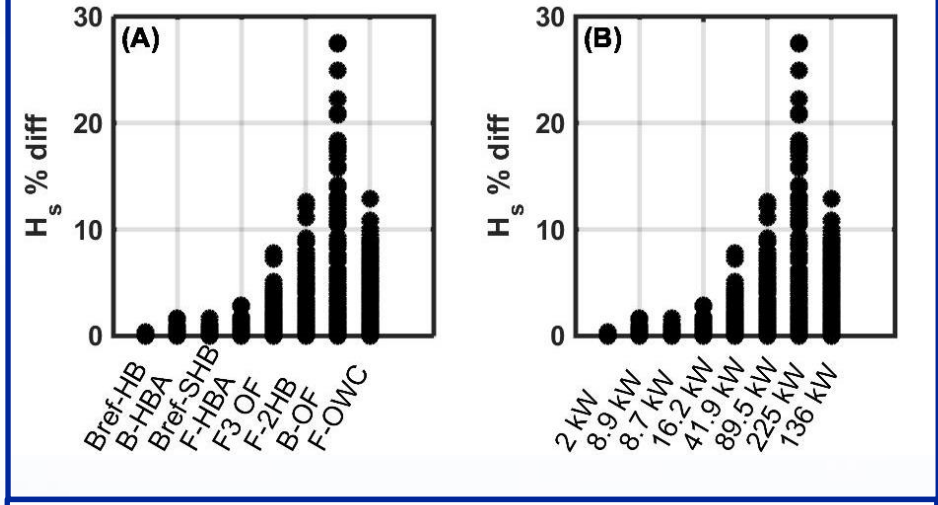
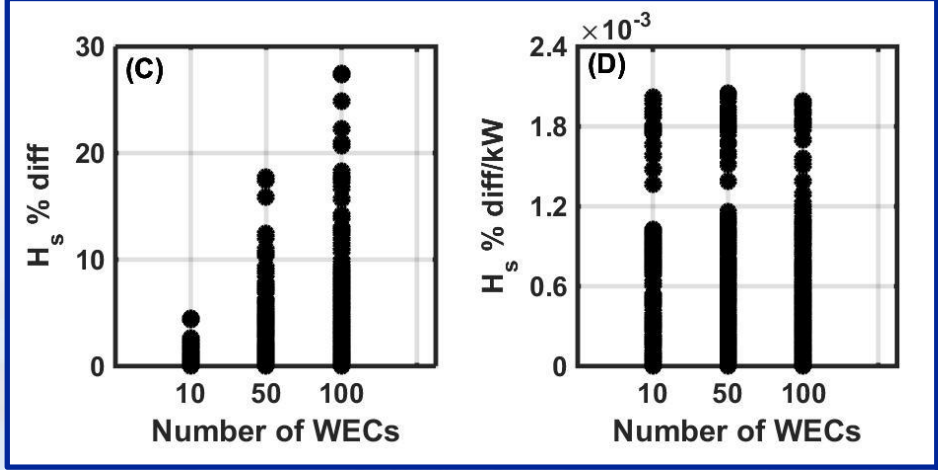
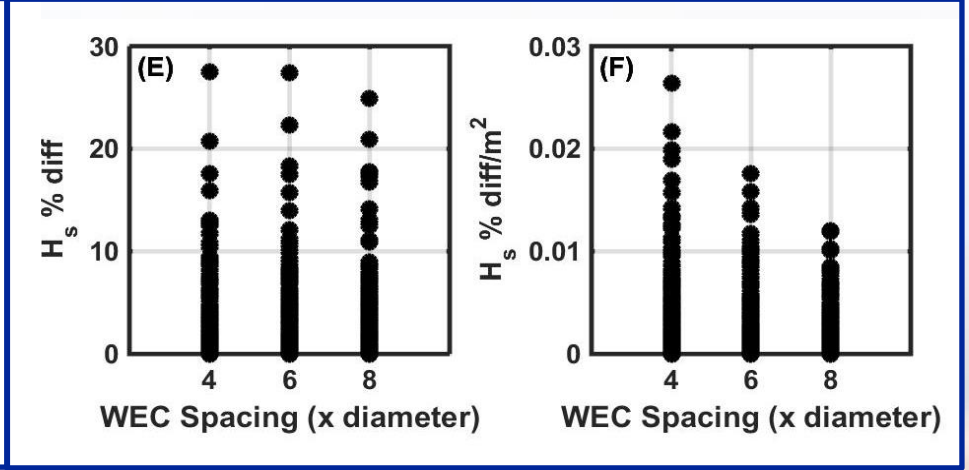
SNL-SWAN Results



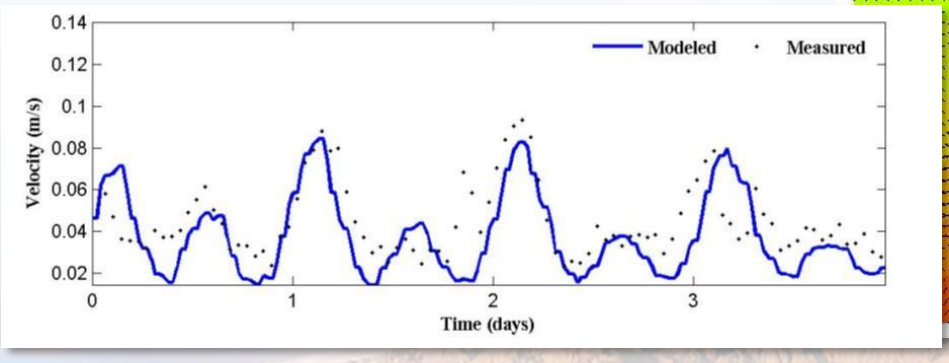
- **Most sensitive to:**
  - WEC device type/power
  - Number of WECs in an array
- **Relatively insensitive to:**
  - WEC spacing

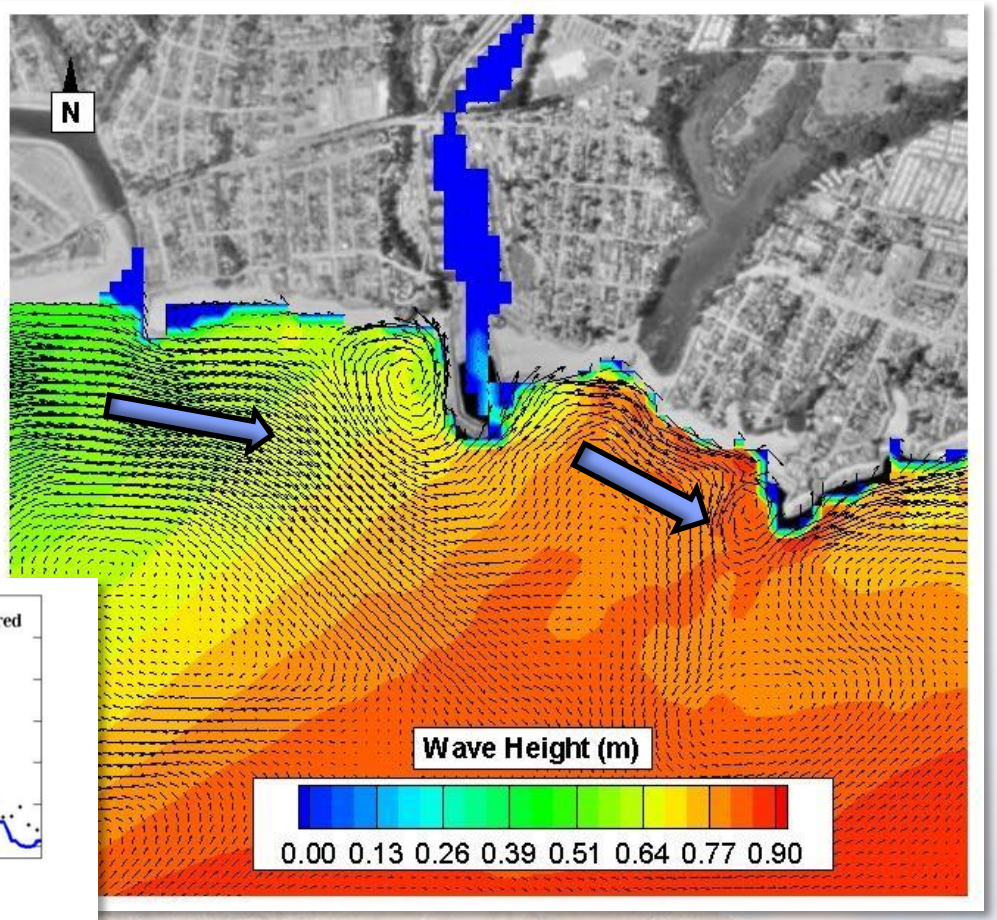




Hydrodynamic Model

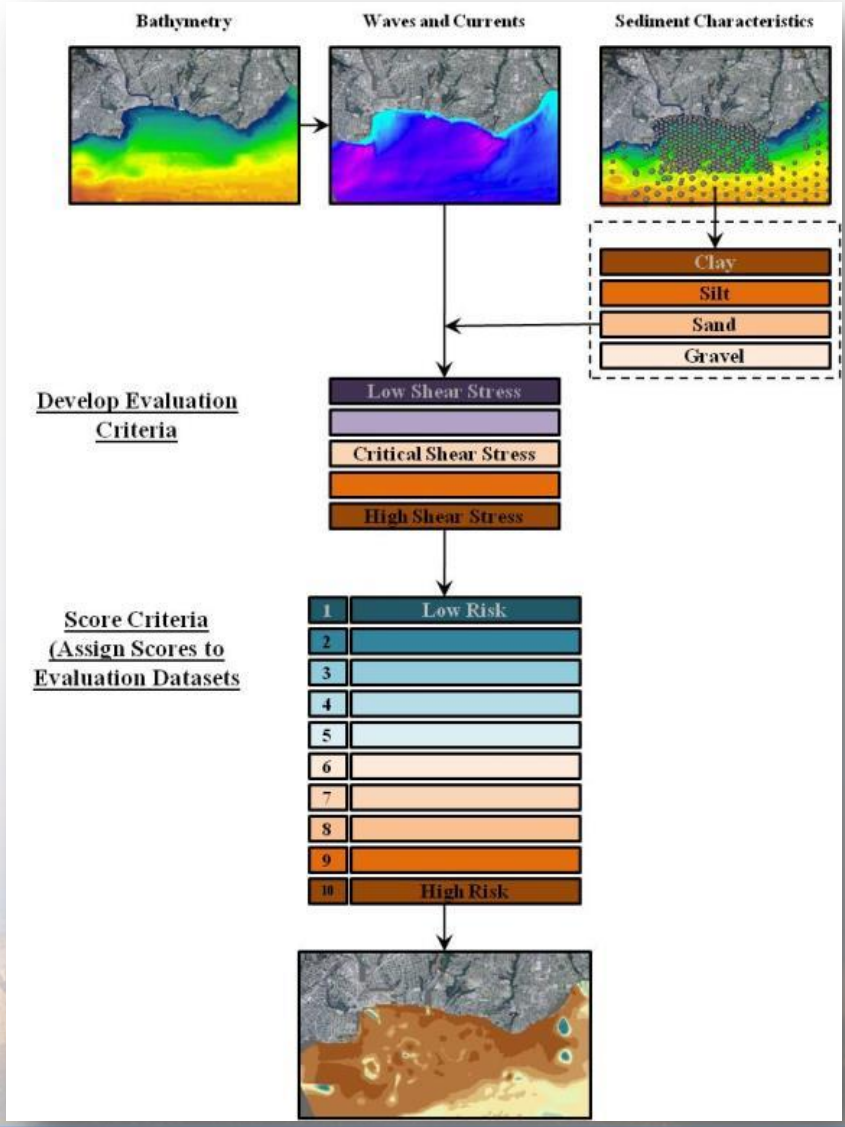
- A 10 km by 10 km domain was used
- Combined wave and current circulation model (SNL-EFDC)
- A nearshore ADCP was used to validate





Seabed Risk Assessment

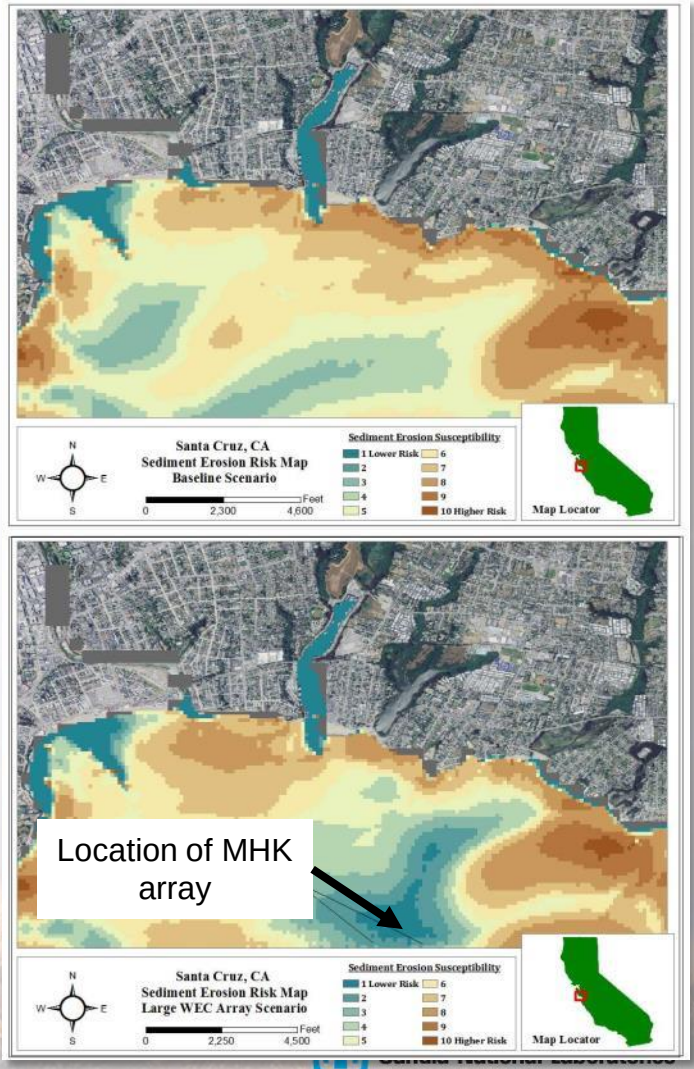
- Bathymetry, modeled waves and currents, and seabed characteristics are integrated in a classification system
- A scoring criteria defines the risk to offshore environment due to seabed stability alterations
- How big is the change?



Example Evaluation

- Spatial maps of stability and mobility potential are developed from the risk assessment

- Comparisons of baseline (above) and array (below) scenarios can be made to evaluate impacts on array infrastructure and the local environment



Monterey Bay
WEC Physical Environmental Effects

- **Small Array Near-Field (near array)**
  - Deep water physical effects are negligible for surface following WEC
  - Potential to impact near-field benthic communities and fish behavior dependent on mooring system
  - **Low**

- **Small Array Far-Field (nearshore)**
  - Minor alterations to sediment transport patterns
    - Potential for **Moderate** near shore sediment transport alteration
  - Negligible alterations in circulation
  - **Low to Moderate** far-field environmental effect

Summary

- **Leveraged decades of hydrodynamic model development**
  - Enhancing models and developing unique analytical methods

- **Quantitative methods can be used to evaluate the effects of MHK arrays in nearshore coastal regions and rivers**
  - Small arrays (~10) of WEC devices have minimal effect on the physical environment – SITE SPECIFIC
  - As array size increases, effects increase and require further study
  - Initial evaluation strongly suggests adaptive management strategies

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