Ocean Observing and Industry: Supporting the NW Economy

*"The **services NANOOS provides are critical** to understanding current and predicting future marine conditions."*

- Paul Williams, Shellfish Program Advisor
Suquamish Tribe Fisheries Department

*"This **current generation of shellfish farmer is reliant upon data and services from NANOOS**. Checking the NANOOS app before seeding a beach or filling a setting tank has become standard practice."*

- Margaret Barrette, Director
Pacific Coast Shellfish Growers Association

*"The coastal tribes of Washington State are shellfish harvesters and at mercy of changing winds that transport HABs from incubation sites offshore. Having the NANOOS automated HAB sampler, with toxin assessment capability, offshore between our harvest beaches and the HAB generation sites will give tribes **the forewarning they need** to adjust sampling protocols and **better protect the health of coastal residents, tribal and non-tribal.**"* *- Joe Schumacker, Quinault Indian Nation Department of Fisheries*

What's at Stake for Washington's Economy?

The most productive commercial shellfish industry on the West Coast

- Washington's shellfish industry generates $270 million annually, and directly and indirectly supports 3,200 jobs.
- Annual sales of farmed shellfish from Washington account for almost 85% of U.S. West Coast sales (including Alaska).

Source: Washington Blue Ribbon Panel on OA; Photos: Benjamin Drummond (left and right); Bryan Penttila (center)

What's at Stake for Washington's Economy?

Valuable wild and recreational fisheries

- Impacts to marine food webs could affect Washington's seafood industry, which generates over 42,000 jobs in Washington and contributes at least $1.7 billion to gross state product.

- Recreational oyster and clam harvesters contribute more than $27 million annually to coastal economies.

Source: Washington Blue Ribbon Panel on OA; Photos (left to right): Washington Association of Conservation Districts, US Dept. Agriculture, City of Seattle

What's at Stake for Washington's Tribes?

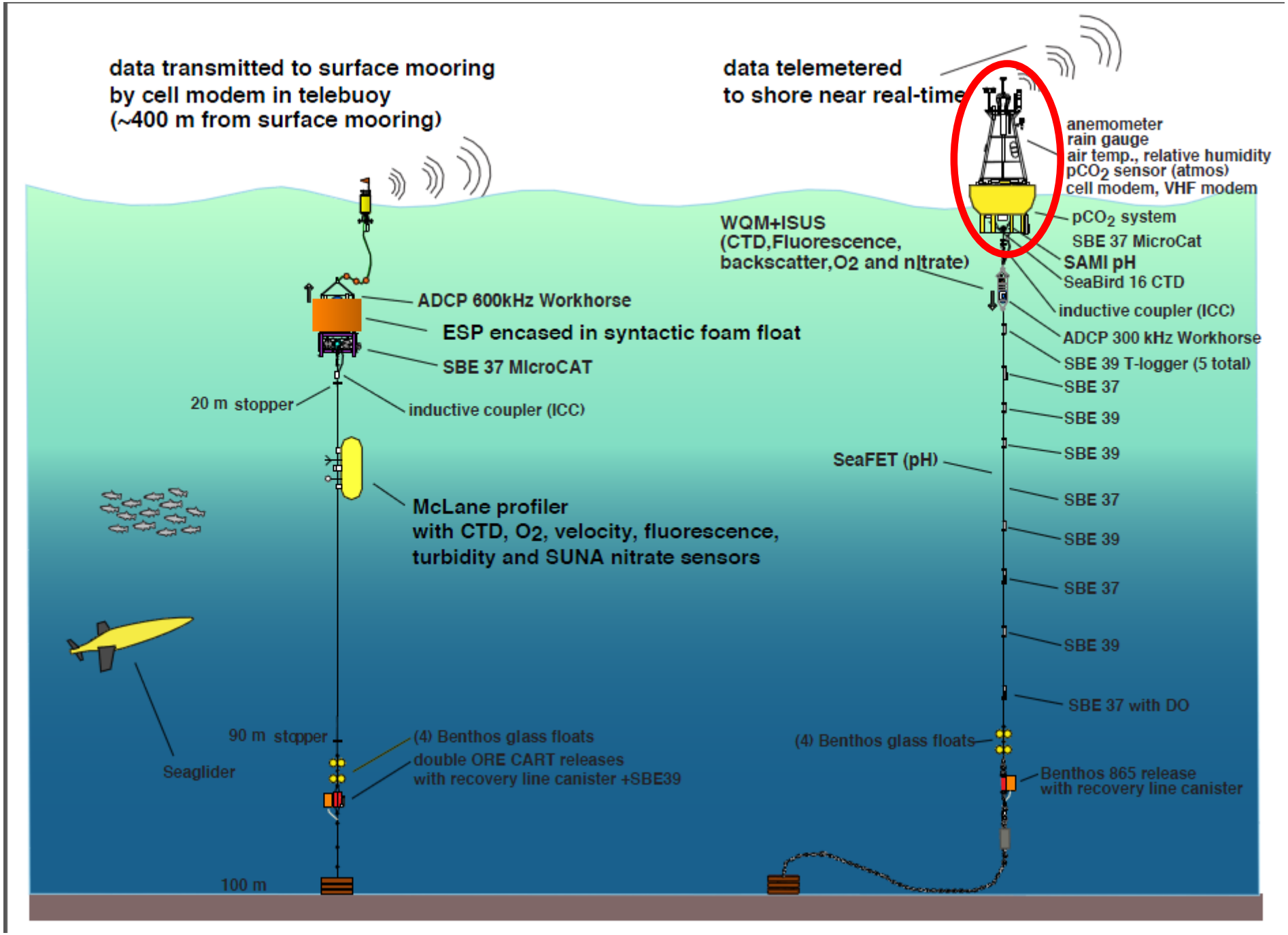
Continued identity and cultural survival of Washington's coastal tribes

- Washington tribes depend upon shellfish for food, income, and connection to their cultural heritage.

Source: Washington Blue Ribbon Panel on OA; Photos: Northwest Indian Fisheries Commission

Real-time Water Quality Data
for Shellfish Growers in the Pacific NW

A partnership btwn NANOOS, NERRS, and shellfish growers since 2004


data transmitted to surface mooring
by cell modem in telebuoy
(~400 m from surface mooring)
data telemetered
to shore near real-time
anemometer
rain gauge
air temp., relative humidity
pCO2 sensor (atmos)
cell modem, VHF modem
pCO2 system
SBE 37 MicroCat
SAMI pH
SeaBird 16 CTD
inductive coupler (ICC)
ADCP 300 kHz Workhorse
SBE 39 T-logger (5 total)
SBE 37
SBE 39
SBE 39
SBE 37
SBE 39
SBE 37
SBE 39
SBE 37 with DO
WQM+ISUS
(CTD,Fluorescence,
backscatter,O2 and nitrate)
ADCP 600kHz Workhorse
ESP encased in syntactic foam float
SBE 37 MicroCAT
20 m stopper
inductive coupler (ICC)
SeaFET (pH)
McLane profiler
with CTD, O2, velocity, fluorescence,
turbidity and SUNA nitrate sensors
Seaglider
90 m stopper
(4) Benthos glass floats
double ORE CART releases
with recovery line canister +SBE39
(4) Benthos glass floats
Benthos 865 release
with recovery line canister
100 m

Cha'ba & NH-10 are national OA buoys…

www.pmel.noaa.gov/co2/story/Strategy+for+OA+Observations

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PMEL CARBON PROGRAM

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Strategy for OA Observations

PMEL is developing a global network of ocean acidification observations

The existing global carbon observatory network of repeat hydrographic surveys, time-series stations and ship-based underway surface observations in the open ocean provide a strong foundation of carbon chemistry observations to begin addressing the problem of ocean acidification. Indeed, much of our present understanding of the long-term changes in the carbon system is derived from the repeat ocean sections and time-series measurements.

Location of planned OA monitoring and research sites and affiliated NOAA labs.

A major project for our group is to **expand the global moored and ship-based network by adding pH and other biogeochemical measurements** to provide important information on the changing conditions in the open ocean and coastal waters. See the map of planned monitoring sites to the right. This network will provide a better understanding of the temporal and spatial scales of variability in ocean carbon chemistry and biology and the observational basis for developing predictive models for future changes in ocean acidification and its consequences for marine ecosystems.

U.S. **coastal and estuarine environments** do not currently have coordinated carbon observing networks, as in the open ocean, and are presently grossly under-sampled. There is a critical need for intensive time series measurements on moored buoys and repeat hydrographic cruises in high productivity coastal and estuarine systems as CO_2 and carbonate ion concentrations in these waters can vary substantially on timescales from hours to decades due to tides, photosynthesis, and river or ground water inputs. In response to that need, we are adding carbon and pH sensors to

RELATED STORIES

Ocean Acidifica …
Fundamental changes in seawater chemistry are occurring throu …

NOAA OA Plan
NOAA researchers and managers are working to

NOAA-UW-NANOOS

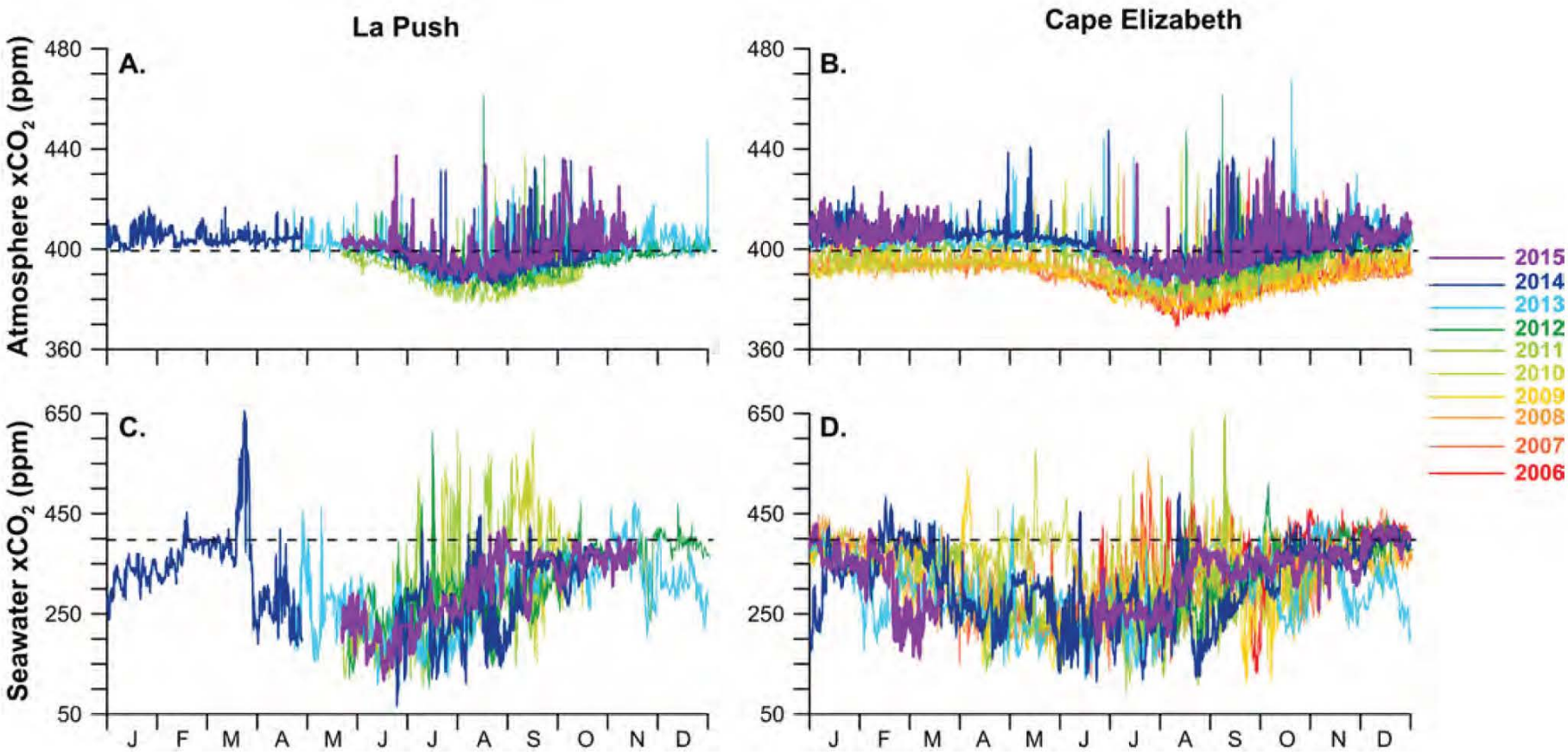
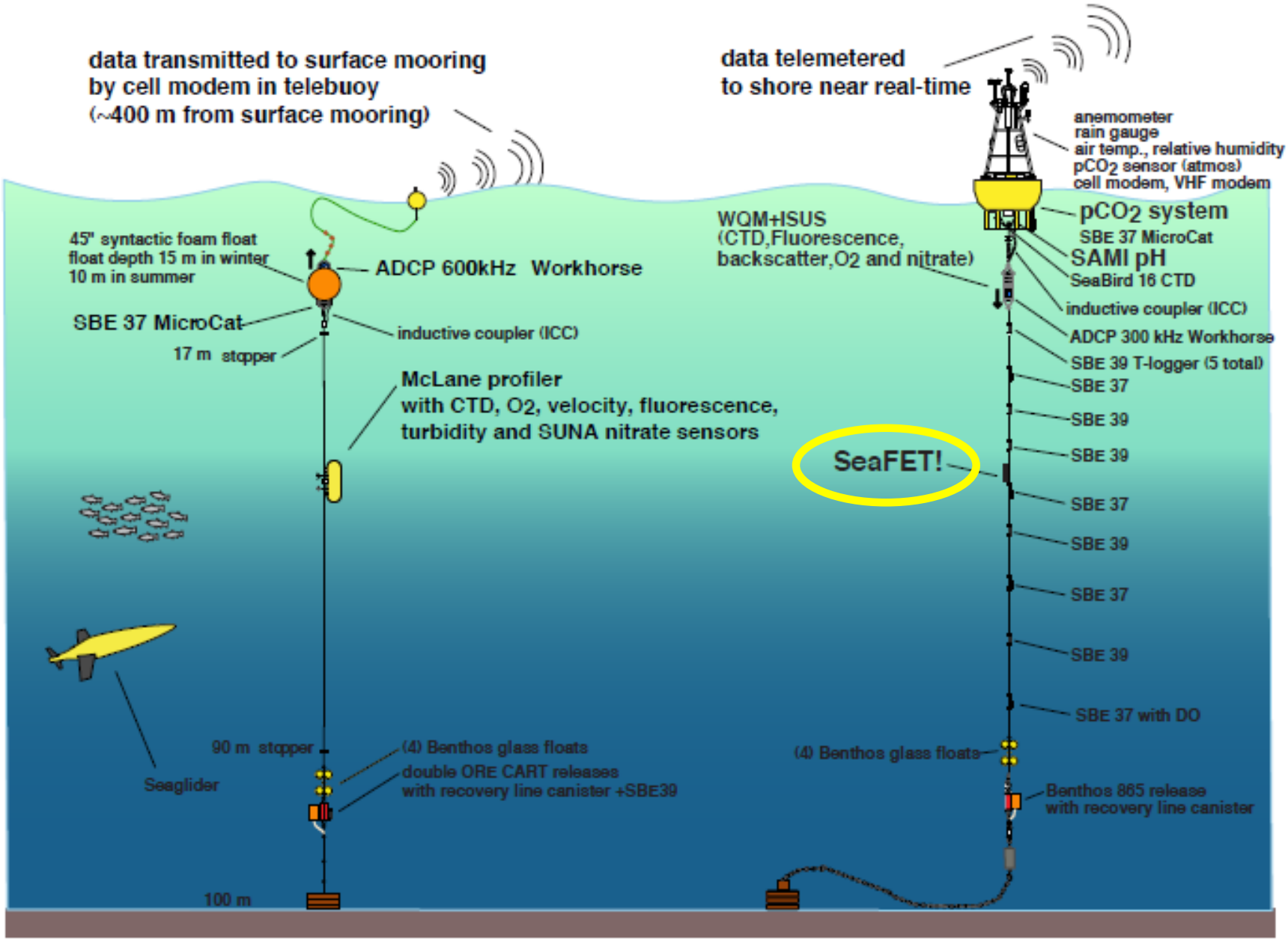


Figure 9. The mole fraction of carbon dioxide (xCO_2) in air at 1.5 m above seawater and in surface seawater at 0.5 m depth on the surface Chá Bă mooring off La Push, WA, and on the NDBC mooring 46041 off Cape Elizabeth, WA. Globally averaged marine surface air 2015 annual mean xCO_2 value of 399 ppm is indicated with a dashed line in each panel. Typical uncertainty associated with quality-controlled measurements from these systems is < 2 ppm for the range 100–600 ppm.

Simone Alin, 2016


data transmitted to surface mooring
by cell modem in telebuoy
(~400 m from surface mooring)
data telemetered
to shore near real-time
anemometer
rain gauge
air temp., relative humidity
pCO2 sensor (atmos)
cell modem, VHF modem
pCO2 system
SBE 37 MicroCat
SAMI pH
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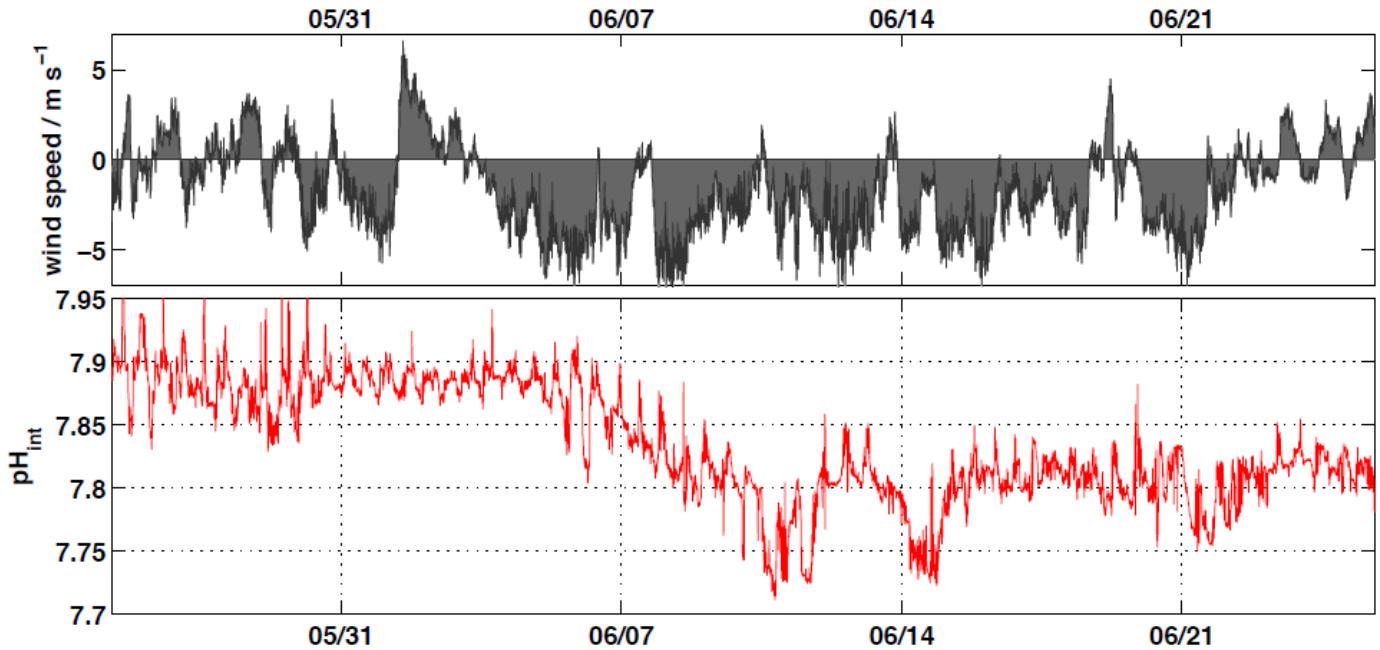
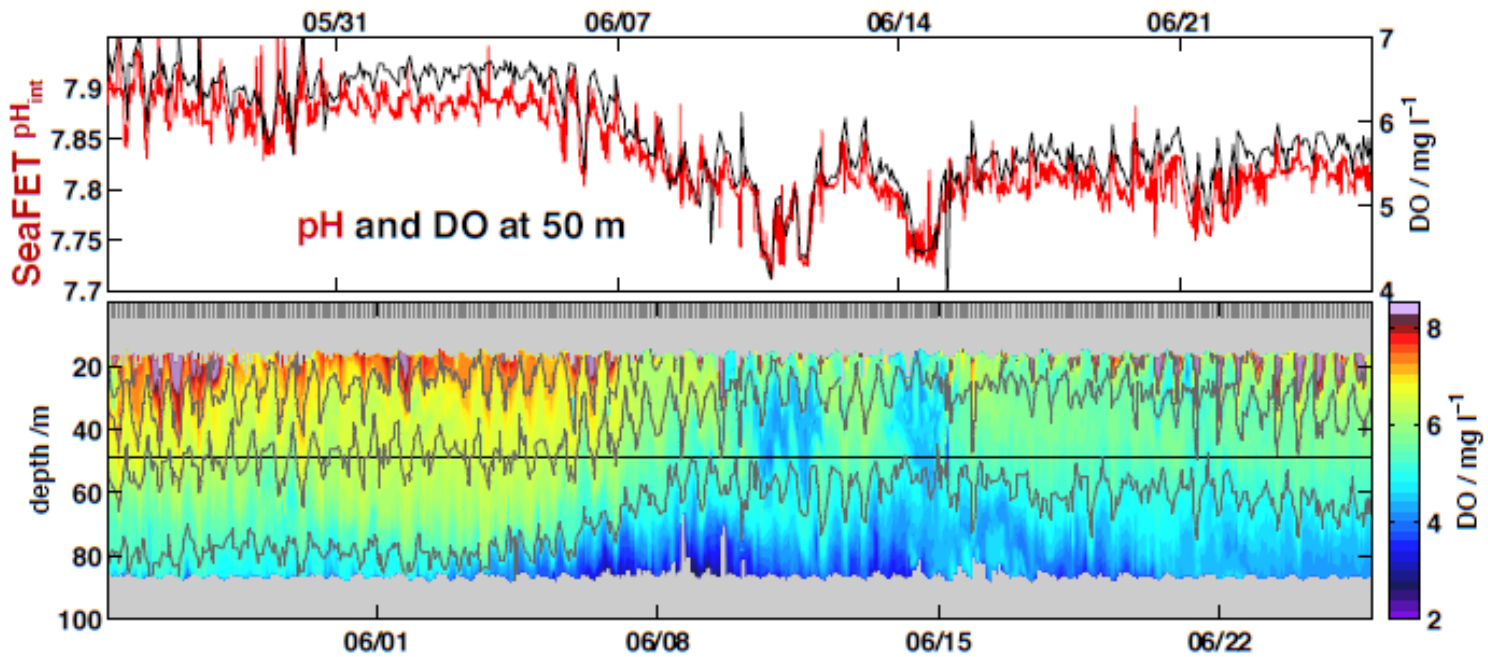
SBE 39
SBE 37 with DO
WQM+ISUS
(CTD,Fluorescence,
backscatter,O2 and nitrate)
SeaFET!
45" syntactic foam float
float depth 15 m in winter
10 m in summer
ADCP 600kHz Workhorse
SBE 37 MicroCat
inductive coupler (ICC)
17 m stopper
McLane profiler
with CTD, O2, velocity, fluorescence,
turbidity and SUNA nitrate sensors
Seaglider
90 m stopper
(4) Benthos glass floats
double ORE CART releases
with recovery line canister +SBE39
100 m
(4) Benthos glass floats
Benthos 865 release
with recovery line canister

Wind

pH


05/31
06/07
06/14
06/21
wind speed / m s^{-1}
5
0
−5
7.95
7.9
7.85
7.8
7.75
7.7
pH$_{int}$


05/31
06/07
06/14
06/21
SeaFET pH$_{int}$
7.9
7.85
7.8
7.75
7.7
pH and DO at 50 m
7
6
5
DO / mg l^{-1}
depth /m
20
40
60
80
100
06/01
06/08
06/15
06/22
8
6
4
2
DO / mg l^{-1}

'Like putting headlights on a car'

Pacific oysters gain from IOOS® data

Promoting Economic Vitality

About six years ago, production at some Pacific Northwest oyster hatcheries began declining at an alarming rate, posing severe economic impact and challenging a way of life held by shellfish growers for more than 130 years.

By 2008, the oyster harvest at Whiskey Creek, a major Oregon supplier to the majority of West Coast oyster farmers, plummeted 80 percent. At about the same time, corrosive, acidified seawater was hitting the shores of the Pacific.

Something had to be done. Oyster production accounts for more than $84 million of the West Coast shellfish industry, which supports more than 3,000 jobs.

"When you see oyster shells dissolving in water, there's a compelling need to know why," says Bill Dewey of Taylor Shellfish Farms in Washington state.

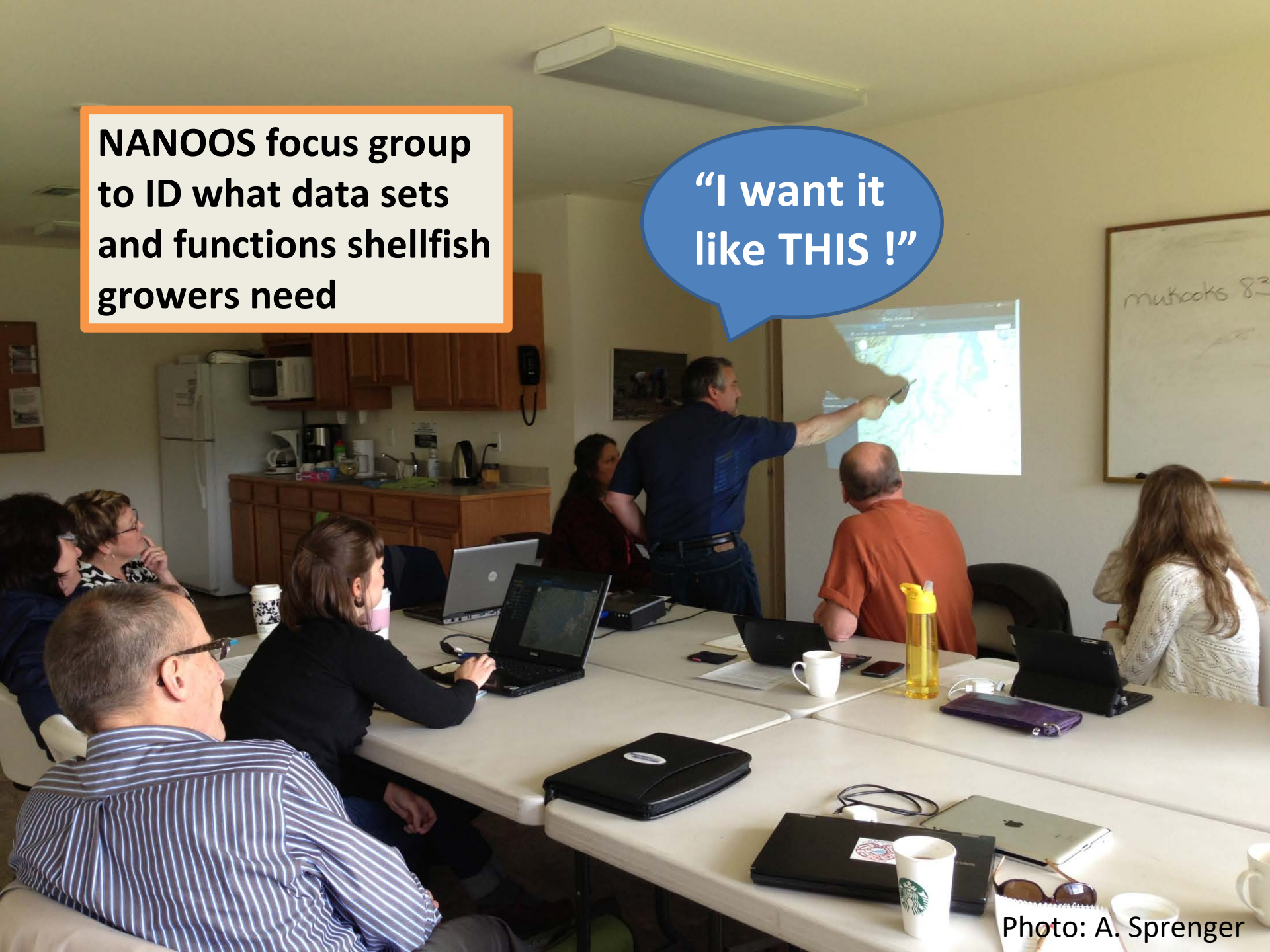
Thanks to a $500,000 federal investment in monitoring coastal seawater strengthened by data and observational information from the U.S. **Integrated Ocean Observing System** (IOOS®) and the **NOAA Ocean Acidification Program**, oyster hatcheries on the verge of collapse just a few years ago are again major contributors to the $111 million West Coast shellfish industry.

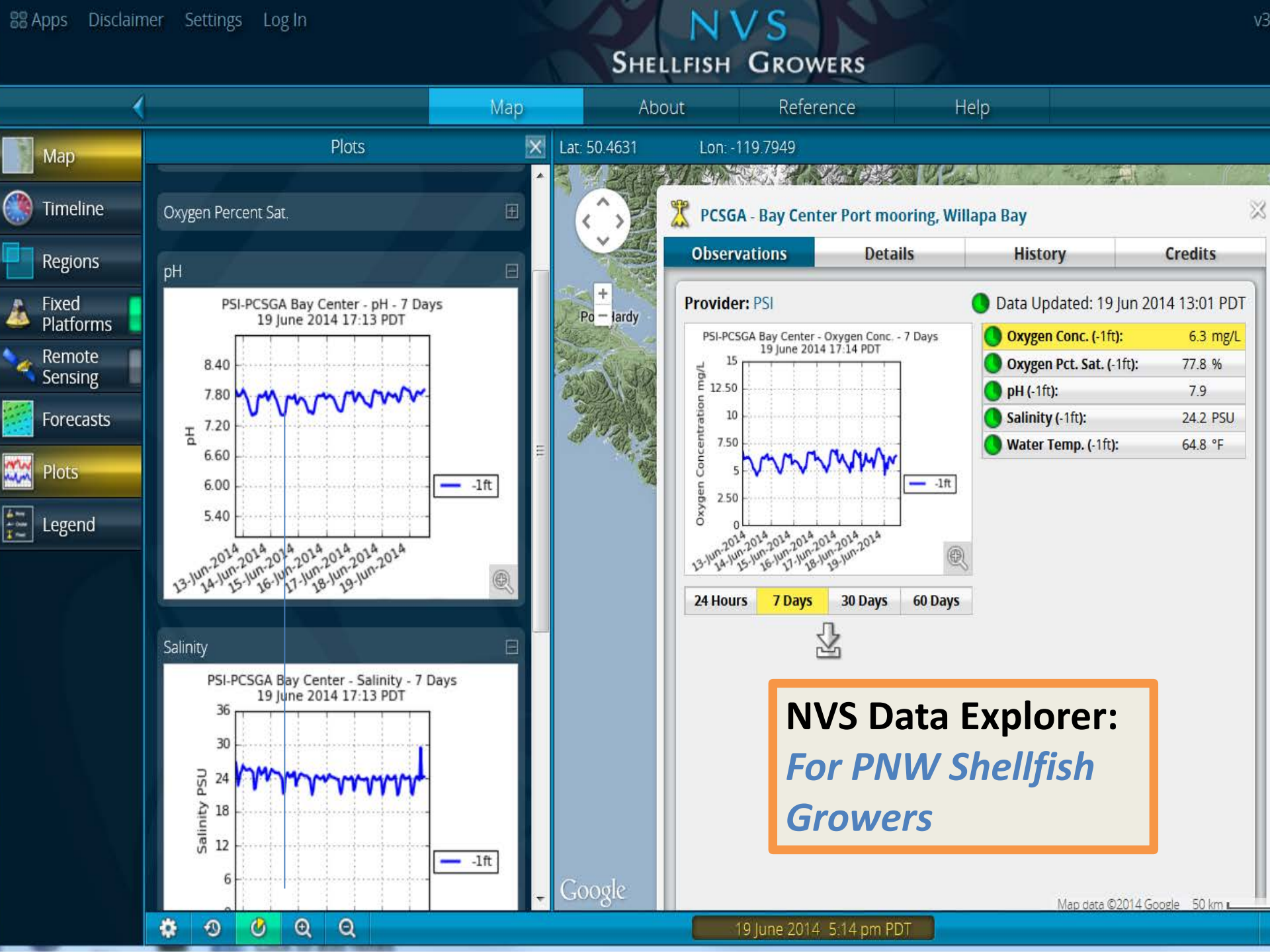
IOOS is a NOAA-led interagency and regional effort aimed at "knowing" — that

IOOS partners in the Northwest Association of Networked Ocean Observing Systems (NANOOS) deployed this buoy in 2010 as part of a three-piece observing array to assess issues in the Northwest, including **ocean acidification**, **hypoxia and harmful algal blooms**, and **climate change**. The coastal buoy will aid computer models that predict ocean and atmospheric conditions. Known as "Chá bă," the buoy is named for the Native American word (pronounced "chay buh") for "whale tail."

(Photo courtesy of Dr. John Payne, Pacific Ocean Shelf

"Putting an IOOS buoy in the water is like putting headlights on a car. It lets us see changing water conditions in real time," says Mark Wiegardt, co-owner of Whiskey Creek Shellfish Hatchery.


NANOOS focus group to ID what data sets and functions shellfish growers need
"I want it like THIS !"
Photo: A. Sprenger



NVS Data Explorer:
For PNW Shellfish Growers

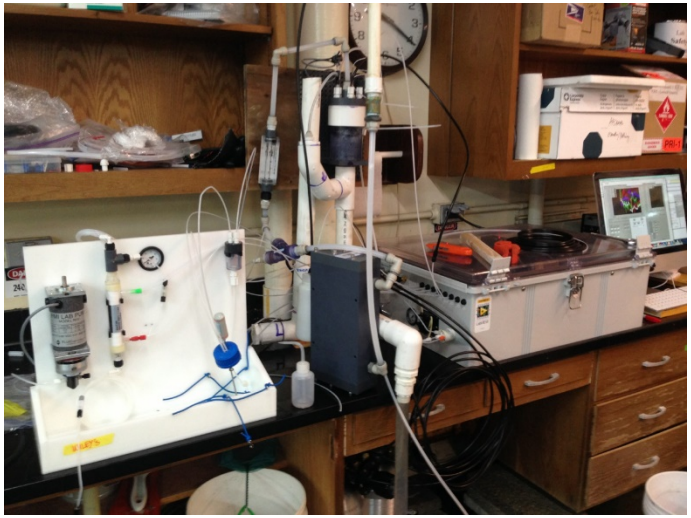
IOOS OTT OA

“Turning the headlight on 'high': Improving an ocean acidification observation system in support of Pacific coast shellfish growers.”

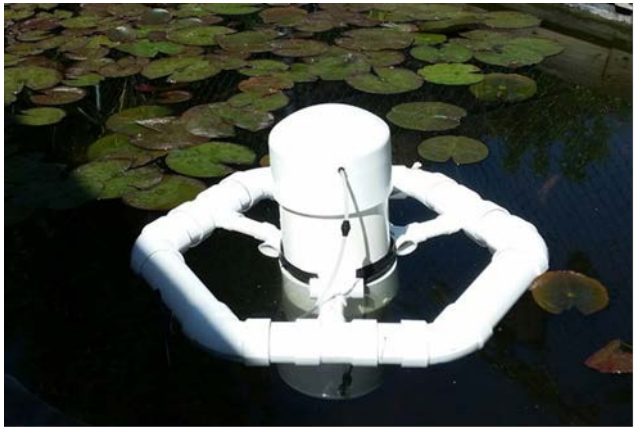
- New “ACDC” pCO_2 sensor
- Lower cost pCO_2 for “weather” grade data
- Strong support from shellfish industry
- Partnerships: UW, OSU, Sunburst, AOOS, CeNCOOS, SCCOOS, NOAA PMEL, PCSGA
- Builds on current MSI award for Burke-o-lators in more hatcheries and new IPACOA portal

Monitoring OA is more than a pH sensor …
… need to understand aragonite saturation state

Burkeolator

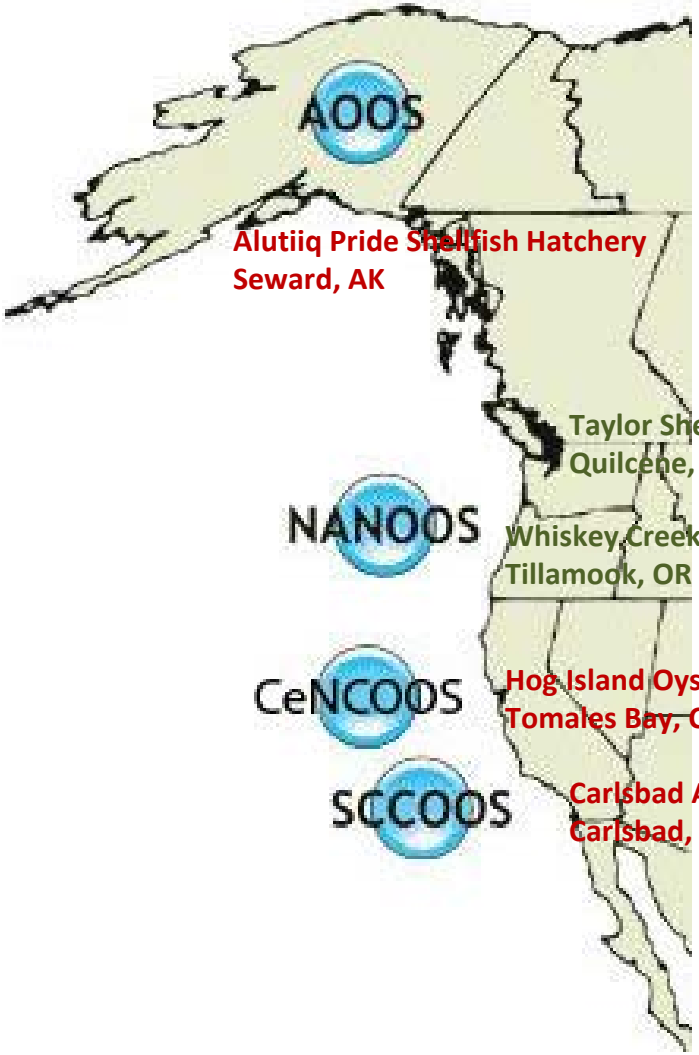


ACDC



We have learned from growers that their **ideal monitoring technology** is: “a bullet proof sensor that delivers pH, aragonite saturation, T, and S. **Similar** to the system we have in place now **but lighter and not so crashy**”
Alan Barton, Pacific Coast Shellfish Growers Association monitoring lead

IOOS Shellfish Industry Partnerships



OAP OCEAN ACIDIFICATION PROGRAM

IOOS

IOOS Shellfish Industry Partnerships

AOOS
Alaska Ocean Observing System

Alutiiq Pride Shellfish Hatchery
Seward, AK

NANOOS

Taylor Shellfish Hatchery
Quilcene, WA

Whiskey Creek Shellfish Hatchery
Tillamook, OR

CeNCOOS

Hog Island Oyster Company
Tomales Bay, CA

Southern California Coastal Ocean Observing System

Carlsbad Aquafarm
Carlsbad, CA

STATE OF OREGON
1859

OAP
OCEAN ACIDIFICATION PROGRAM

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Science-Grower Partnerships

Wiley Evans,
Hakai Institute

Simone Alin,
NOAA PMEL

QA

Tessa Hill,
UC Davis

Burke Hales,
OSU

Todd Martz,
SIO

AOOS
Alaska Ocean Observing System

Alutiiq Pride Shellfish Hatchery
Seward, AK

NANOOS

Taylor Shellfish Hatchery
Quilcene, WA

Whiskey Creek Shellfish Hatchery
Tillamook, OR

CeNCOOS

Hog Island Oyster Company
Tomales Bay, CA

Southern California Coastal Ocean Observing System

Carlsbad Aquafarm
Carlsbad, CA

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OAP
OCEAN ACIDIFICATION PROGRAM

IOOS

Science-Grower Partnerships

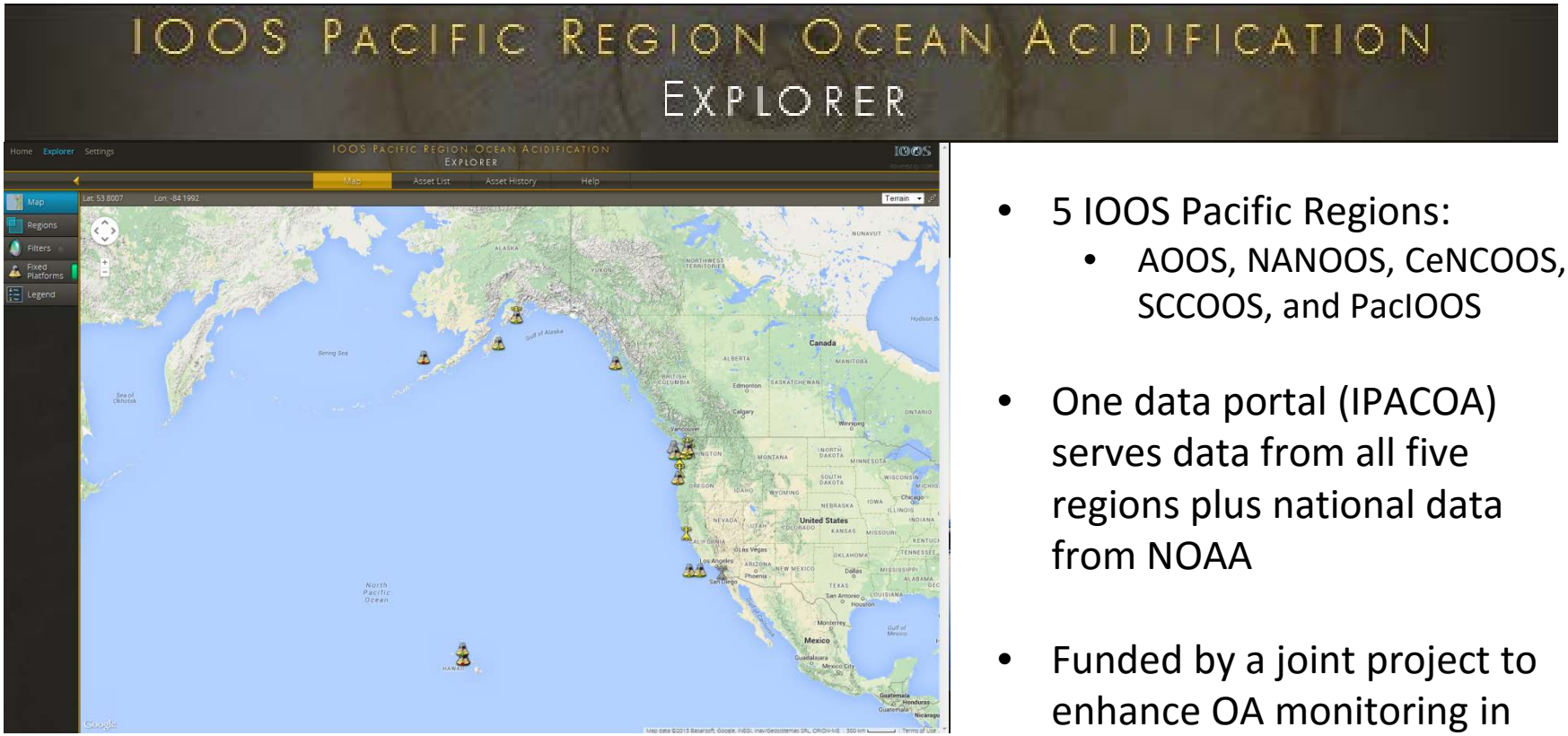
Site	On-site	Regional support	Regional Expert
Alutiiq Pride Shellfish, Seward, AK	J. Hetrick* (APSH)	J. Ramsay (UAF/APSH)	W. Evans (Hakai Institute)
Taylor Shellfish, Quilcene, WA	B. Eudeline* (Taylor)	G. LeBon (NOAA/PMEL)	S. Alin (NOAA/PMEL)
Whiskey Creek Shellfish, Netarts, OR	A. Barton* (WCSH)	S. Smith/D. Hubbard (OSU)	B. Hales (OSU)
Hog Island Oyster Co., Marshall, CA	T. Sawyer* (HIOC)	G. Susner (UCD-Bodega)	T. Hill (UCD-Bodega)
Carlsbad AquaFarm, Carlsbad, CA	T. Grimm* (CAF)	K. Shipley (UCSD-SIO)	T. Martz (UCSD – SIO)

*Hatchery manager responsible for designating routine maintenance responsibilities to hatchery personnel.

This partnership will expand to other places, and has to BC thanks to Hakai:

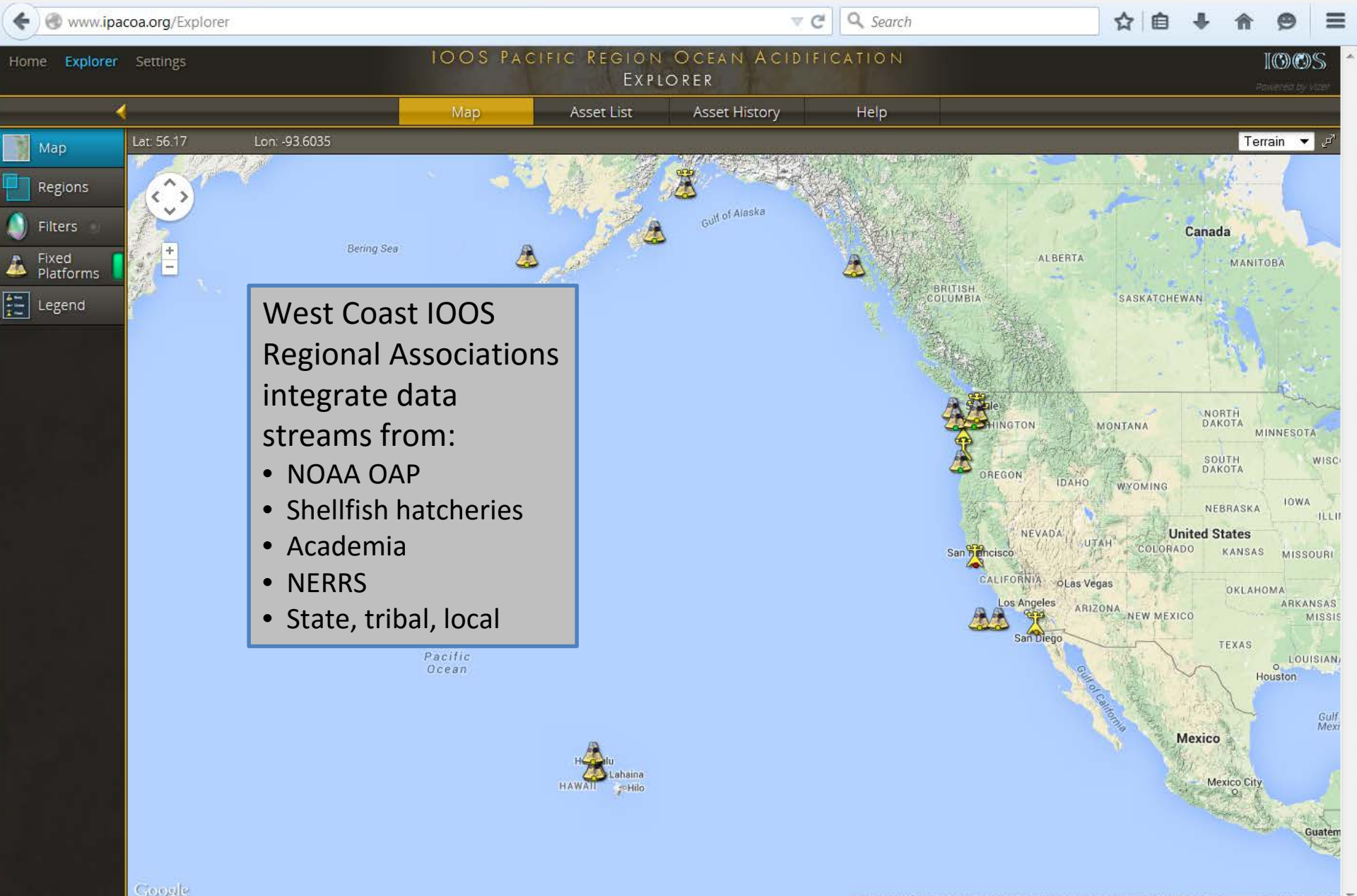
From Ron Zebel: *"Fantastic job Wiley. At the OceansAlaska hatchery,* ***we learned more about our water quality in 7 hours of Burke-O-Lator data than we did in 7 years of monitoring with off the shelf instrumentation****. We have adjusted our soda ash injections upward and are going forward with expanded kelp bioconditioning."*

Working Together within the Pacific: ***IOOS Pacific Region Ocean Acidification data portal***



- 5 IOOS Pacific Regions:
  - AOOS, NANOOS, CeNCOOS, SCCOOS, and PacIOOS
- One data portal (IPACOA) serves data from all five regions plus national data from NOAA
- Funded by a joint project to enhance OA monitoring in shellfish hatcheries

IPACOA: IOOS Pacific Region ocean acidification data portal



West Coast IOOS Regional Associations integrate data streams from:

- NOAA OAP
- Shellfish hatcheries
- Academia
- NERRS
- State, tribal, local

IPACOA: IOOS Pacific Region ocean acidification data portal

www.ipacoa.org/Explorer

Home Explorer Settings

IOOS Pacific Region Ocean Acidification Explorer

Map | Asset List | Asset History | Help

Map
Regions
Filters
Fixed Platforms
Legend

Lat: 62.1368 Lon: -172.002

Terrain

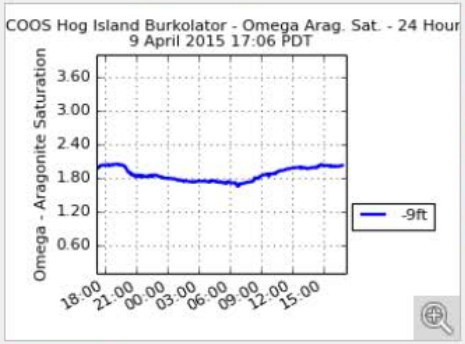
Bering Sea

CeNCOOS Burkolator at Hog Island Oyster Farm

Observations | Details | Credits

Provider: Hog Island Oysters

Data Updated: 9 Apr 2015 16:45 PDT



Alkalinity (-9ft):	2034.8 µmol/kg
CO2 Water (-9ft):	363.8 µatm
TCO2 (-9ft):	1862.1 µmol/kg
Omega Arag. Sat. (-9ft):	2
pH (-9ft):	8
Salinity (-9ft):	29.7 PSU
Water Temp. (-9ft):	59.5 °F

24 Hours | 7 Days | 30 Days | 60 Days

Link

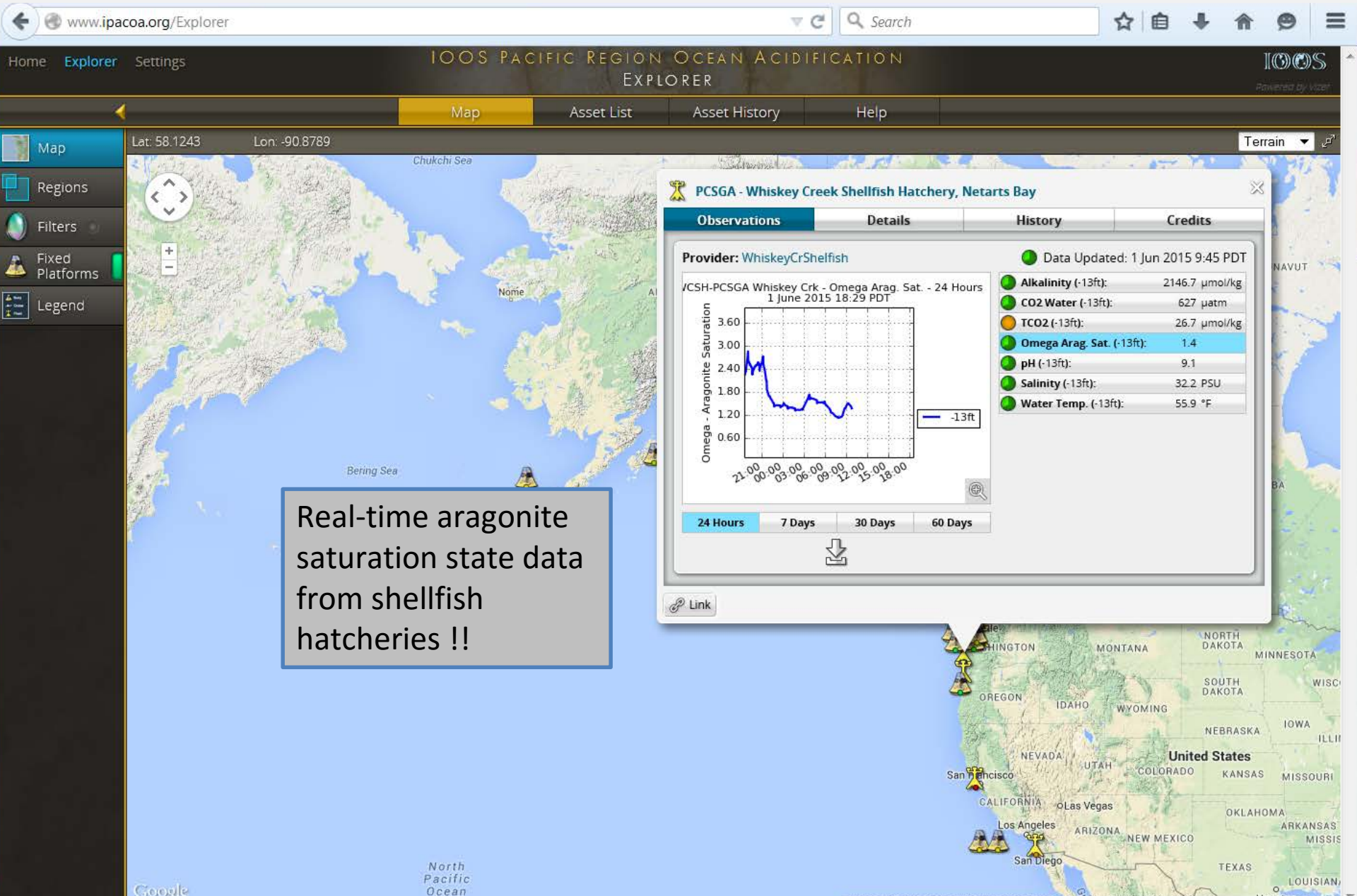
Real-time aragonite saturation state data from shellfish hatcheries !!

NEVADA UTAH COLORADO KANSAS United States CALIFORNIA Las Vegas Los Angeles ARIZONA Phoenix NEW MEXICO San Diego

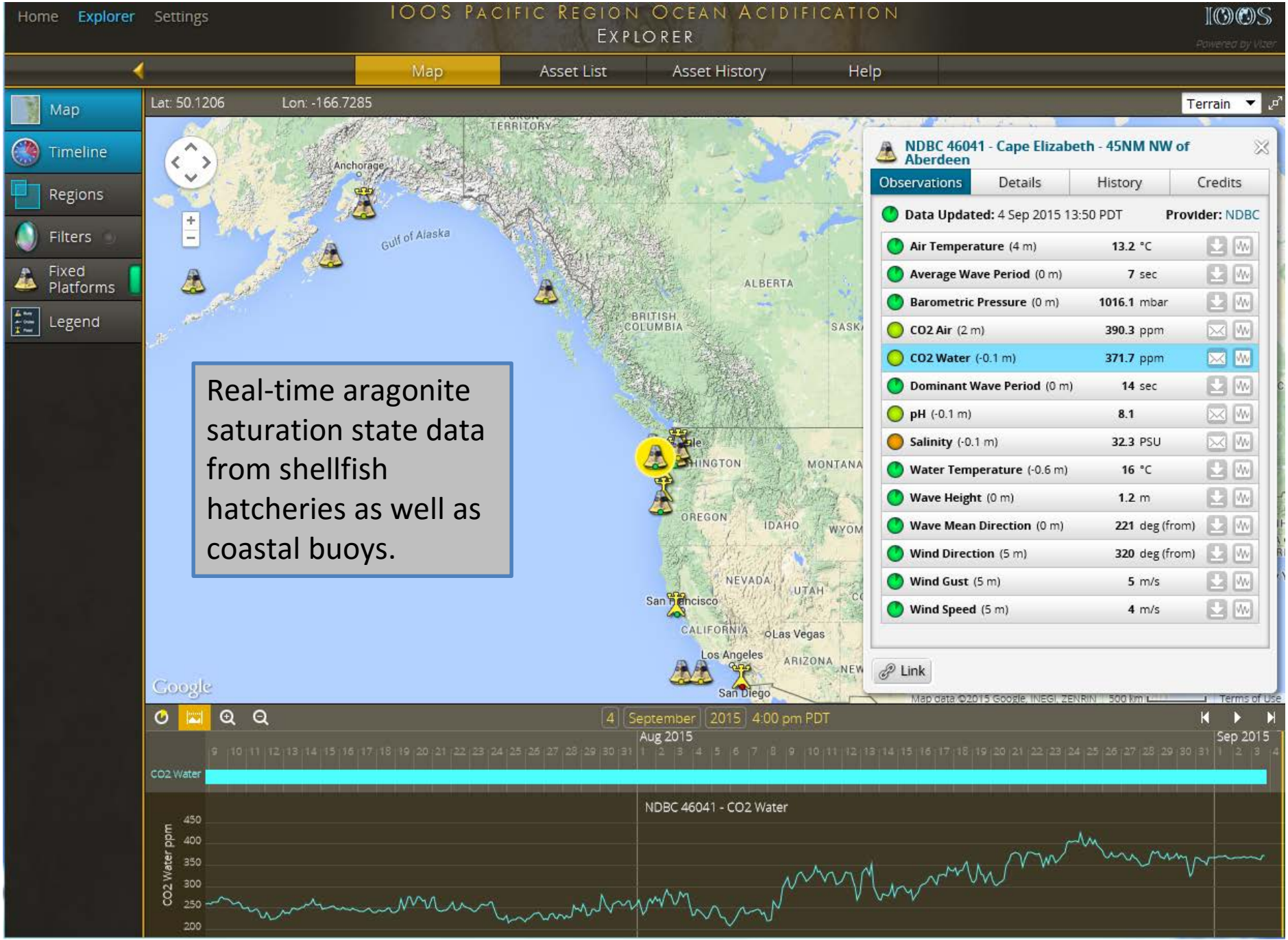
Google North

Map data ©2015 Google, INEGI, Inav/Geosistemas SRL, SK planet, ZENRIN 500 km Terms of Use

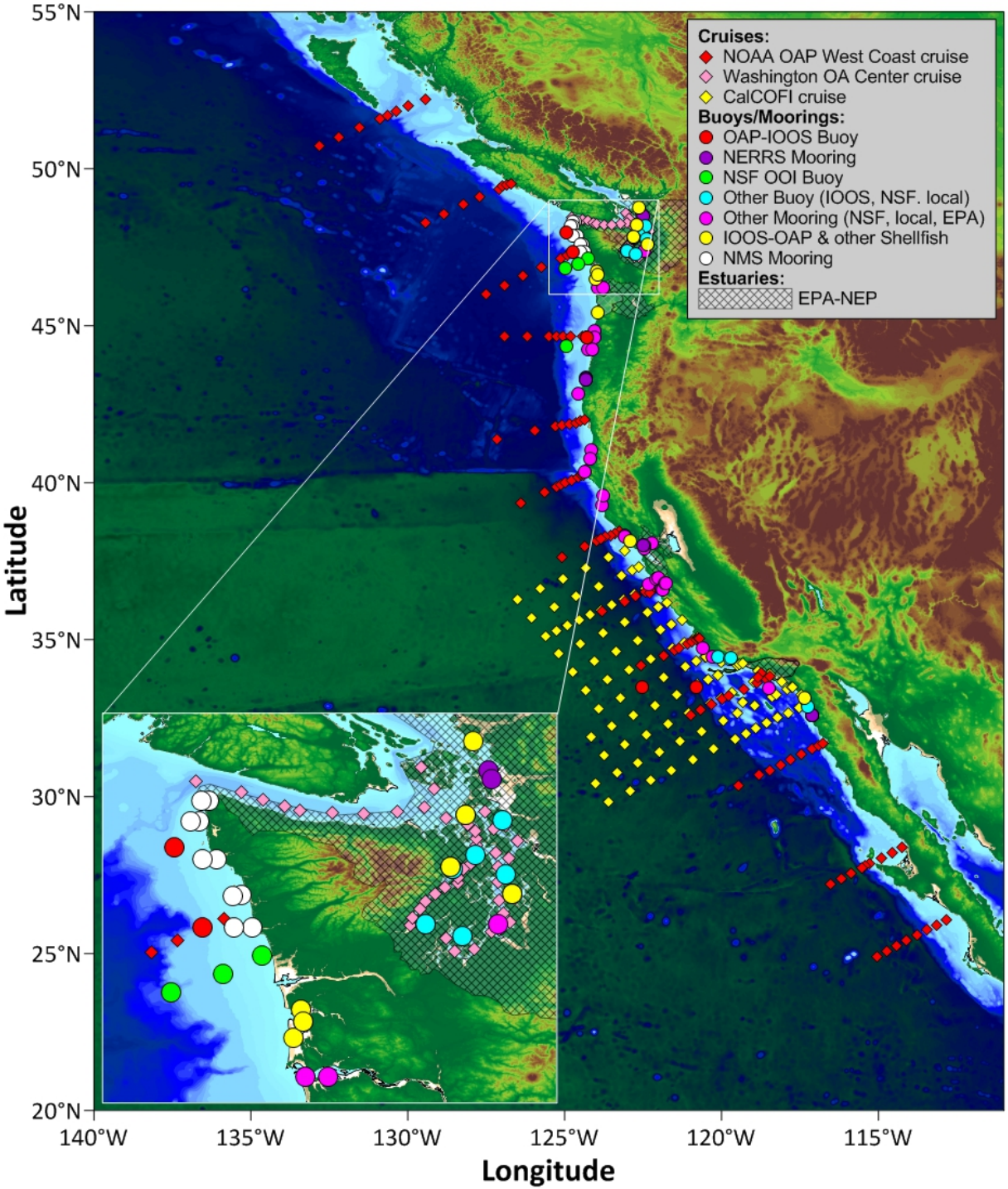
IPACOA: IOOS Pacific Region ocean acidification data portal



IPACOA: IOOS Pacific Region ocean acidification data portal



Real-time aragonite saturation state data from shellfish hatcheries as well as coastal buoys.



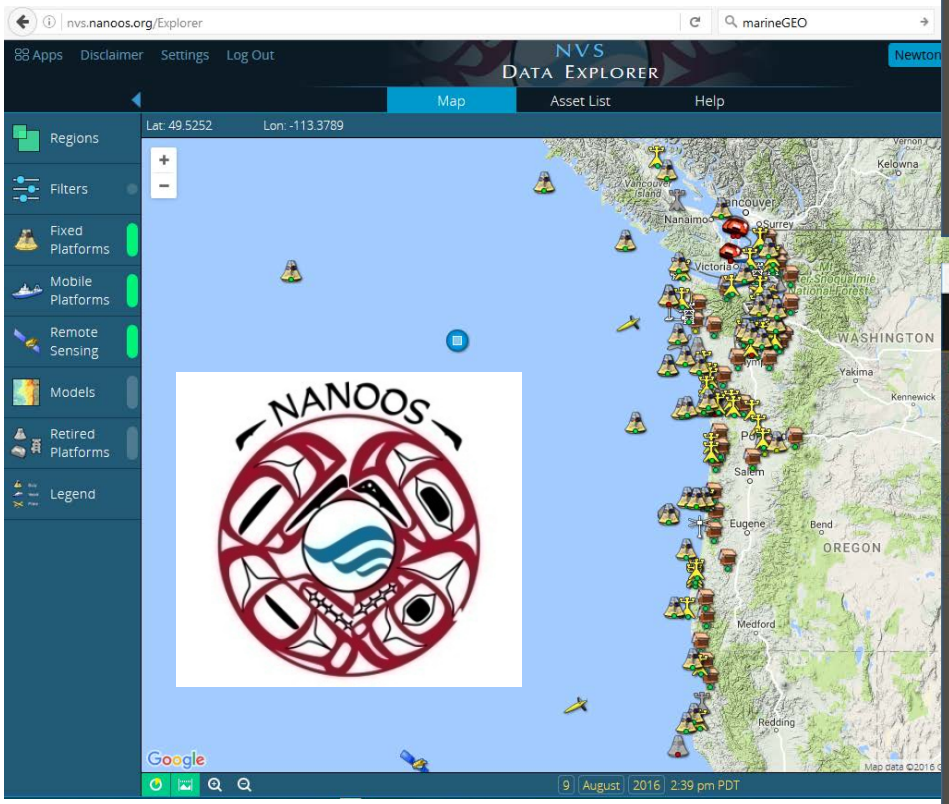
West Coast Ocean Acidification and Hypoxia asset inventory

WCOAH Panel developed an WCOAH monitoring framework

IOOS RAs are updating the inventory for optimizing the strategy

Pacific Coast Collaborative, state govt's, etc. involved on policy information needs

From NANOOS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Help
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Lon: -113.3789
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Mobile Platforms
Remote Sensing
Models
Retired Platforms
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Remote Sensing
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GOA-ON
Global Ocean Acidification Observing Network
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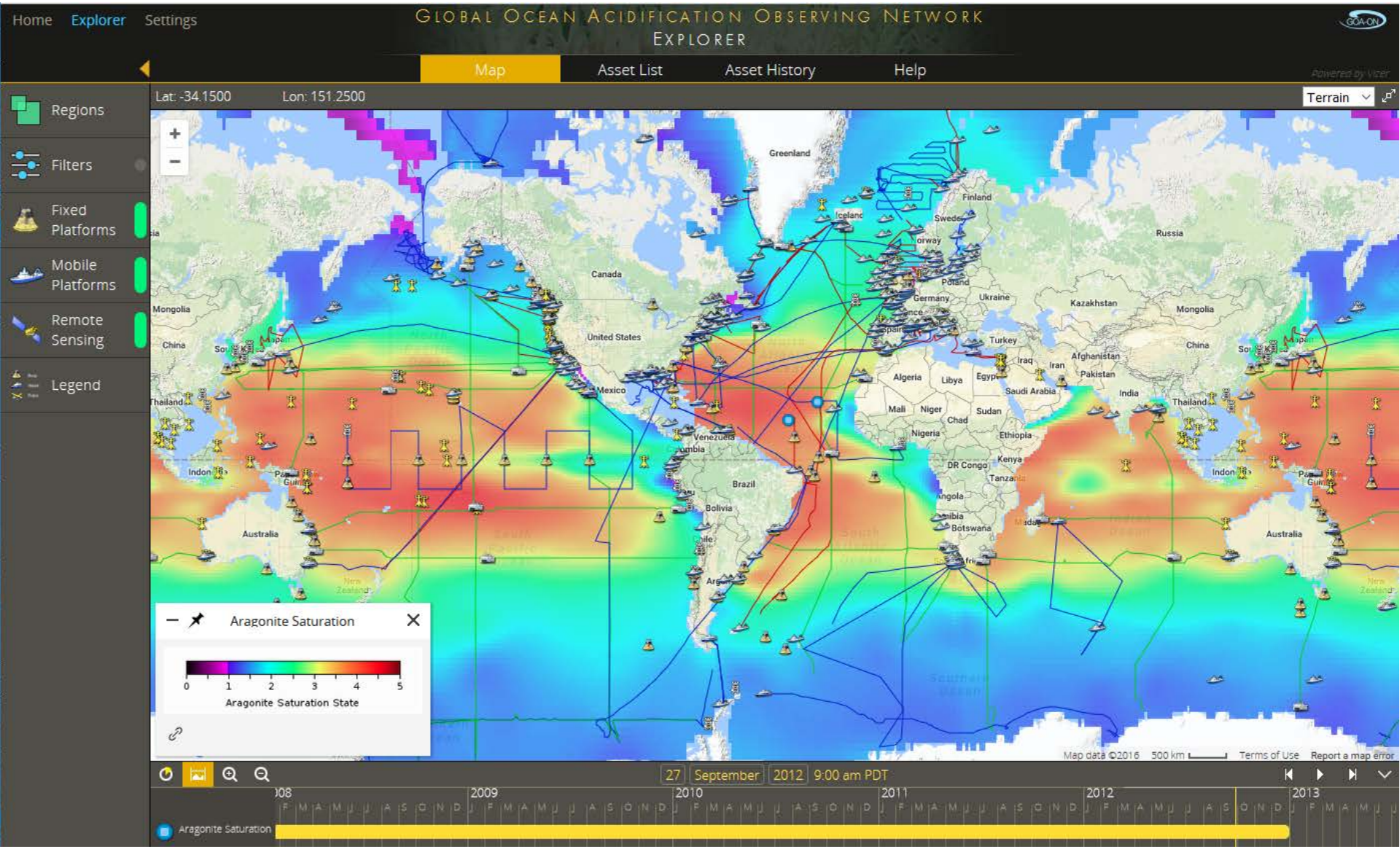
The GOA-ON interactive data portal

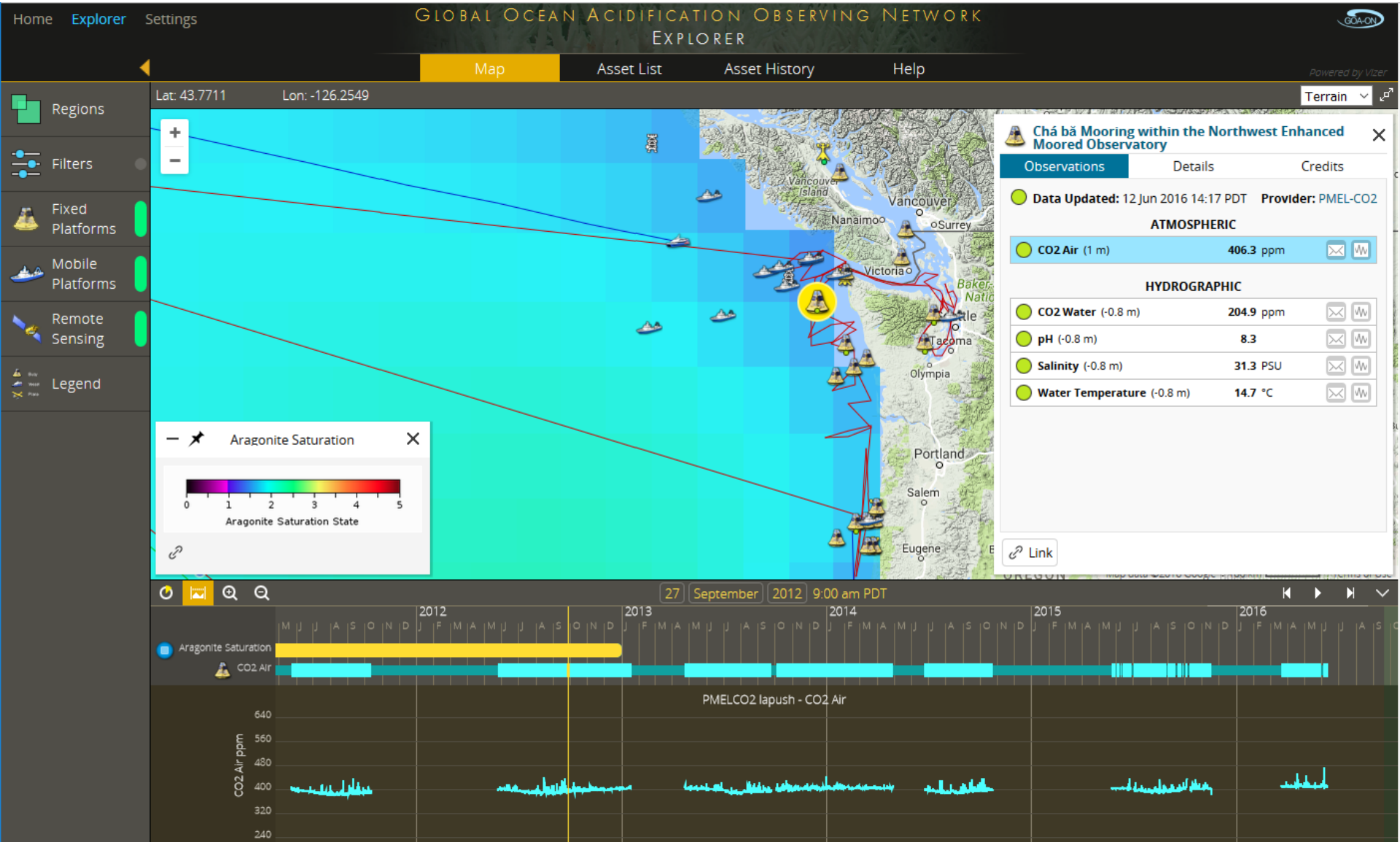
Featuring global OA data, asset inventory, metadata, data synthesis products, etc.

GOA-ON
Global Ocean Acidification Observing Network



The GOA-ON interactive data portal

GOA-ON
Global Ocean Acidification Observing Network



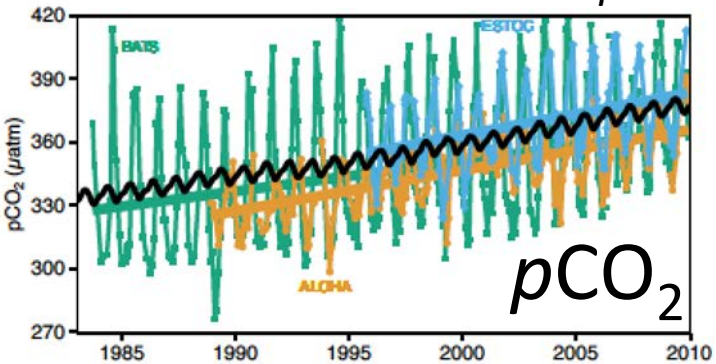
GOA-ON

Global Ocean Acidification Observing Network

3rd workshop, Hobart, TAS

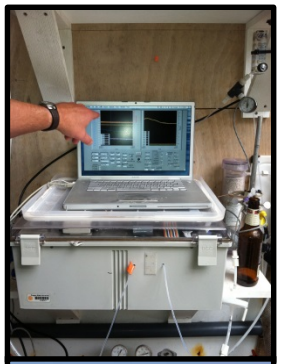
130 scientists from 37 nations

Source: IPCC Report



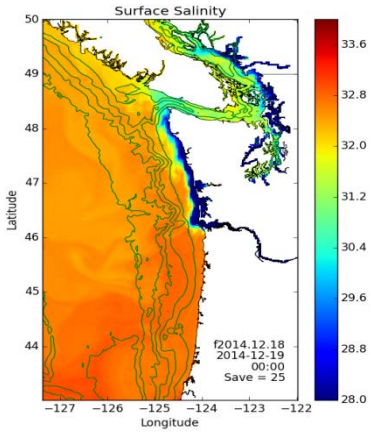
OA is
a global condition
with
local effects

Decision critical info for adaptation



Real-time observations at the hatchery or growing sites

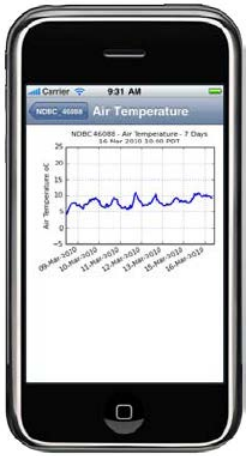
Real-time observations at the adjacent estuary, sea, or ocean



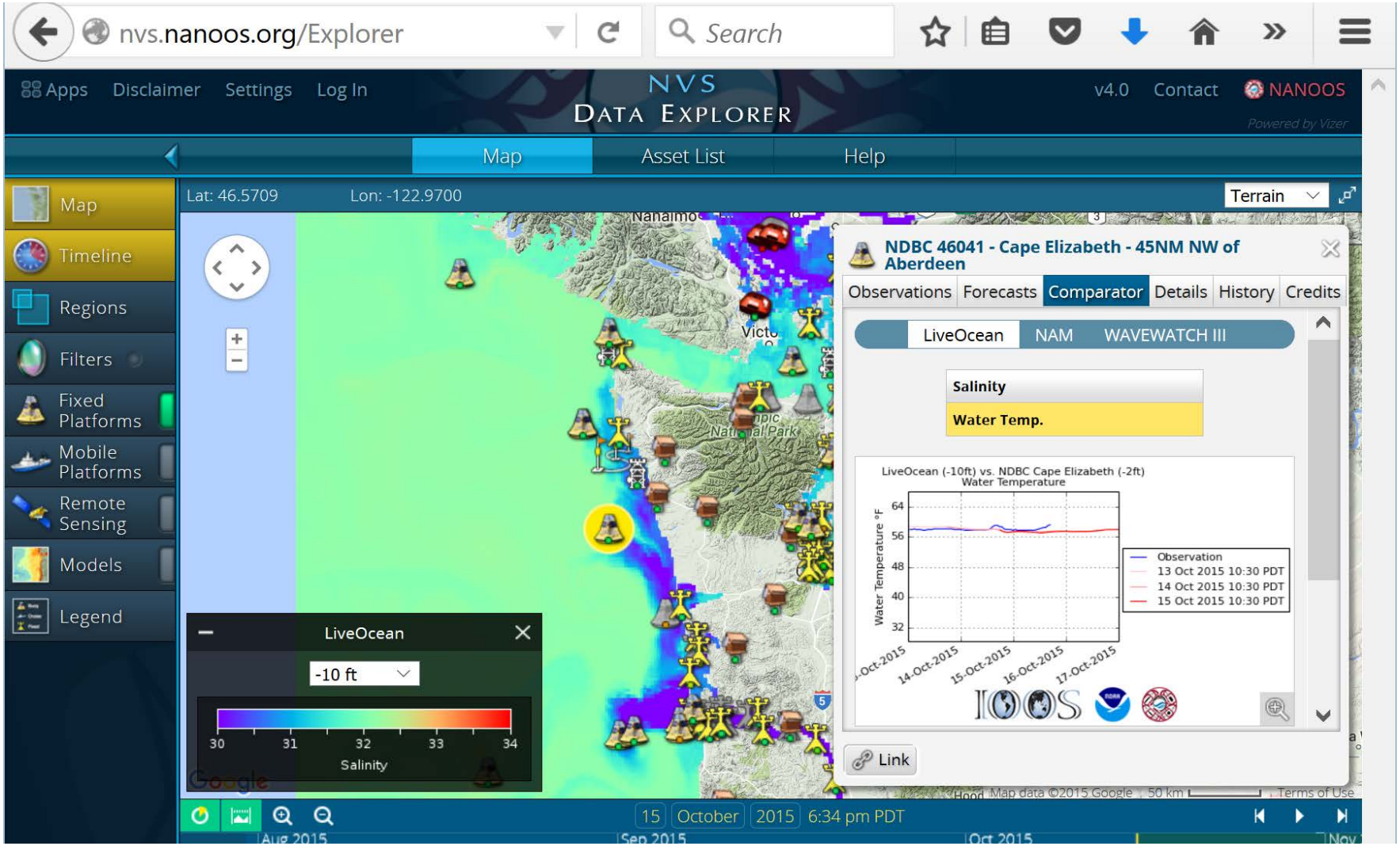
Regional forecasts on days to weeks scale (weather)

Forecasts at months to years scale (seasonal to interannual)

Communicated !!

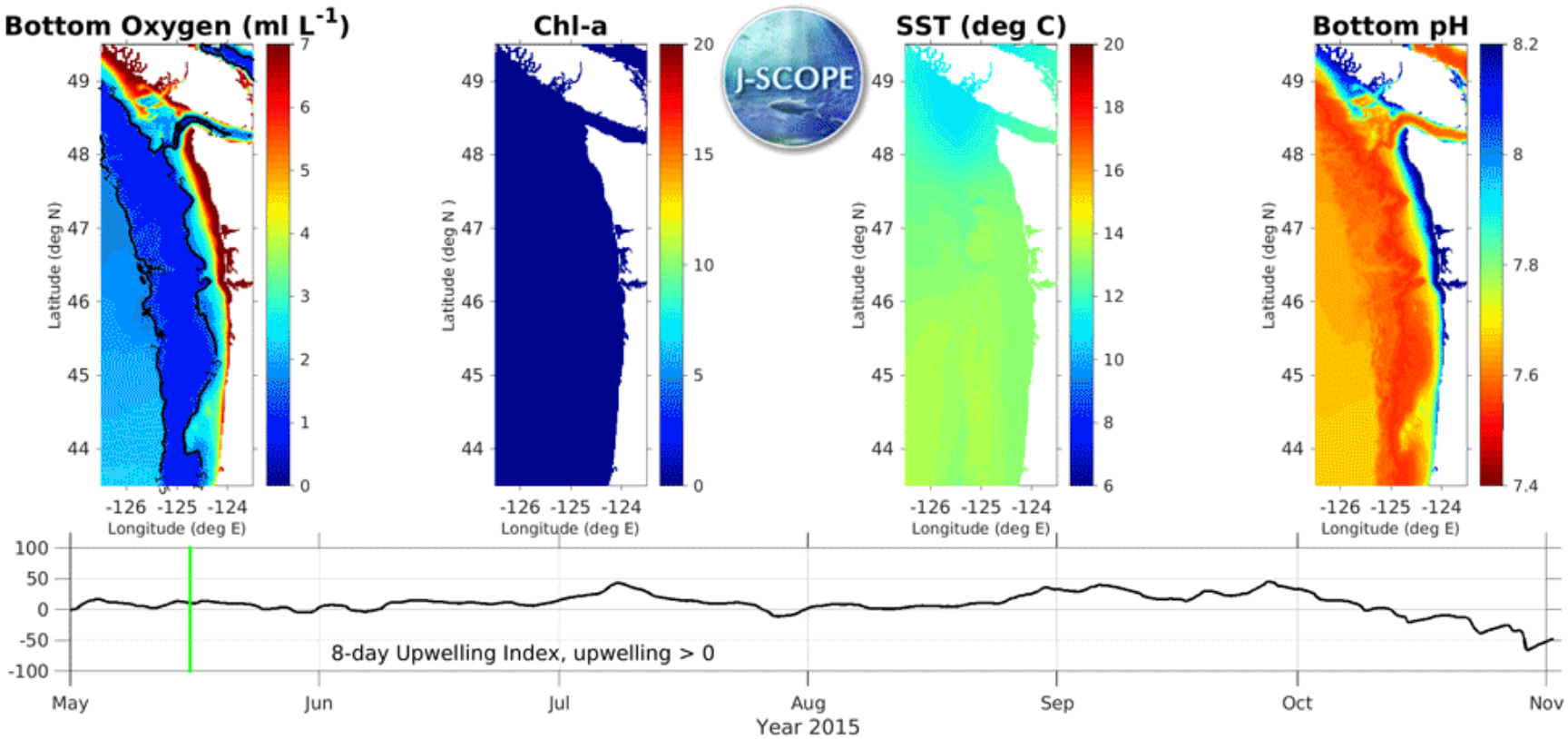


NANOOS & WOAC: UW Live Ocean



MacCready et al., UW

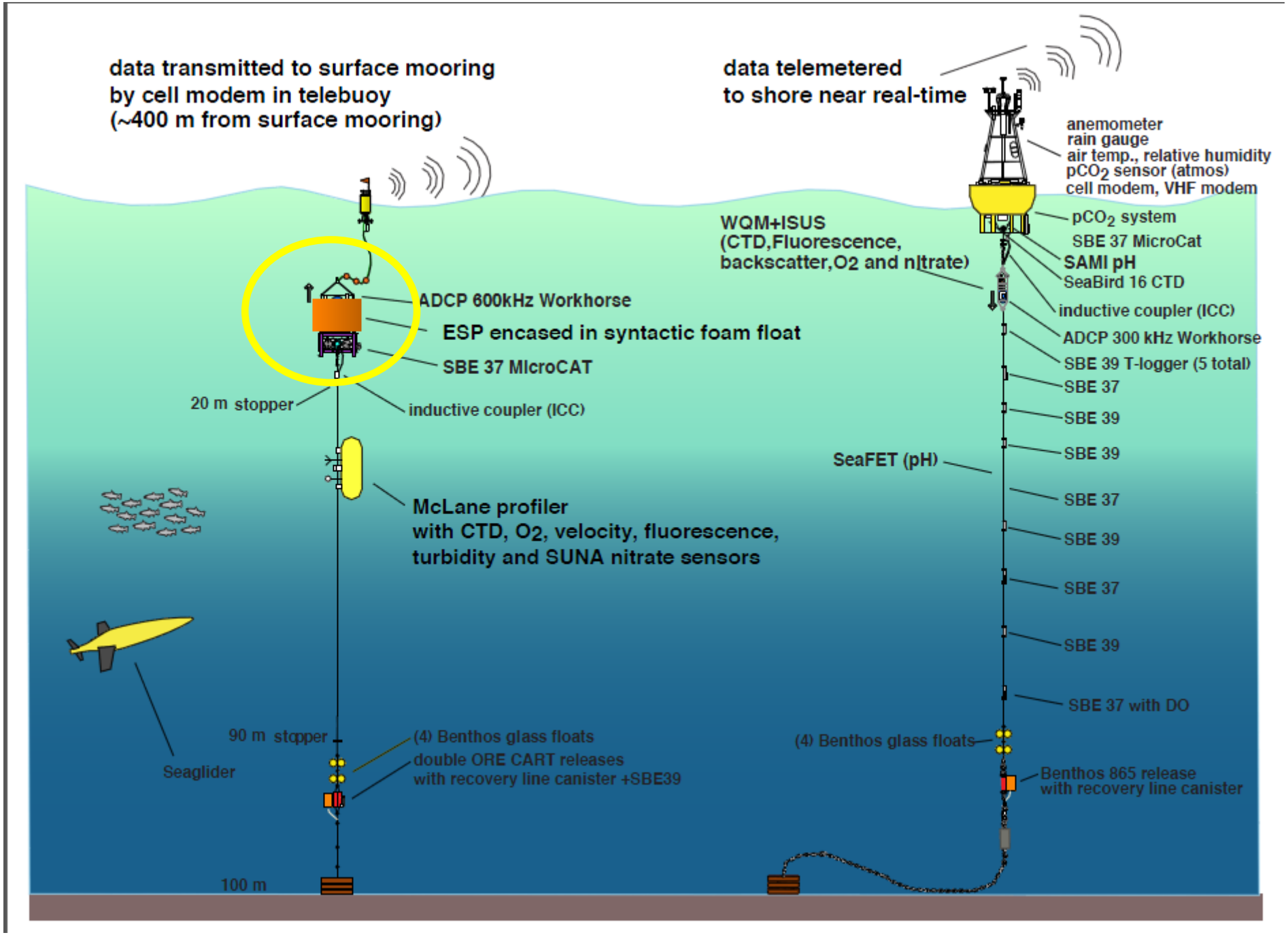
Breaking ground to seasonal ecosystem forecasting: hypoxia, OA, sardines



Siedlecki et al., UW

Multiple stressors re supporting PNW economy

- OA
- HABs
- Hypoxia
- Marine heat waves
- Coastal resiliency: tsunami
- Navigation, safety
- Lack of knowledge


data transmitted to surface mooring
by cell modem in telebuoy
(~400 m from surface mooring)
data telemetered
to shore near real-time
anemometer
rain gauge
air temp., relative humidity
pCO2 sensor (atmos)
cell modem, VHF modem
pCO2 system
SBE 37 MicroCat
SAMI pH
SeaBird 16 CTD
inductive coupler (ICC)
ADCP 300 kHz Workhorse
SBE 39 T-logger (5 total)
SBE 37
SBE 39
SBE 39
SBE 37
SBE 39
SBE 37
SBE 39
SBE 37 with DO
WQM+ISUS
(CTD,Fluorescence,
backscatter,O2 and nitrate)
ADCP 600kHz Workhorse
ESP encased in syntactic foam float
SBE 37 MicroCAT
20 m stopper
inductive coupler (ICC)
SeaFET (pH)
McLane profiler
with CTD, O2, velocity, fluorescence,
turbidity and SUNA nitrate sensors
Seaglider
90 m stopper
(4) Benthos glass floats
double ORE CART releases
with recovery line canister +SBE39
(4) Benthos glass floats
Benthos 865 release
with recovery line canister
100 m

IOOS OTT: HABs

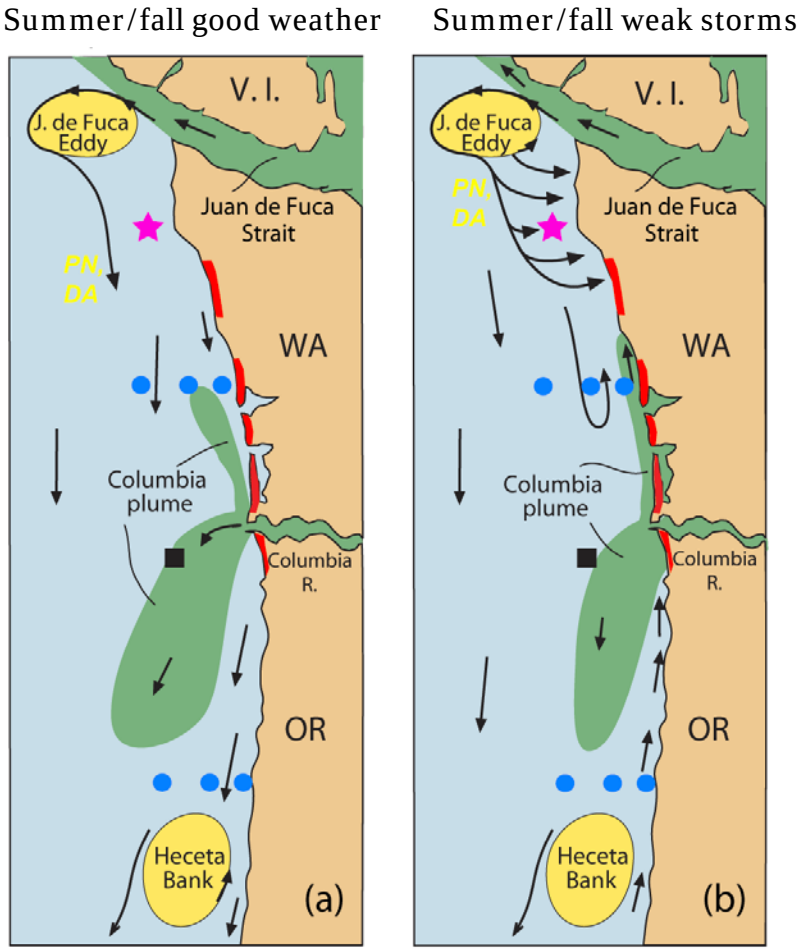
"Operational ecological forecasting of harmful algal blooms in the Pacific Northwest using an environmental sample processor"

- ESP on Cha'ba at La Push
- Detects *Pseudo-nitzschia* species and toxicity
- Strong support from coastal tribes and state
- Partnerships: UW, NOAA NWFSC, MBARI, NOAA CCEHBR, NWIC, Spyglass, WHOI
- NANOOS serving data
- HAB bulletin developments

Deploying ESP on an existing NANOOS real-time moored observatory in the U.S. Pacific Northwest

Mickett (UW), Moore (NOAA) et al. US IOOS OTT funding

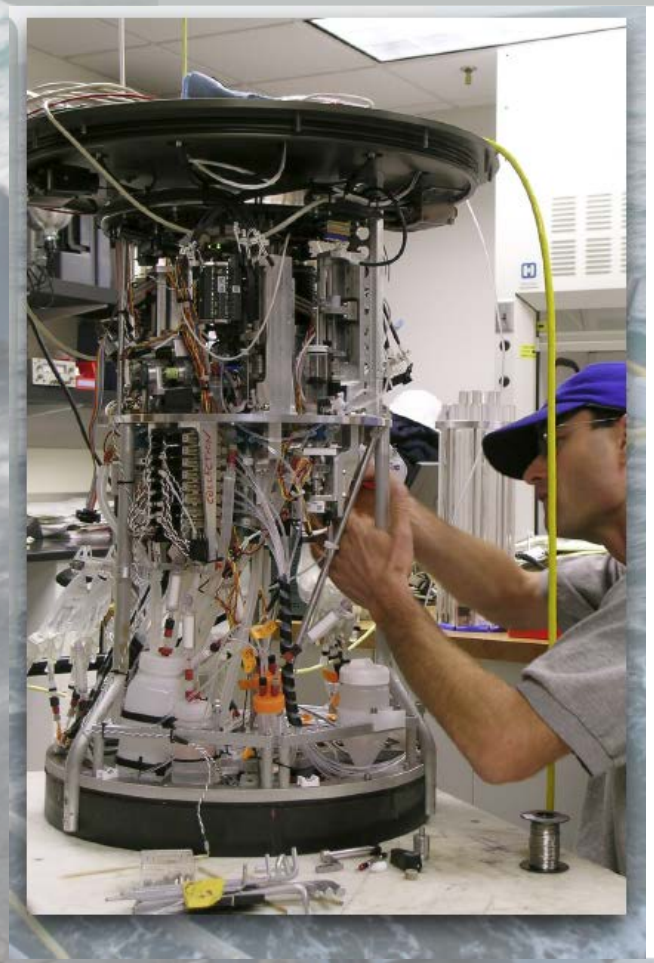
- NANOOS mooring updated with ESP
- OOI Endurance Array moorings
- NDBC wind buoy
- Razor clam beaches
- Fresher plume water
- Semi-retentive areas



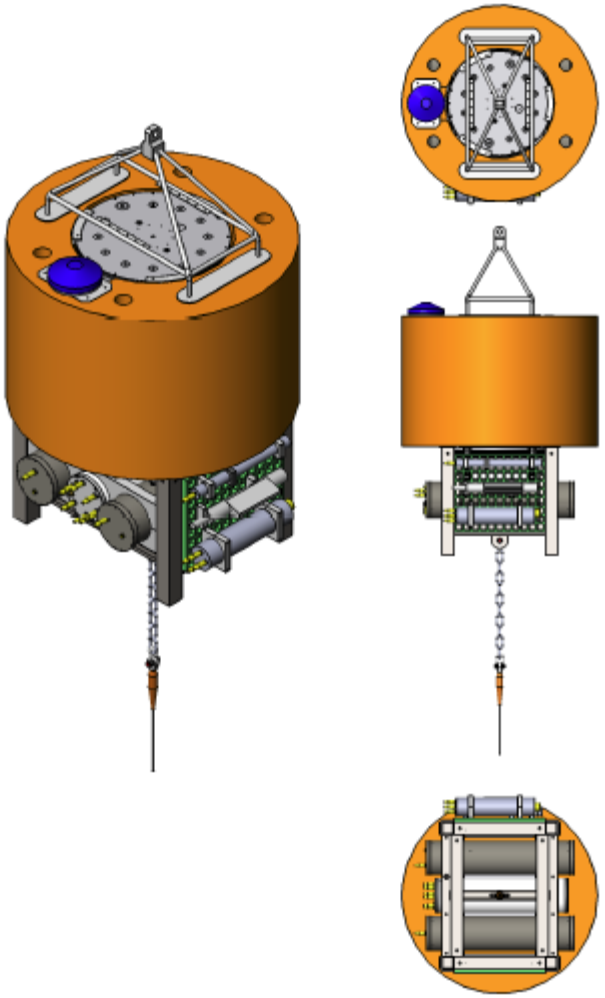
[modified from Hickey et al. 2013]

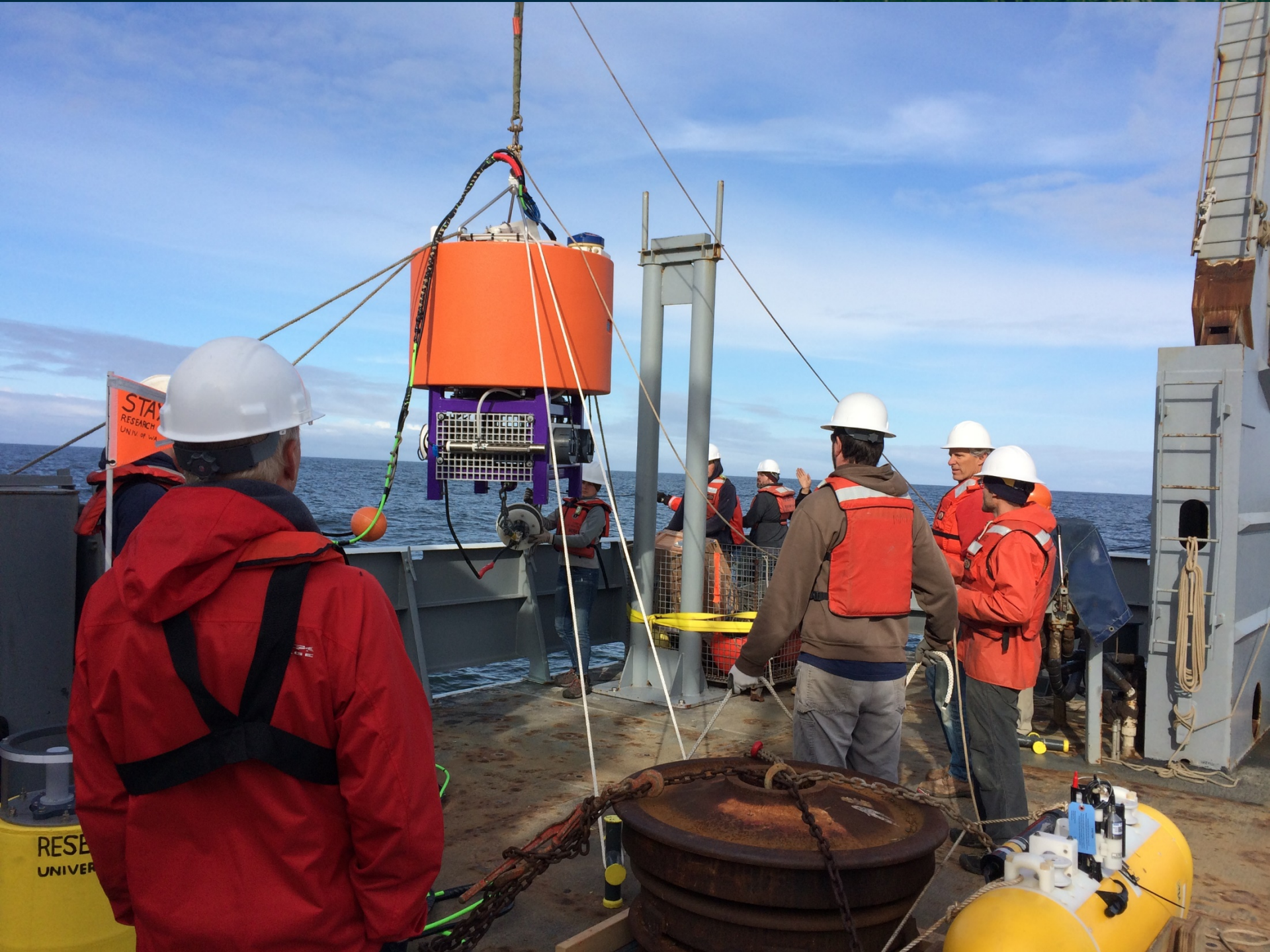
NEMO Environmental Sample Processor

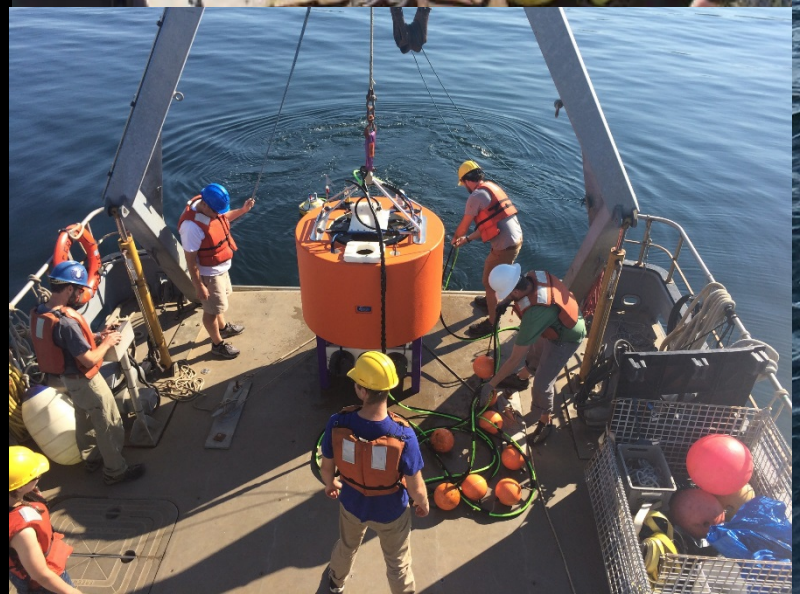
- APL lead of 7-institution effort.
- designed and built the mooring infrastructure, pressure case, power system, telemetry system, and pump sampling system.
- significantly expands the scope of deployment environments for the ESP.



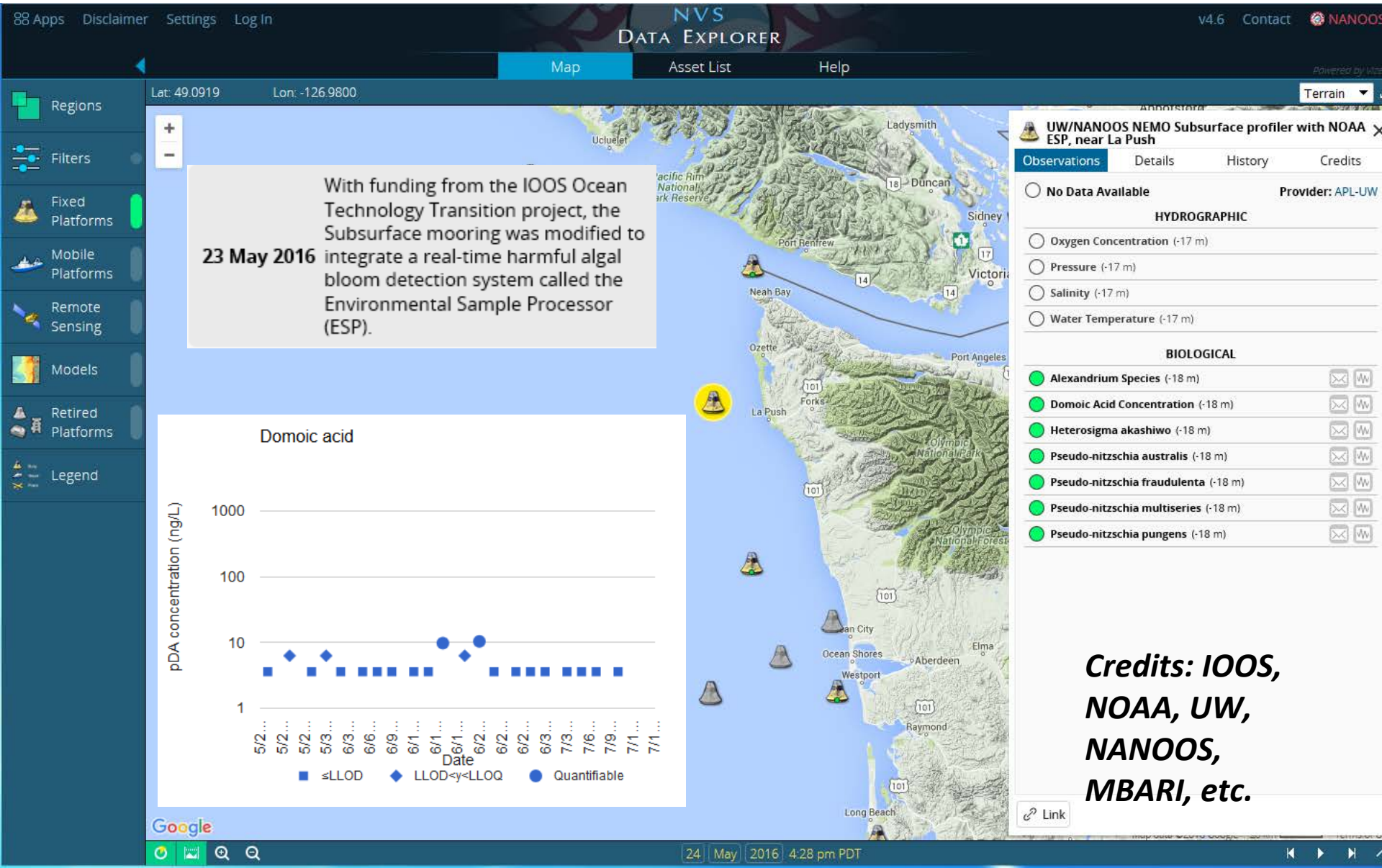
ITEM NO.	DESCRIPTION	QTY.
1	FRAME BASE, GALVANIZED STEEL	1
2	NEMO MOORING CONTROLLER	1
3	ESP BATTERY HOUSING	2
4	ESP ASSEMBLY	1
5	750M SYNTACTIC FOAM	1
6	THRU LIFT FRAME, 316SS	1
7	TELEDYNE SENTINEL ADCP	1
8	FIBERGLASS GRATING	2
9	SATLANTIC SUNA	1
10	SEABIRD 37	1
11	SATLANTIC SEAFET	1




STA
RESEARCH
UNIV. OF WA
RESE
UNIVER



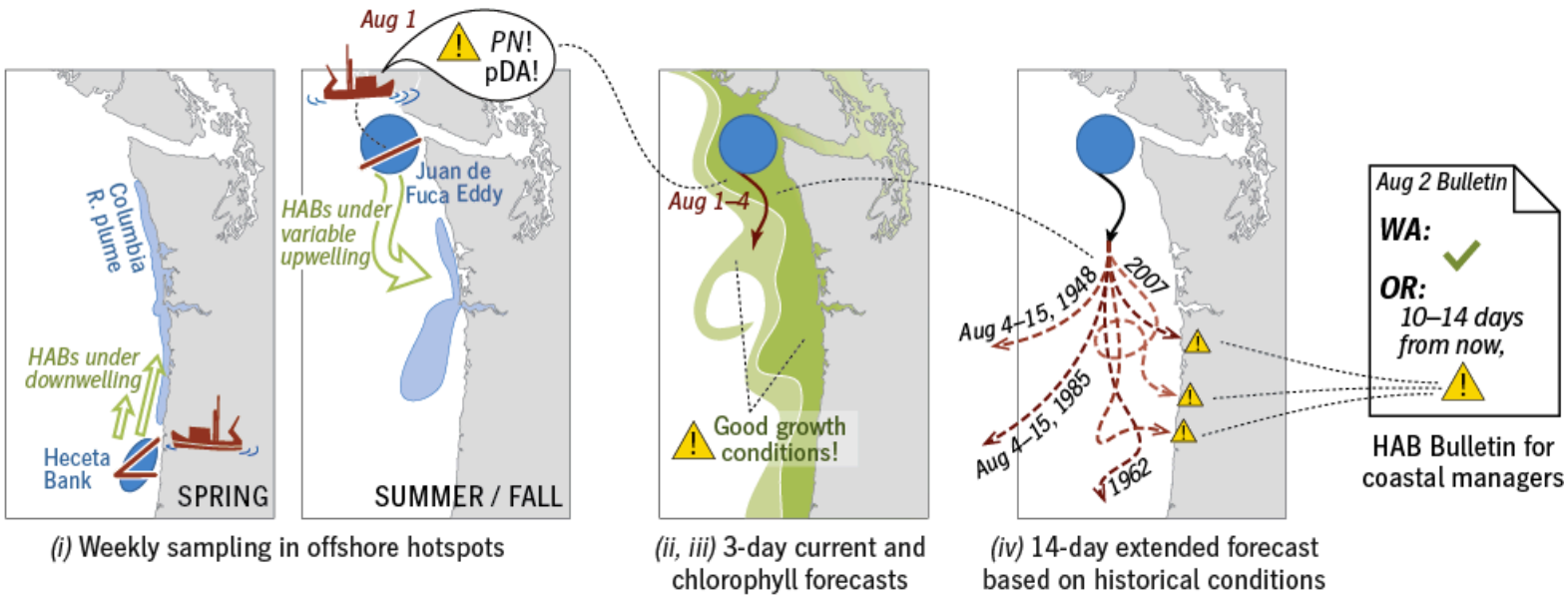
ESP detected Domoic Acid



Credits: IOOS, NOAA, UW, NANOOS, MBARI, etc.

Predicting Harmful Algal Blooms (HABs) in the Pacific Northwest:

NCCOSS NOAA MERHAB award for a sustained early-warning HAB prediction system



Proposal to develop a forecast model that combines:

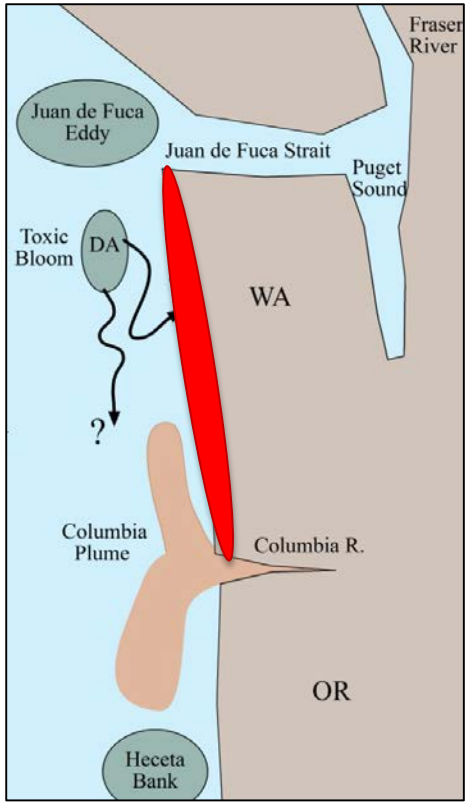
- Offshore sampling of known hotspots and beaches
- Short-term (~3 days) ocean forecasts with particle tracking and reduced false-positives
- Extended forecast based on historical conditions over many years

Produce publicly available forecasts and targeted predictions to managers for known shellfish harvesting dates

The Pacific Northwest HAB Bulletin

Slide courtesy of Vera Trainer

A full season HAB closure (e.g., 2002-03, 2007-08) causes $20.4 million in lost spending, impacting 339 jobs and $10.6 million in labor income



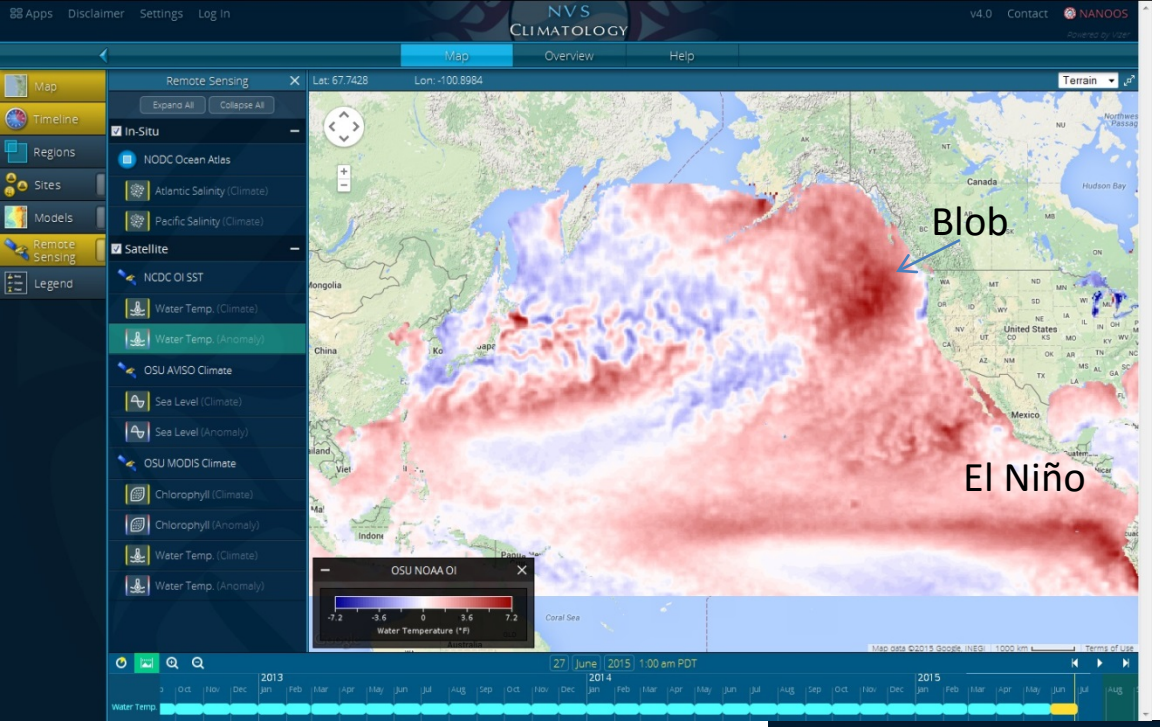
***** Fall storms – toxic cells escape the eddy, reach the coast, contact humans***

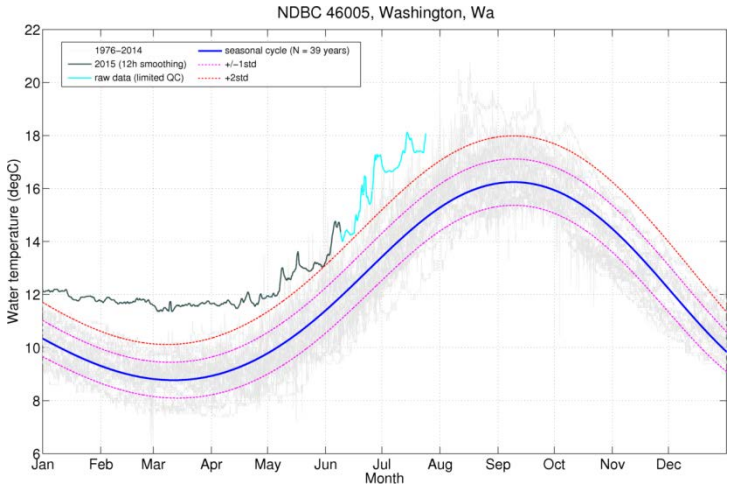
Source: Barbara Hickey and Vera Trainer; Trainer et al. (2009): Limnol Oceanogr; Dyson and Huppert (2010): Harmful Algae

Track the "Blob" using the NANOOS Visualization System (NVS) Climatology App

http://nvs.nanoos.org/Climatology

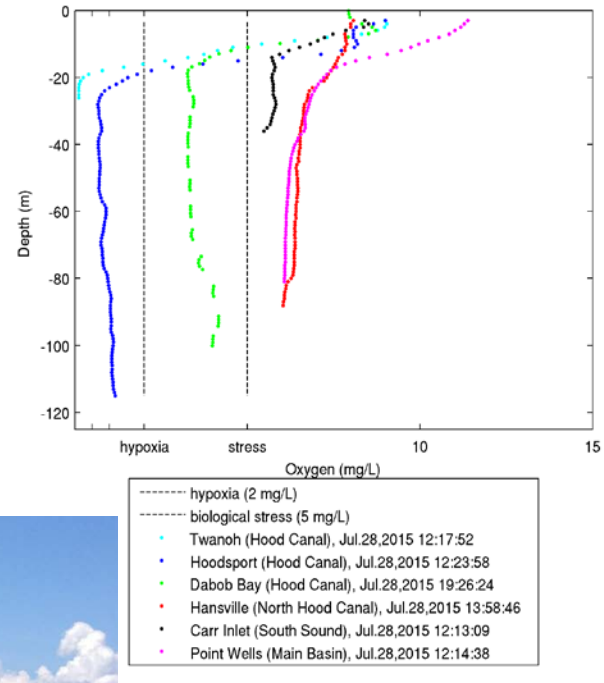
Users can track anomalies for satellites, buoys and nearshore moorings in real time.

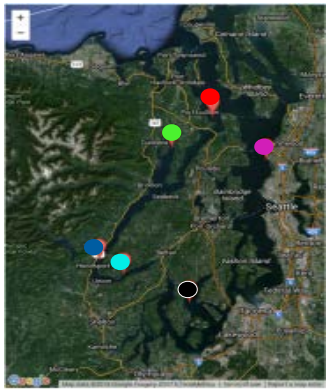




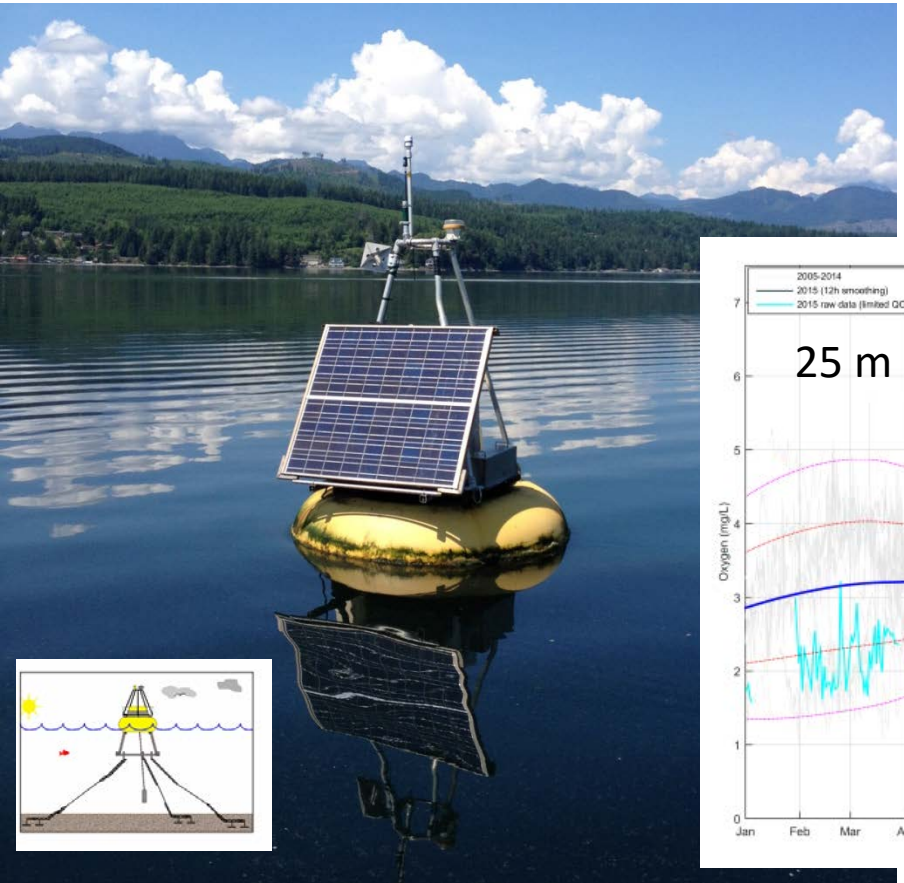
Monitoring fish kill risk using NANOOS NVS Climatology App and UW NANOOS profiling buoys

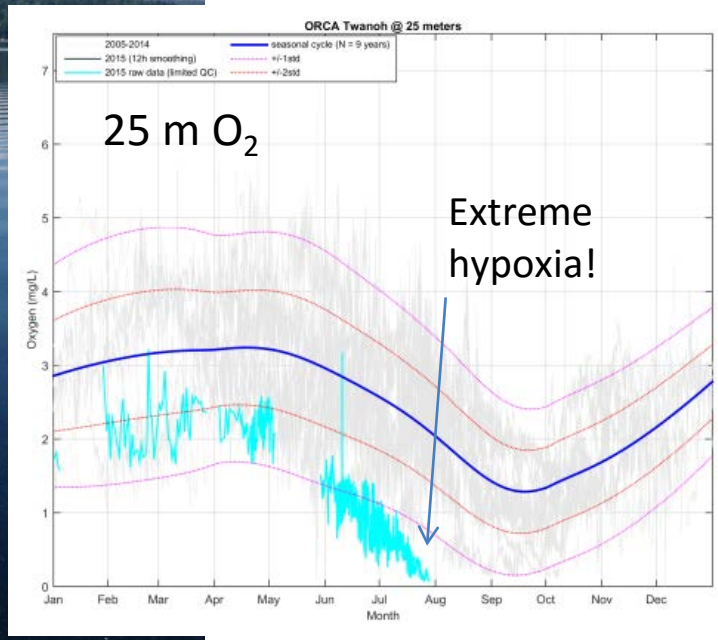
The warm, less dense 'blob' water did not flush Hood Canal, WA, resulting in extreme hypoxia. The Skokomish tribe & WDFW used our info to inform their response.



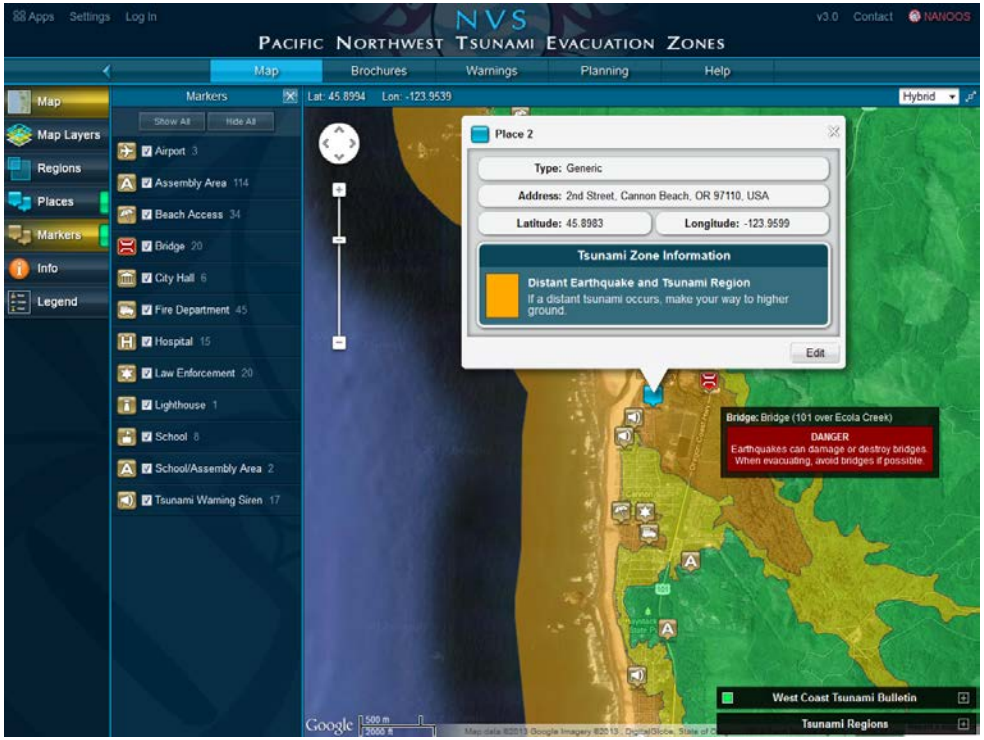


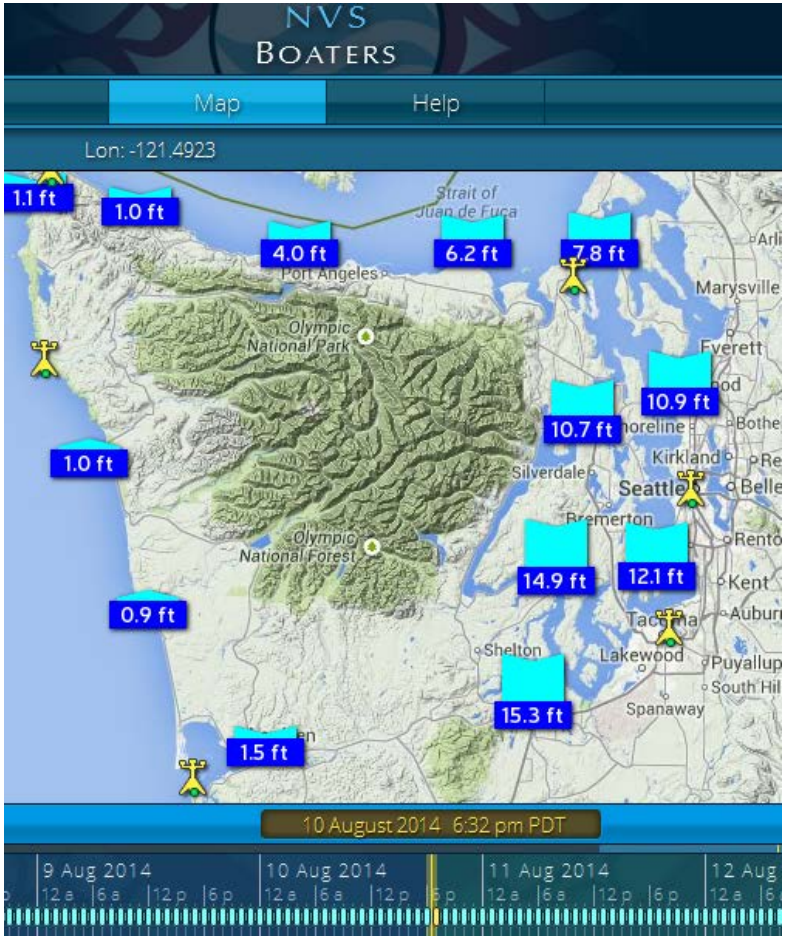
http://nvs.nanoos.org/





- Tsunami preparedness
- Boating safety





What are people saying about NANOOS?

*"**NANOOS provides critical life safety information** to the public, aiding coastal communities to build resiliency."*

- Jonathan Allan, Coastal Geomorphologist
Oregon Department of Geology and Mineral Industries

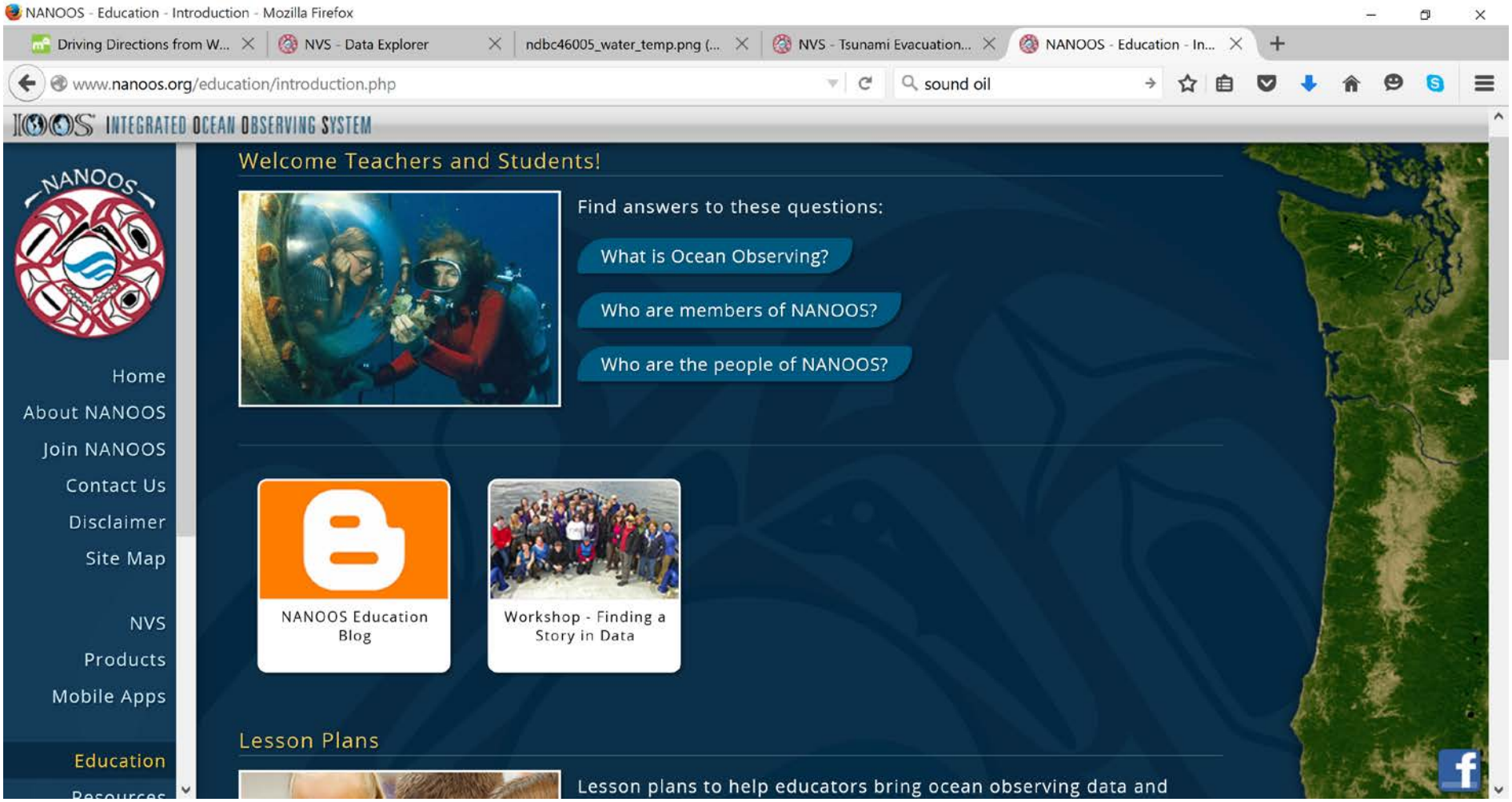
*"NWIC students are excited about because this buoy **blends the latest technology with the needs of the Lummi Nation community**. It will give students real-time place-based data … a number of students have stated that going on NANOOS cruises **solidified their desire to become marine scientists**."*

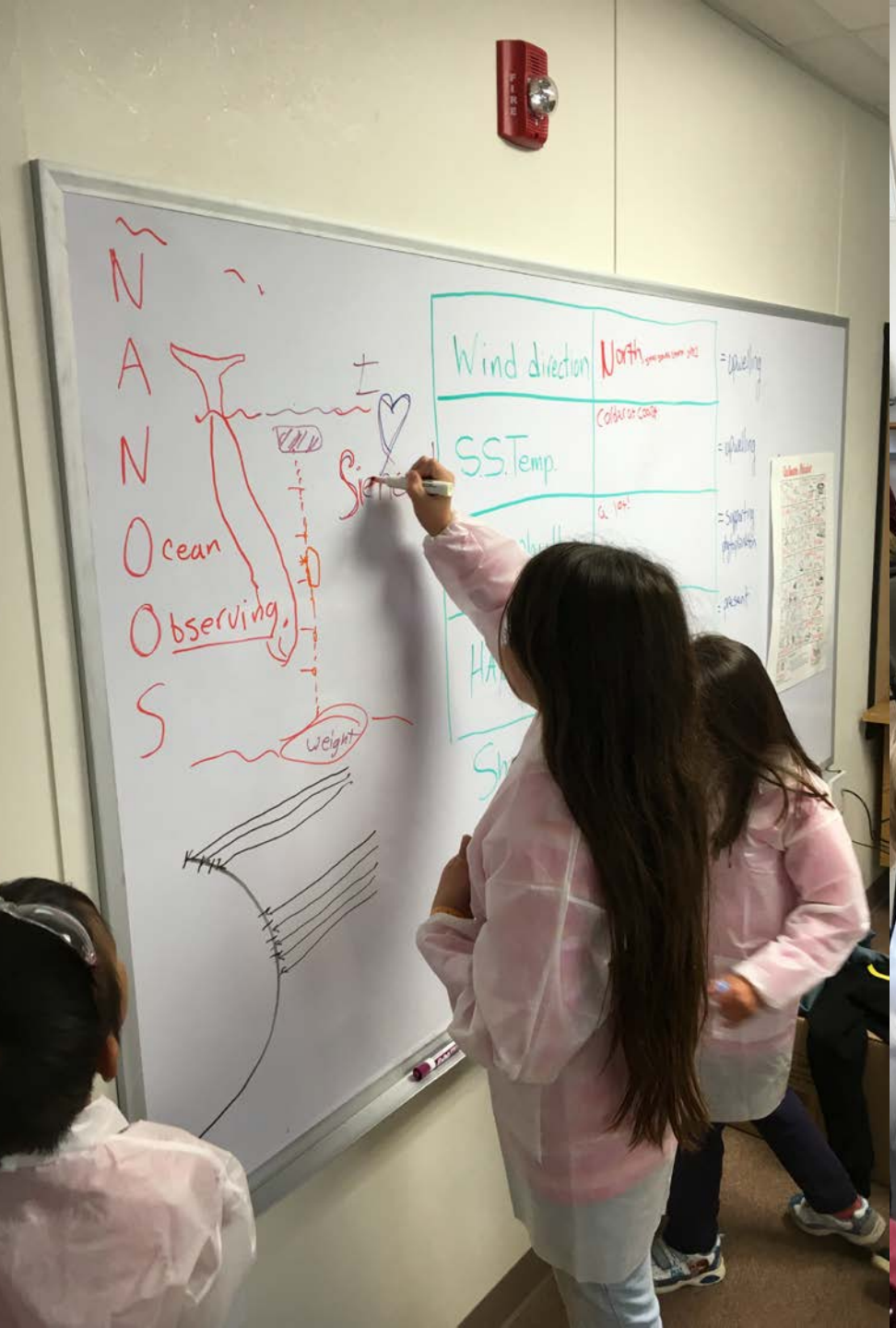
- Marco Hatch, NWIC, Salish Sea
Research Center Director

*"Ships crossing the Columbia River Bar face **one of the most dangerous harbor entrances in the world**. The Columbia River Bar Pilots rely on weather forecasts, real time buoy data along with wave and current models when determining safe times for ships to cross the bar. **NANOOS provides an excellent location for us to see and compare all the available data sources**."*

- Captain Dan Jordan, Columbia River Bar Pilots

- Education … ocean literacy




NANOS
Ocean
Observing
Wind direction
North
S.S. Temp.
Weight