Nov 17th, 9:15 AM - 10:00 AM

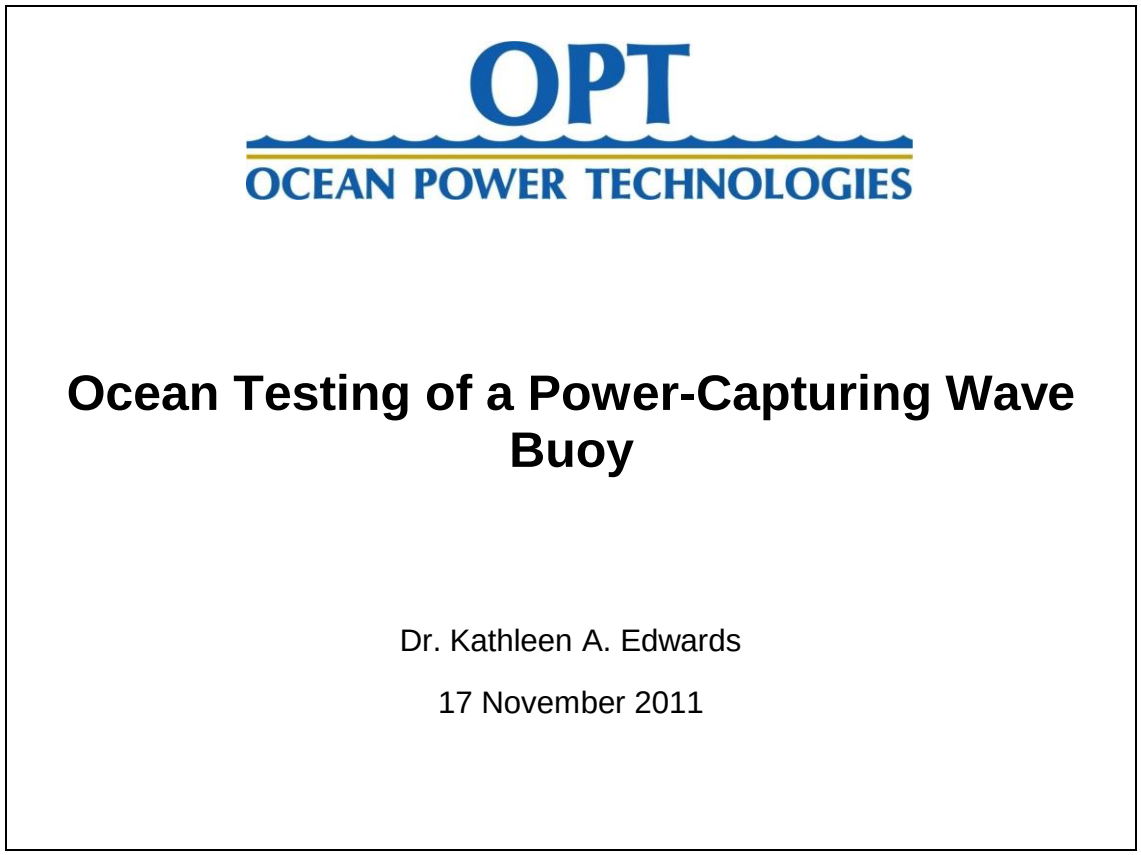
Session 1 Presentation: Ocean Testing of a Power-Capturing Wave Buoy

Kathleen Edwards
Ocean Power Technologies

Session I – Use of wave measurements to support operations, as well as alternative energy.

Various technologies are used to accurately measure waves in the ocean. In some places, knowing the impact that the waves are having on structures is critical to operations. For example, officials may close a coastal road after detecting overtopping waves or cancel maintenance on offshore wind facilities. This session assesses developments and applications in the field of wave monitoring and their practical use to support various operations. Participants help define how wave research and observation programs culminate in providing information for end-users. The following paper and extended abstracts relate to the use of wave measurements to cope with a range of issues from coastal erosion and climate change to marine spill response and flooding.

Session Presentation by Dr. Kathleen Edwards



Objective

- **Overview of design process for buoys that generate power from ocean waves**
- **Role of wave measurements in analysis**
- **Example: Recent deployment off New Jersey**

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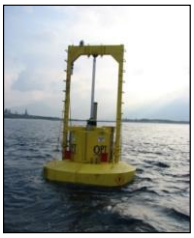
The Company: Ocean Power Technologies

- **Commenced active operations in 1994**
- **Headquarters in Pennington, NJ. Subsidiary in Warwick, UK**
- **50 employees, primarily engineers and scientists**
- **Nearly 15 years experience in producing electrical power from ocean waves**
- **Ocean-tested, proprietary technology – 48 patents issued**
- **Listed on NASDAQ (symbol OPTT)**

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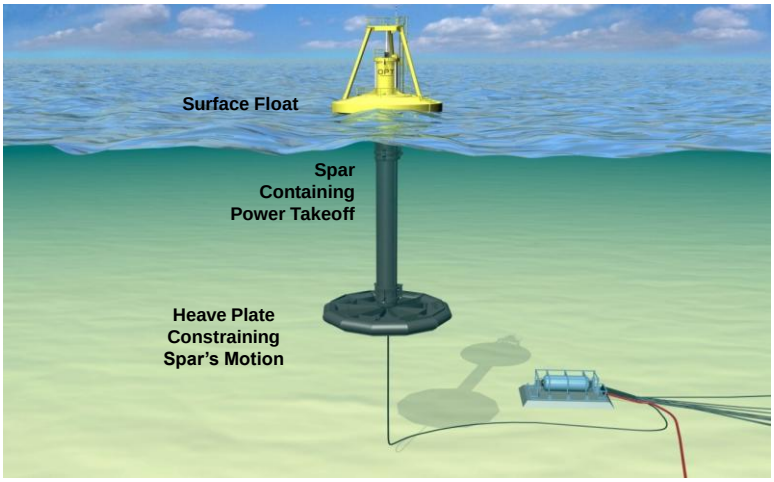
PowerBuoy Schematic

- Converts linear motion of float along spar into electrical power to grid (utility) or payload (autonomous)



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Recent PowerBuoy Activities

- Completed grid connection of Hawaii PowerBuoy
- Received Lloyd's Register Certification of PB150 PowerBuoy design
- Completed construction and deployed PB150 PowerBuoy in Scotland; progress made on construction of Oregon PB150
- Successful 3-month deployment of LEAP PowerBuoy, recovered 10/31/2011

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Design Workflow

Project Requirements
Client needs
System functions

Characterize site
Operational sea states
Survival conditions

Design Concept
Modular components

Predict power
for site

Predict loads
Survival, fatigue

Structural Design

Mechanical subsystems
Mechanical to electrical power
Reliability, manufacturability

Electrical subsystems
Power conditioning, delivery
Maximize efficiency
Reliability, manufacturability

Testing
In tank
On the bench
At sea

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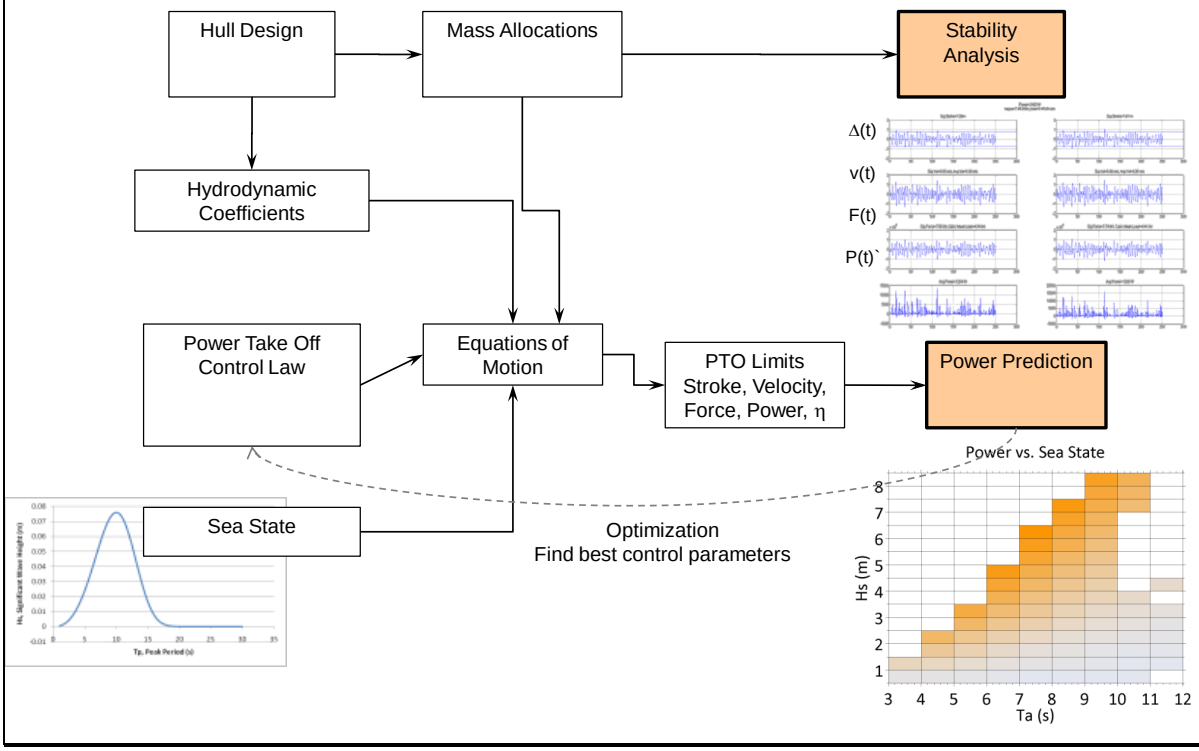
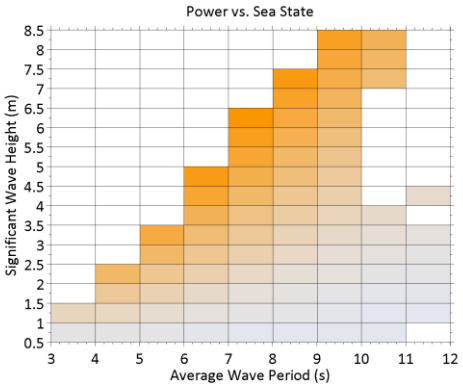
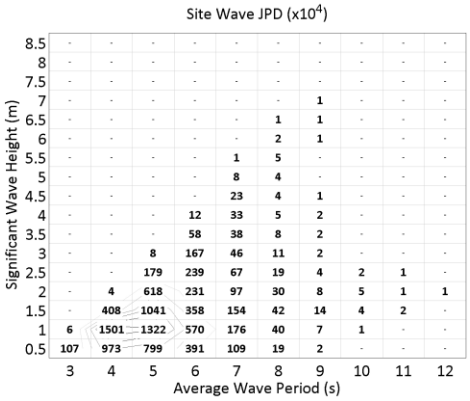
Power Prediction Model



Power Matrix

- **Output of OPT's models: PowerBuoy motions in waves**
- **Time-averaged power for each sea state**
- **In each state, PTO damping optimized for power production and safe operation**
- **Include efficiency of mechanical input to electrical output**
- **Combine with site wave JPD to obtain annual average power**





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LEAP Deployment

- **Littoral Expeditionary Autonomous PowerBuoy**
- **Contracting Agency: Naval Undersea Warfare Center (NUWC) Keyport**
  Contracting Officer's Representative (COR): Matt Binsfield
  Email: matthew.c.binsfield@navy.mil
  Phone: (360) 315-5862
- **Autonomous power source for radar payload used for surface current mapping. Requires continuous power delivery independent of wave conditions**
- **On 10/31/2011, completed 3-month ocean test off NJ**

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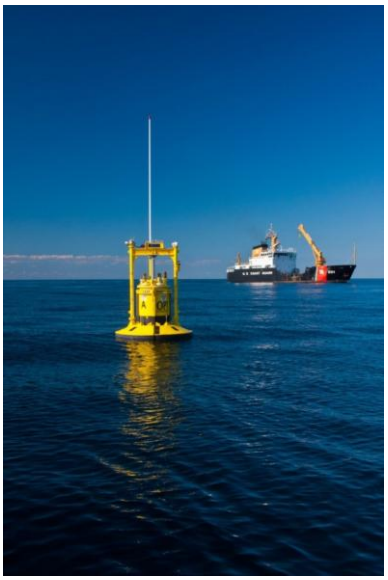
LEAP PowerBuoy off New Jersey Coast



LEAP PowerBuoy
Deployed by US Coast Guard

LEAP PowerBuoy After Hurricane Irene
Photo provided by Michael Woods

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Role of Wave Information in LEAP

- **Given observed sea state, predict power**
  - Compare to power measurements transmitted by satellite
- **Source of wave measurements**
  - ADCP deployed at LEAP ocean test site
    - Accurate wave information available upon recovery
    - Instrument on ocean floor; to be recovered shortly
  - Until ADCP returns, wave measurements from NDBC buoys
    - Network streaming real-time processed wave data
    - Free of charge

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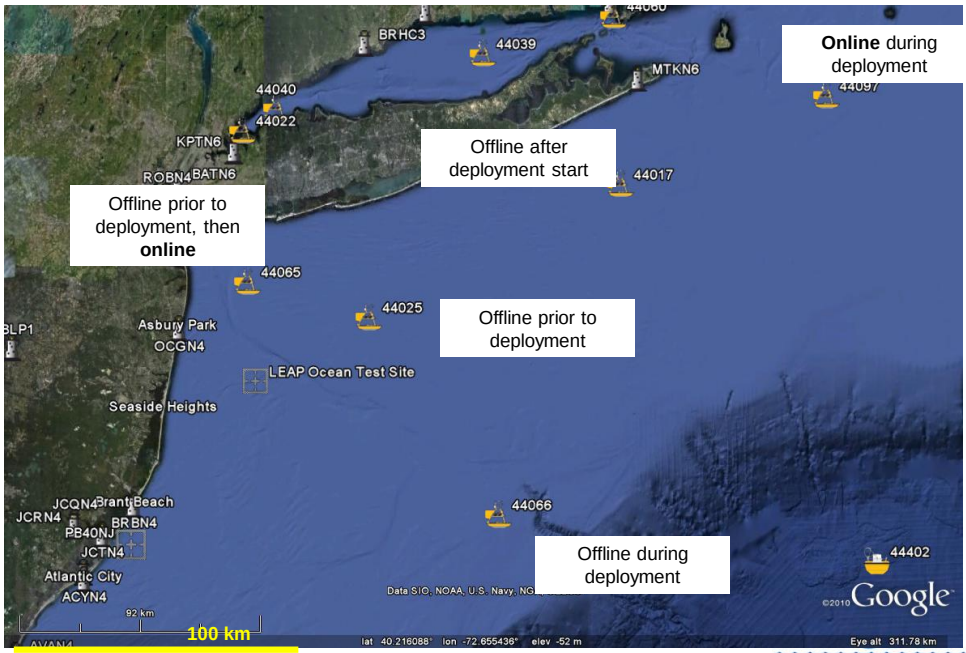
NDBC Regional Network during LEAP



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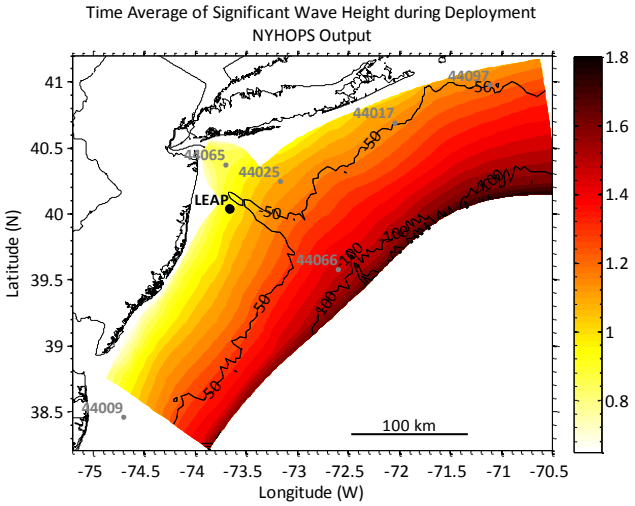
Spatial Variation of Wave Height



- Justification for use of remote NDBC wave measurements until ADCP is recovered
- NYHOPS, regional wave model that includes wind wave growth, breaking, and dissipation. Stevens Inst. of Technology.

Nickitas Georgas, 2010: Establishing Confidence in Marine Forecast Systems: The design of a high fidelity marine forecast model for the NY NJ Harbor Estuary and its adjoining waters. Blumberg A.F., Aikman, F. III, Herrington T.O., Hires, R.I., and P.D. Miller, PhD Dissertation, Stevens Institute of Technology. 295p.

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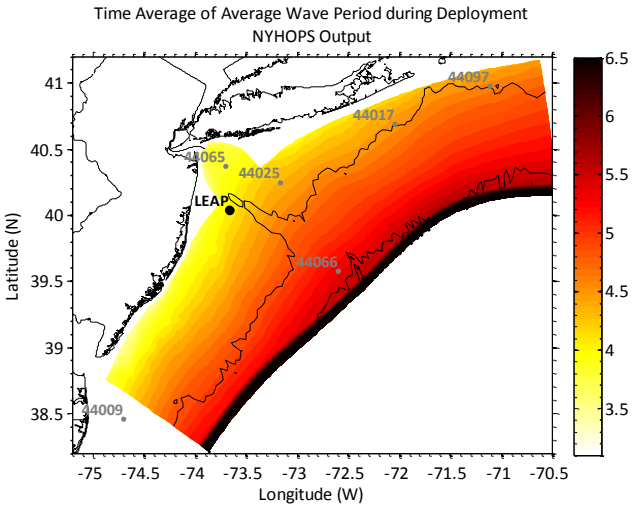
Spatial Variation of Wave Period



•NYHOPS (Georgas, 2010)

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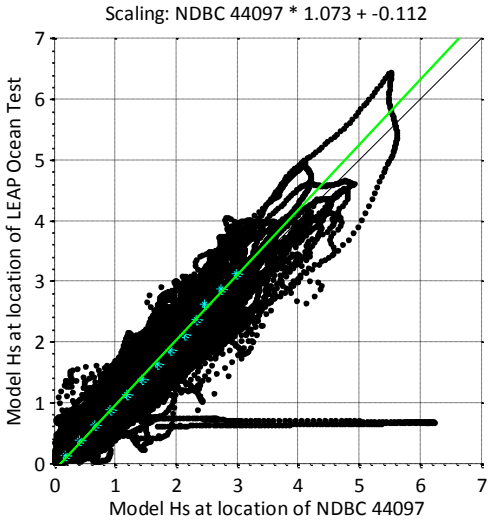
Scaling NDBC Measurements to LEAP Site



•Model output from NYHOPS (Georgas, 2010)
•When ADCP is recovered, will use ADCP data instead

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System Mooring

- Single-point mooring designed to withstand survival wave, currents, and wind conditions estimated from NDBC measurements
- Mooring loads estimated with OrcaFlex (commercial software)
- Survived maximum wave height H_{max}=18m during Hurricane Irene

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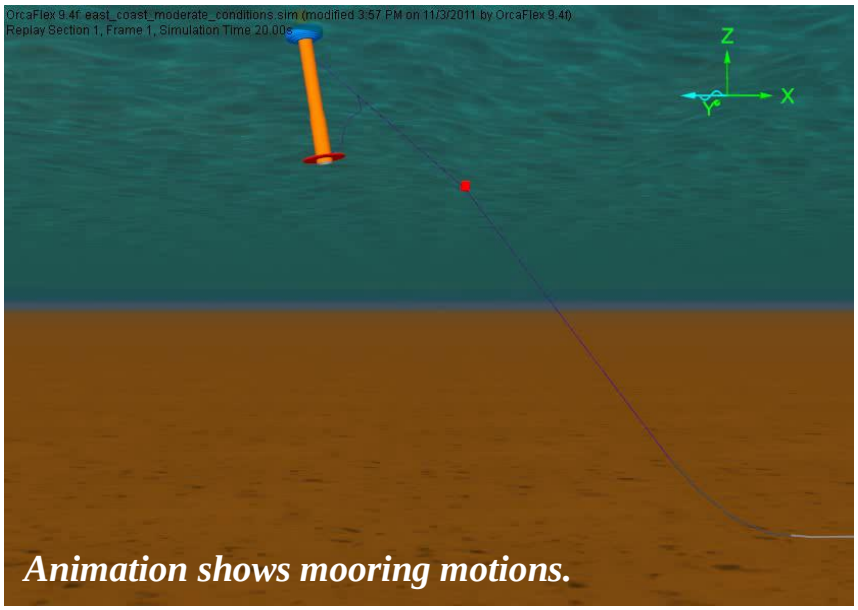
Animation of Mooring Design Model



Animation shows mooring motions.

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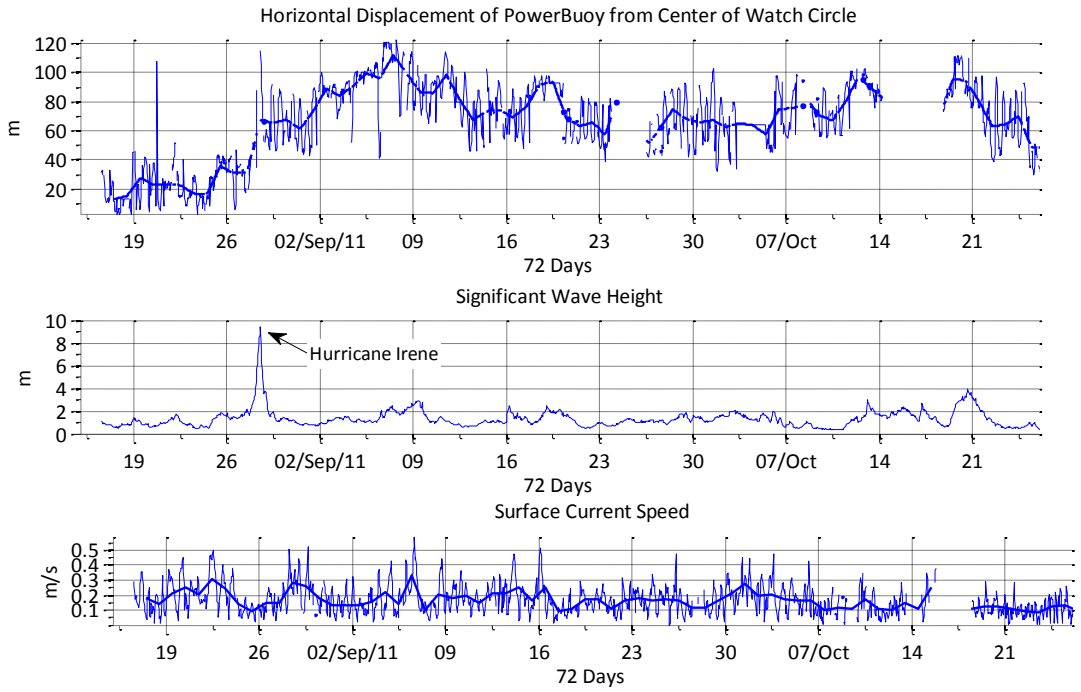
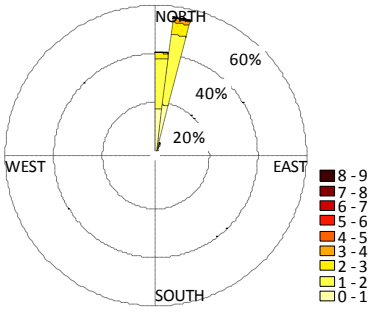
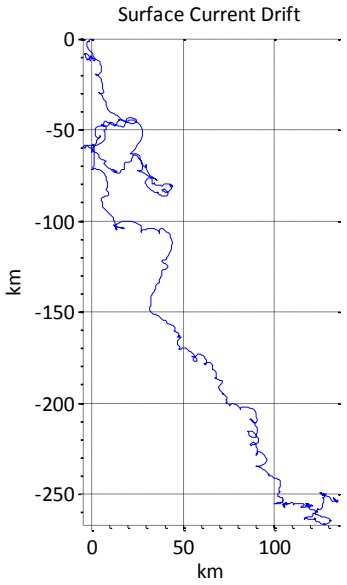
Performance of Single-Point Mooring



Positioned South in Watch Circle

Distribution of H_s by Direction That Wave Propagates From





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PowerBuoy Measurements

- **Data collected by sensors throughout PowerBuoy**
- **Measurements transmitted by satellite in near real-time**
- **Transmission was reliable and sufficient for test monitoring and reporting**

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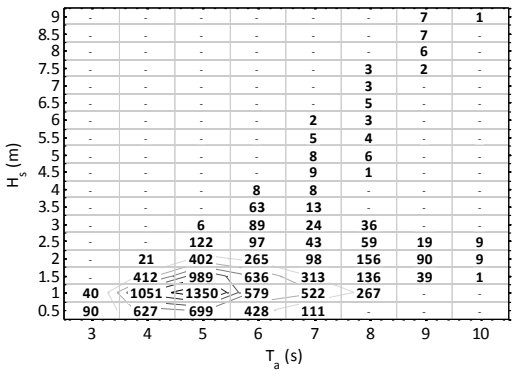
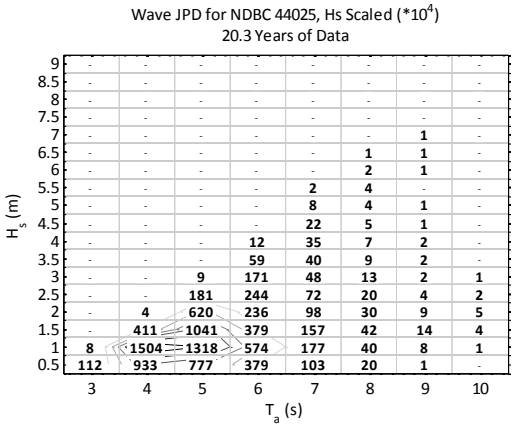
Sea States Observed during LEAP





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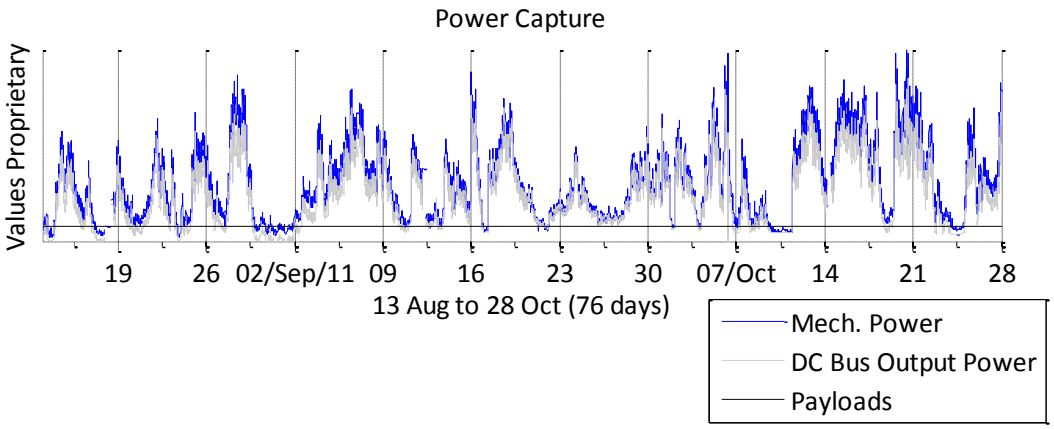
Power Capture



- LEAP: Up to 2 kW
- Other OPT products: Up to 150 kW

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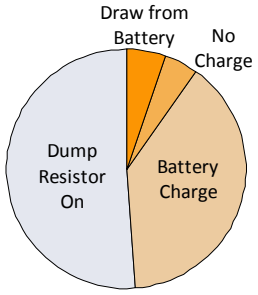
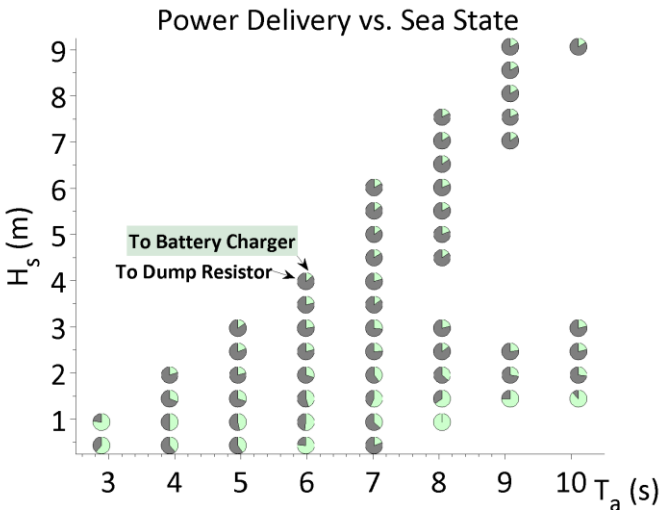
Power Delivery

Time Spent in Power Delivery Modes



•When low waves, still powered payloads via battery storage

•Delivery uninterrupted throughout ocean test



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Payloads

- Transmission of data collected by payload to ground node continuously during 3-month deployment
- Radar transmission powered continuously during deployment (except for planned 6 hour shutdown shortly after deployment)
- Radar signal received at all shore stations
- First marine deployment of payload
- Buoy may be used a sensor/system testbed for other programs; flexible design accommodates other payloads

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Inspection on Aug 31, After Irene

- Inspection topside and mooring system down to anchor
- No damage from hurricane
- Provided power throughout

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System Control

- **Designed for full autonomous operation**
  - Control algorithm governs power capture, delivery, and battery management in high, moderate, and low waves
- **Even for this prototype, minimal operator intervention after deployment**
- **As needed, parameters can be altered and system monitored via operator interface**

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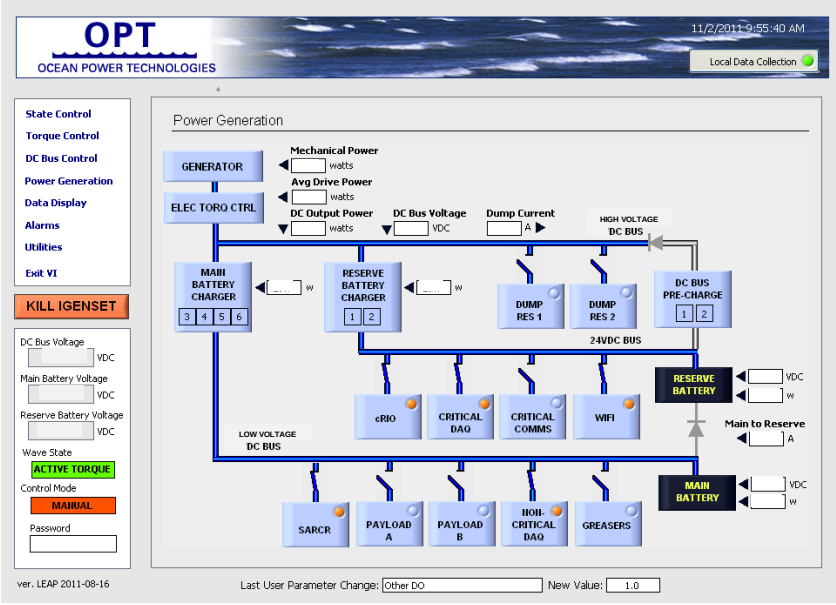
Operator Interface for Monitoring



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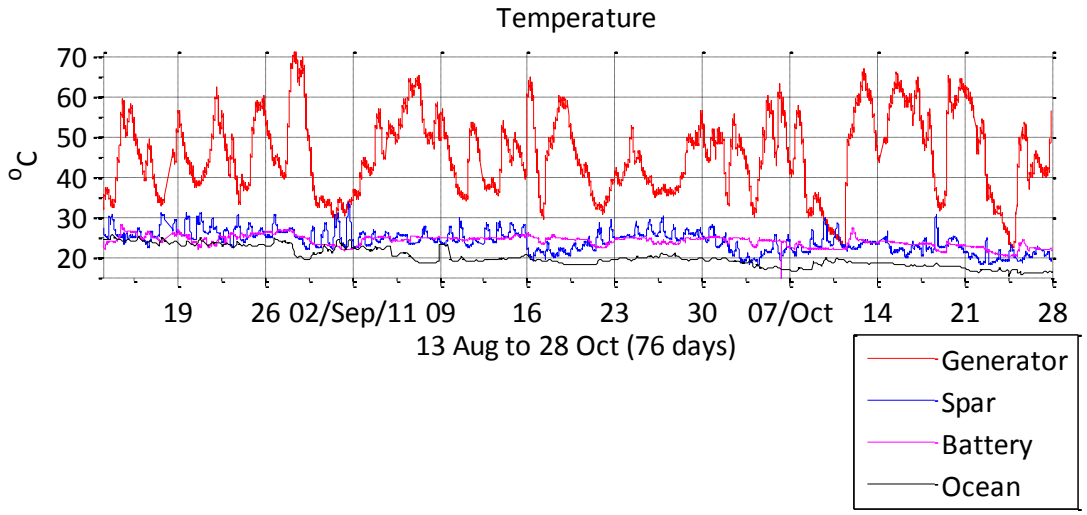
Example of Reported Information



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Conclusions

- **LEAP ocean test demonstrated design, manufacture, deployment, and functional performance of system**
- **Autonomous power capture and continuous delivery of power to payload**
- **Wave measurements presently obtained from NDBC until ADCP recovered; used to compare measured and predicted power generation**

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Wave Measurement Wish List

- **Real-time data transmission; data easily integrated with PowerBuoy measurement stream**
- **Measurements collected near PowerBuoy**
- **Continuous datastream (few instrument or data transmission failures)**
- **Easily deployed, recovered, maintained without expert skill**
- **Reasonable cost of purchase and operation (deployment, data streaming, replacement parts, recovery)**

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