The Endurance Array

Jack Barth (Project Scientist), Ed Dever (Project Manager/Principal Investigator), Jon Fram (Systems Engineer), Bob Collier (former Project Manager/Principal Investigator, cyberinfrastructure), Tom Kearney (Operations and Management)

Chris Wingard, Craig Risien, Linda Fayler, Walt Waldorf, Tully Rohrer, Stuart Pearce, David Neiman, Russ Desiderio, Kent Fletcher, Jeff Woods, Ian Black

... in collaboration with our WHOI (buoys, design, etc.), UW (cabled infrastructure: Deb Kelley, Orest Kawka) and Rutgers/Raytheon (cyberinfrastructure) colleagues

barth@coas.oregonstate.edu  edever@coas.oregonstate.edu  jfram@coas.oregonstate.edu
Endurance Array

- Science drivers
- Array design
- Instruments & sampling
- Deploy, recover, deploy, ...
- Present status
A1 Global Biogeochemistry and Carbon Cycling
A2 Ocean-Atmosphere Exchange
A3 Ocean Circulation, Mixing and Ecosystems
A7 Climate Variability and Ecosystems
A9 Coastal Ocean Dynamics and Ecosystems - Hypoxia on Continental Shelves
A10 Coastal Ocean Dynamics and Ecosystems Shelf/Slope Exchange.
Endurance and Cabled Array off Oregon
Endurance Array

- Cross-shelf mooring lines at Newport and Grays Harbor (N & S of Columbia River)

- Oregon Line connected to the Cabled Array

- 6 deployed gliders year-round

- 20 platforms:
  - EA ~240 sensors
  - Cabled EA ~39 sensors

- Locations chosen based on existing long-term data
Endurance Array: Oregon Line

As designed:

- Full water column
- Cross-shelf resolution
- High power, high bandwidth via cable to 80 & 500m
- Benthic platforms

500m = Slope
- poleward undercurrent
- boundary mixing
- vertical migration

25m = Inner Shelf
- waves
- link to nearshore
- river-driven flows

80m = Middle Shelf
- upwelling jets/fronts
- sand/mud bottom
- hypoxia
- wind stress curl

To PN1B of the RSN cable
Endurance Array: Oregon Line

As designed:

- Full water column
- Cross-shelf resolution
- High power, high bandwidth via cable to 80 & 500m
- Benthic platforms
Endurance Array: Washington Line

Endurance Array – Grays Harbor Line

- Endurance
- Washington
- Inshore
- Shelf
- Offshore

Endurance Washington Offshore
Endurance Washington Shelf
Endurance Washington Inshore
Cabled Array off central Oregon

Cabled Slope Base Moorings
200 m Platform & Shallow Profiler
Deep Profiler
Seafloor Platform

Surface Mooring

S. Hydrate Ridge

Deep Profiler

2900 m

200 m Platform & Shallow Winched Profiler

Deep Profiler

6 gliders

Cabled Offshore Moorings
200 m Platform & Shallow Profiler
Deep Profiler
Benthic Package

Shelf Surface Mooring

Inshore Surface Mooring

Inshore Surface Placing Profiler Mooring

Slope Base - PN1A

PN1B

OR Offshore

OR Shelf

PNID 80m

25m

61.5 m

142 m

NODES and J-BOXES

Primary Node

Low Voltage Node

Medium Power J-Box

Low Voltage J-Box

200 m Platform & Shallow Winched Profiler

Deep Profiler

2900 m

6 gliders
Cabled Benthic Experiment Package

Designed & Built at OSU
Operating since summer 2014

Instruments
• CTD, O₂, pH, pCO₂
• Chl-a, OBS, CDOM
• ADCP, fast point velocity,
• hydrophone
• Multi-frequency bioacoustics (on nearby platform)

Kent Fletcher
Endurance Array: Washington Line

BIG BUOYS
- wind, rain, humidity
- air pressure & temperature,
- long & short wave radiation
- wave spectra, air-sea pCO₂
- surface CT & velocity

GLIDERS
- CTD, O₂, PAR
- Chl-a, OBS, CDOM
- velocity

WIRE FOLLOWING PROFILER
- CTD, O₂, PAR
- Chl-a, OBS, CDOM
- point velocity

7m on MOORINGs
- CTD, O₂,
- Chl-a, OBS, CDOM
- point velocity
- Spec. Irrad., NO₃,
- pH, pCO₂, ADCP

SURFACE PIERCING PROFILERS
- CTD, O₂, PAR
- Chl-a, OBS, CDOM
- point velocity
- Spec. Irrad., NO₃,

MOORING ANCHORS
- CTD, O₂,
- Chl-a, OBS, CDOM
- Fast point velocity
- pH, pCO₂, ADCP
- Bioacoustic sonar, camera,
- Integrated pressure

- Many instrument types
  - See oceanobservatories.org
- Stretch hoses → bandwidth & power
• Design & Build
  – Started 1-Sep-2009
  – 5+1 year build.
• All Endurance platforms and sensors have been deployed
• Operate and Maintain
Default Sampling Strategy

- **Big Surface Moorings**
  - Burst interval 15 min to 1 hour, depending on sensor
  - Mooring powered by wind & solar. Some instruments with batteries.

- **Inshore Surface Moorings**
  - Burst interval 15 min to 1 hour, depending on sensor
  - Mooring powered by lithium batteries. Some instruments with batteries.

- **Wire Following Profiler**
  - 3 profiles per day
  - 25 cm vertical resolution

- **Coastal Surface Piercing Profiler**
  - 2-3 profiles per day, depending on depth & sea state
  - 25 cm vertical resolution (1.5 cm for CTD, 300 cm for nitrate)

- **Cabled Infrastructure**
  - Always on except for reagent or lamp-limited sensors
  - Bioacoustic sonar and camera share power source

- **Gliders**

---

Details in document posted to oceanobservatories.org

Uncabled platforms telemeter decimated data at least twice a day
Mooring Integration
Ocean Observing Center

Collaboration with WHOI on mooring design
Shipping & Dockside Reassembly

OOC Parking lot
Packed Deck
Deploy
## 2016 Operational Schedule

<table>
<thead>
<tr>
<th></th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Argentine Basin</strong></td>
<td>Shipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Refurb</td>
<td></td>
<td></td>
<td></td>
<td>Palmer Cruise</td>
</tr>
<tr>
<td><strong>55 South</strong></td>
<td>Shipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Palmer Cruise</td>
</tr>
<tr>
<td><strong>Irminger</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Armstrong Cruise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Papa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brown Cruise Jun-Jul</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pioneer</strong></td>
<td>- Glider Cruise</td>
<td>- 2/1 Quarterly Info Days</td>
<td></td>
<td></td>
<td></td>
<td>Armstrong Cruise</td>
<td>Armstrong Cruise</td>
<td>- Reseed Gliders via Armstrong Cruise</td>
<td>Armstrong Cruise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Endurance</strong></td>
<td>- Ship out fm WHOI - Reseed Gliders</td>
<td></td>
<td>Thompson Cruise Apr-May</td>
<td></td>
<td></td>
<td></td>
<td>- Ship out fm WHOI - Reseed Gliders</td>
<td>Atlantis Cruise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RSN</strong></td>
<td>-1/19 Quarterly Info Days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sikullaq Cruise Jul-Aug</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Endurance Array Gliders

- Lithium batteries → 3 month deployments
- 20 km per day
- CTD, $O_2$, PAR, Chl-a, OBS, CDOM, velocity
Endurance Array Glider Coverage

- 6 planned, 2 averaged
- ADCP sometimes off (battery, electronics)
- Science bay sometimes off (battery)
**Endurance Array**

**Platform Regular**

**Data Collection**

**Start Dates**

- **Endurance Array – Grays Harbor Line**
  - 4/15-
  - 10/14-
  - 4/15-
  - 10/14-

- **Endurance Array – Newport Hydrographic Line**
  - 4/15-
  - 8/15-
  - 4/15-
  - 8/16-
  - 8/14-
  - 4/14-
  - 4/15-

**Giders**

- bridge Grays Harbor and Newport lines

**Surface Buoys**

- meteorological measurements
- surface boundary layer measurements
- two-way communication
- power to benthic sensors

**Profiling**

- move sensors vertically through the water column

**Multi-function Nodes (MFN)**

- anchor mooring to seafloor
- platform for mounting sensors

**Communications**

Endurance Array will have multiple types of communications enabling researchers to modify and interact with experiments in real time. These include satellite communications.

**Benthic Experiment Packages (BEP)**

- enable experiments requiring high power and high bandwidth

**Cabled Infrastructure**

- Primary and Low-Voltage Nodes
- enable experiments requiring high power and high bandwidth
- provide interface with RSN

**Communications**

Endurance Array will have multiple types of communications enabling researchers to modify and interact with experiments in real time. These include satellite communications and high bandwidth cabled connections.
**Washington Offshore Wire Following Profiler: 2 years of success**

- CTD
- Oxygen
- Velocity
- PAR
- FLORT
Coastal Surface Piercing Profiler

Endurance CSPP Deployments

- Grays H Shelf
  - green: collected data
  - red: at sea stoppage
  - grey: no planned data

- Grays H Inshore
  - Cabled → uncabled conversion

- Newport Shelf
- Newport Inshore

Date Range: 04/15 to 10/16
Endurance Array Platform Regular Data Collection Start Dates

- Cabled Endurance: when platforms on, instruments worked except CAMDS, sometimes ZPLSC & OPTAA
- CAMDS
  - Digital still camera
  - Kongsberg
- OPTAA
  - Optical attenuation & absorption
  - WET Labs ac-s
- ZPLSC
  - Zooplankton sonar, coastal
  - Simrad EK60
# Surface Mooring Instrument Data Summary

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
<th>Issues and Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAMDS</td>
<td>Digital still camera</td>
<td>Very little data, software incomplete, frequent hardware failures, late procurement &amp; poor quality</td>
</tr>
<tr>
<td>OPTAA</td>
<td>Optical attenuation and absorption</td>
<td>No battery, so turns off if mooring fails. Long service interval so often not deployed. Significant biofouling.</td>
</tr>
<tr>
<td>FDCHP</td>
<td>Air-sea Flux direct covariance</td>
<td>Frequent instrument hardware failures, late procurement</td>
</tr>
<tr>
<td>NUTNR</td>
<td>Dissolved nitrate</td>
<td>Frequent instrument hardware failures, significant biofouling</td>
</tr>
<tr>
<td>PCO2W</td>
<td>Aqueous partial pressure carbon dioxide</td>
<td>Finicky instrument, so major setup problems, now OK</td>
</tr>
<tr>
<td>VEL3D</td>
<td>High-frequency 3D point velocity</td>
<td>Mooring software was unable to operate sensor until recently</td>
</tr>
<tr>
<td>ZPLSC</td>
<td>Zooplankton sonar</td>
<td>Late procurement, occasional hardware or configuration failure, calibration under development</td>
</tr>
<tr>
<td>PCO2A</td>
<td>Air and sea partial pressure carbon dioxide</td>
<td>Significant fouling on buoys, but now mitigated</td>
</tr>
<tr>
<td>PHSEN</td>
<td>pH</td>
<td>Finicky instrument, so some setup problems, now OK</td>
</tr>
<tr>
<td>ADCPT/S</td>
<td>Acoustic Doppler current profiler</td>
<td>Occasional instrument hardware failure or battery miscalculation</td>
</tr>
<tr>
<td>CTDBP</td>
<td>Conductivity, temperature, pressure</td>
<td>Occasional battery miscalculation Some biofouling</td>
</tr>
<tr>
<td>DOSTA</td>
<td>Dissolved Oxygen, stable (vs. fast DOFST)</td>
<td>Significant biofouling</td>
</tr>
<tr>
<td>FLORT</td>
<td>Florescence (chlorophyll-a, optical backscatter, CDOM)</td>
<td>No battery, so turns off if mooring fails Some biofouling</td>
</tr>
<tr>
<td>METBK</td>
<td>Bulk meteorology (short &amp; long wave radiation, air pressure, temperature, relative humidity, wind, rain)</td>
<td>Occasional instrument hardware failure</td>
</tr>
<tr>
<td>PRESF</td>
<td>Bottom pressure</td>
<td>No problems</td>
</tr>
<tr>
<td>SPKIR</td>
<td>Spectral irradiance</td>
<td>No battery, so turns off if mooring fails Some biofouling</td>
</tr>
<tr>
<td>VELPT</td>
<td>Mean 3D point velocity</td>
<td>Occasional instrument hardware failure or battery miscalculation</td>
</tr>
</tbody>
</table>
Biofouling

Buoy sensors covered (PCO2A, METBK-CT)

CSPP painting shows mitigation measures can work
Endurance Array Summary
operate, maintain, deliver data, improve, make efficient, collaborate, work transparently, share ...

Opportunities
• Use data
• Add instruments
• Change sampling
• Ancillary projects
• Join a cruise
• Talk with us
Subsurface Instruments have often become autonomous

• Stretch hoses
  - WA Shelf & Offshore surface moorings hoses send power and data
• Inshore mooring and WFP hoses send data
• Revised hoses succeeded on latest Pioneer deployment
• Mooring Electronics
  - Custom & complex, so many failure points—better each time
  - Long build & service intervals—being fixed
• Connectors on all subsea controllers upgraded to titanium