OOI Endurance Array
Sustained Data for a Changing Ocean

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7 June 2022
OOIFB NE Pacific Data Workshop

OOI cruise entering Yaquina Bay on R/V Thomas G Thompson, summer 2020

OOI OCEAN OBSERVATORIES INITIATIVE

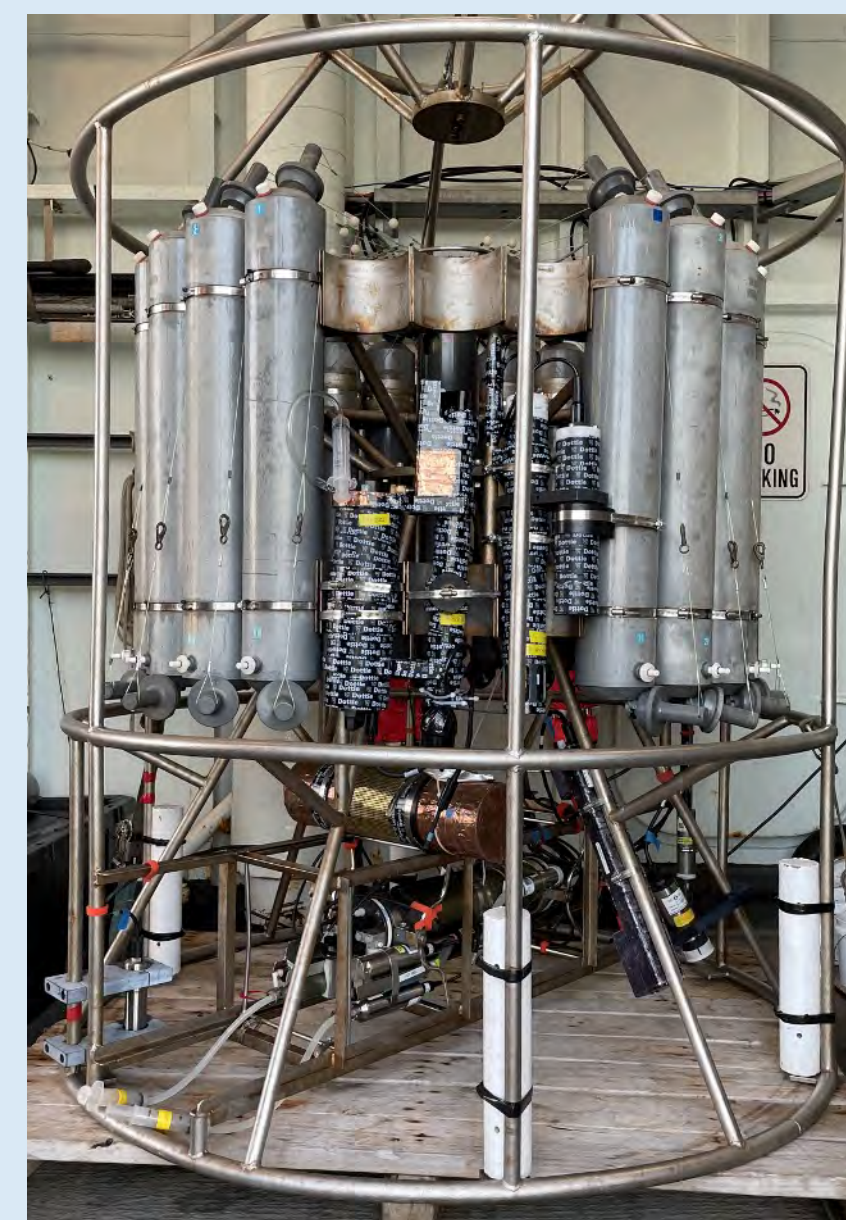Oregon State University

NSF

Coastal Endurance Array

- Long-term observations of fundamental scientific and societally relevant processes including ocean heat waves, hypoxia and ocean acidification
- Insights into impacts of Columbia River, California Current System, wind, El Niño, Pacific Decadal Oscillation
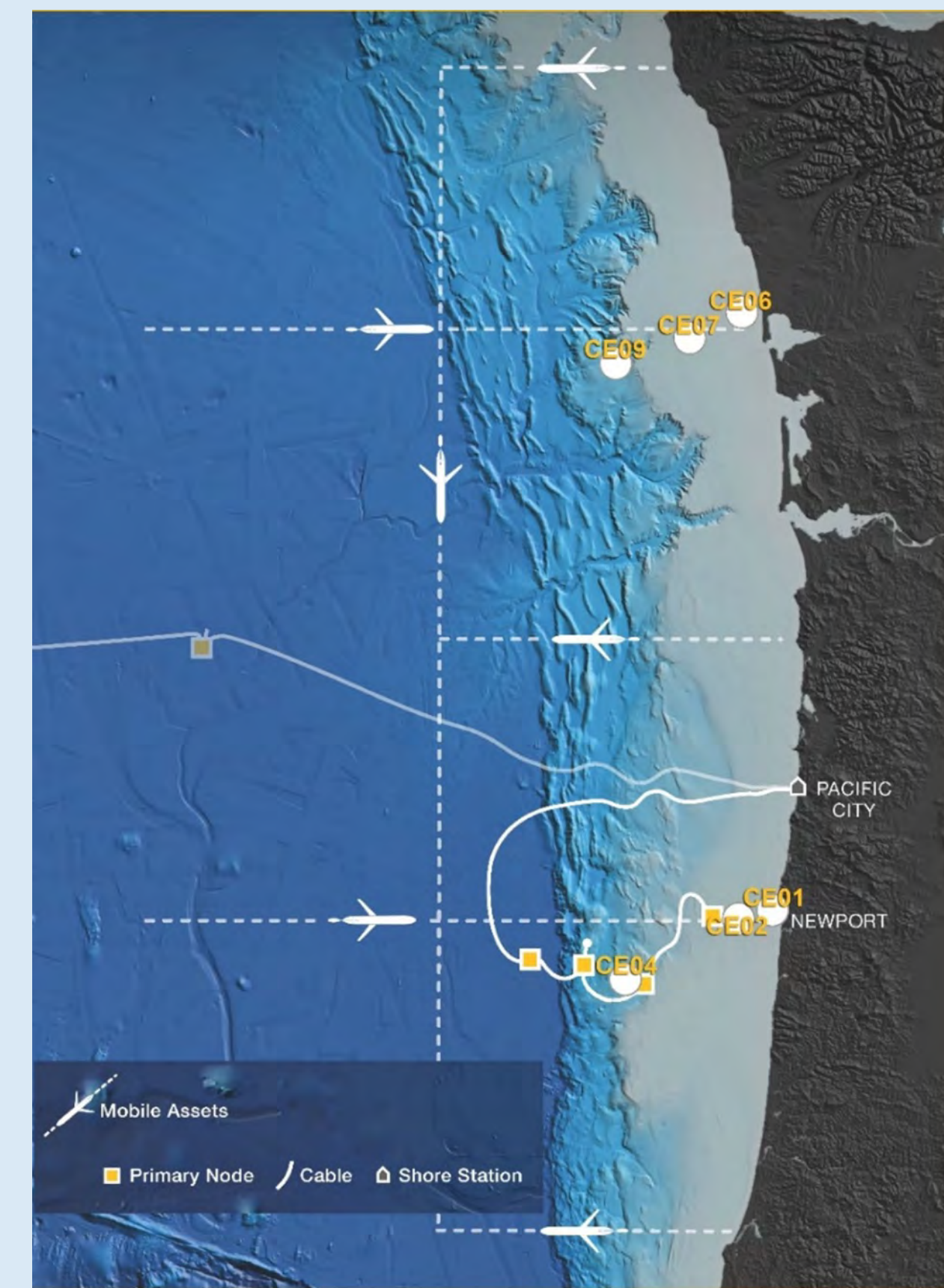
Operated by OSU (uncabled, Ed Dever) and UW (cabled, PI Deb Kelley)

OOI moorings on R/V Sikuliaq, spring 2022

pCO2 system on OOI buoy

Side by side comparison of pH sensors

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Coastal Endurance Array

- Surface moorings turned in spring and fall. Glider deployments and water sampling occur on these cruises.

- Surface profilers at inshore sites deployed mid-spring – early fall. Surface profilers at shelf sites deployed as practical over winter.

- Regional Cabled Array platforms turned in summer.

- Generally, maintain 4 gliders year-round. Prioritize gliders along mooring lines. Shallow glider lines cover inshore of 200 m. Deep glider lines extend to 128°W. Often send gliders along 126°W line.
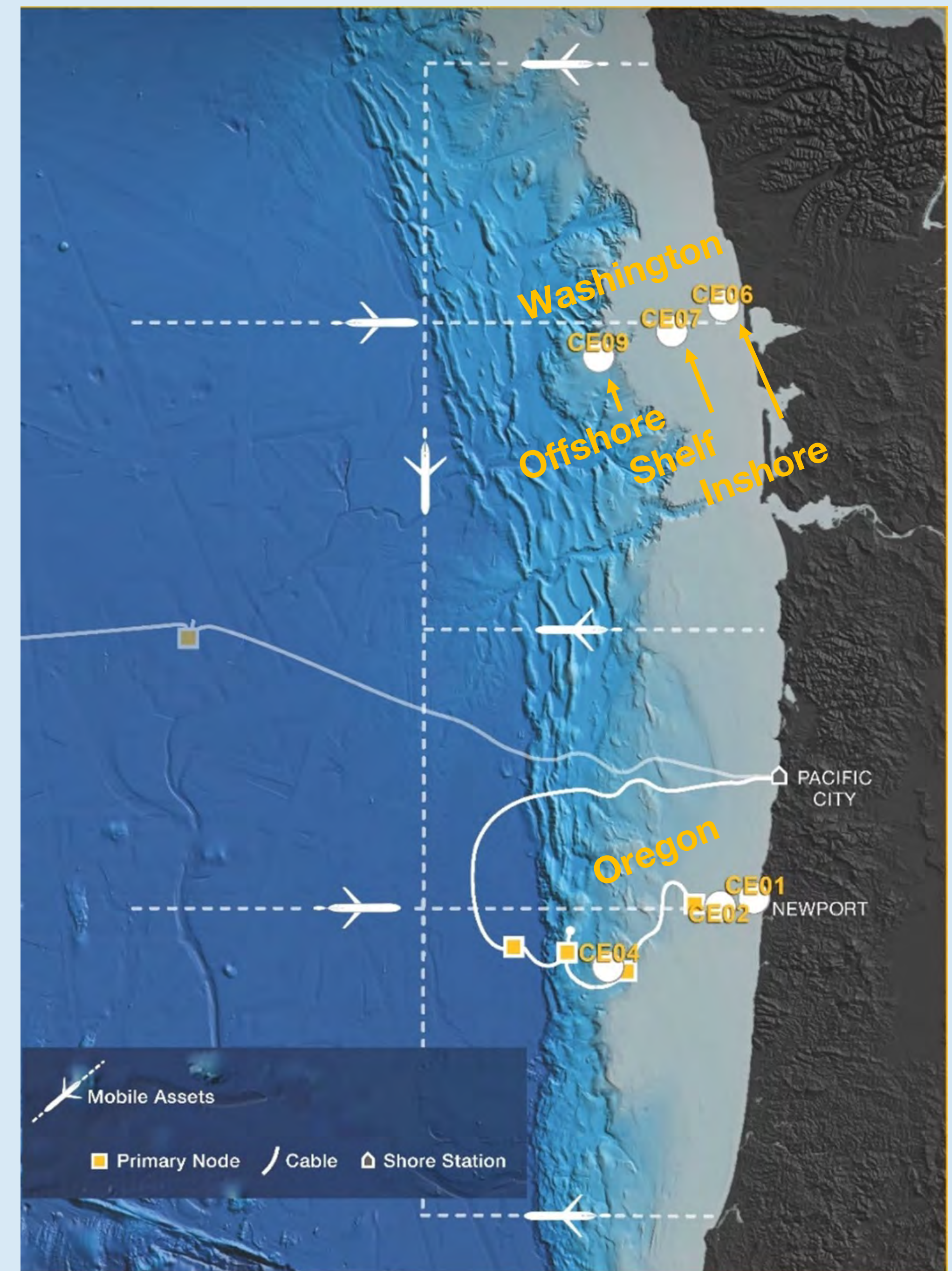
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Endurance Array
Washington Line

Surface Profiler instruments include:
- CTD
- Dissolved O_2
- Nitrate
- PAR
- Single point velocity (Nortek Aquadopp)
- Spectral irradiance
- spectrophotometer

Bottom (BEP) instruments include:
- Water property instruments
- Bio-acoustic sonar (Kongsberg EK-60)
- Digital still camera
- hydrophone

COASTAL ENDURANCE ARRAY: OREGON LINE

(WET Labs) Sea-Bird Thetis profiler

TO SURFACE

TO SURFACE

TO BOTTOM

TO SURFACE

BEP

Bio-acoustic sonar

Digital still camera

hydrophone

SHELF 80 M
- Surface Mooring (CE02SHSM)
- Surface Piercing Profiler Mooring (CE02SHSP)
- Cabled Benthic Experiment Package (CE02SHBP)
- Primary Node (PN1D)
- Med. Powered J-Box (MJ01C)
- Digital Still Camera
- Hydrophone
- Bio Acoustic Sonar

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Biogeochemical Measurements on Endurance Array

Notes:

- QC quality control
- HITL Human in the Loop, review by an OOI data team member (now weekly)
- Automated QC flags are based on IOOS Quality Assurance of Real-Time Oceanographic Data (QARTOD)

Measurement	Instrument	Remarks
Dissolved oxygen	Aanderaa Optode 4831	Multi-point calibration, UV light biofouling mitigation since 2018, HITL annotations historical and current. Fixed depth, profilers, gliders
Chl-a, CDOM, OBS	WET Labs (Sea-Bird) ECO triplet-w	HITL annotations historical and current. Fixed depth, gliders, profilers
Downward irradiance	Satlantic (Sea-Bird) OCR507 ICSW	HITL annotations current, UV light biofouling mitigation since fall 2019. Historical annotations planned for summer 2022, fixed depth, profilers, gliders (PAR only)
nitrate	Satlantic (Sea-Bird) SUNA V2	ISUS replaced by SUNA in 2018, HITL annotations current. Historical annotations planned for summer 2022. Fixed depth, profilers
Spectrophotometer (Optical attenuation and absorption)	WET Labs (Sea-Bird) AC-S	HITL annotations current, automated QC tools in development . Fixed depth, profilers
pH	Sunburst SAMI pH	HITL annotations histotical and current, automated QC flags applied. Fixed depth, cabled shallow profiler
pCO2 water	Sunburst SAMI pCO2	HITL annotations historical and current, automated QC flags applied. Fixed depth, cabled shallow profiler
pCO2 air-sea	Pro-Oceanus pCO2-pro	HITL annotations historical and current, automated QC flags applied. Surface buoy
Bio-acoustic sonar	ASL AZFP (uncabled) Kongsberg EK-60 (cabled)	Raw data available, standardized plots using Echopype in progress. Fixed depth

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Accessing Endurance and water column Regional Cabled Array OOI data and use cases

We've tried to take the FAIR principles into account and make OOI data accessible in different ways for different user groups.

Complicated by OOI compute on demand architecture

Still at least one year out from assigning DOI's to data.

method	potential use cases	remarks
OOI Data Explorer	Exploration, Classroom, proposals	Includes most of OOI (except for hydrophone, ZPLSC, video)
OOI M2M API	Routine access of telemetered and recovered data	For expert user, most complete source of data, metadata, annotations
OOI Gold Copy THREDDS and Data Explorer ERDDAP	Routine access of telemetered and recovered data	For expert user, uses pre-calculated values from M2M, no wait for calculation of values
OOI Data Portal GUI	Exploration, Classroom, proposals	Largely superseded by Data Explorer
NANOOS	OOI data in context of other regional measurements	Endurance (including cabled Endurance), only archives last 60 days of data
GOA-ON	OOI data in context of other related OA measurements	Endurance data, similar user interface to NANOOS
Interactive Oceans	Exploration, Classroom, proposals	Focus on Regional Cabled Array, Endurance also there
Glider Data Assembly Center (DAC)	Exploration, OOI data in context of regional measurements	All OOI glider data are submitted to the DAC, OOI Data Explorer pulls from the DAC
NDBC	Exploration, OOI data in context of regional measurements	Buoy data only, 10-minute averages

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Other OOI Arrays

- Common sensor types, sampling strategies, and data access facilitate comparison between different arrays.

- Regional Cabled Array and Station Papa place the coastal Endurance Array measurements within a broader geographical context.

- Coastal Pioneer and Endurance provide the ability to perform comparison/contrast between different coastal regions

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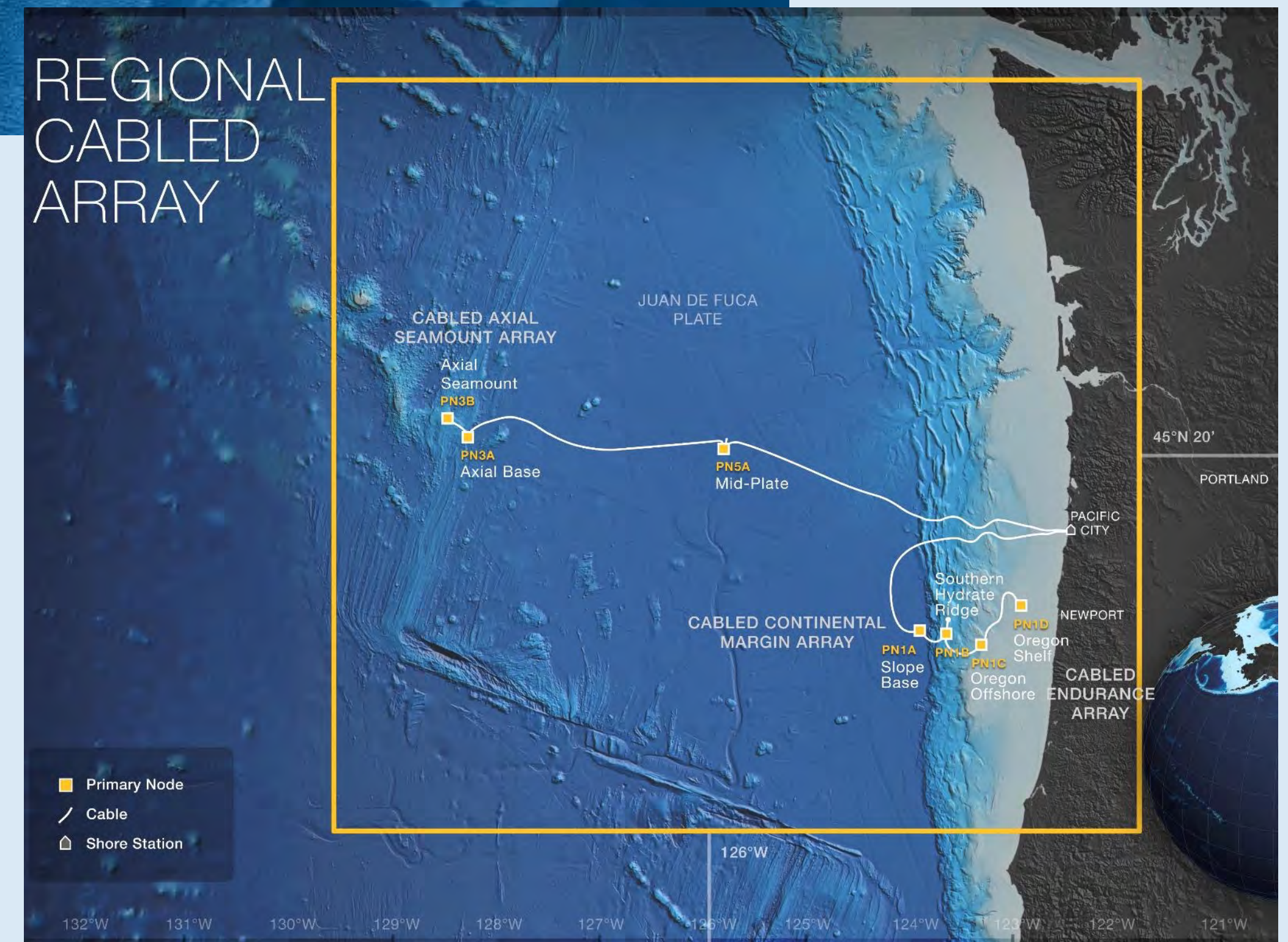
Other measurements: Regional Associations of the Integrated Ocean Observing System (IOOS)

- The Northwest Association of Networked Ocean Observing Systems (NANOOS) is the Regional Association IOOS in the Pacific Northwest, primarily Washington and Oregon.

- The NANOOS Visualization System pulls OOI data. NVS includes in situ, remote, and model data.

- The aggregation of OOI data with that of many other observing systems and models helps address regional science questions, perform cross-validation of data, and provides redundancy in case of individual platforms going offline.

- Similar regional IOOS associations provide data off of northern and central California (CeNCOOS) and southern California (SCCOOS).
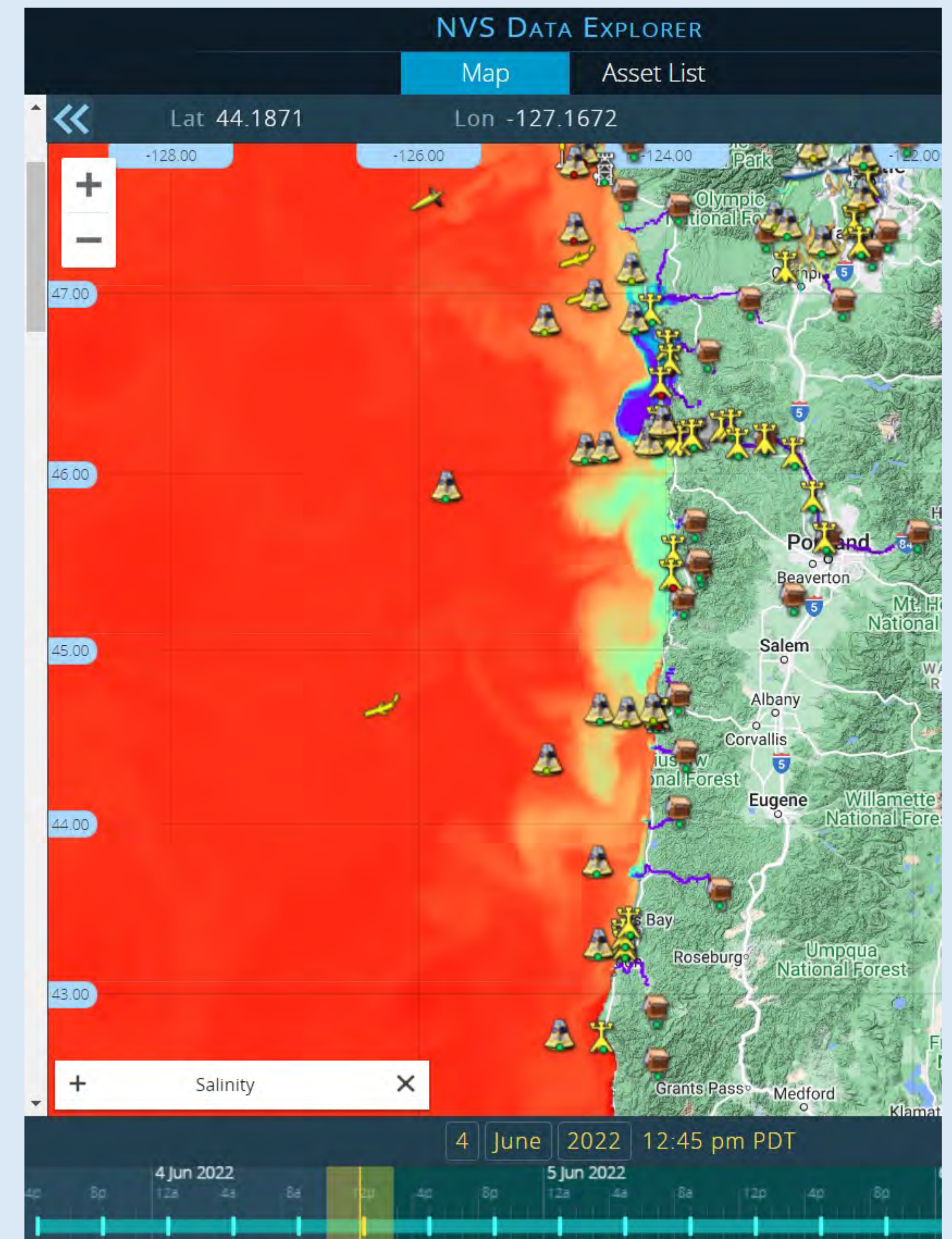
NVS Data Explorer with UW LiveOcean surface salinity

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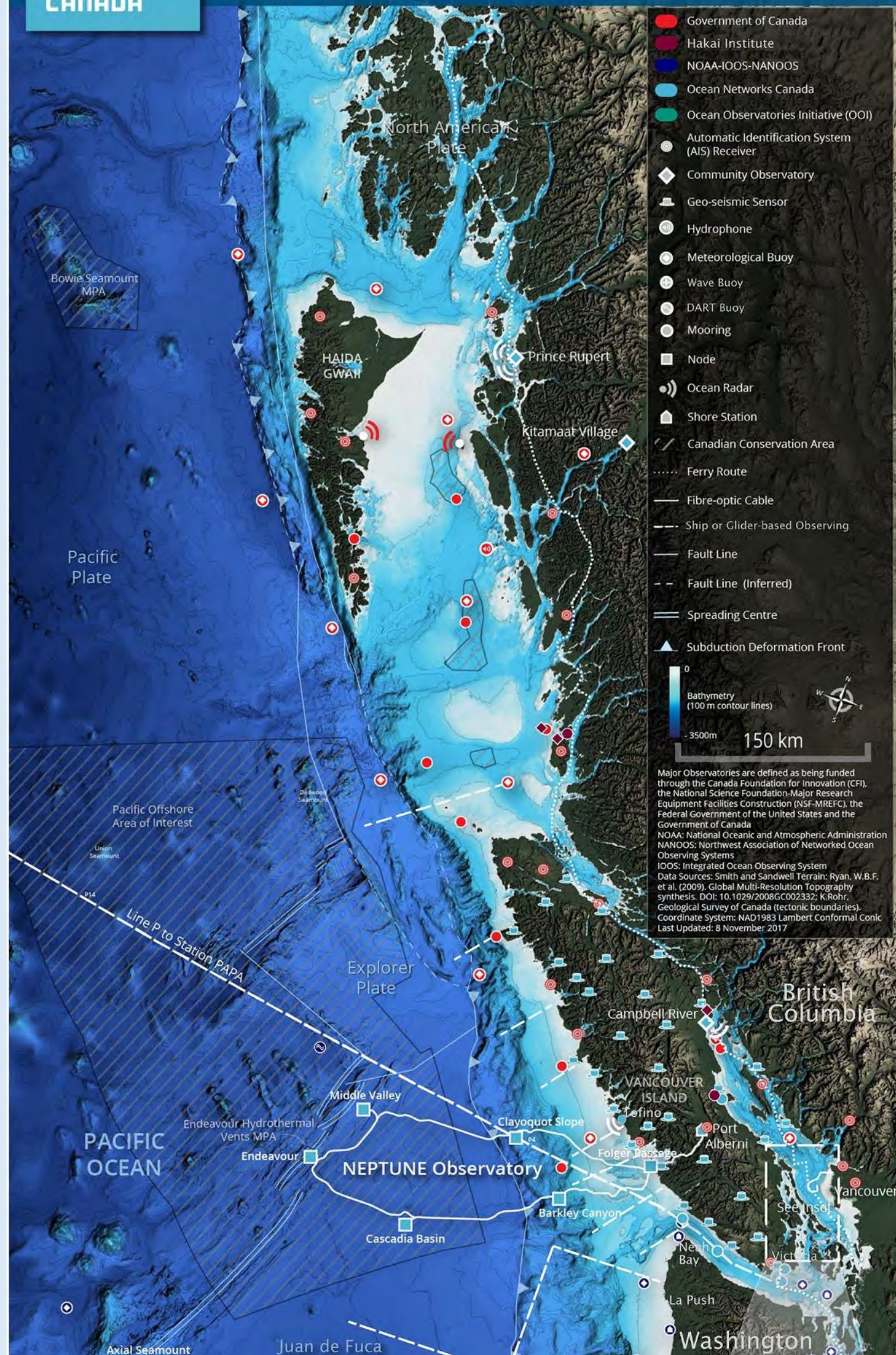
Better Regional Ocean Observing Through Cross-National Cooperation: A Case Study From the Northeast Pacific

- NEP ocean observing elements are operated by government agencies, Native American Tribes, First Nations groups, not-for-profit organizations, and private entities.

- By sharing data, experiences and lessons learned, the regional ocean observatory is better than the sum of its parts.

- There is room for improved coordination on instrument types, sampling, biofouling protection, best practices, metadata, and data quality assurance and control, etc.

- Sampling gaps include:
  - shelf break processes off Vancouver Island
  - long-term surface and subsurface measurements of chemical properties and rates.
  - information on the causes of variability in phytoplankton community structure, as well as growth rate information for phyto- and zooplankton.
  - automated physical sampling of phytoplankton at HAB initiation sites

NORTHEAST PACIFIC MAJOR OBSERVING SYSTEMS

OCEAN NETWORKS CANADA

Legend:
- Government of Canada
- Hakai Institute
- NOAA-IOOS-NANOOS
- Ocean Networks Canada
- Ocean Observatories Initiative (OOI)
- Automatic Identification System (AIS) Receiver
- Community Observatory
- Geo-seismic Sensor
- Hydrophone
- Meteorological Buoy
- Wave Buoy
- DART Buoy
- Mooring
- Node
- Ocean Radar
- Shore Station
- Canadian Conservation Area
- Ferry Route
- Fibre-optic Cable
- Ship or Glider-based Observing
- Fault Line
- Fault Line (Inferred)
- Spreading Centre
- Subduction Deformation Front

Bathymetry (100 m contour lines)

150 km

Map labels: North American Plate, Pacific Plate, Explorer Plate, Bowie Seamount MPA, HAIDA GWAII, Prince Rupert, Kitamaat Village, Pacific Offshore Area of Interest, Line P to Station PAPA, Campbell River, British Columbia, VANCOUVER ISLAND, Tofino, Port Alberni, Vancouver, Middle Valley, Endeavour Hydrothermal Vents MPA, Endeavour, NEPTUNE Observatory, Clayoquot Slope, Folger Passage, Barkley Canyon, Cascadia Basin, Neah Bay, La Push, PACIFIC OCEAN, Axial Seamount, Juan de Fuca, Washington

Second map labels: PACIFIC OCEAN, Middle Valley, Endeavour Hydrothermal Vents MPA, Endeavour, NEPTUNE Observatory, Clayoquot Slope, Folger Passage, Barkley Canyon, Cascadia Basin, Juan de Fuca Plate, Axial Seamount, 3B, 3A, Mid-Plate, 5A, OOI Cabled Array, OOI Endurance Array: Washington Line, Grays Harbor, Washington, Seattle, Columbia River, Astoria, VENUS Observatory, Strait of Georgia, Saanich Inlet, Pacific City, Newport, Hydrate Ridge, 1B, 1A, 1D, OOI Endurance Array: Oregon Line, Oregon, Coos Bay, North American Plate, Pacific Plate, ISLAND, Port Alberni, Vancouver

STATION PAPA
P26 [50° N, 145° W]

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Other Regional Measurements (Gliders)

- Glider data are aggregated in the IOOS glider Data Assembly Center (DAC).

- Data on the DAC have a common format that is independent of the glider platform (Slocum, Spray, Seaglider).

- The DAC includes both real time and historical data.

- OOI pushed data to the DAC. The OOI glider data available through the DAC are identical to that available through the Data Explorer.

- Cross-shore glider lines maintained by several operators extend along the California Current.

- Off Oregon and Washington, the DAC provides access to OOI glider data as well as other historical and current glider data.

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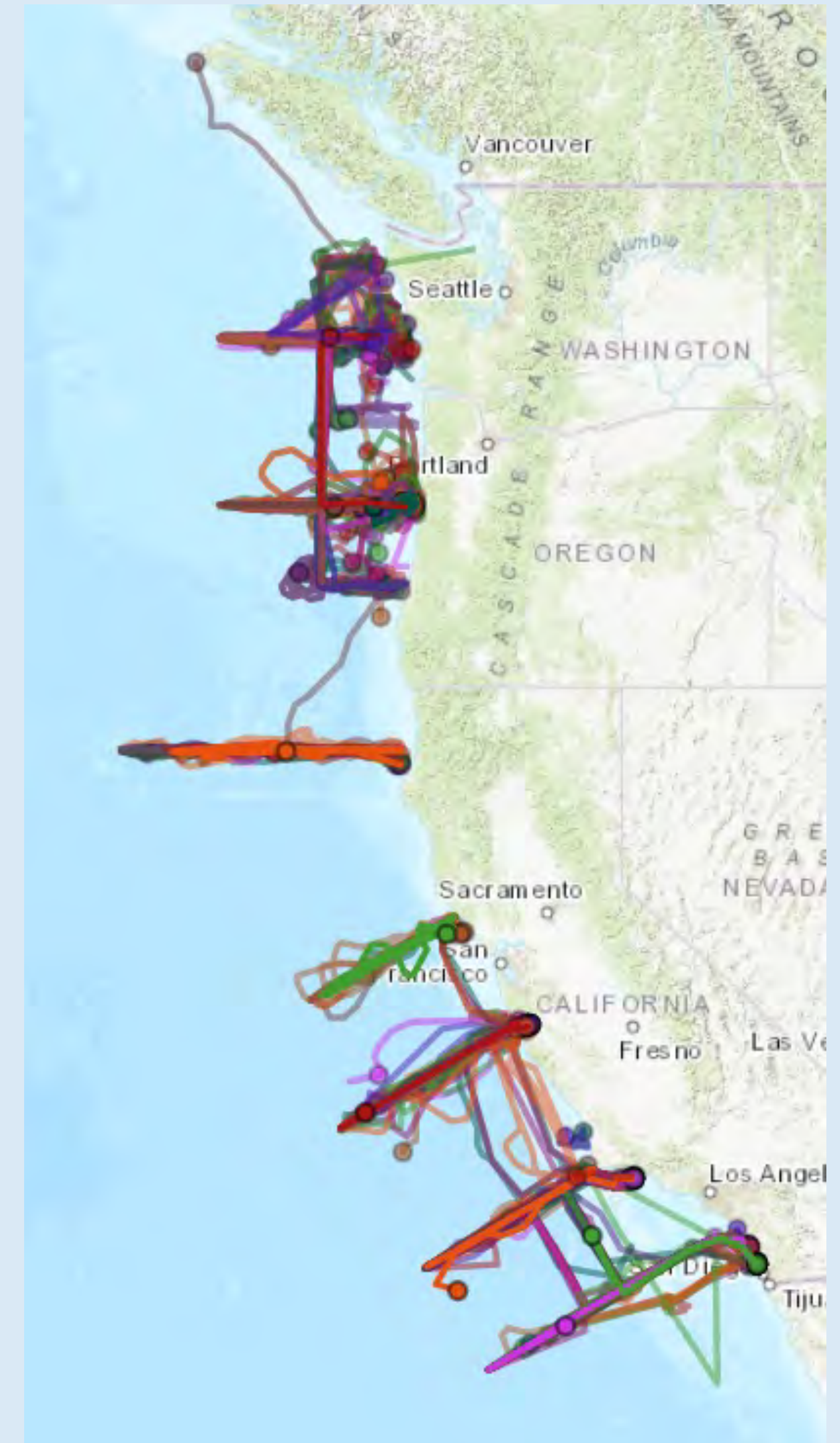
Marine Heat Waves

- As the OOI data record becomes longer, we can construct seasonal cycles and departures from those seasonal cycles.

- Barth *et al.* (2018) first showed the connection between the warm blob in the Gulf of Alaska and the anomalies seen at the Washington offshore site.

- Risien *et al.* (2020) used McLane profiler data at the Washington offshore site to explore interannual variability temperature, dissolved oxygen and bio-optical properties

Station Papa

Endurance WA offshore
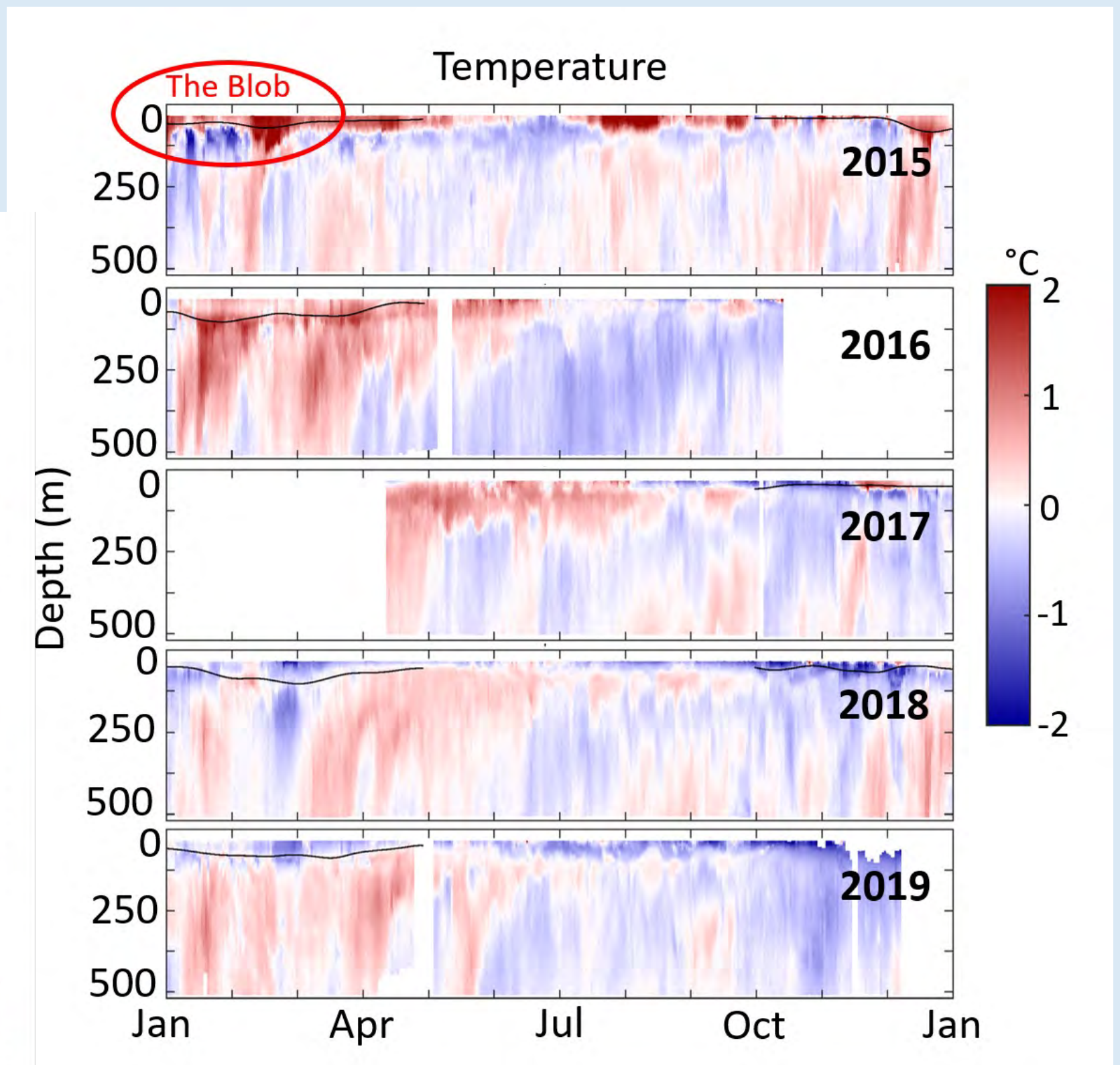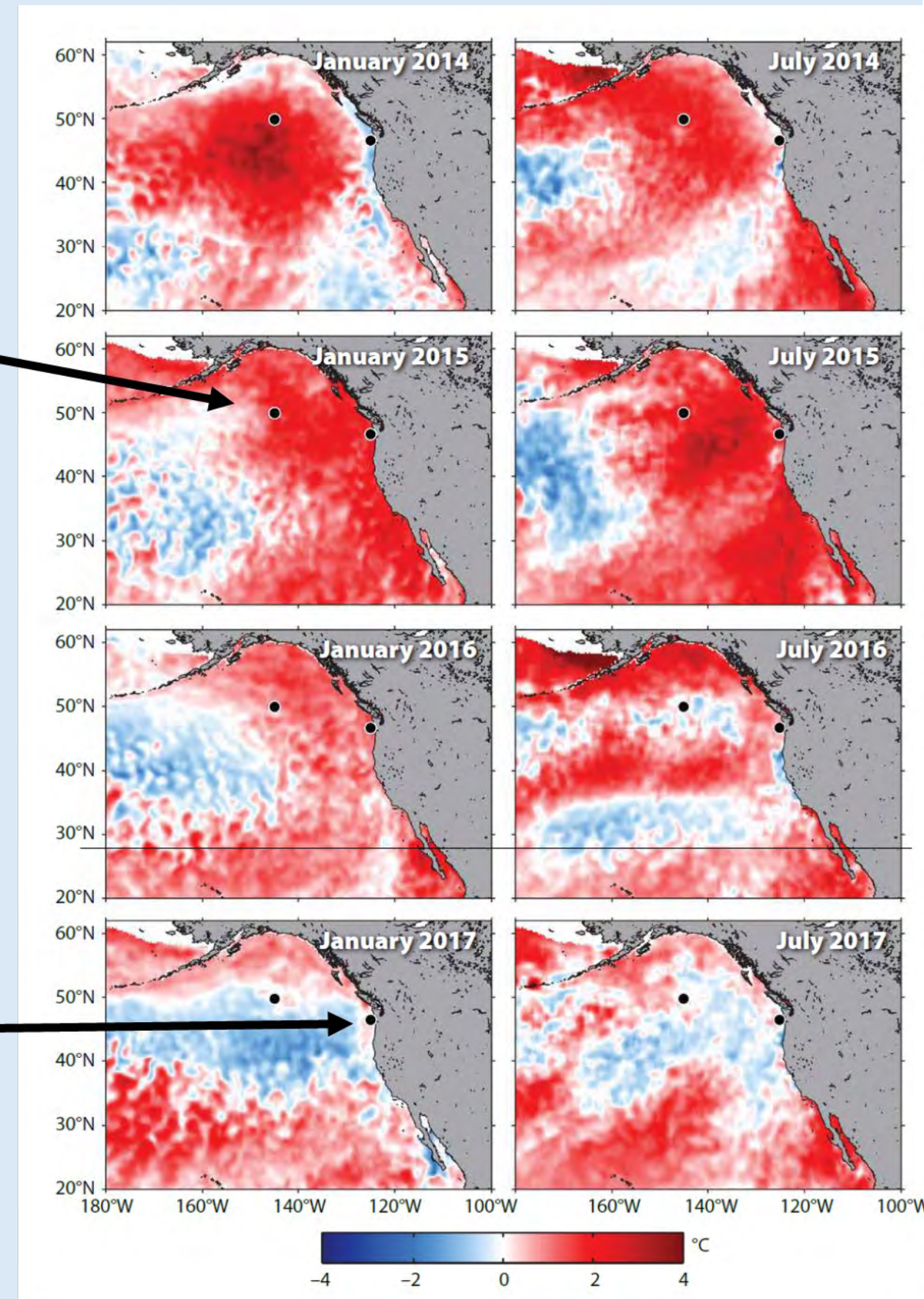
Risien *et al.* (2020), Sustained, High-Resolution Profiler Observations from the Washington Continental Slope, Abstract #OS036-0005 presented at Ocean Sciences Meeting 2020, San Diego, CA, 16-21 Feb.

Warm Blob initially centered in N. Pacific just south of Station Papa, moves inshore to coastal Endurance Array in late 2014.

Barth *et al.* Oceanography 31(1):90–97, https://doi.org/10.5670/oceanog.2018.114.

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Hypoxia

- Endurance Array includes measurements from moorings, profilers, and gliders.

- Seasonal hypoxia observed off Washington and Oregon in response to summer upwelling.

- Endurance measurements have been compared with J-SCOPE model predictions by Siedlecki *et al.*

- Improving oxygen measurement data quality remains an important goal of OOI.
  - mitigating biofouling on near surface mooring sensors with AML UV antifouling lights.
  - planning air calibrations of glider oxygen measurements.
  - taking bottle samples of DO between mooring cruises as practical
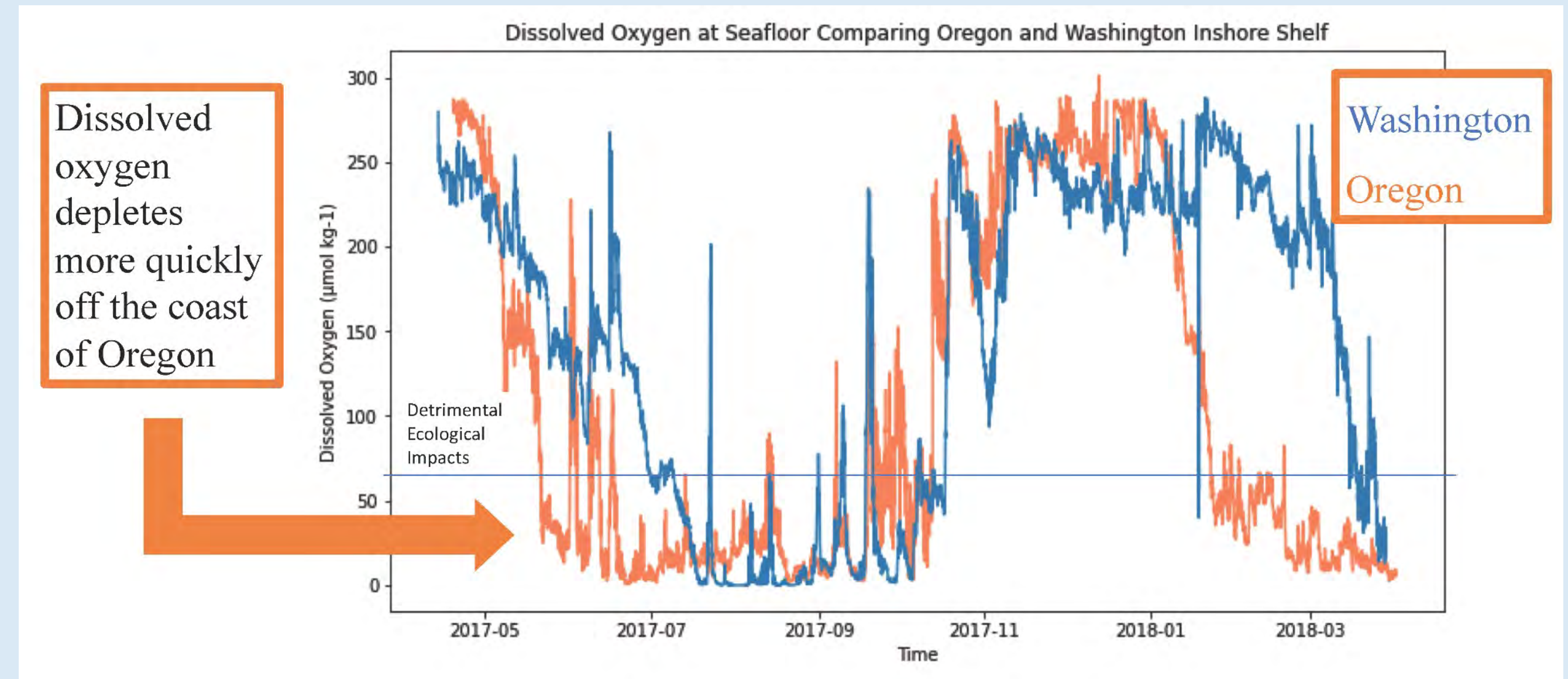
Andrea Selkow (Austin College) studied dissolved oxygen (DO) off the Washington and Oregon coasts using the OOI Endurance Array as part of a virtual REU through the Rutgers University Ocean Data Labs and Rutgers Research Internships in Ocean Science (RIOS). She was advised by Prof. Tom Connolly (Moss Landing Marine Labs, San Jose State Univ.)

Andrea Selkow. "Low Dissolved Oxygen off Washington and Oregon Coast Impacted by Upwelling in 2017" Data Labs 2020 Virtual Research Experience For Undergraduates (REU), 31 July 2020 datalab.marine.rutgers.edu/2020-virtual-reu/. Accessed 4 June 2022.

Ocean Acidification

- **NP** = SOCAT-v4 (1976-2015) + other ship data in North Pacific region

- **OC** = SOCAT-v4 + other ship data in Outer Coast (WA) region

- CR = Columbia River (not used here)

- CE = Cape Elizabeth NDBC buoy (2006-2013), pCO2 measured with MApCO2, pH estimated

- OOI WA offshore and WA shelf (2015-2022), pCO2 measured with Pro-Oceanus pCO2-pro, pH measured at 7 m with SAMI-pH

- OOI OR offshore and OR shelf (2015-2022)

GOA-ON EXPLORER
Map   Asset List
Lat 46.4376   Lon -1
CE
National Forest
NP   OC   Olymp
WA shelf
WA offshore
Astoria
NP   CR   Por
Tillamook   Beave
OR shelf
Newport   Albany
Corvallis
OR offshore
Siuslaw

pH comparison

- Amplitude and timing of seasonable cycle between CE and WA offshore and shelf buoys reasonable, some offset at WA shelf

- North Pacific and OR offshore and shelf comparisons qualitatively good

- Geographic variability in OOI data

- Seasonal cycle fit is poorest at OR offshore (gray dots represent individual monthly averages)
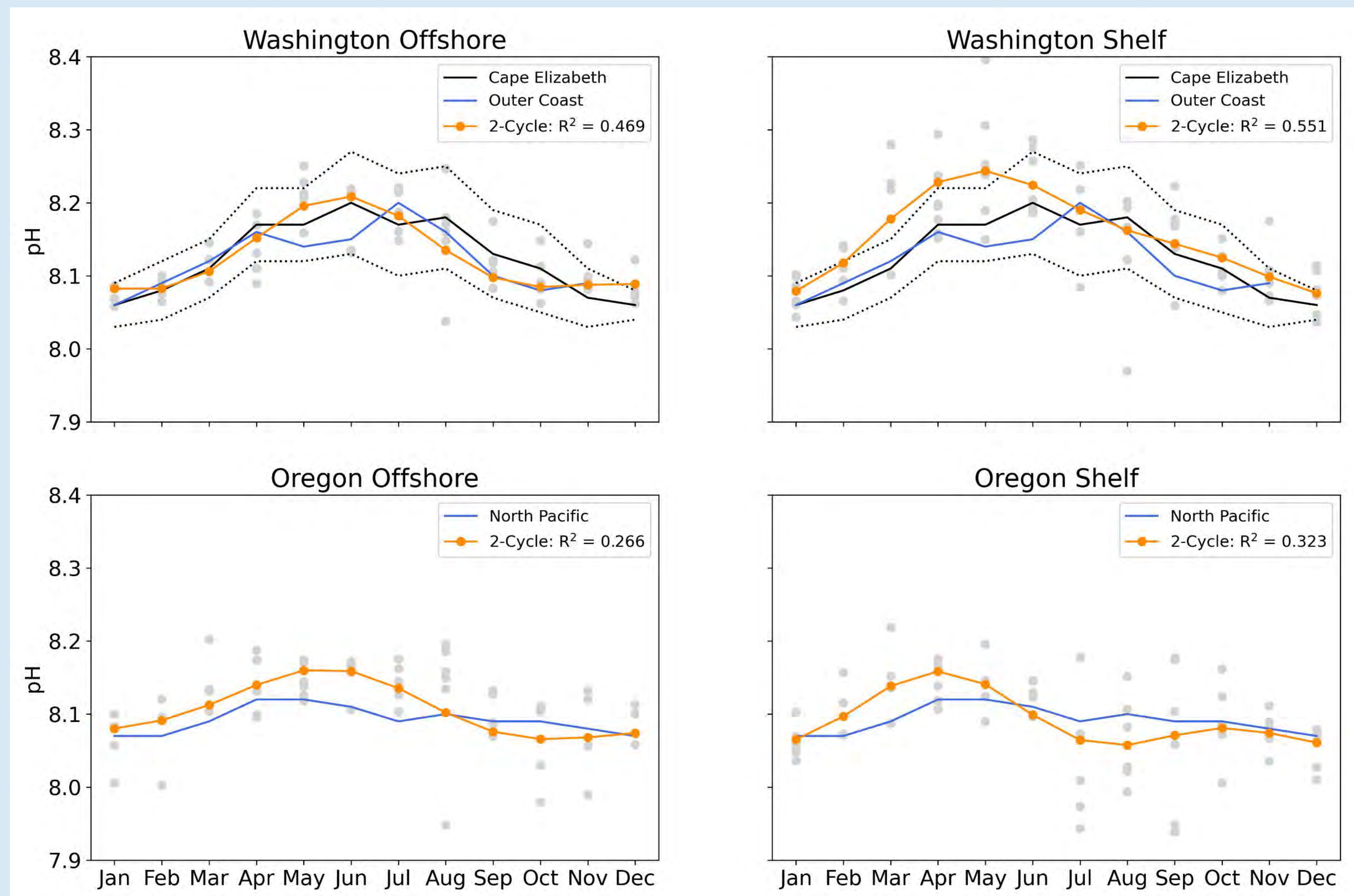
Thank you!

OOI Endurance Contact Information

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