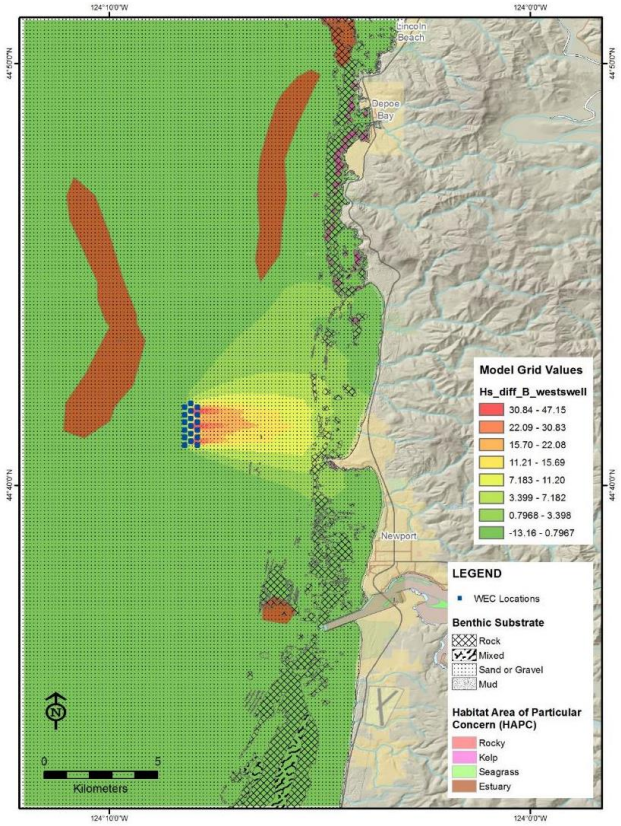

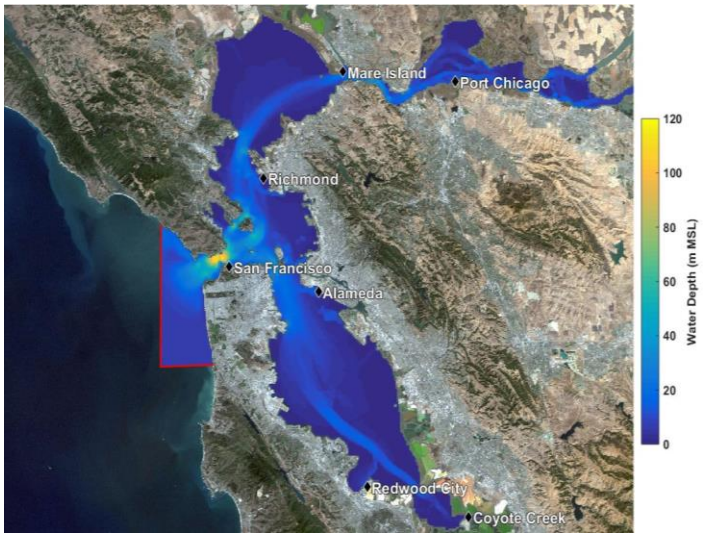

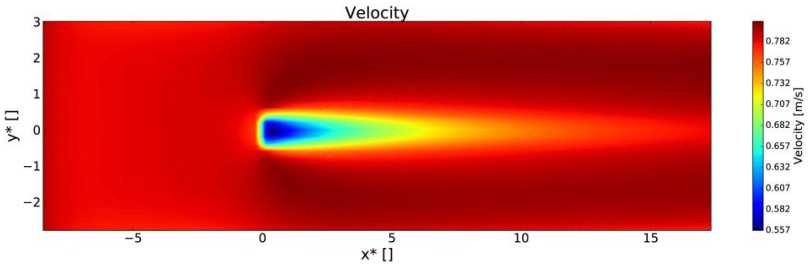

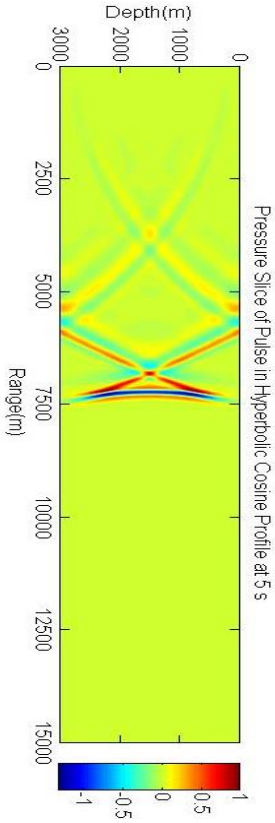

Improvements to Hydrodynamic and Acoustic Models for Environmental Prediction

Jesse Roberts & Craig Jones

Sandia National Laboratories, Integral Consulting
jdrober@sandia.gov , 505.844.5730
cjones@integral-corp.com , 831.466.9639

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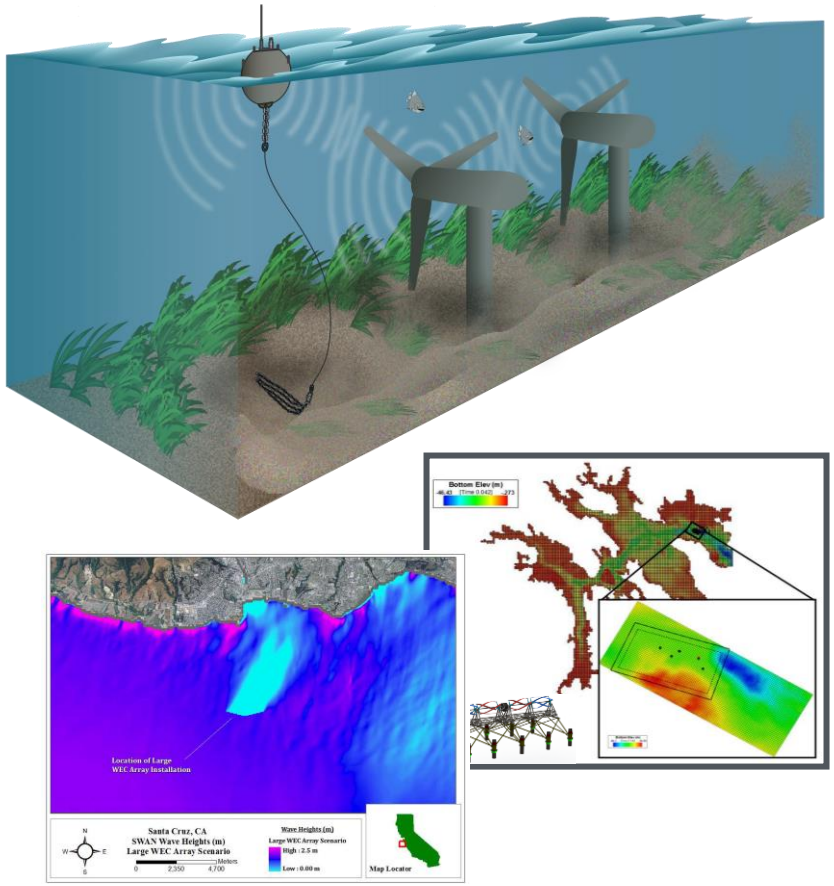
Hydrodynamic and Acoustic Models for Environmental Prediction:

Goal: *Reduce costs and time* for environmental compliance

- Understand marine and hydrokinetics (MHK) environmental effects
- Retire and mitigate risk



The Challenge: Characterization of environmental effects must come prior to deployment necessitating virtual evaluation tools.

Partners

Sandia National Laboratories | integral consulting inc. | H.T. HARVEY & ASSOCIATES Ecological Consultants | MONTANA STATE UNIVERSITY | BAYLOR UNIVERSITY | UNIVERSITY OF EXETER | MOTT MACDONALD

Program Strategic Priorities

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- Conduct R&D for Innovative MHK systems and components
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- **Support research focused on retiring or mitigating environmental risks and reducing costs**
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

Market Development

- Support project demonstrations to reduce risk and build investor confidence
- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets
- Exchange of data information and expertise

Project Strategic Alignment

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- **Support research focused on retiring or mitigating environmental risks and reducing costs**
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

The Impact

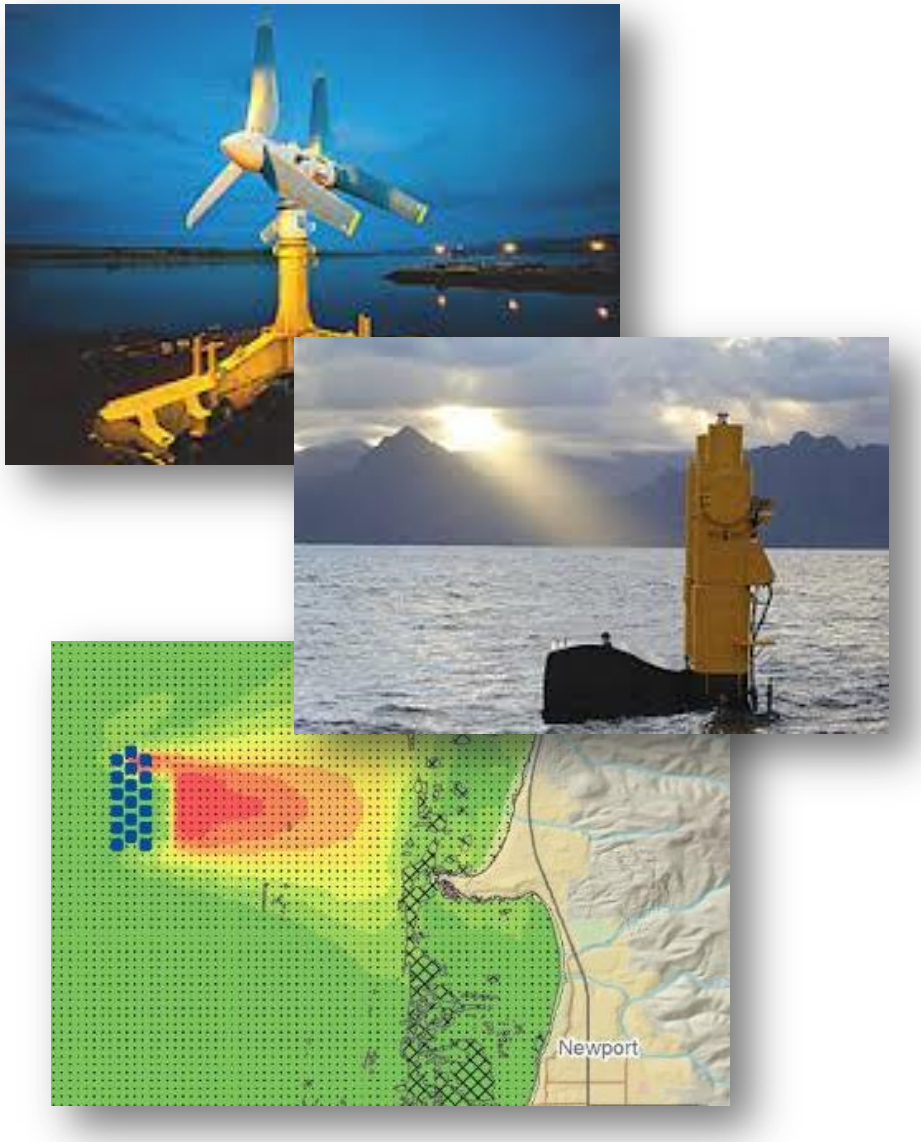
- Mature the nation's knowledge on the environmental effects of MHK arrays through quantification
- Put tools in the hands of the MHK industry
- Retire negligible environmental risks and streamline environmental permitting
- **Reduce unsustainable environmental compliance and monitoring costs**

The Products

- 'MHK-friendly' software tools
- Guidance and best practices manuals

Technical Approach

- Develop “MHK-friendly” modeling tools
- Quantify relationships between arrays and the environment
- Leverage respected and user-friendly tools
  - SNL-**SWAN**
  - SNL-**Delft3D**-CEC, SNL-**EFDC**
  - **Paracousti, CHAMP**
- Tech outreach
  - Classes, manuals, tutorials

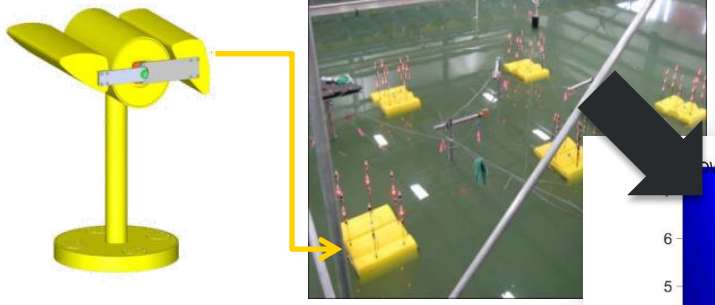


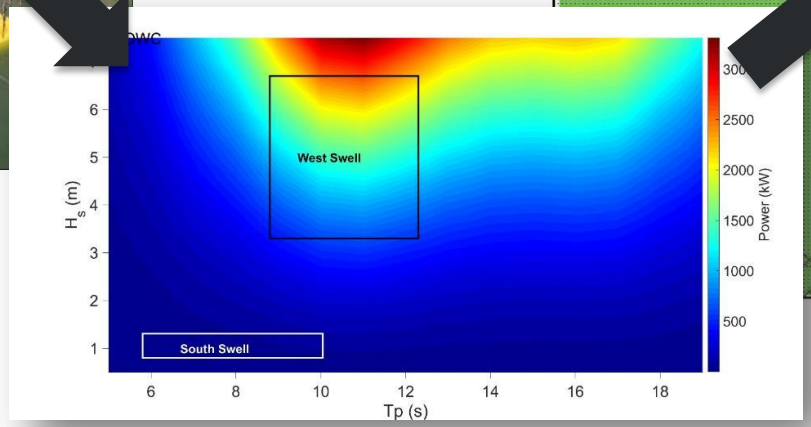
Offshore WEC Array Modeling

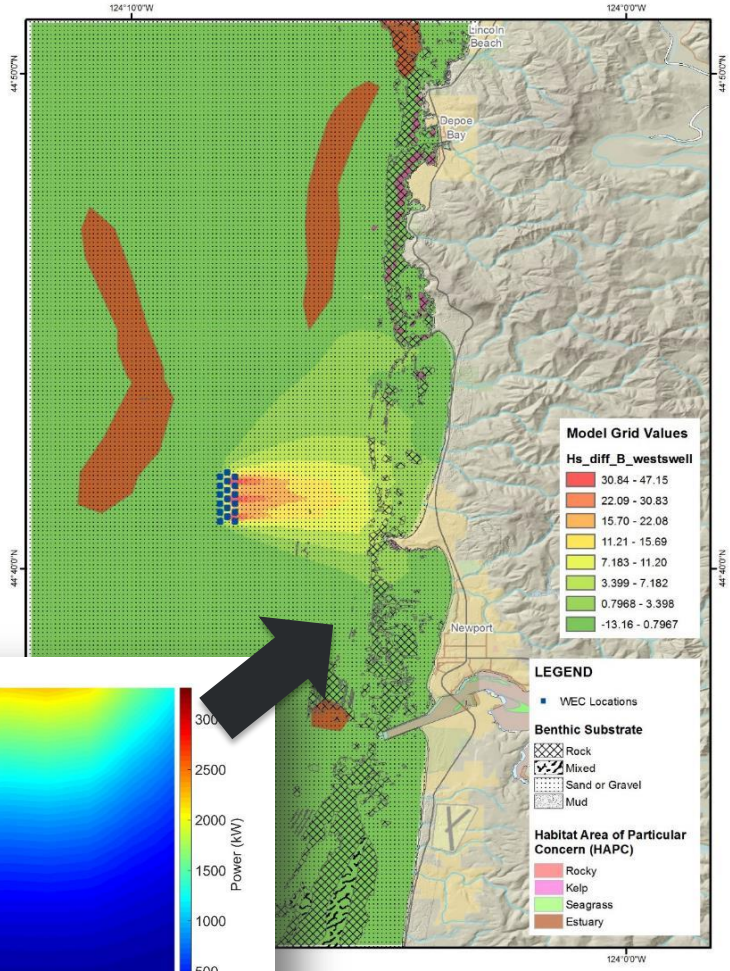
SNL-SWAN: Models wave propagation due to the presence of wave energy converter (WEC) devices

- WEC module absorbs wave energy as a function of device characteristics
- Validation against flume-scale data sets
- Applied at various sites to evaluate WEC array size/configuration vs. environmental effects
- Technical outreach

Ohio State University Tsunami Wave Basin Array Experiments



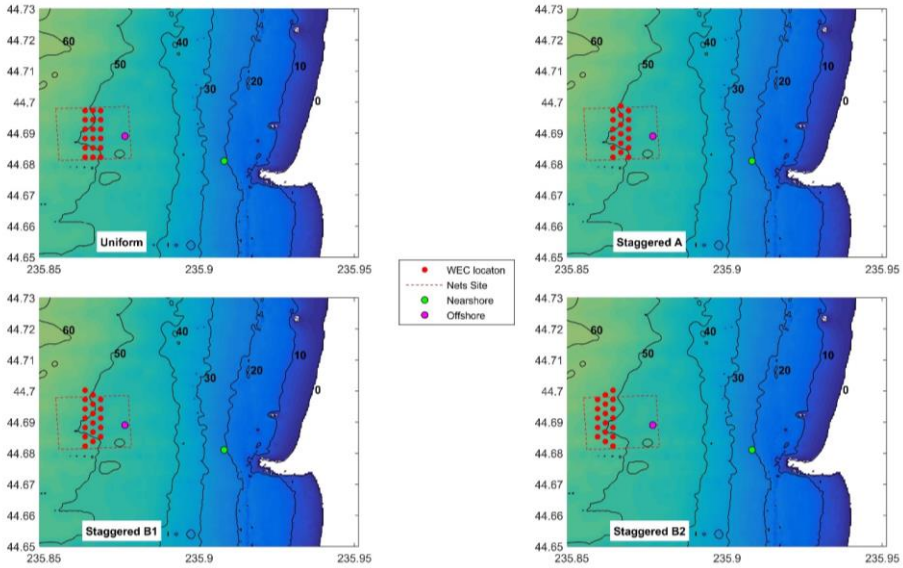


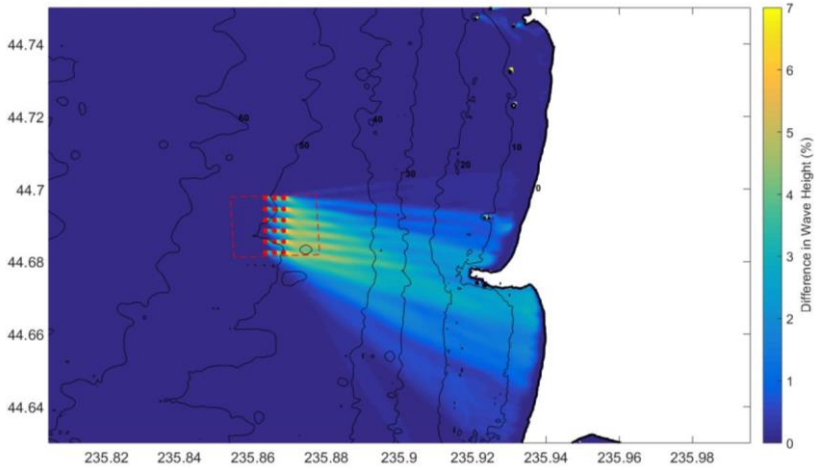


Quantitative tools to reduce environmental compliance costs and retire/mitigate risk

Offshore WEC Array Modeling

- Oregon and Monterey Bay sites used as case studies for WEC array modeling tools
- Extensive data sets available for baseline model evaluation
- The model evaluations of variable WEC arrays provide excellent case studies

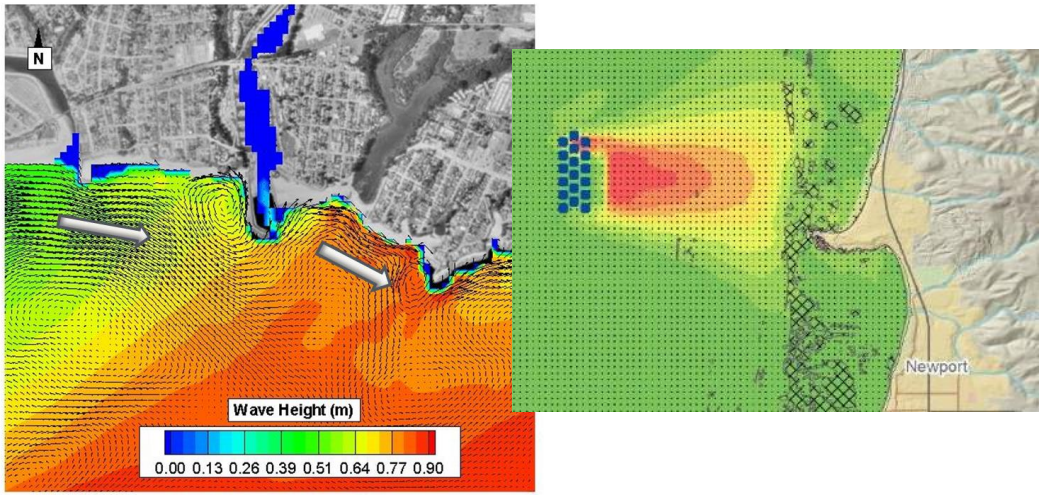


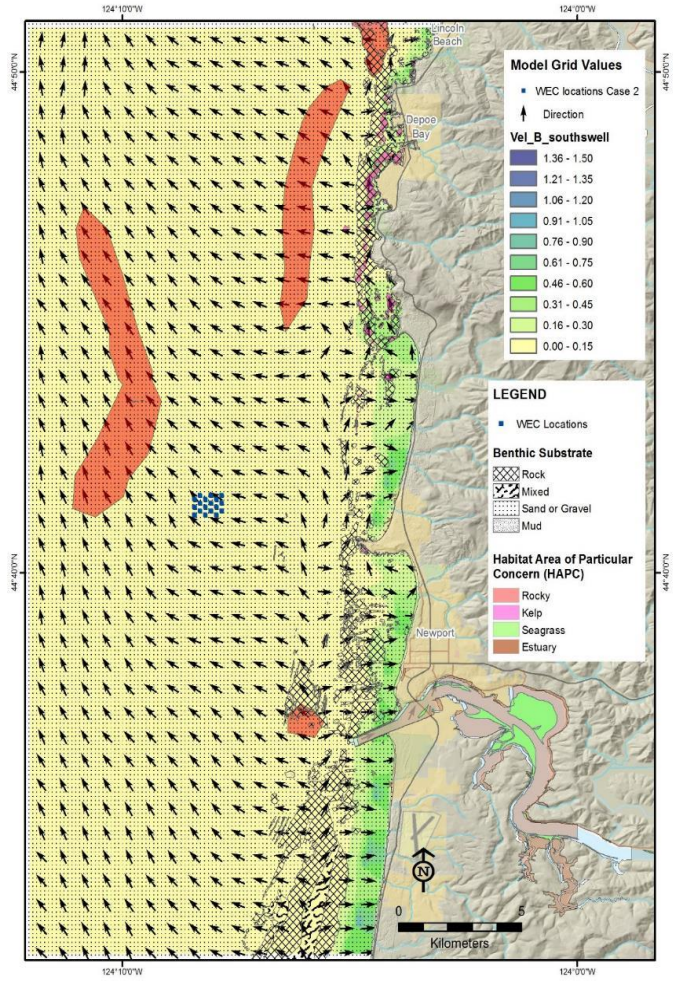


Outcome: Small numbers of WEC devices (~<10) unlikely to meaningfully change physical environment

Offshore WEC Array Modeling

- Hydrodynamic models integrate wave and circulation simulations
- Combined results can be used to quantify spatial patterns of potential environmental stressors
- Can be overlain with Habitats of Potential Concern for Assessment





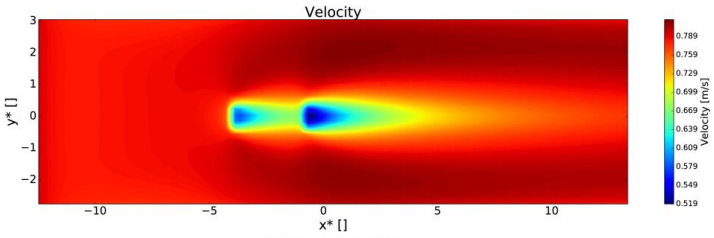
Accomplishments and Progress

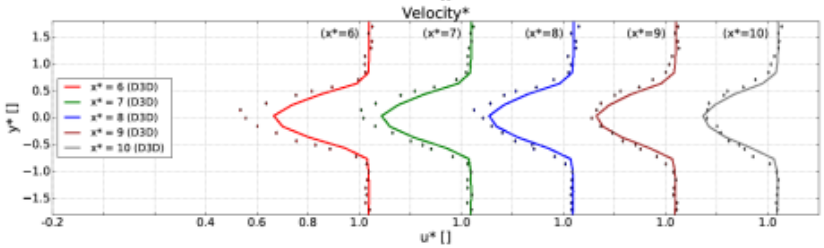
CEC Array Modeling

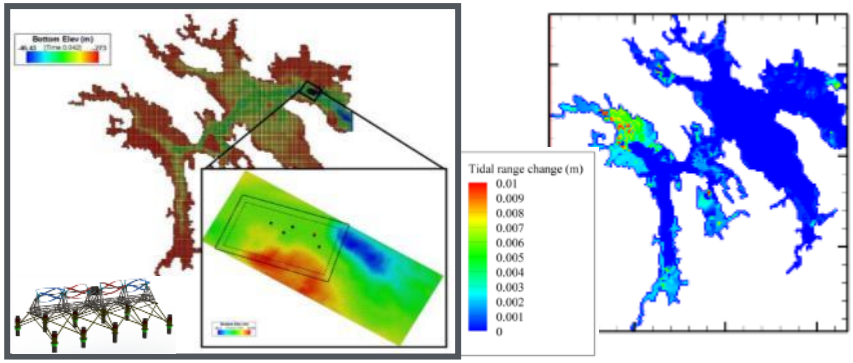
SNL-Delft3D-CEC: Evaluation of current energy conversion (CEC) devices to maximize power production and minimize environmental effects

- Modeling includes:
  - **CEC module (simulates wake generation)**
  - Sediment dynamics module
- Validation against flume-scale data sets
- Applied at various sites to evaluate CEC array size vs. environmental effects
- Technical Outreach
  - User's Manual, training courses and materials

Quantitative tools to reduce environmental compliance costs and retire/mitigate risk







CEC Array Modeling

Model Validation and Migration to Delft3D

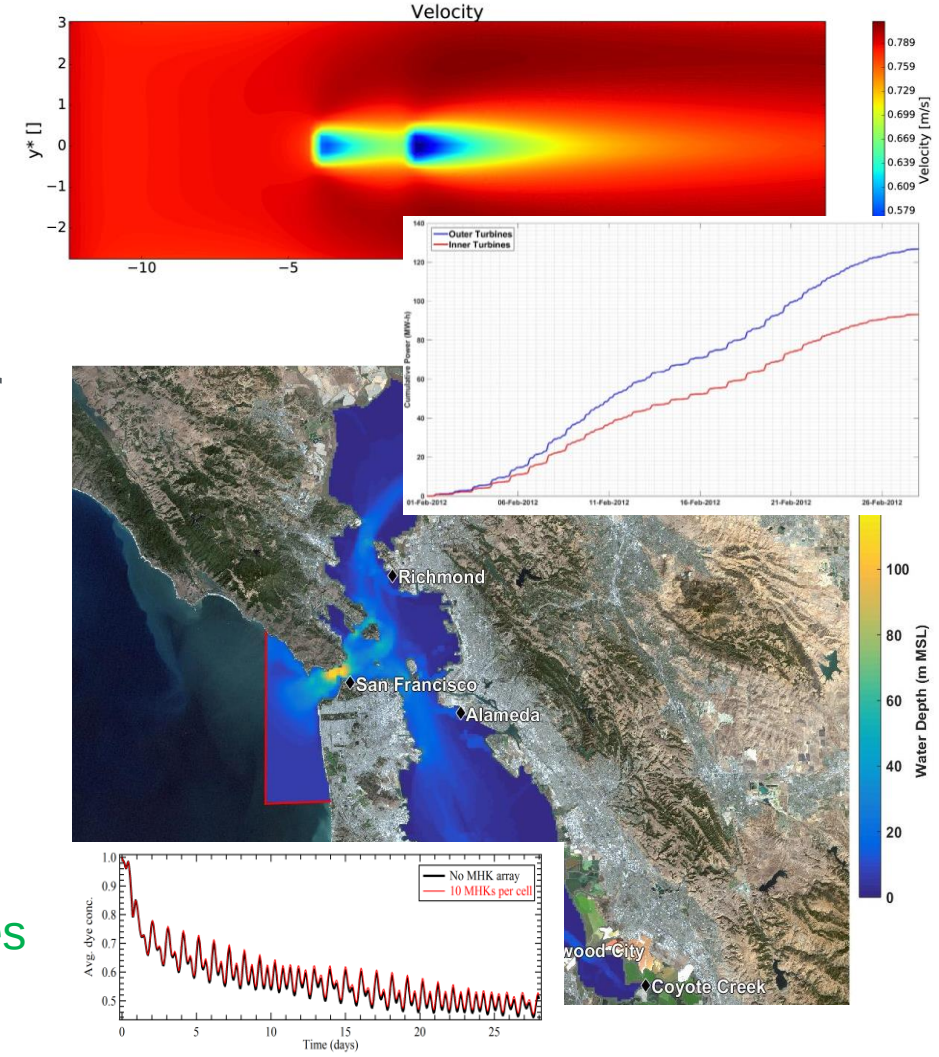
Model Application: San Francisco Bay

- Investigated **tidal flushing and water level alterations**
- **Minor effects** observed for **largest CEC array**

SNL-Delft3D-CEC Tech Transfer

- Three courses for FY17 (Verdant, ORPC, Alaska)

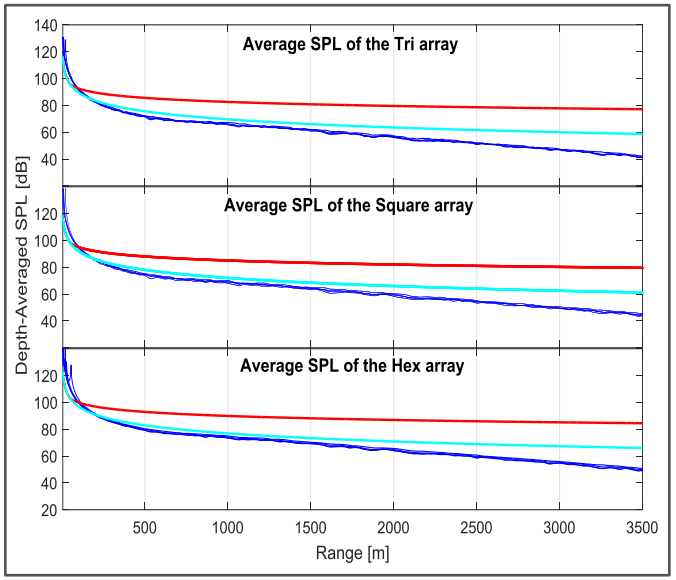
Outcome: small numbers of CEC devices (~<10) unlikely to cause meaningful changes to physical environment

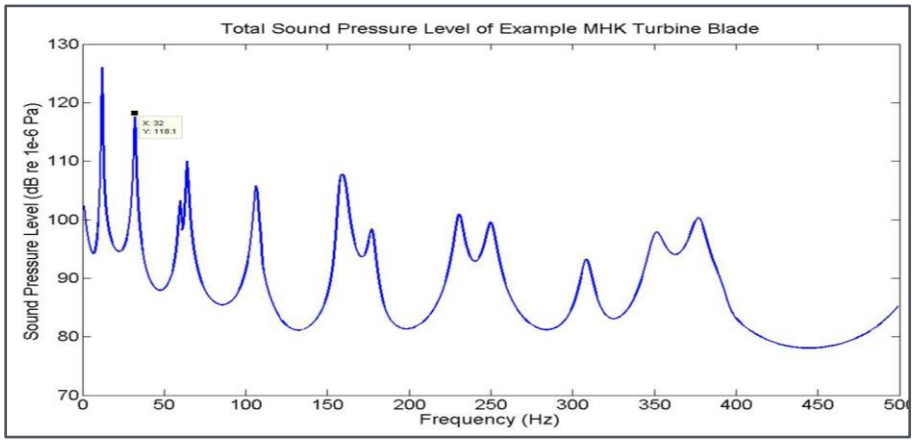


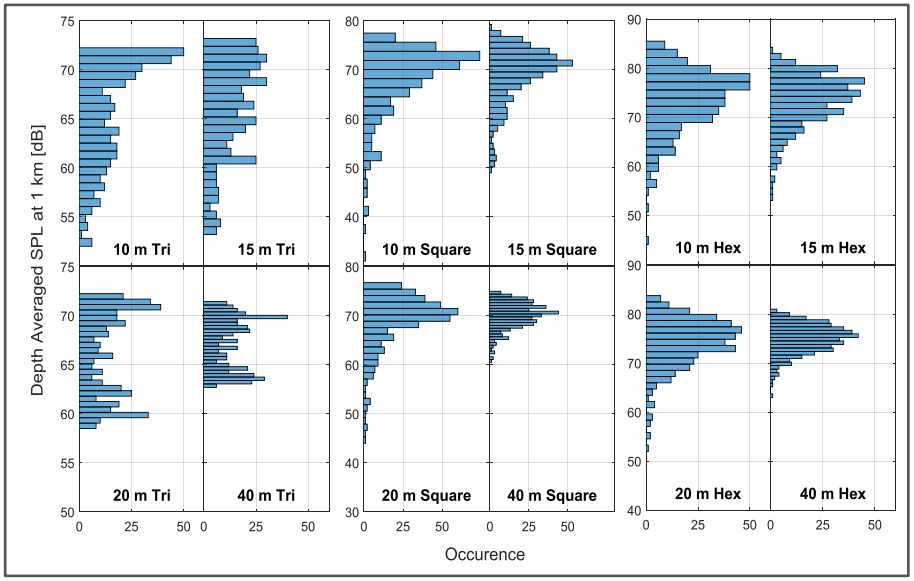
MHK Acoustic Modeling

MHK Acoustics

- Predict impacts of MHK generated noise
- Sound source characterization for turbines
- **Paracousti**: Sound propagation modeling from the source through the marine environment
- Provide quantification of sound pressure levels as a function of depth and distance from MHK devices



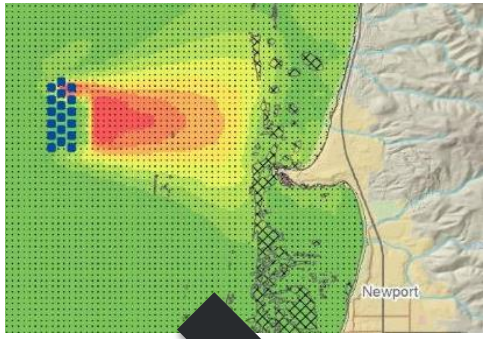


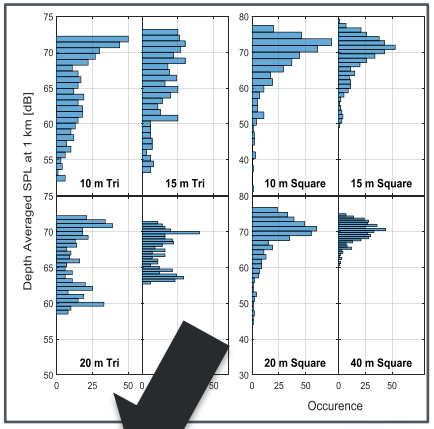


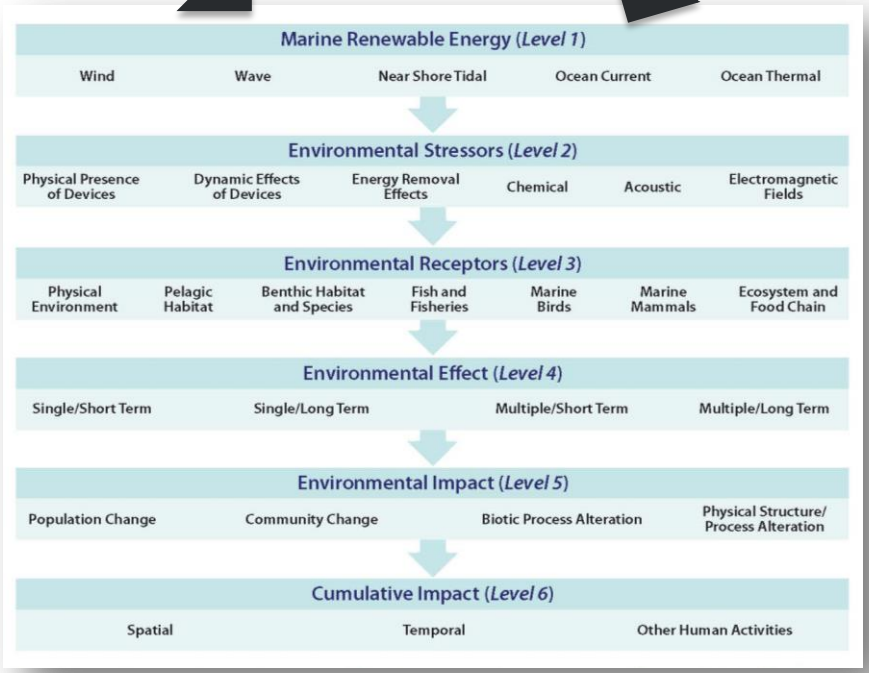
Environmental Assessment

- Waves, currents, seabed characteristics, and acoustics can be integrated into quantifiable metrics
- Scoring criteria can define the risk to environmental receptors due alterations
- *How big is the change?*

Quantitative tools streamline the assessment process







Project Plan, Schedule, Budget

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Phase 1: FY13–15; Phase 2: FY16–18 **(Merit Review FY15)**
- All milestones met on time and on budget

Budget History					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$750,000	-	$860,000	-	$735,000	-

- Go/No-Go decision points
  - FY15: (1) Wave site selection, (2) Deltares agreement, (3) Acoustic generation validation data
  - FY16: MHK acoustic source modeling
    - Transition from predictive acoustic source software development to acoustic model propagation enhancements to enable relatively rapid assessment of uncertain acoustic sources

Research Integration & Collaboration

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Partners, Subcontractors, and Collaborators:

integral consulting inc.

H.T. HARVEY & ASSOCIATES Ecological Consultants

MONTANA STATE UNIVERSITY

MOTT MACDONALD

BAYLOR UNIVERSITY

UNIVERSITY OF EXETER

Communications and Technology Transfer:

1) SNL-SWAN available at http://energy.sandia.gov/energy/renewable-energy/water-power/market-acceleration-deployment/snl-swan-sandia-national-laboratories-simulating-waves-nearshore/. December 15, 2014.
2) SNL-Delft3d-CEC available at http://energy.sandia.gov/energy/renewable-energy/water-power/market-acceleration-deployment/snl-delft3d-cec/. September 30, 2016.
3) Journal Publication: Renewable Energy 89 (2016) 636-648. Accepted 12/17/2015.
4) MHK Regulator's workshop 2014 and 2015: Panel Expert Presentation – Environmental Effects of MRE on ***P****hysical* ***S****ystems* **(Reported: ~<10 devices have minimal effect on *PS*)**
5) IMREC/METS 2015: Platform presentation (SNL-SWAN development and release)
6) IMREC/METS 2016: Platform presentation (WEC Array), Poster presentation (Acoustics)
7) EWTEC 2015: 4 platform presentations – 3 on WEC tasks, 1 on acoustic tasks
8) Tethys Webinar 2015: Presentation– Effects of WECs on wave and sediment circulation

Next Steps and Future Research

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FY17/Current research:

- Link SNL-SWAN with WEC-SIM and Delft3D
- Compare SNL-SWAN against WAMIT/NEMOH
- Evaluate and refine spatial environmental assessment tool (SEAT) to best support an Environmental Assessment
- Integration of CEC-module within Delft3D-FM
- Alpha version, uncertainty quantification within Paracousti
- Training course materials and delivery

Proposed future research:

- Formal guidance on WEC array optimization with SEAT case study
- Incorporation of SNL-SWAN within TU-Delft SWAN release
- Paracousti-UQ sensitivity analysis