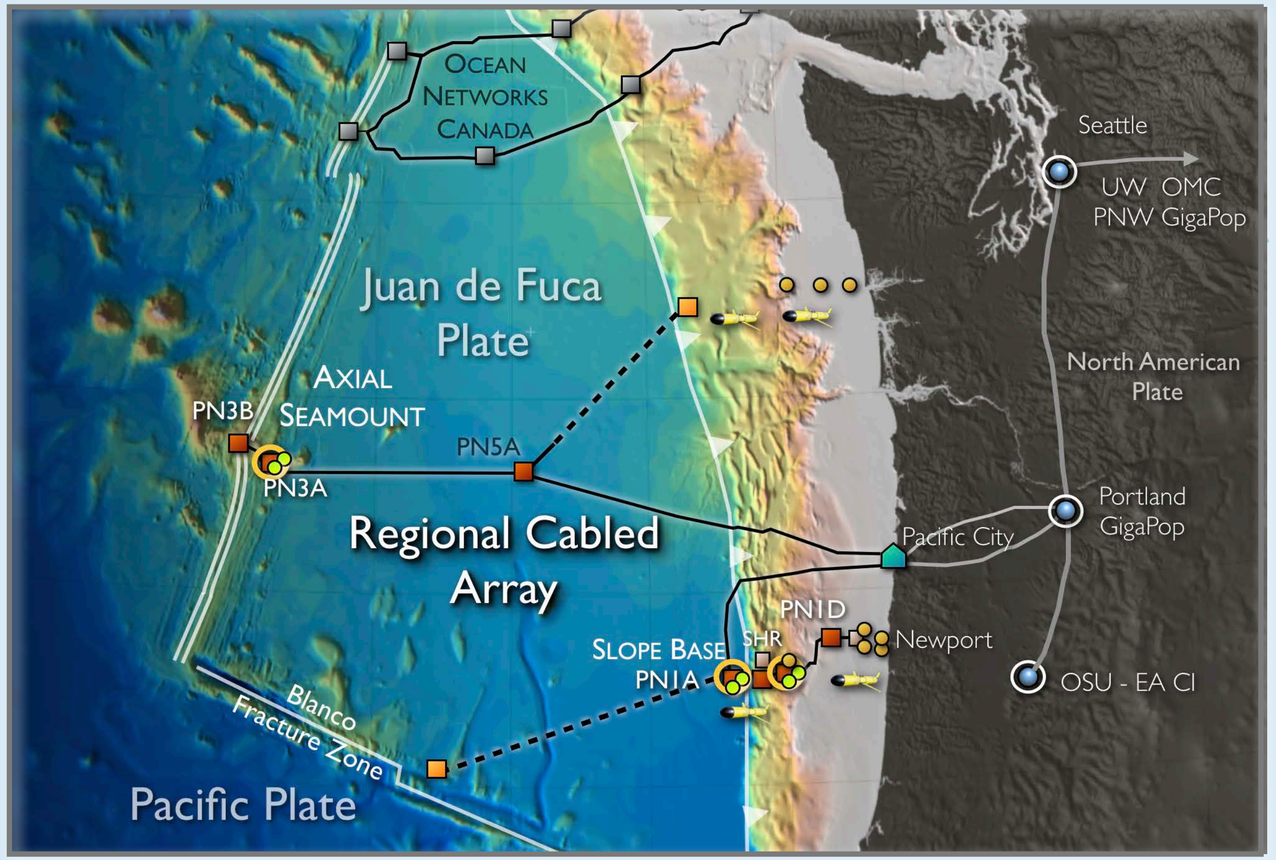
OCEAN OBSERVATORIES INITIATIVE

Regional Cabled Array Update
OOIFB Meeting

Deb Kelley & RCA Team

October 27, 2022



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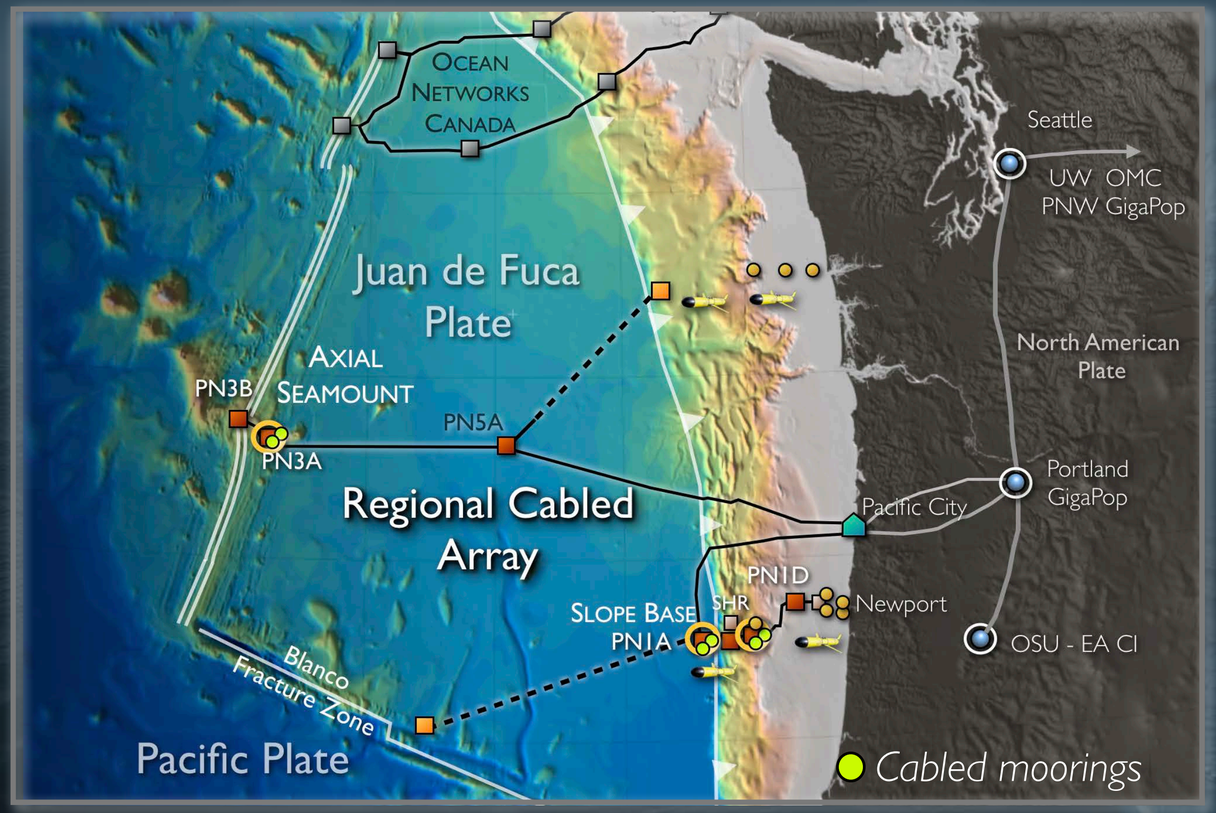
Regional Cabled Array: Why NE Pacific



275 scientists involved in 16 proposals that formed the foundation for this system

Some of most productive waters in worlds' oceans, large potential energy reserves - methane ice deposits, wave energy etc

Significant Societal Impacts: M9 earthquake, ocean acidification - climate change, low oxygen events, big storms

Real-time monitoring >150 instruments

- Offshore seismic activity, tsunami's
- Seafloor and water column organisms
- Methane seeps and novel microbial communities
- Ocean chemistry (pH, oxygen, CO_2, nitrogen etc)

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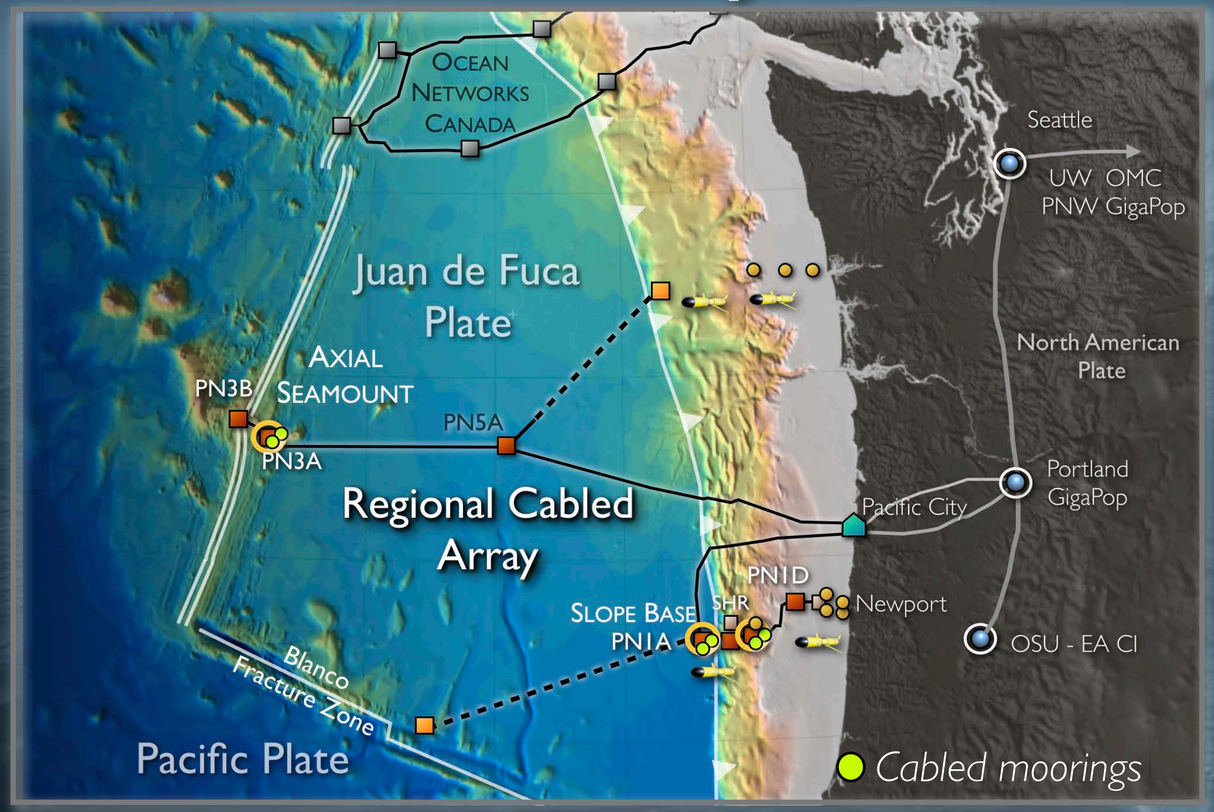
NSF-OOI's Regional Cabled Array



Primary Infrastructure

- 900 km of high bandwidth (10 Gbs) and high power (8 kW) **primary** cables & nodes

Secondary Infrastructure - APL

- 33,000 m of extension cables
- 18 junction boxes provide 375V and 1 Gbs
- 6, up to 2700 m tall instrumented moorings with wire crawlers connected to the cable
- >150 instruments provide 24/7 real-time data with two way communication - response capabilities
- highly expandable for science, industry, education

Bringing Power and the Internet Into the Ocean

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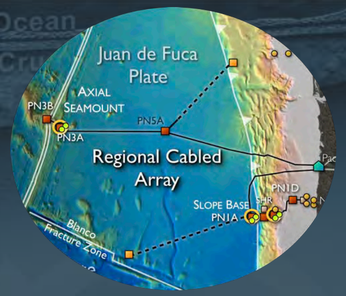
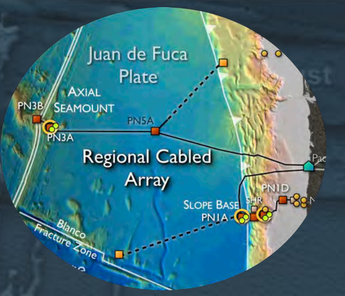
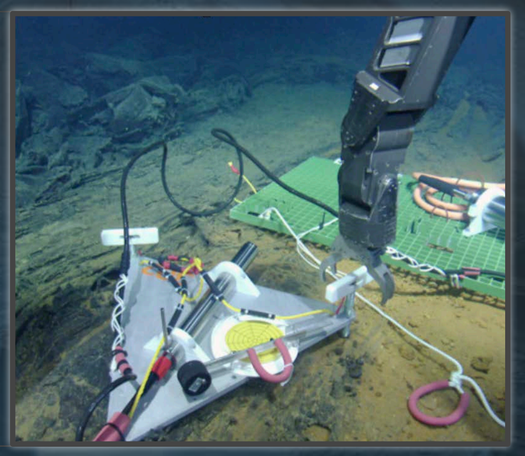


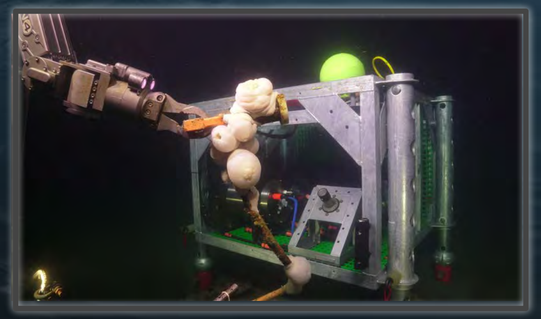
Science Themes Addressed by RCA Infrastructure



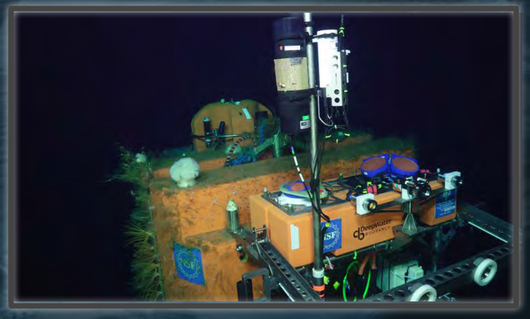
Climate variability, ocean food webs, and bio-geochemical cycles



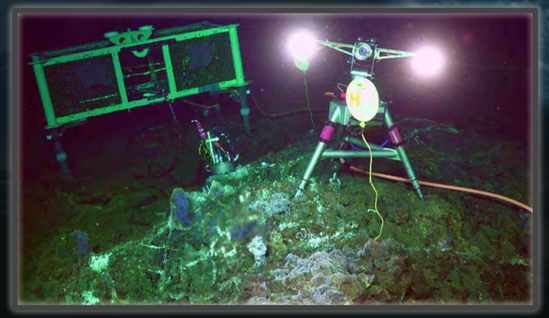
Global and plate-scale geodynamics



Coastal ocean dynamics and ecosystems



Turbulent mixing and biophysical interactions



Fluid rock interactions and the sub-seafloor biosphere

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The Regional Cabled Array Team University of Washington

Total FTE: 23.53

OOI Program Management Office

Deborah Kelley
Principle Investigator/Project Scientist
0.5 FTE

Contract/Grant
Office of Special Programs

Brian Ittig
Program Management
1 FTE

Chief Financial Officer
Laurie Bryan
0.75 FTE

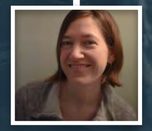
Mike Harrington
Senior Principal Engineer
0.25 FTE

SCIENCE & DATA TEAM

Cruise Data Tech.
& Non Cots Inst Refurb
1.0 FTE

Mike Vardaro
Research Scientist
0.5 FTE

Orest Kawka
Senior Scientist
Non Cots Inst. Refurb
1.0 FTE



Wendi Ruef
Lead Data Scientist
1.0 FTE

Students
(4)

Data Scientist
1.1 FTE

Chuck McGuire
Chief Engineer
0.5 FTE

Network Engineer
0.5 FTE

Shore Station
1.5 FTE

Note: Cruise Support: 2.9 FTE

ENGINEERING TEAM

Secondary Node
Senior Electrical
Engineer
& Refurb Team
0.7 FTE

Deep Profiler
Mooring Principal
Engineer
& Refurb Team
1 FTE

Shallow Profiler
Mooring Principal
Electrical Engineer
& Refurb Team
2 FTE

Vertical Mooring /
Shallow Profiler/Pic
Principal Engineer
& Refurb Team
1.53 FTE

Cabled Instruments
Senior Engineer
& Refurb Team
3.9 FTE

Logistics/BEP Lead
Field Engineer
& Refurb Team
0.55 FTE

Primary Node
Chief Engineer
& Refurb Team
0.1 FTE

Software
Engineer
1.25 FTE

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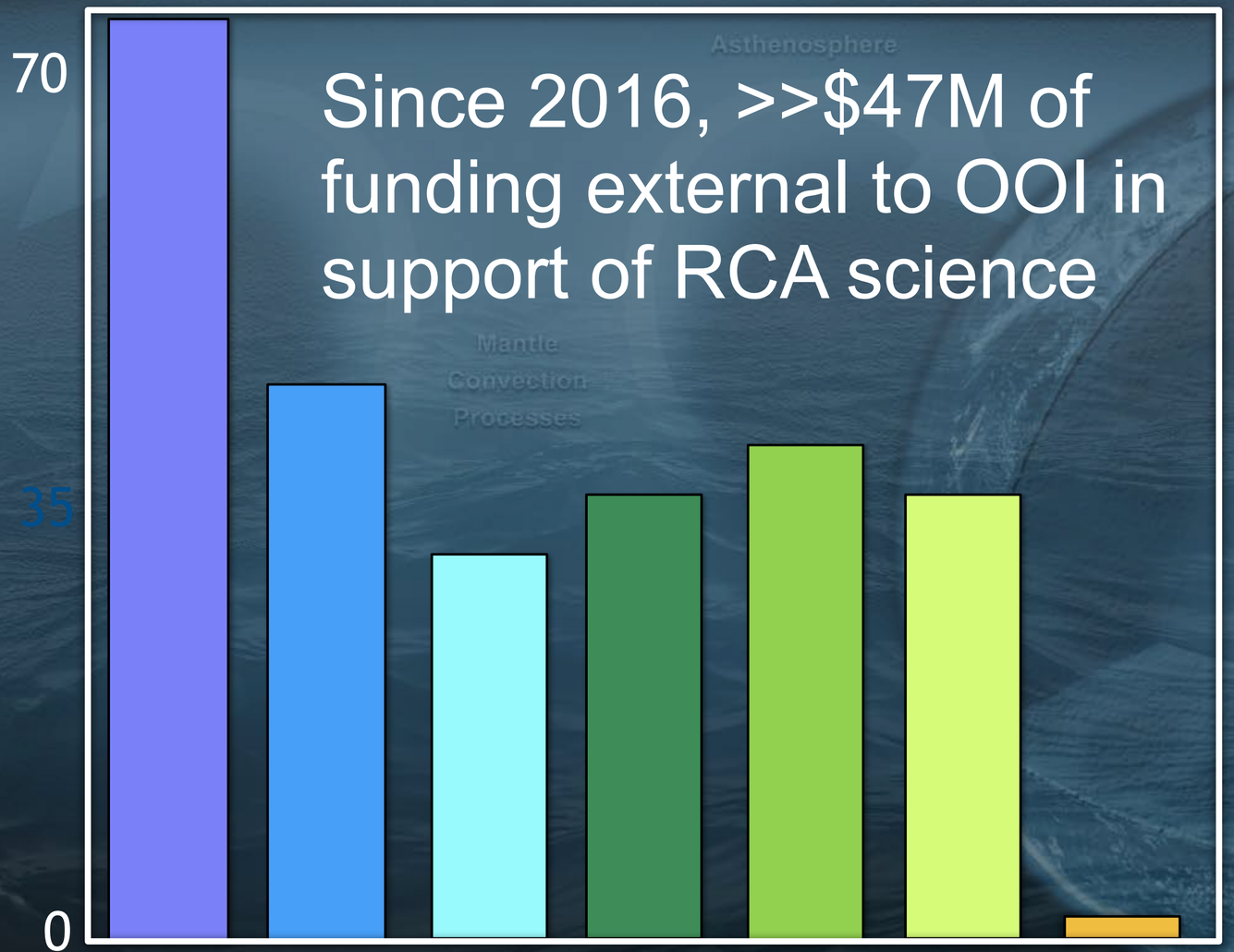
Diverse Portfolio for Funding External To OOI

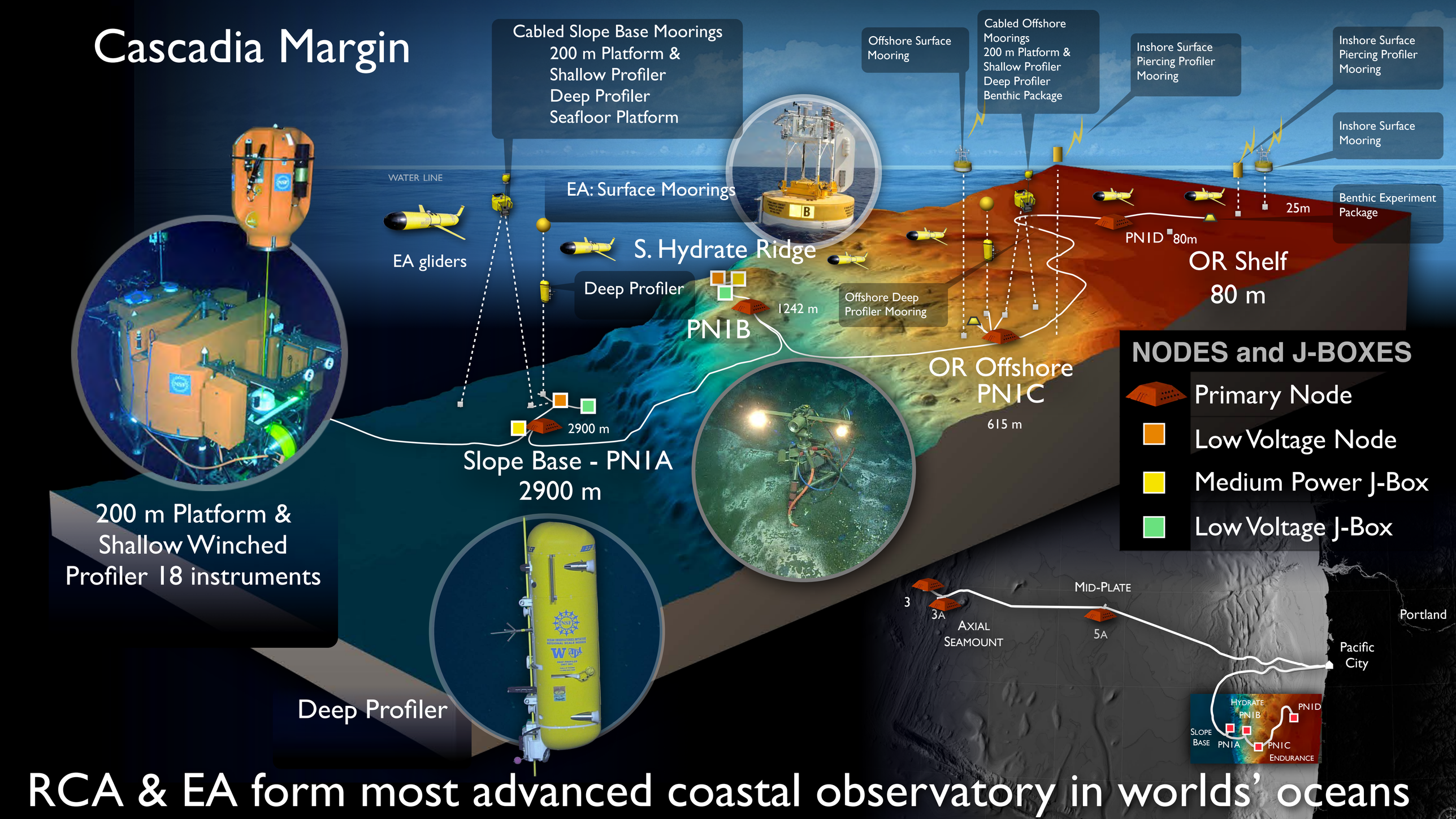


- 75 Total Funded awards (PI and Subawards)
- 45 PI Awards
- 30 Co-PI awards
- 35 PI's
- 40 Co-PIs
- 35 Institutions (including JPL and MARUM - Germany)
- 2 Industry

Diverse Portfolio = NSF, Office of Navy Research, NASA, Bureau of Ocean Energy Management, MARUM Germany

RCA team works with scientists to ensure technically feasible and help with field programs

Cascadia Margin



RCA & EA form most advanced coastal observatory in worlds' oceans

State-of-the-Art Shallow Profiler Moorings with winched profilers: event response capabilities - one of a kind in the oceans

- Hosts an array of up to18 diverse instruments - unprecedented coregistered high resolution data in space and time
- Profiler makes 9 trips/day
- 2-way real-time communications allows adaptive sampling -.e.g. response to thin layers, storms, megaplume formation, etc

Providing unprecedented high resolution, continuous data on the ocean environment

Significant discovery opportunities - >40,000 profiles, AI development

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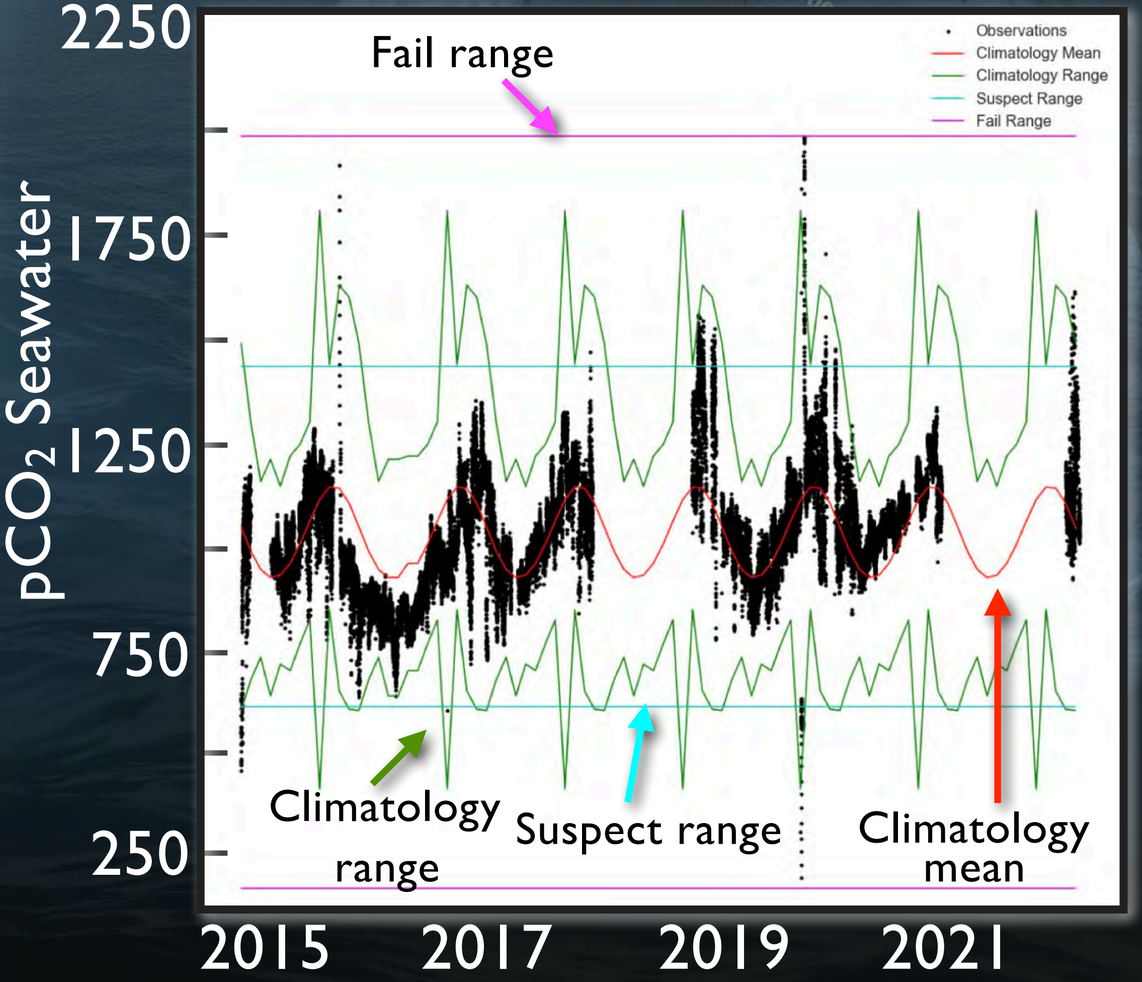
Shallow Profilers provide unparalleled "imaging" of ocean processes at Slope Base, Oregon Offshore, and Axial Seamount

Platform Interface Controller
(stationary science pod)

pH
broadband hydrophone
fluormeter
CTD-dissolved oxygen
5-beam ADCP
150 kHz ADCP
Digital still camera

Winched Shallow Profiler

pH
3W fluormeter
CTD-dissolved oxygen
PCO2
nitrate
Spectral irradiance
PAR
current meter+ temperature



pCO_2 measurements coregistered with 17 instruments in space and time

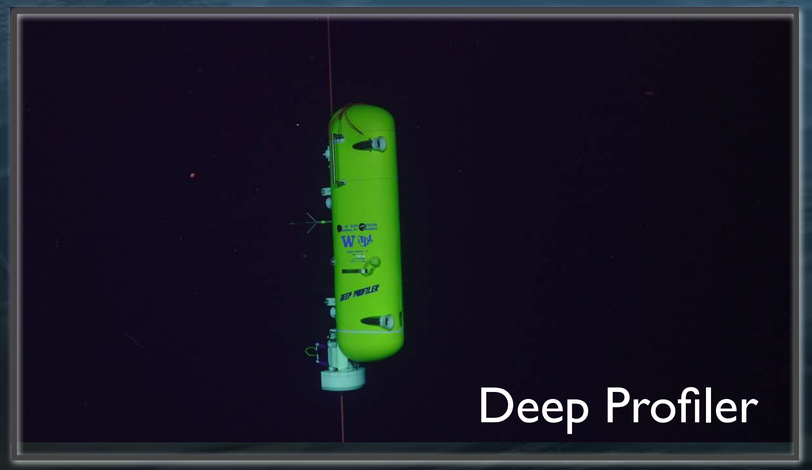
No were else in the oceans do we have such measurements!

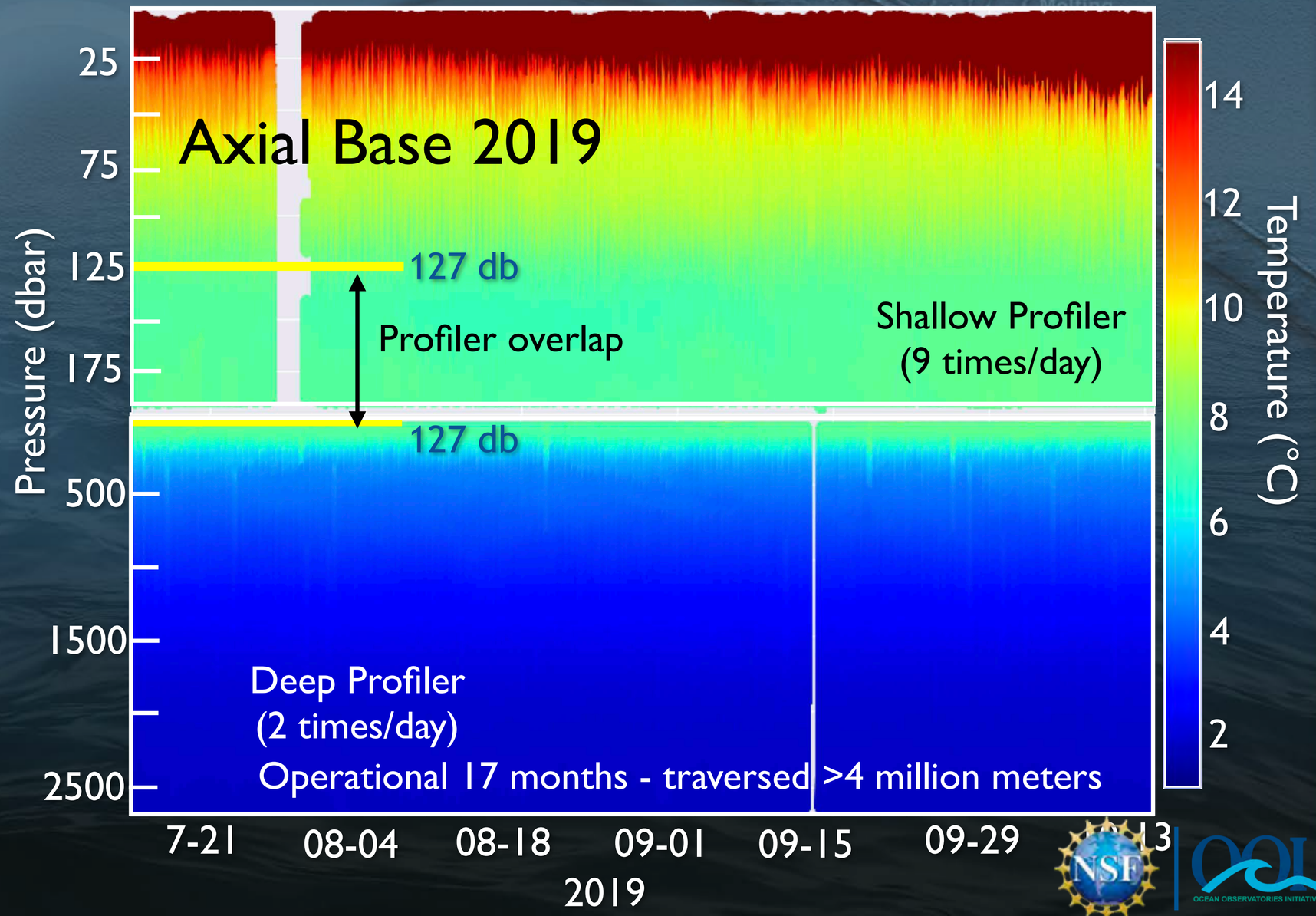
pCO_2 significant data QA/QC effort

Wendi Reuf: RCA

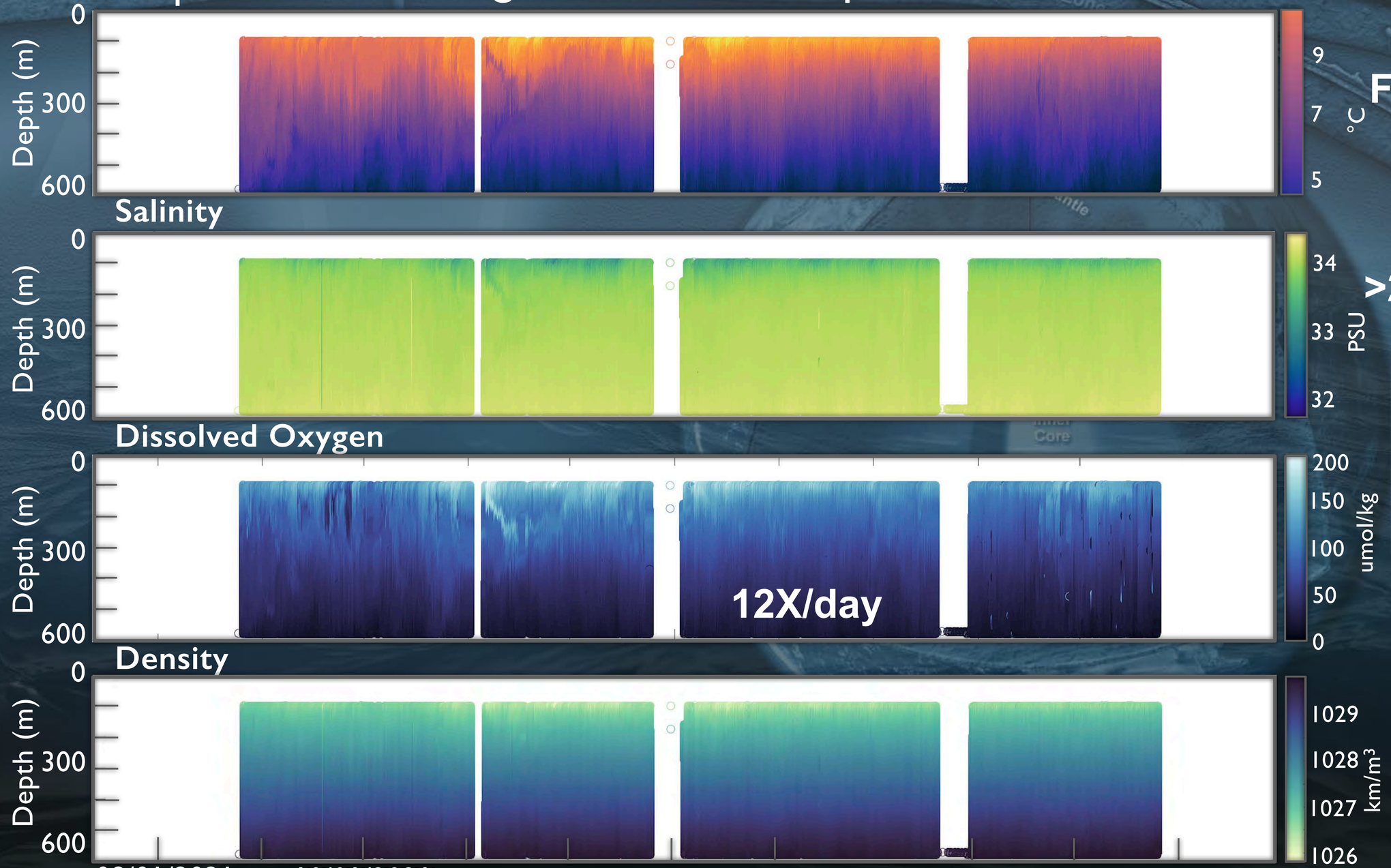
Real-time monitoring of ocean environments across full ocean depths - critical to detecting warm blobs

Shallow Profilers are paired with Deep Profiler moorings Slope Base, Oregon Offshore, Axial Base





Oregon Offshore Deep Profiler

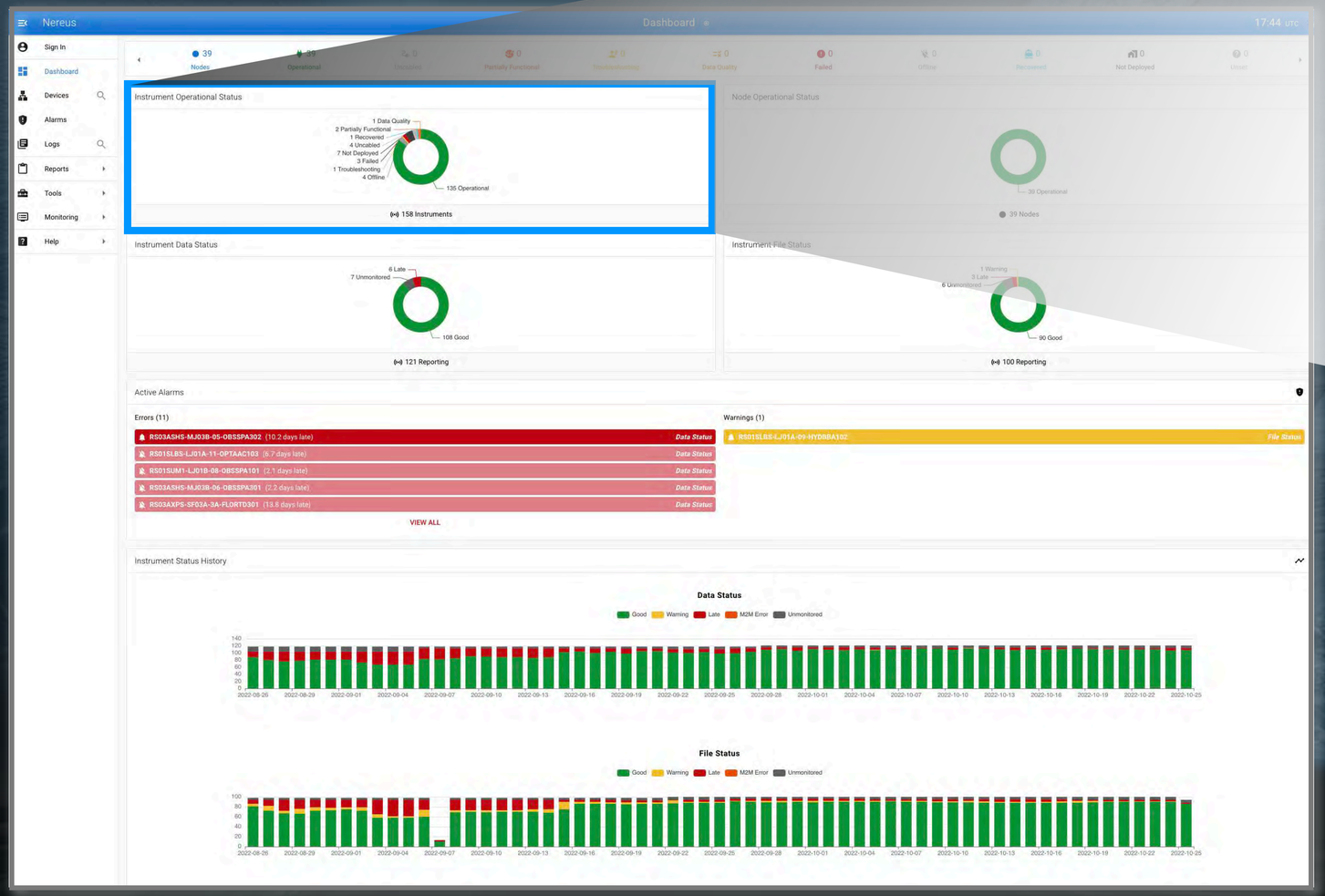


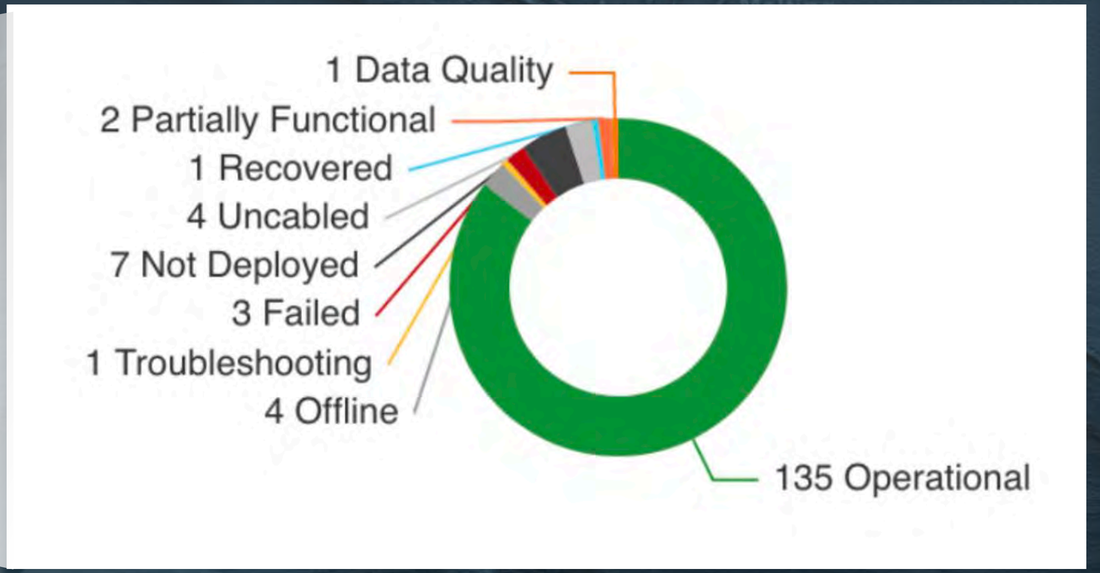
Fully operational since vehicle turned August 2021

>2.6 million meters traversed!

OR Margin 600 m

How Do We Track Complex Infrastructure? RCA Developed NEREUS for Operational and Data Status, and Logging/ Resolution of Issues

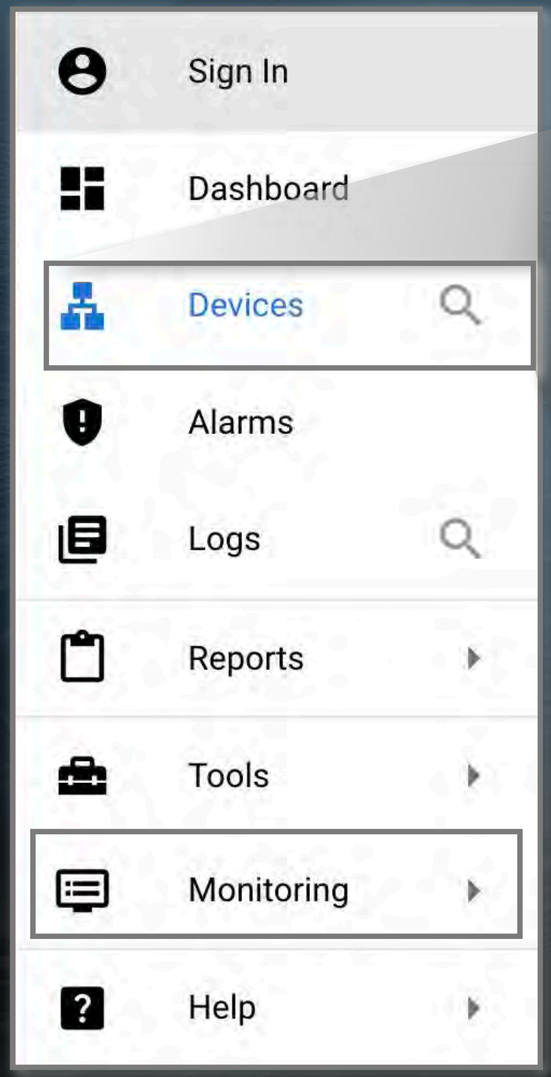




- With real-time "fire hose" of engineering and science data, RCA needed to develop its own advanced dashboard to monitor system (spanning Primary Nodes to each sensor) and data flow status
- Provides alerts, logs, reports, M2M status etc

Developed by K. .Roseburg RCA Engineer

RCA Developed NEREUS for Operational and Data Status, and Logging/Resolution of Issues

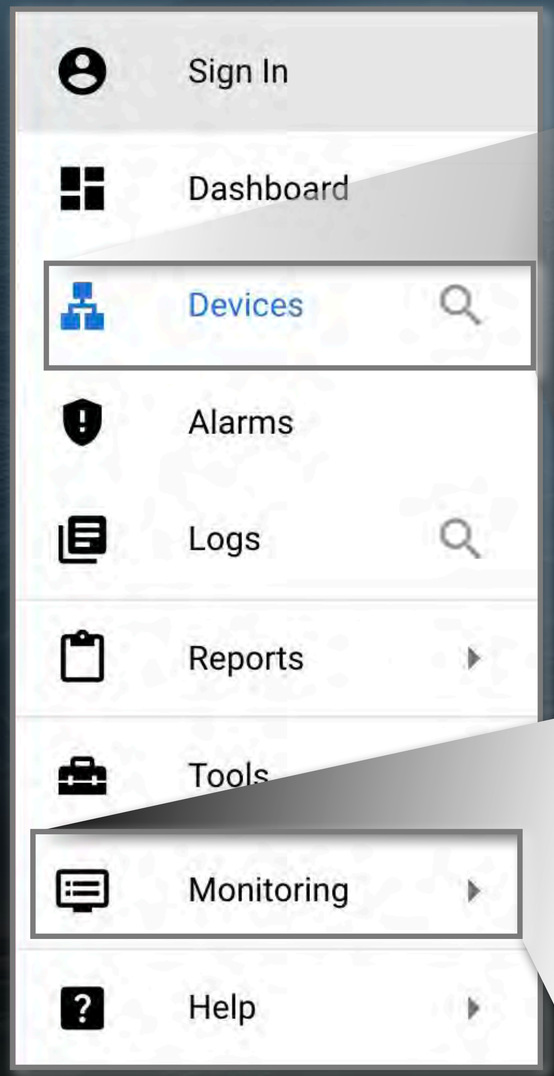


Node, Junction Box, to Instrument Status

Instrument	Operational Status	Alerts	Data Status	File Status	Ping Status
RS03AXPS-SF03A-3A-FLORTD301	Operational	Silenced	Late	Late	Good
RS03AXPS-SF03A-3B-OPTAAD301	Operational	Enabled	Good	Good	Good
RS03AXPS-SF03A-3C-PARADA301	Operational	Enabled	Good	Good	Good
RS03AXPS-SF03A-3D-SPKIRA301	Operational	Enabled	Good	Good	Good
RS03AXPS-SF03A-4A-NUTNRA301	Operational	Enabled	Good	Good	Good
RS03AXPS-SF03A-4B-VELPTD302	Operational	Enabled	Good	Good	Good
RS03AXPS-SF03A-4F-PCO2WA301	Operational	Enabled	Good	Good	Good

RCA Developed *NEREUS* for Operational and Data Status, Logging/Resolution of Issues etc

Node, Junction Box, to Instrument Status



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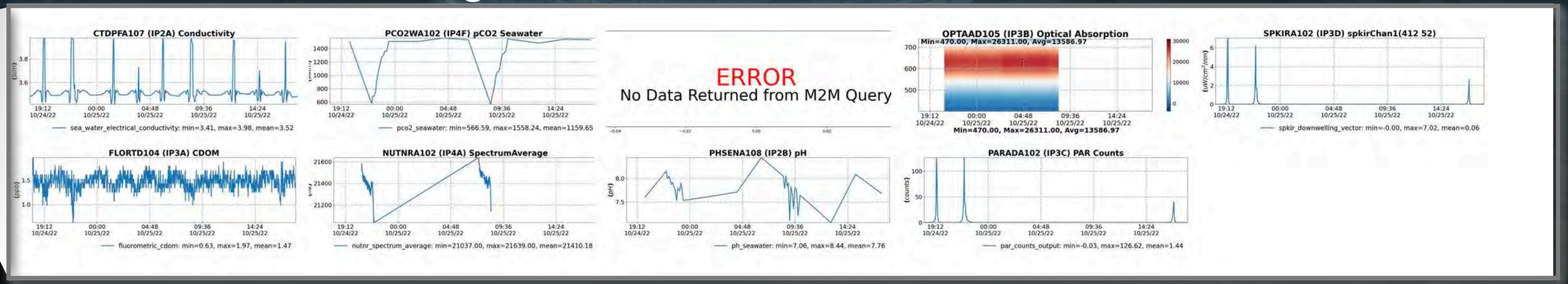
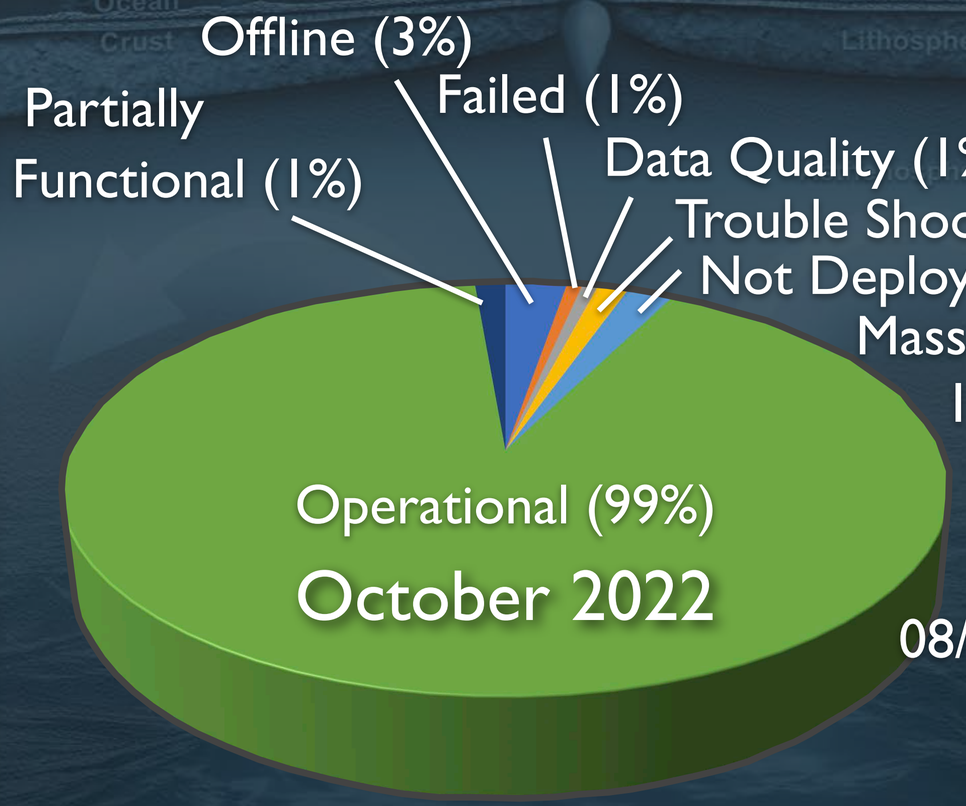
M2M Instrument Data Plots

SF01B: Oregon Offshore Winched Shallow Profiler

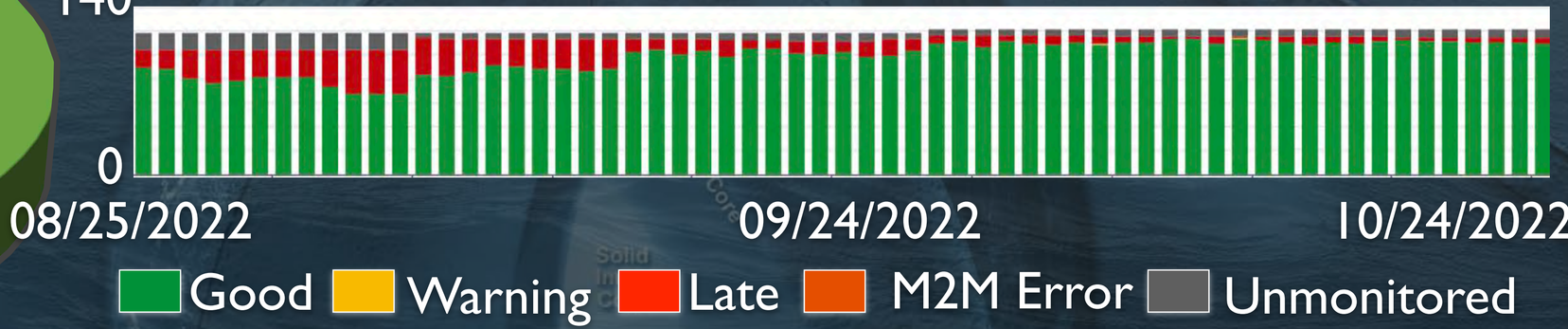


Operational Status Through Nereus

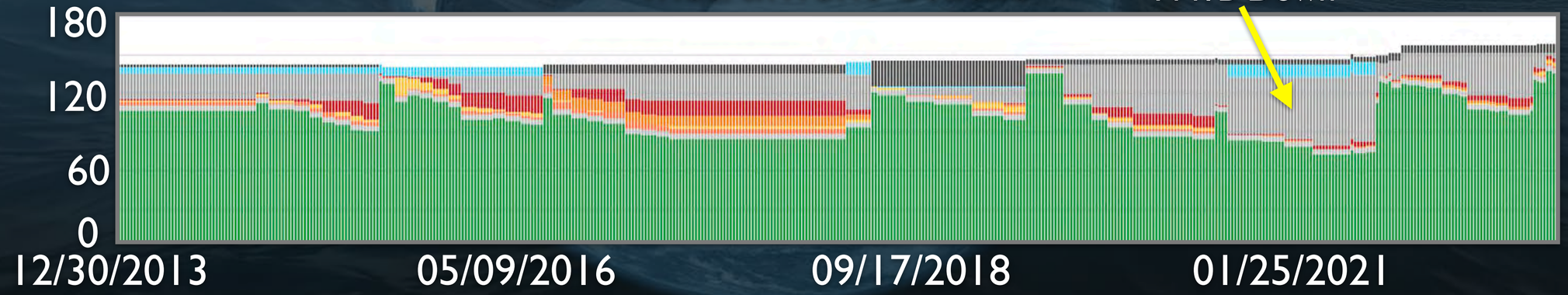
Total Instruments 150



Data Status



Instrument Status



Operational
Uncabled
Partially Functional
Troubleshooting
Data Quality
Offline
Recovered
Not Deployed
Unset

Quality Control: Data Review

Human-in-the-Loop Dashboard

Large data volume required development of a HITL Dashboard on the cloud (AWS)

- Quick view of assets on one page, viewable by variable (i.e. temperature) or site (i.e. Axial)
- RCA array data harvested from UW cloud-based zarr files to allow for fast access and interactivity of multiple large datasets
- Overlay climatology, nearest neighbors, previous data, QC flags
- Rotate between set timespans (day, week, month, year, deployment period)

Developed by Wendi Ruef and Don Setiawan

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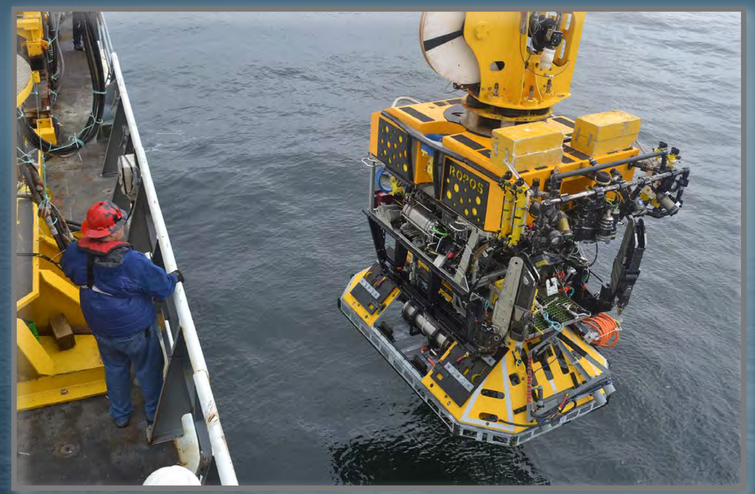
Regional Cabled Array VISIONS'22 Operations and Maintenance Cruise

Highly Complex, Completed All Goals and More

August 5 - September 16, 2022



Canadian ROV *ROPOS*

- Five Legs, *154* Berths, 26 students, *25 48 ft trailers* transported 500,000 lbs of gear to-from Newport
- ROV *ROPOS* 60 dives over 33 at-sea days, 1400 nm transited

R/V *Thompson*

R/V *Shallow Profiler Platforms on Way to Newport*

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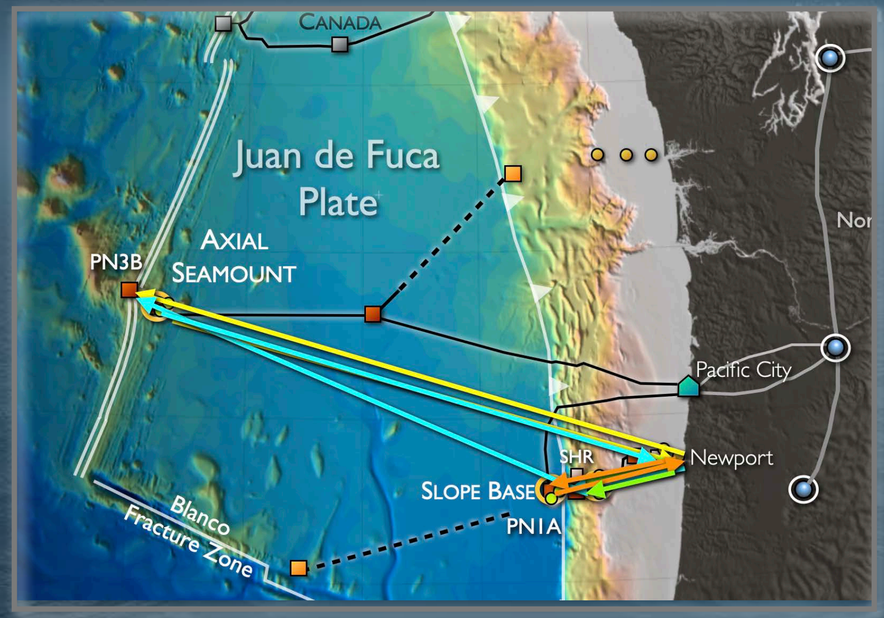
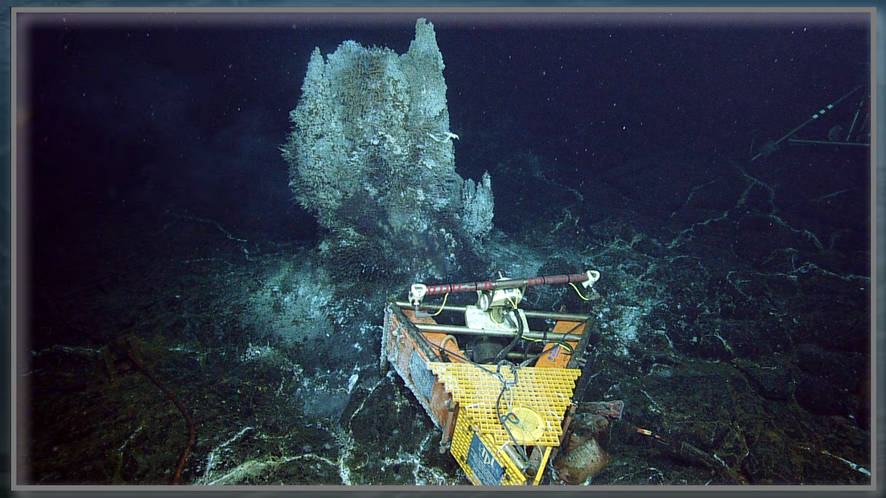
Regional Cabled Array VISIONS'22 Operations and Maintenance Cruise





- 222 OOI Core instruments recovered and reinstalled (turned)
- 3 Secondary Nodes, 3 Benthic Experiment Platforms, 3 Deep Profiler vehicles turned
- 3 Instrumented Platform Interface Assemblies and 3 instrumented winched Science Pods turned
- 500 m of extension cables installed, Southern Hydrate Ridge operational with plug into PN3B
- 4 PI Instruments turned, 6 PI instruments recovered, 9 PI instruments installed

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Primary Node PN3B Repair BY APL and Installation by IT Intrepid Successful: Southern Hydrate Ridge Operational

377 ft

Reterminating the fiber

Primary Nodes are Big "Beasts" 14,000 lbs, 18' long, 16' wide

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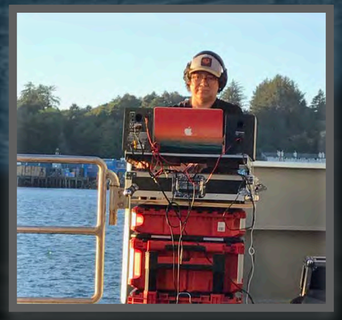
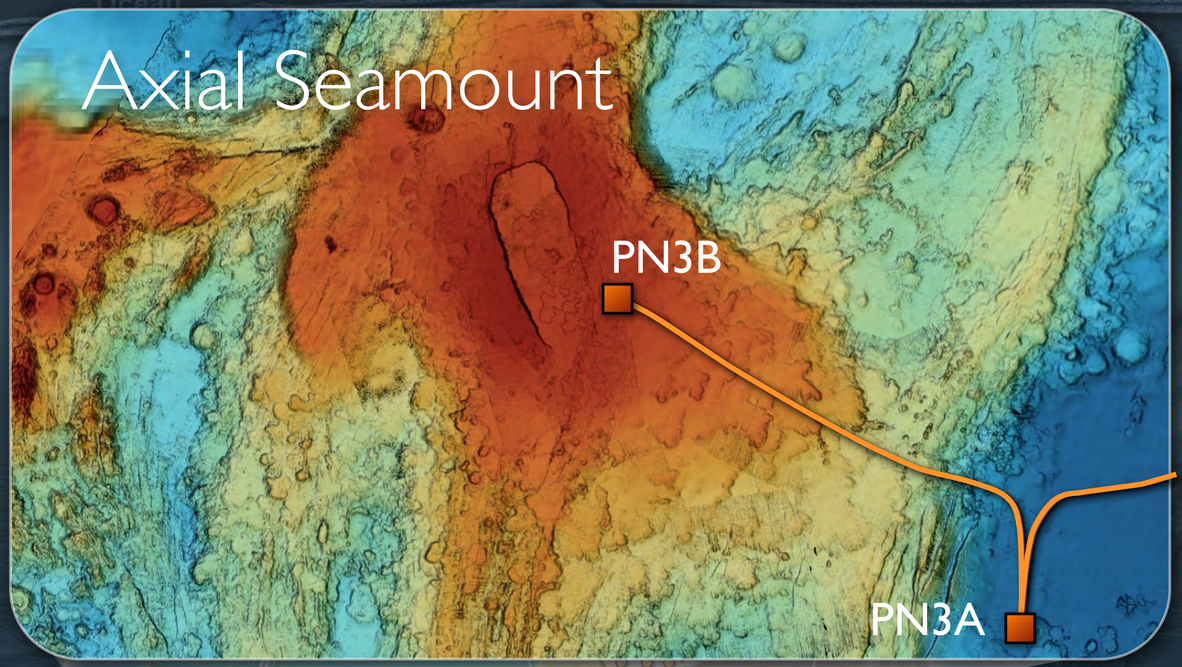
VISIONS'22 at Sea Experiential Learning Program

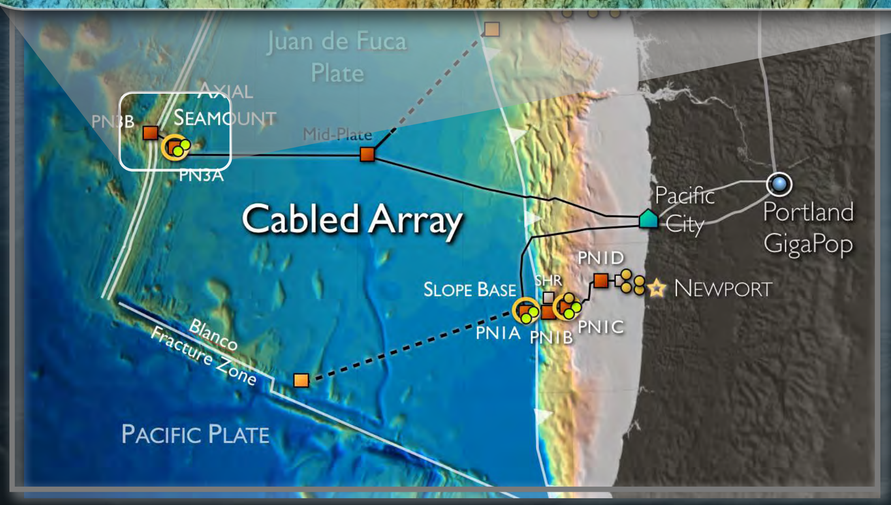
- 20 Undergraduate students and 3 graduate students participated on the cruise spanning oceanography, bioengineering, pre-med, ocean policy, geology etc.
- 3 VISIONS'21 undergrads returned as student "ambassadors" to mentor the V22 students
- 4 VISIONS students work in our lab (3 returning)
- 2 past VISIONS (V14 & V18) participants sailed - are new APL engineer staff



Christina Ramierz

Amy Larsen





Axial erupted in 1998, 2011, and April 24, 2015 - Poised to Erupt again

Significant focus of research community

Axial Seamount
An advanced submarine volcanic observatory

- >70% of the volcanism on Earth occurs under water in systems like the one off our coast - largest mountain chain on Earth
- Emit huge amounts of heat, chemicals and biological material from the seafloor into the overlying ocean, but poorly studied temporally
- One of most extreme environments on Earth

Axial is the largest and most magmatically robust volcano off the WA-OR coast

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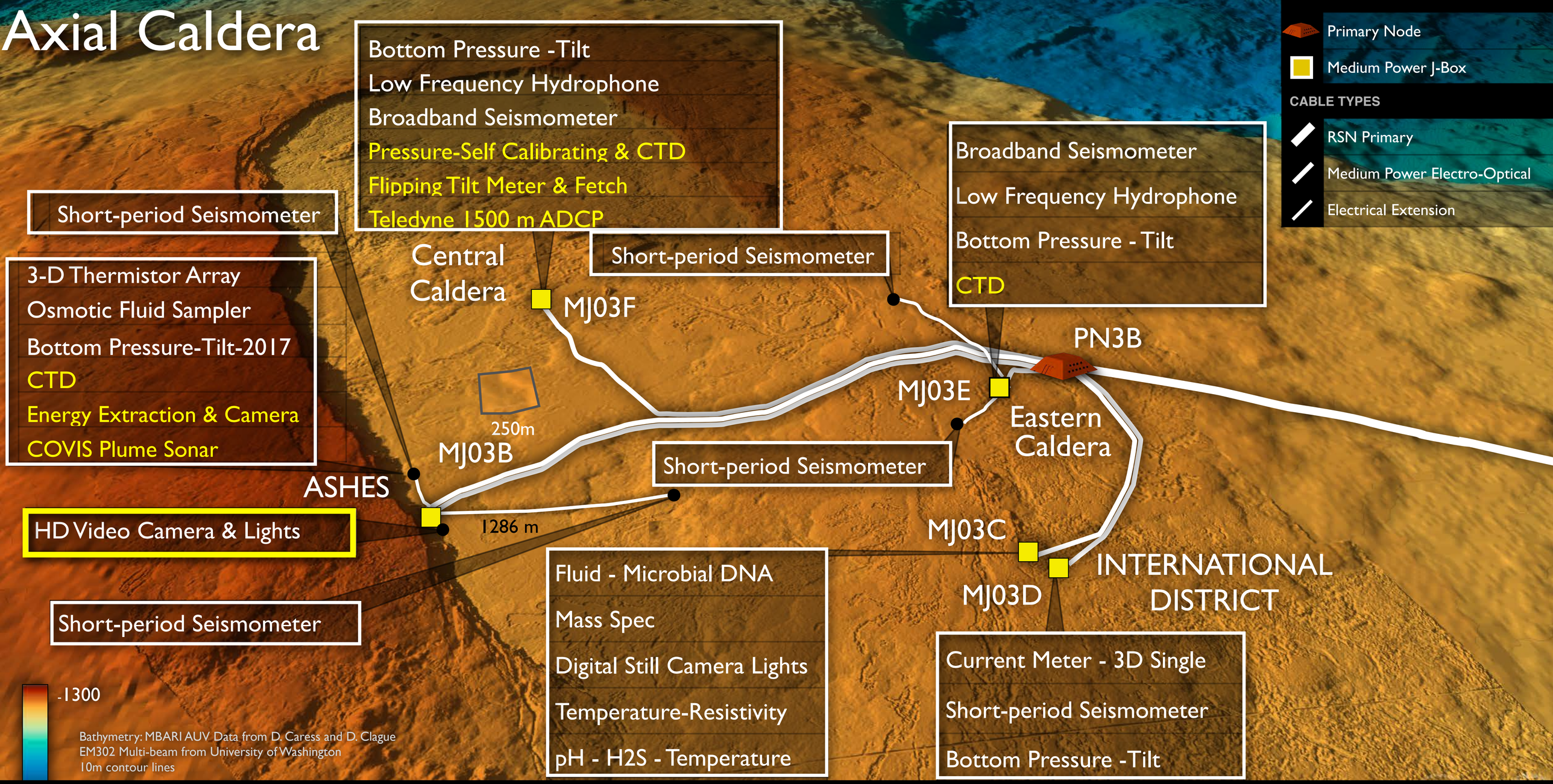
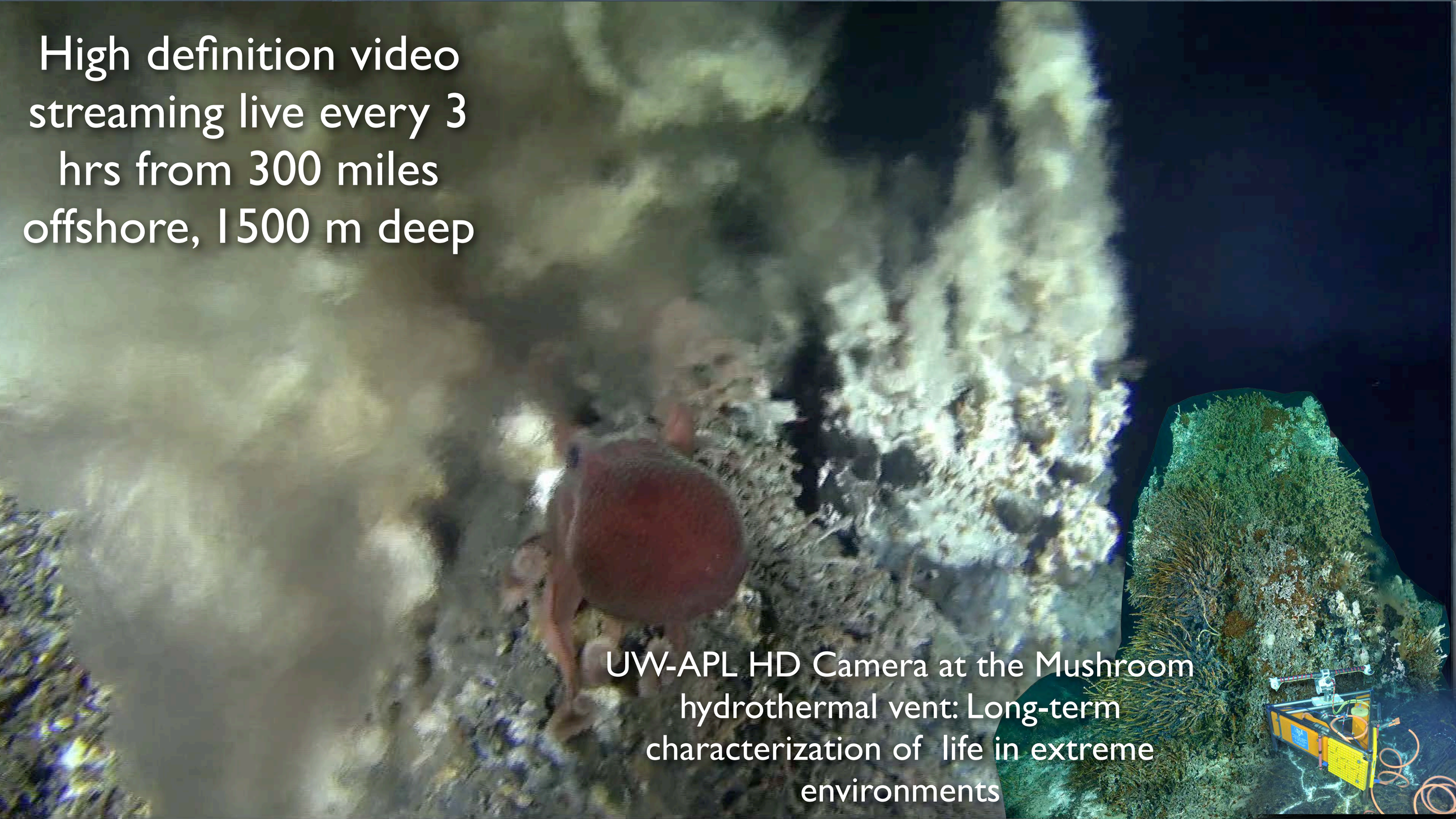


Cabled instruments allow co-measure earthquakes, changes in vent fluid temperature-chemistry, seafloor inflation and deflation, and microbial and macrofauna communities

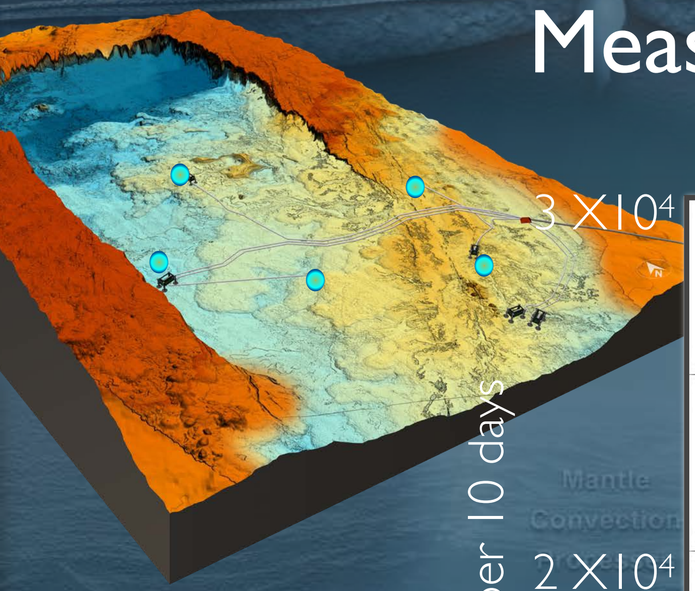
PI Instruments

High definition video streaming live every 3 hrs from 300 miles offshore, 1500 m deep



UW-APL HD Camera at the Mushroom hydrothermal vent: Long-term characterization of life in extreme environments

Measuring the heart-beat of a submarine volcano



Full Catalog (10 day bin)

Earthquakes detected
Earthquakes located

http://axial.ocean.washington.edu

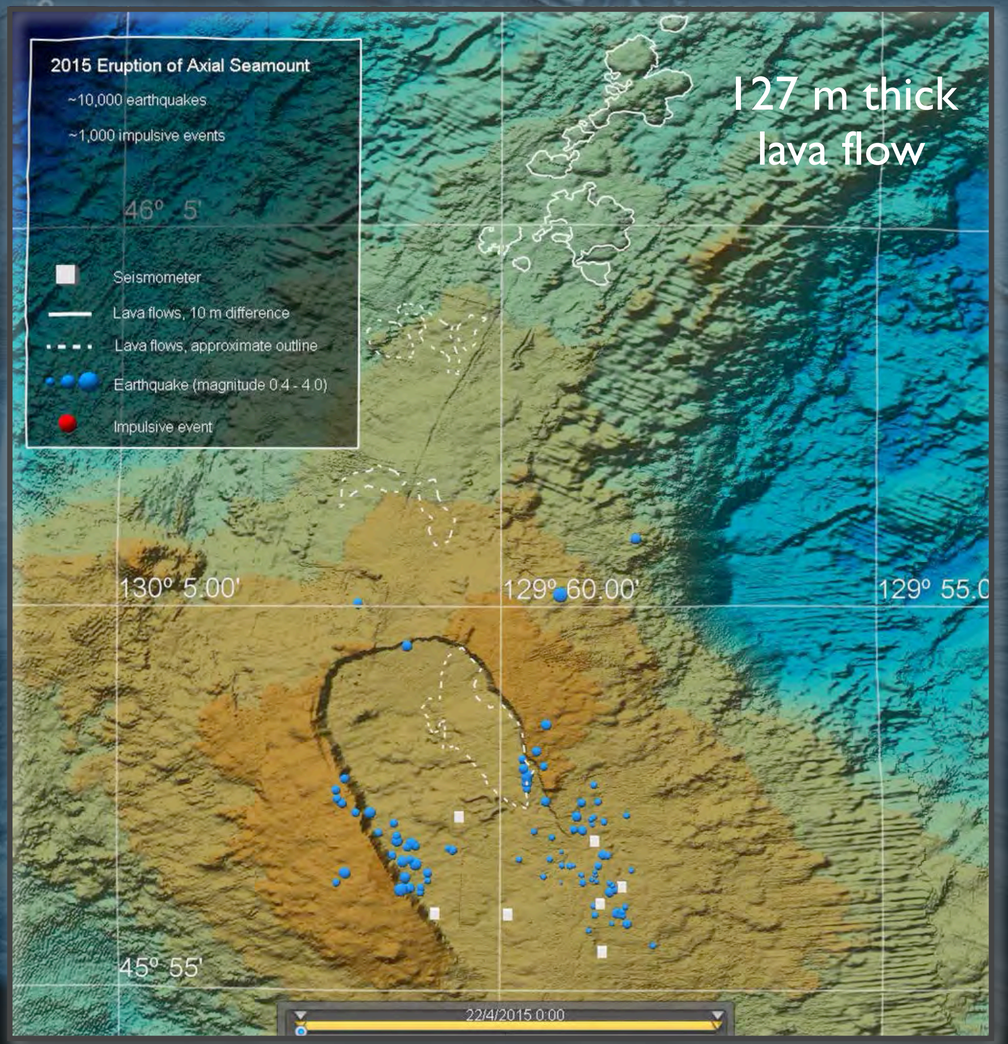
Earthquakes per 10 days

3×10^4
2×10^4
1×10^4
0

2014 2015 2016 2018 2020 2022

2015 eruption
>8,000 earthquakes
in 24 hrs

Wilcock et al., Science *2016*

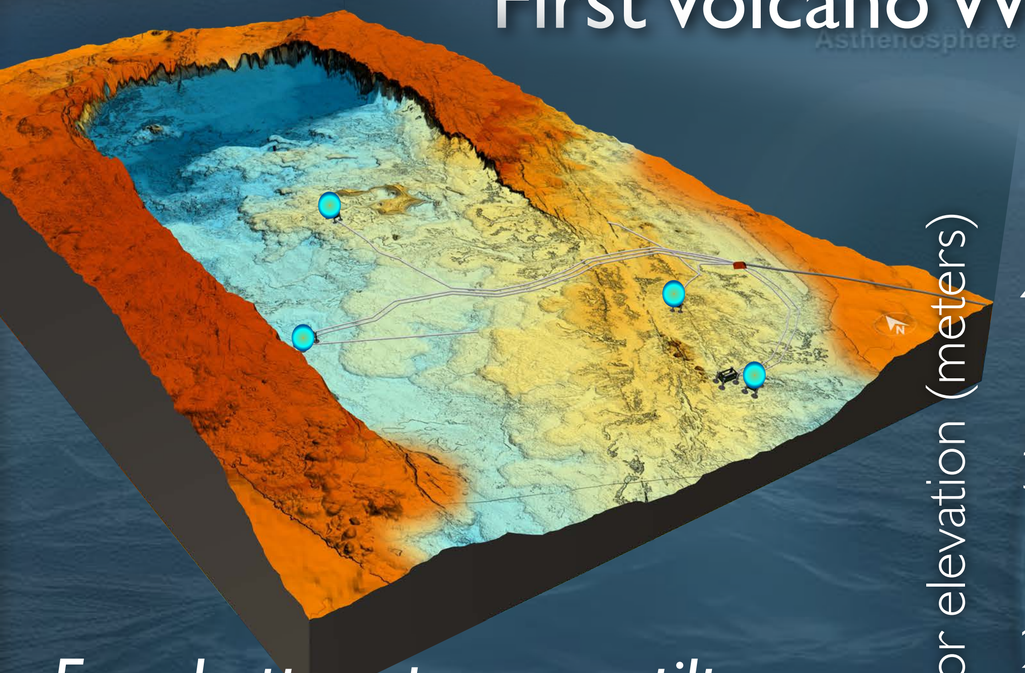


Earthquakes

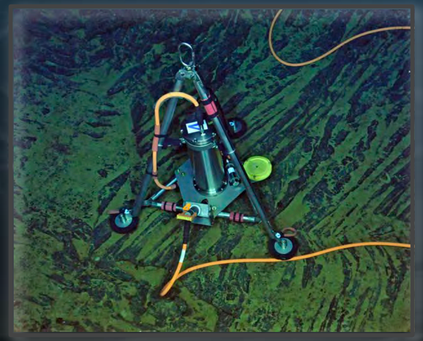
Hydroacoustic events (explosions)

See William Wilcocks Science Plenary "Preparing for the next eruption of Axial Seamount"

Instrument Highlight: Axial Seamount Bottom Pressure Tilt
First Volcano Where Eruption May be Predicted



Four bottom pressure-tilt instruments across caldera

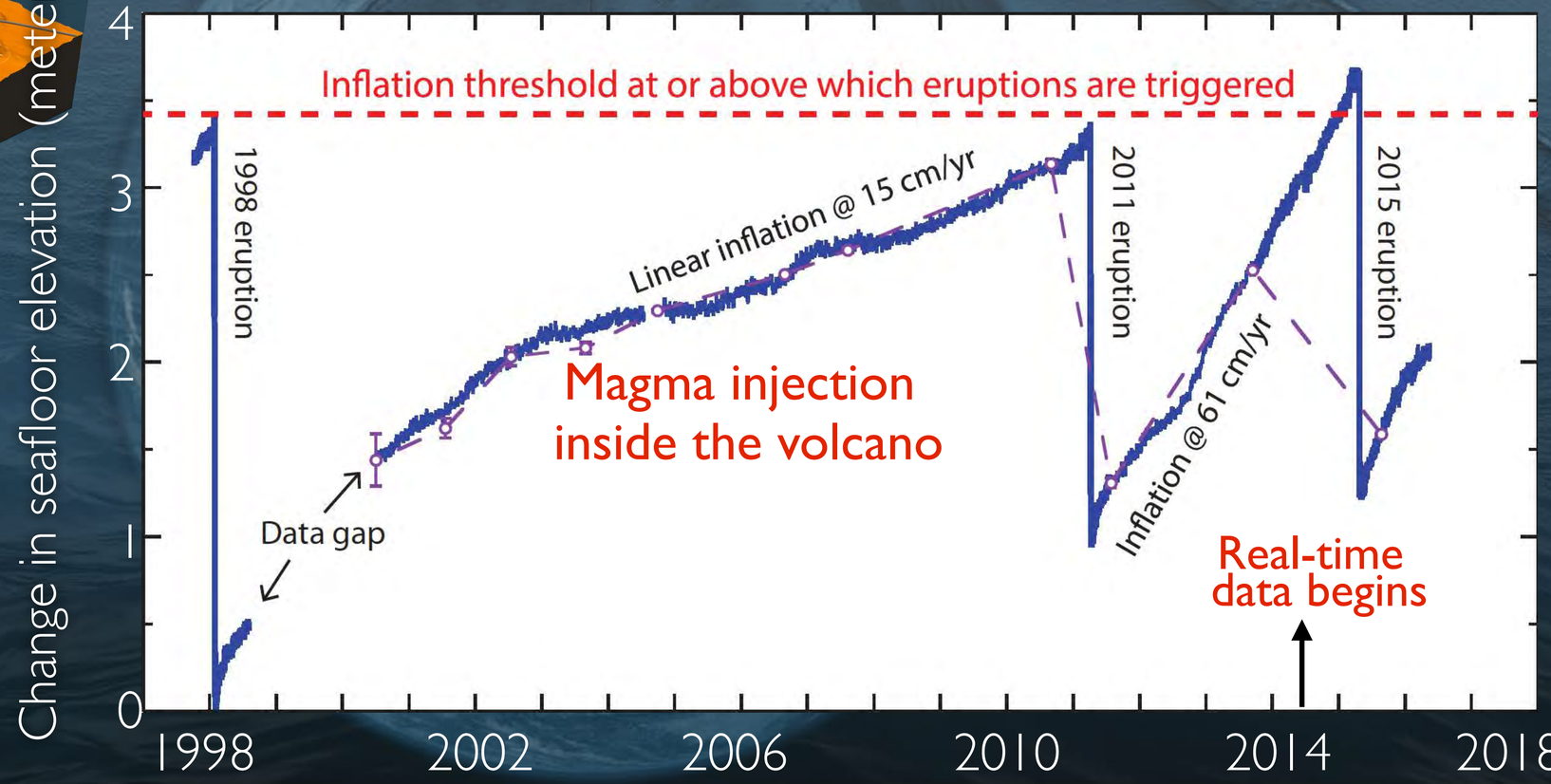


International District

Central Caldera

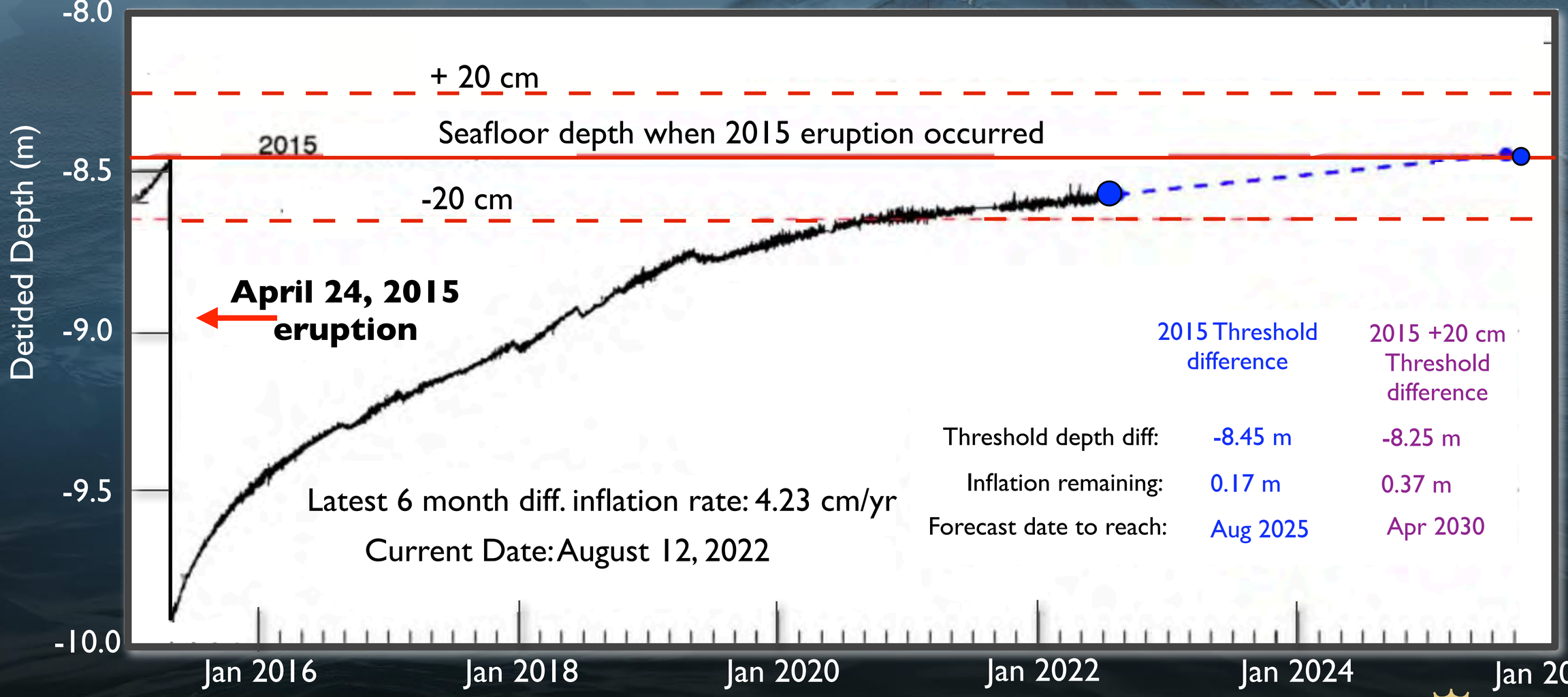
2015 ash from lava fountaining at 1500 m!

The Seafloor is on the Move

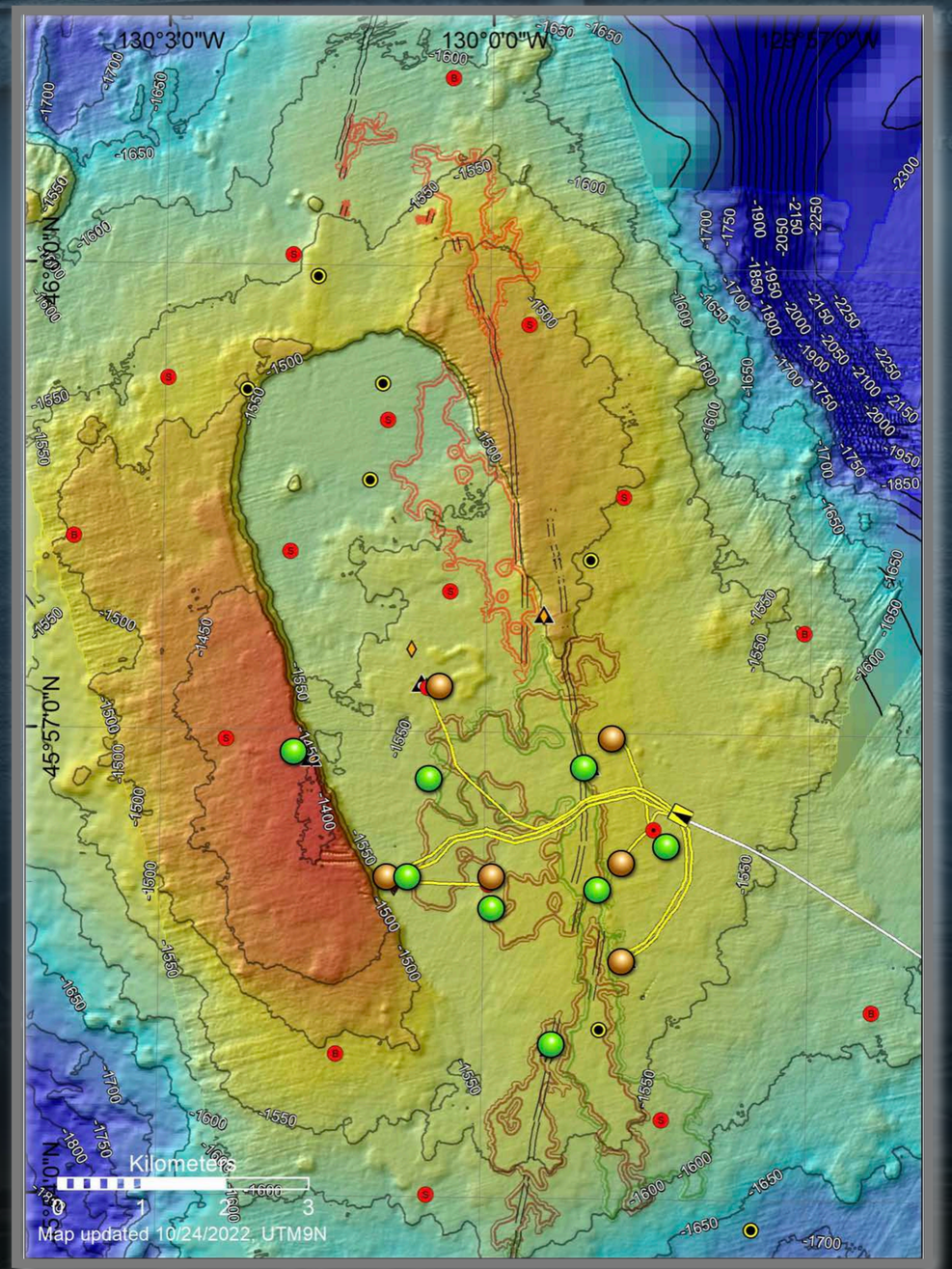


When will Axial Erupt Again?

Axial Seamount Bottom Pressure Tilt
First Volcano Where Eruption May be Forecasted



https://www.pmel.noaa.gov/eoi/axial_blog.html



W. Chadwick (OSU), S. Nooner (UNC), D. Caress (MBARI), D. Kelley (UW)* "Collaborative Research: Multi-scale Geodetic Monitoring at Axial Seamount" (OCEXXXX-MGG) 2023-2028

- Although the summit of the volcano has inflated 85%-90% of its pre 2015 eruption level, geodetic monitoring coupled with seismometers and cabled and uncabled pressure sensors suggests that the magma supply rate has been waning since 2015, pushing the forecast for the next eruption out 4-9 years.
- Addition of bench marks across caldera, and repeat very high resolution AUV surveys will examine migration of melt impacting location and degree of uplift, seismicity, faulting…

RCA cabled seismometers

Chadwick current bench marks

* *Funding for at-sea staffing, calibration and testing*

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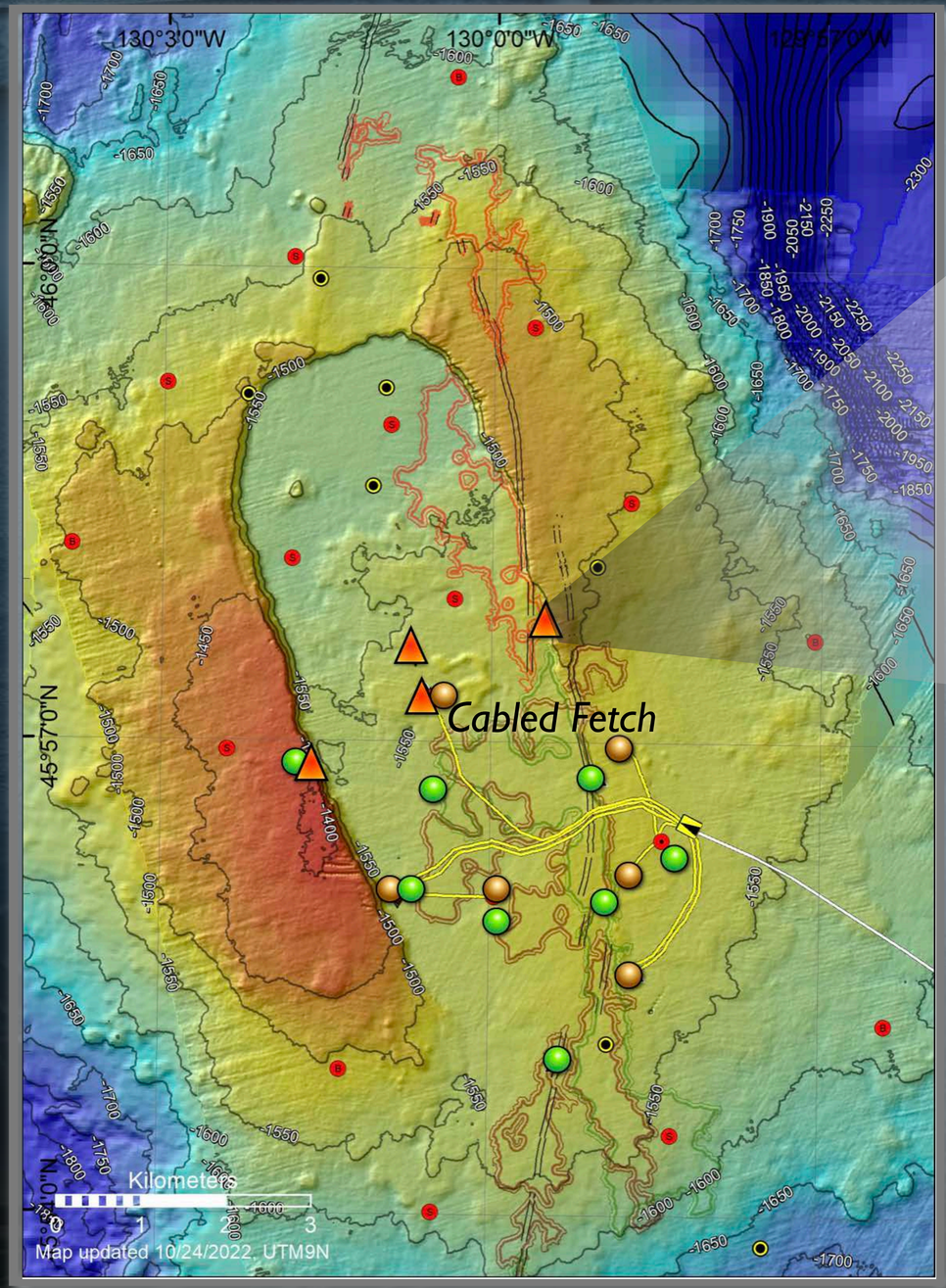
W. Wilcock and D. Manalang (UW) "An Acoustic Array At Axial Seamount for Geodesy and Autonomous Vehicle Support" (OCE2130060-MGG) Will apply for 10 year duration



- Monitor horizontal strain along baselines that connect 4 acoustic transponders.
- Movement of buried outward dipping faults during the volcanic cycle.
- Measure rates of fault slip associated with increase in seismicity during inflation.
- Precise navigation for AUV's - are in conversation with D. Caress (MBARI) for collaborative effort with their AUV.

RCA cabled seismometers

Chadwick bench marks

Fetch Acoustic Ranging Transponders talk to cabled Fetch, temperature, pressure

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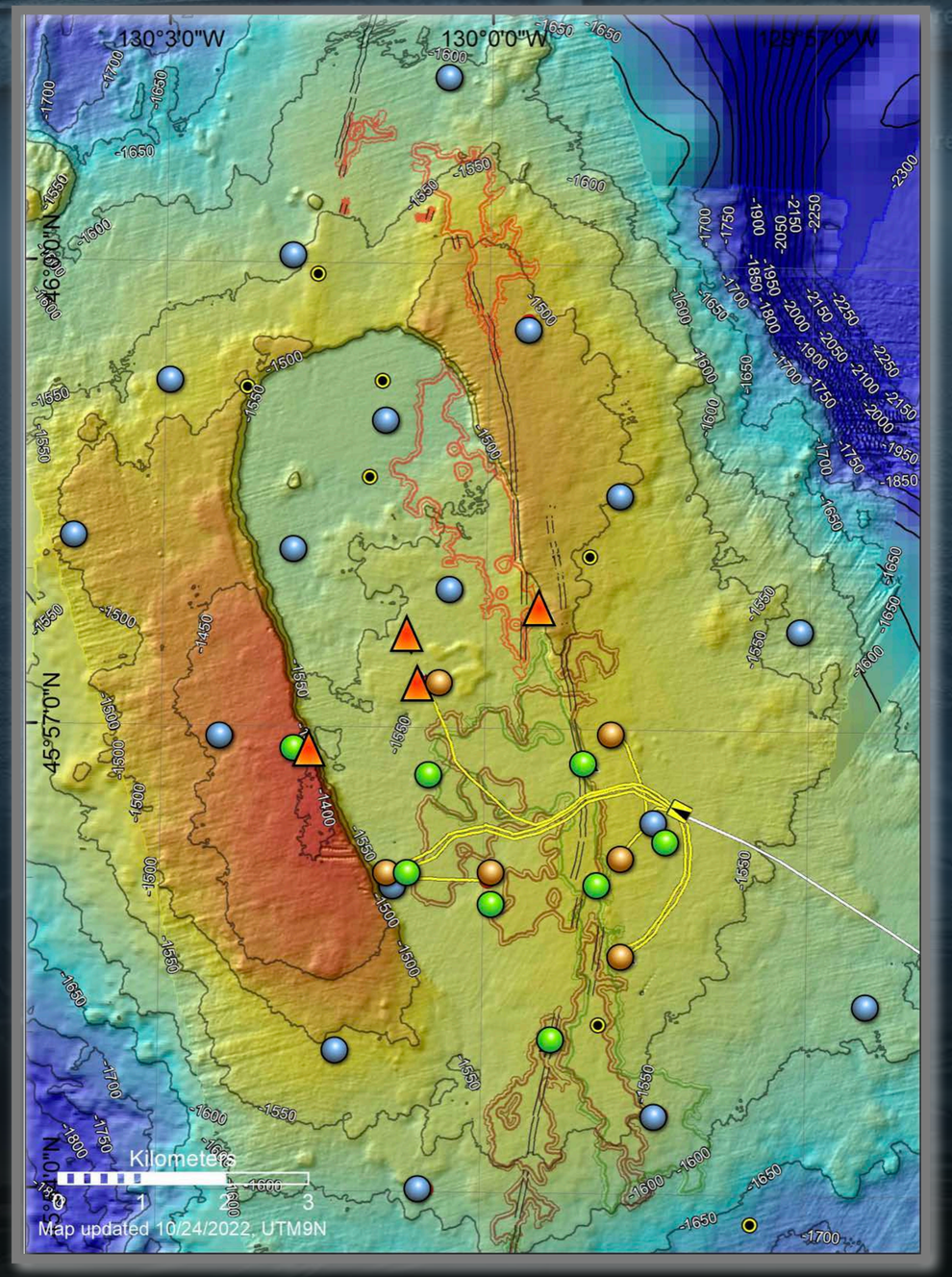

W. Wilcock (UW), M. Tolstoy (Columbia-UW), F. Waldhouser (Columbia) "Collaborative Research: Caldera Dynamics and Eruption Cycles at Axial Seamount" (OCE195096-MGG)

Two-year field experiment iinstalled15 ocean bottom seismographs (OBS) to cover the whole caldera and portions of the south and north rifts.

The open access data will address three hypotheses, that: 1) magmatic processes related to the shallow reservoir exert primary control on caldera and rift structure; 2) the complex shallow reservoir geometry reflects and affects the evolution of magma transport and storage; and 3) magma from the deeper part of the system can be rapidly mobilized and interact with the shallow reservoir over short timescales (weeks/months).

- *RCA cabled seismometers*
- *Chadwick bench marks*
- *Fetch Acoustic Ranging Transponders*
- *Uncabled Seismometers (15)*

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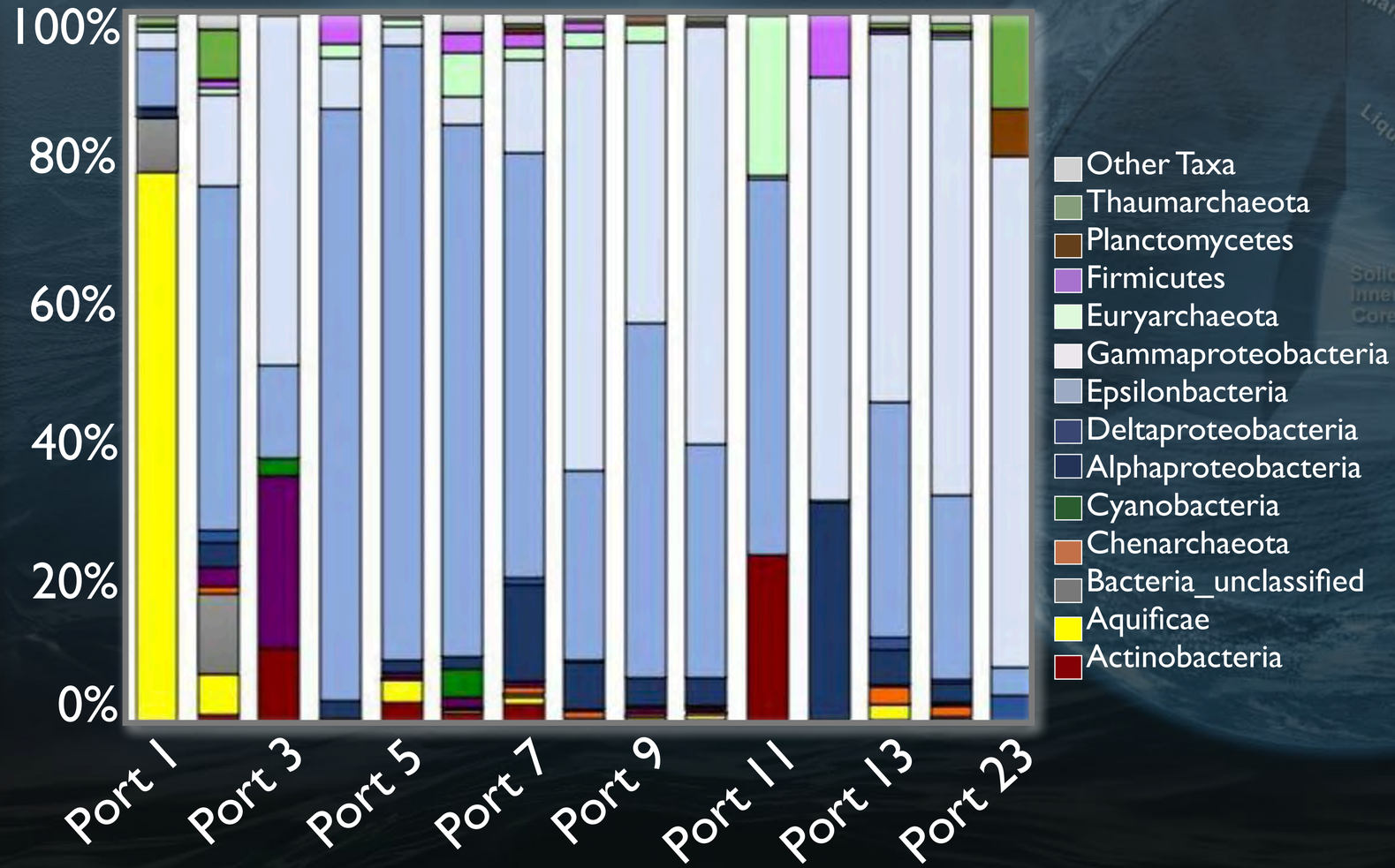
R. Anderson, Carleton College (OCE2045697-Bio) "CAREER: Temporal dynamics of microbial and viral function and adaptation in hydrothermal vents" 5 years.

RCA Cabled Microbial In-Situ DNA Sampler

Microbial Taxa El Gordo Diffuse Flow Vent

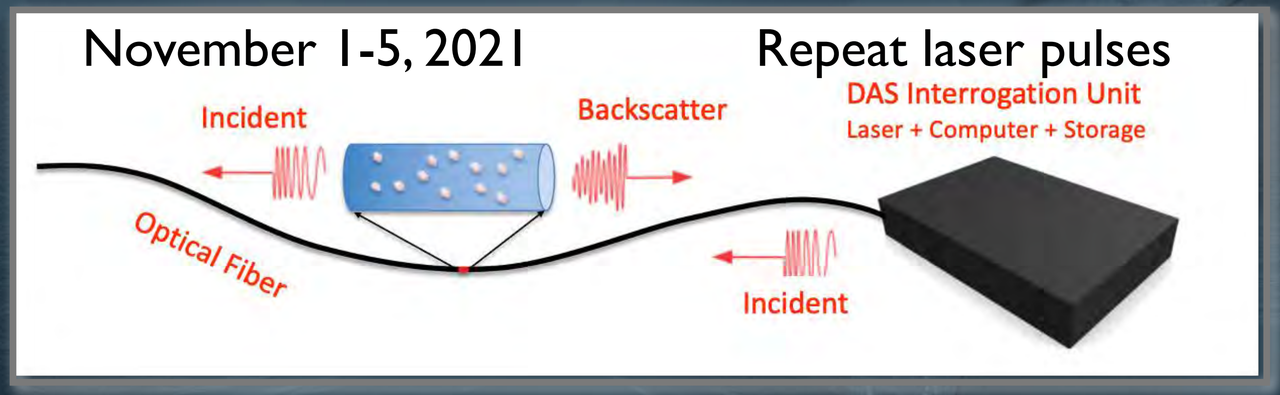


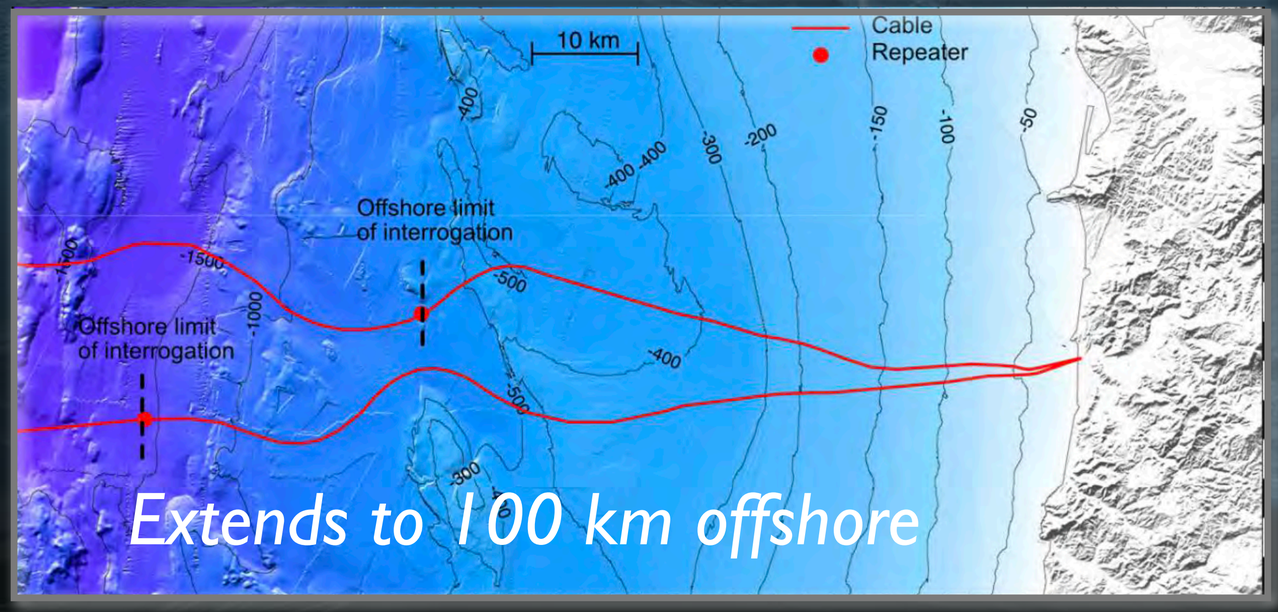
Times Series DNA Sampling 2016-2017 (*Courtesy R. Anderson*)

- Rich time-series of microbial and viral metagenomics every 10-20 days for 3 years
- Increase understanding of microbial function in subsurface in response to perturbations - help constrain marine biogeochemical cycles
- New insights into marine viral ecology in habitats outside commonly studied surface oceans

W. Wilcock, UW "A Community Test of Distributed Acoustic Sensing on the Ocean Observatories Initiative Regional Cabled Array" (OCE2141047- MGG)

20 PIs From 7 Institutions Looking at the Data





45°30'

45°00'

125°10' 124°40' 124°10'

First Community Experiment

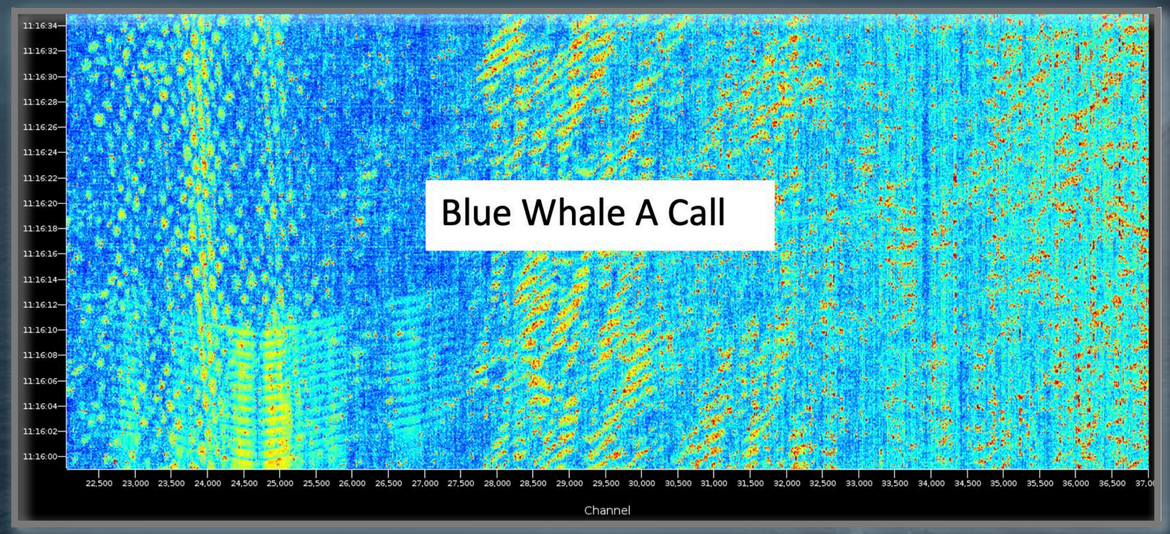
Collection Team

William Wilcock[1]
Zhongwen Zhan[2]
Ethan Williams[2]
Paul Bodin[1]
Dale Winebrenner[1]
Brad Lipovsky[1]
Marine Denolle[1]
Shima Abadi[1]
Meagan Wengrove[3]
Doug Toomery[4]

[1]*University of Washington*
[2]*Caltech*
[3]*Oregon State University*
[4]*University of Oregon*

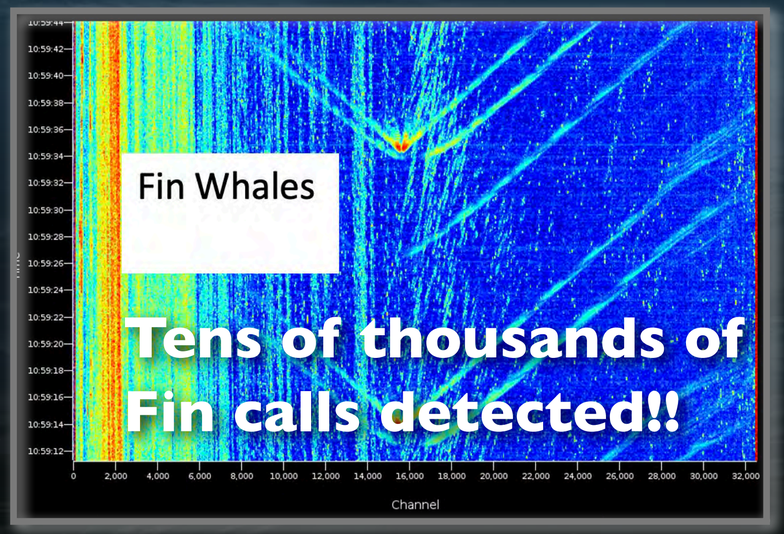
Over the 4 day experiment, 26 TB of data were collected from 1000 hz to 200 Hz - a sensor every 3 to 30-50 m, respectively

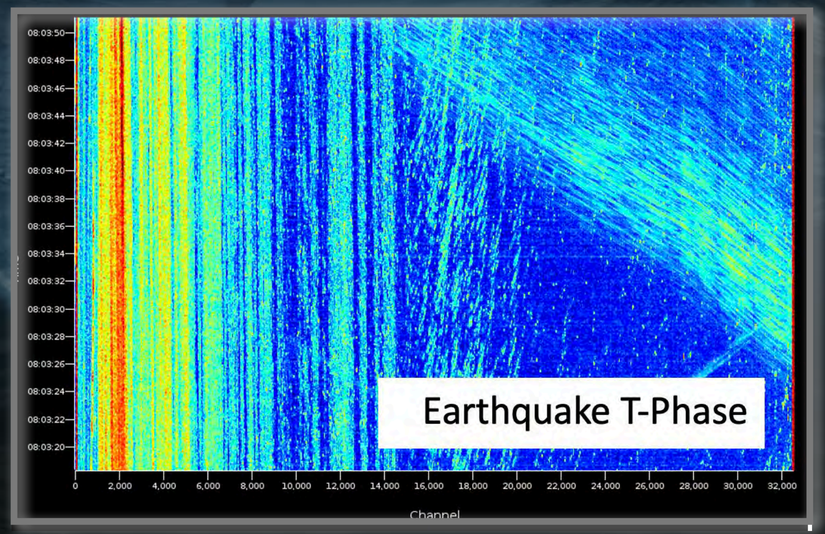
OptaSense Waterfall Plots 15-25 Hz



Potential Science

- Shallow Structure and Faults
- Ocean wave spectra, compliance and currents
- Earthquake signals, including T phases
- Infragravity waves and internal tides
- Marine Mammals
- Ship noise





Courtesy: W. Wilcock

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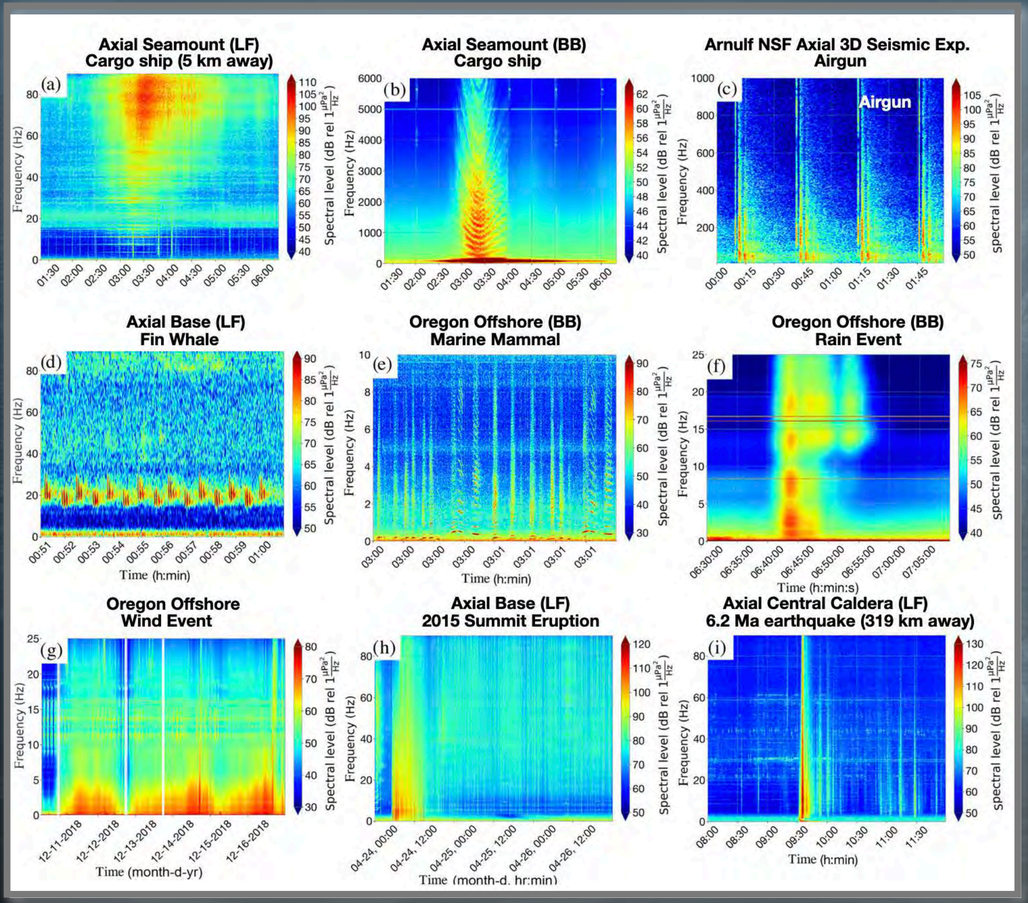
An Overview of Ambient Sound Using Ocean Observatories Initiative Hydrophones (Ragsland et al., 2022)



RCA broadband and low frequency hydrophones allow:

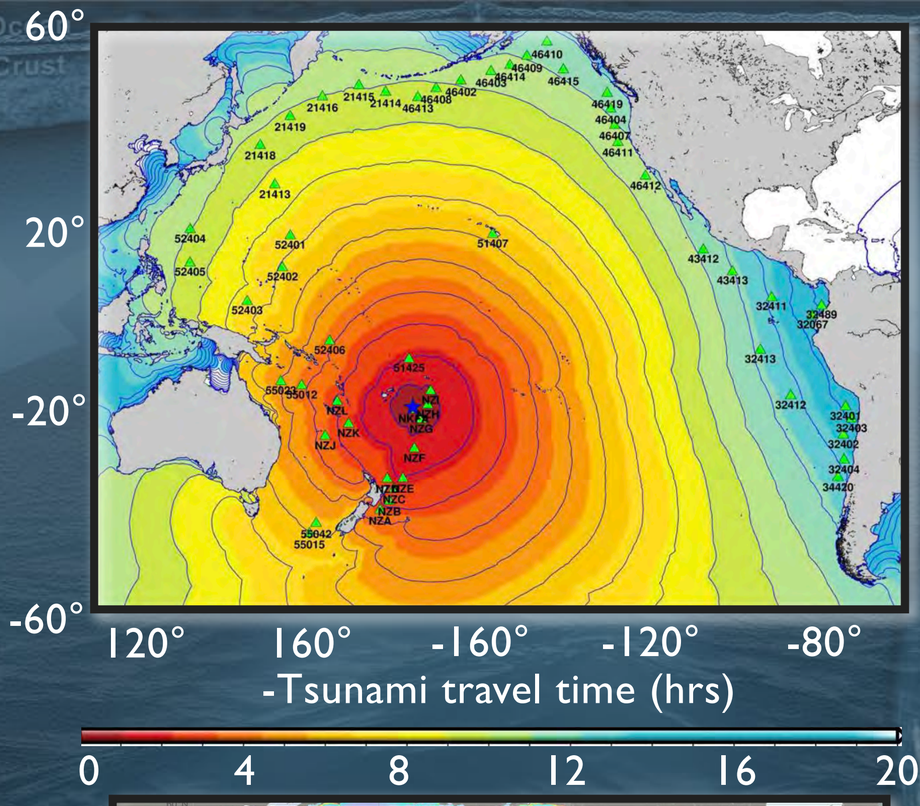
- Rare offshore monitoring of Fin whale migration, and seasonal fluctuations and decade-long evolution of their calls
- *In situ* offshore high temporal resolution meteorological measurements to study wind and rain noise in the NE Pacific.
- Evaluation of commercial ship sounds with impacts on the oceanic environment and marine life.
- Monitoring volcanic eruptions, and both local and far-field earthquakes
- Development of cloud computing and AI

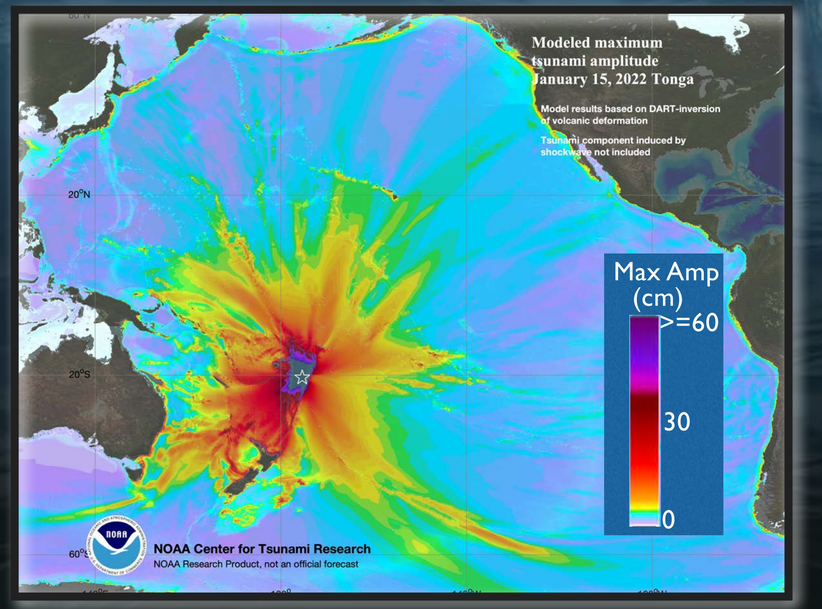
Shima Abadi ONR Award: Date-driven analysis and prediction of ocean noise on the NE Pacific continental slope

Developed OOIPy for easy access and exploration of data

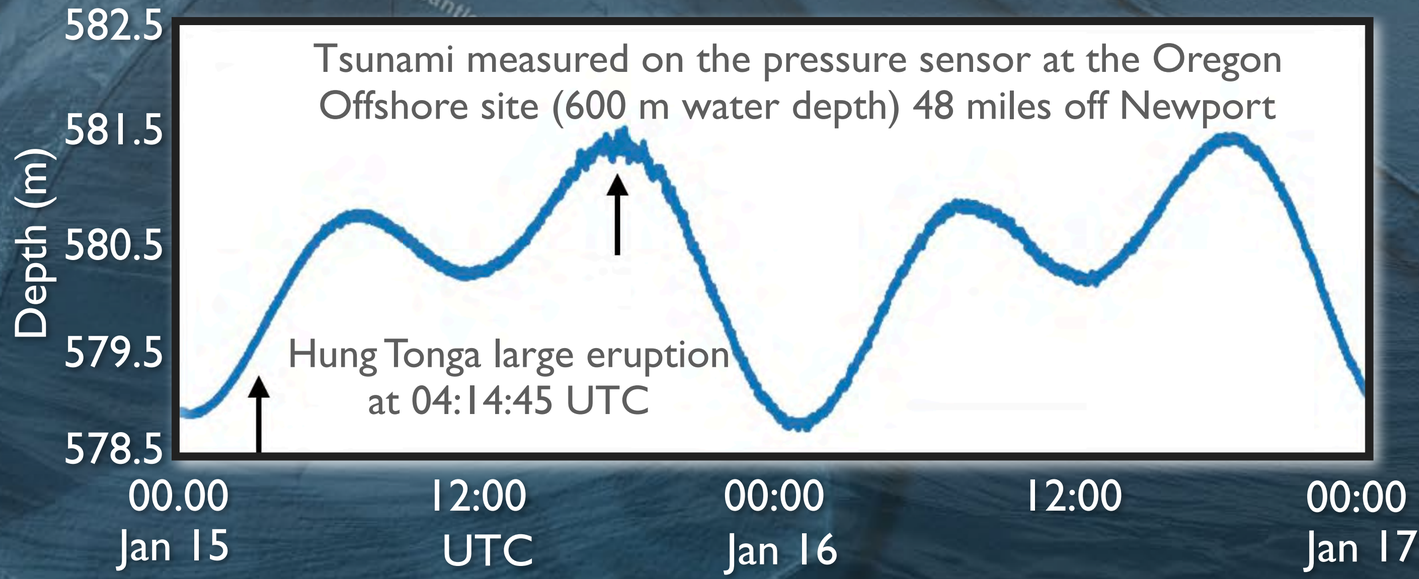
RCA Geohazard Applications

Tonga Tsunami: Oregon Offshore BEP Detection



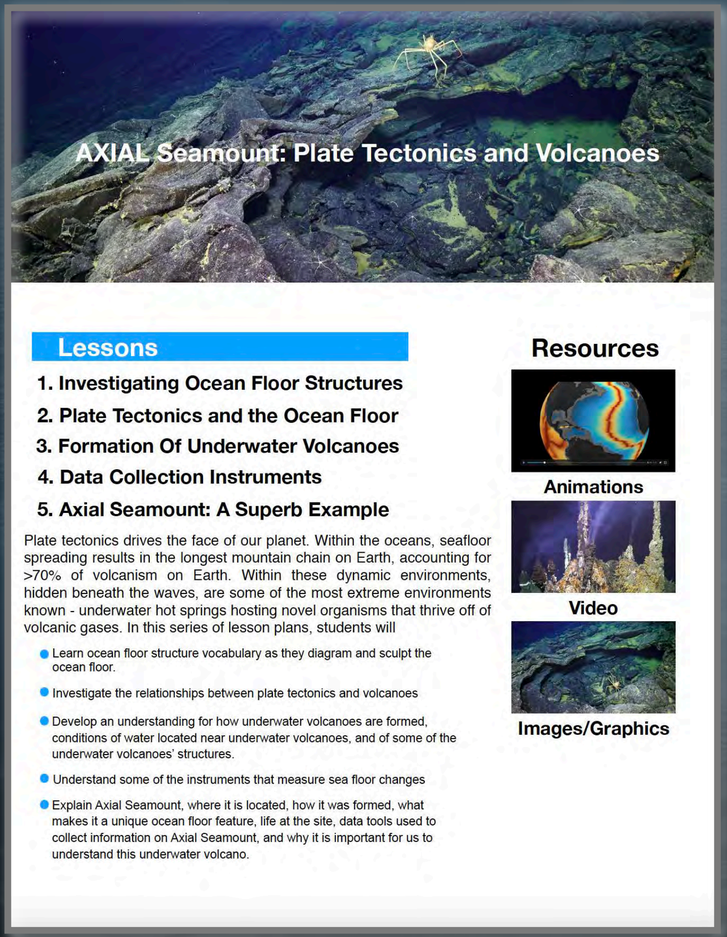


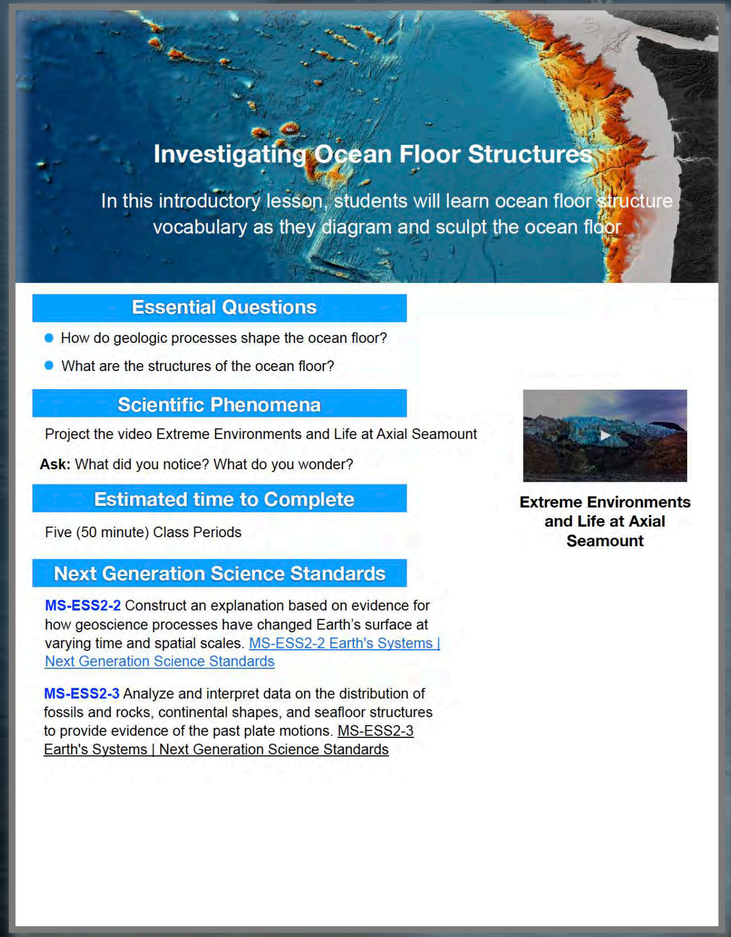
Modeled maximum tsunami amplitude

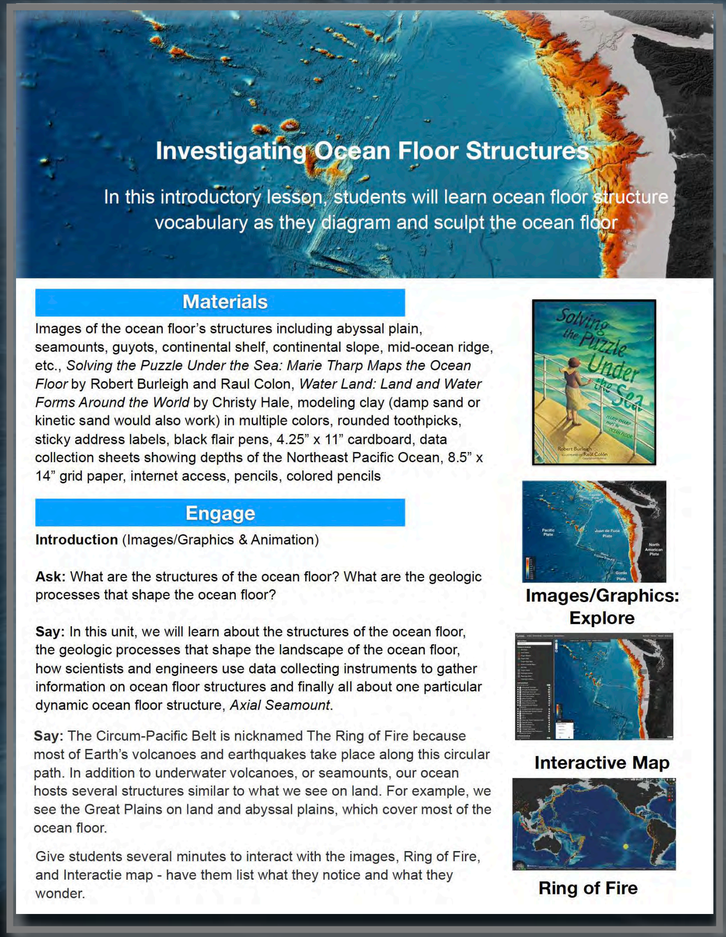


- Late in the afternoon Hung Tonga volcano explosions produced 5 km-wide ash column between 17:00 -18:30 local time. A much larger eruption started the following day (15 January 2022) at 17:14 local time (04:14:45 UTC,).
- RCA data incorporated into NOAA Tsunami Warning Database

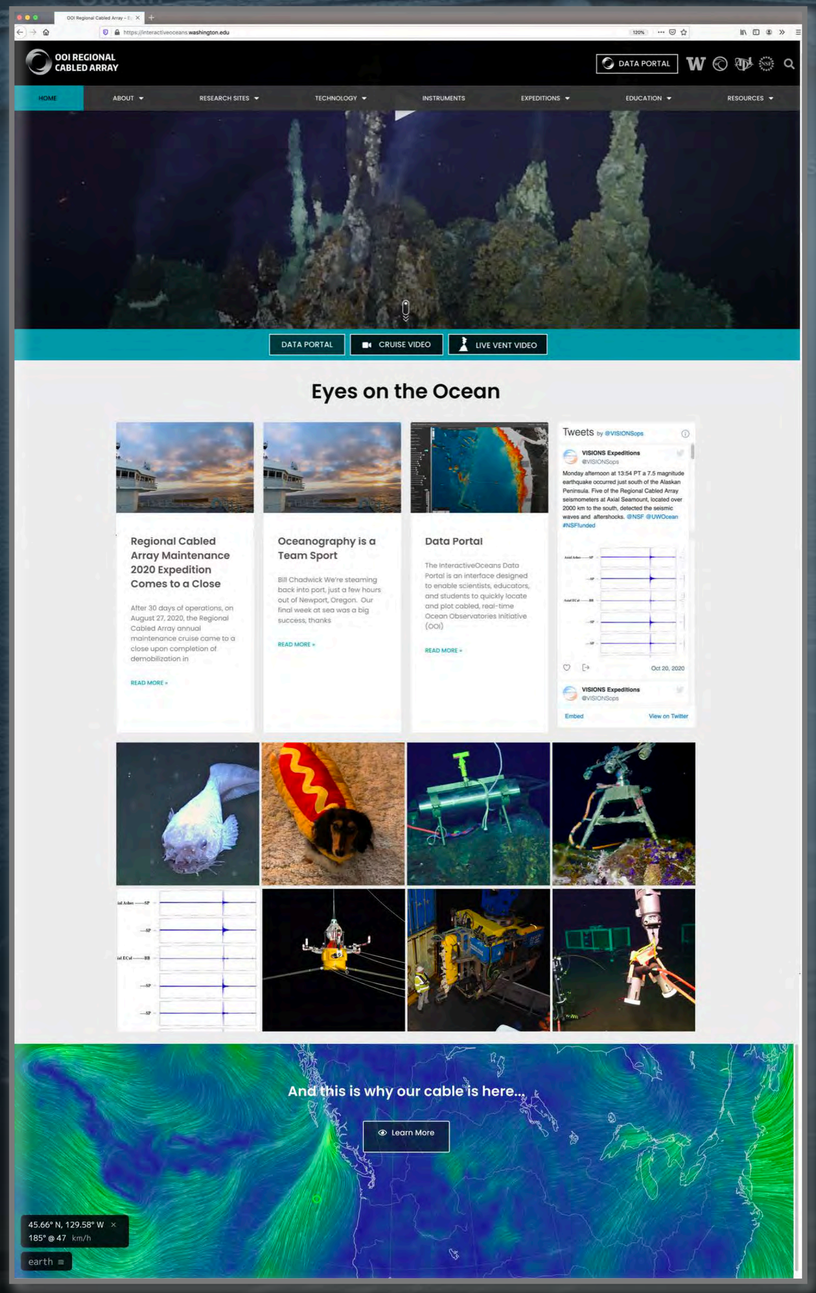
K. Borders , West Sound STEM, WA"K12 Ocean Observatories Initiative (OOI) Workshop Series" (OCE2122351 -Education) Bringing RCA-OOI data into the classroom

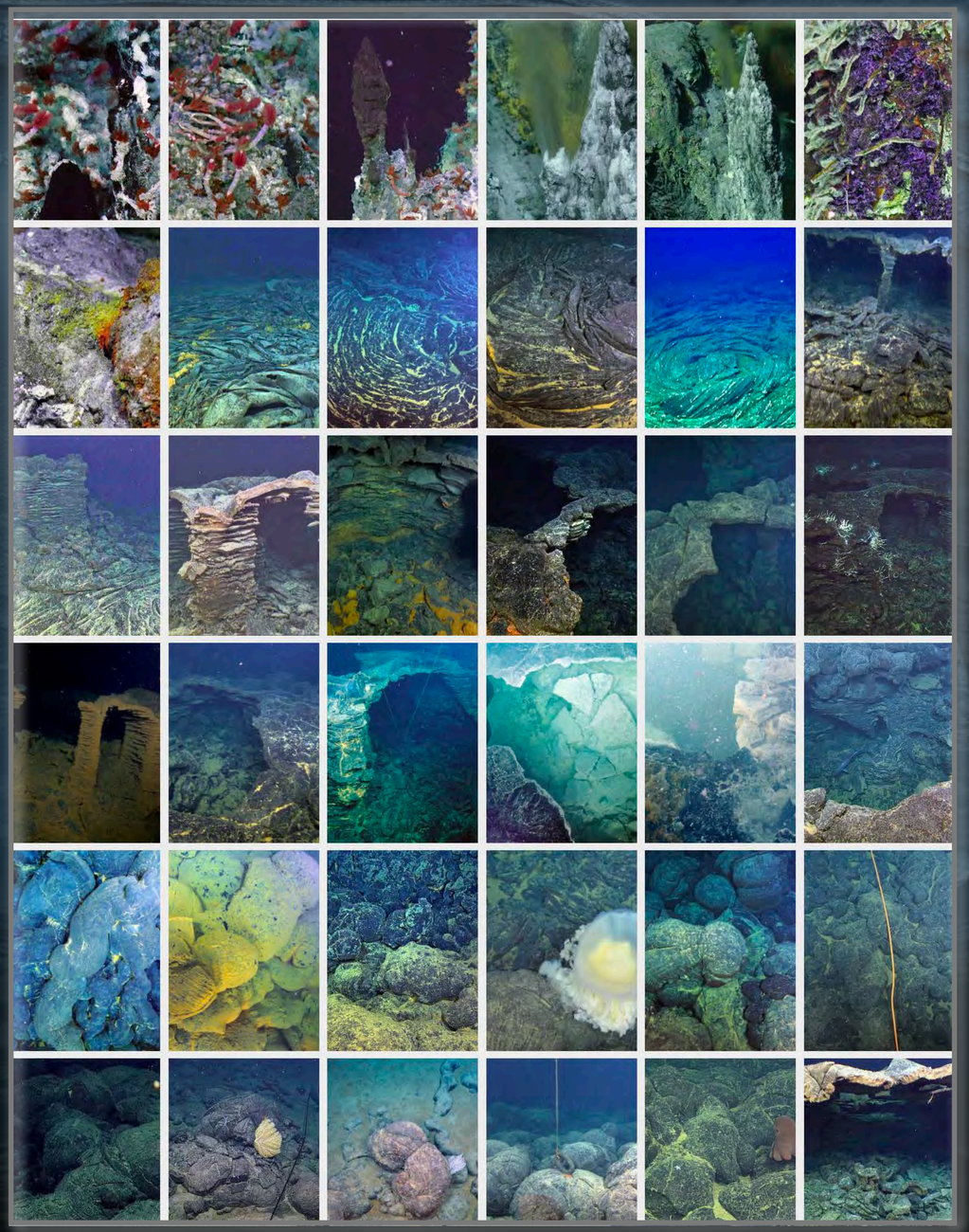






3 multi-week long modules: Plate Tectonics - Axial Seamount example, Geohazards - seismic and pressure (tsunami) data; the "warm blob" and climate change - Shallow Profilers





Resources

RCA science and technology

All research sites

Extensive video library

Over 3,000 images (perfect for outreach)

Biological catalog for Axial and the Cascadia Margin/Slope Base

Data portal hosts >600 data stream

UW Cloud-Hosted Educational Site interactiveoceans.washington.edu & Data Portal






THANK YOU!



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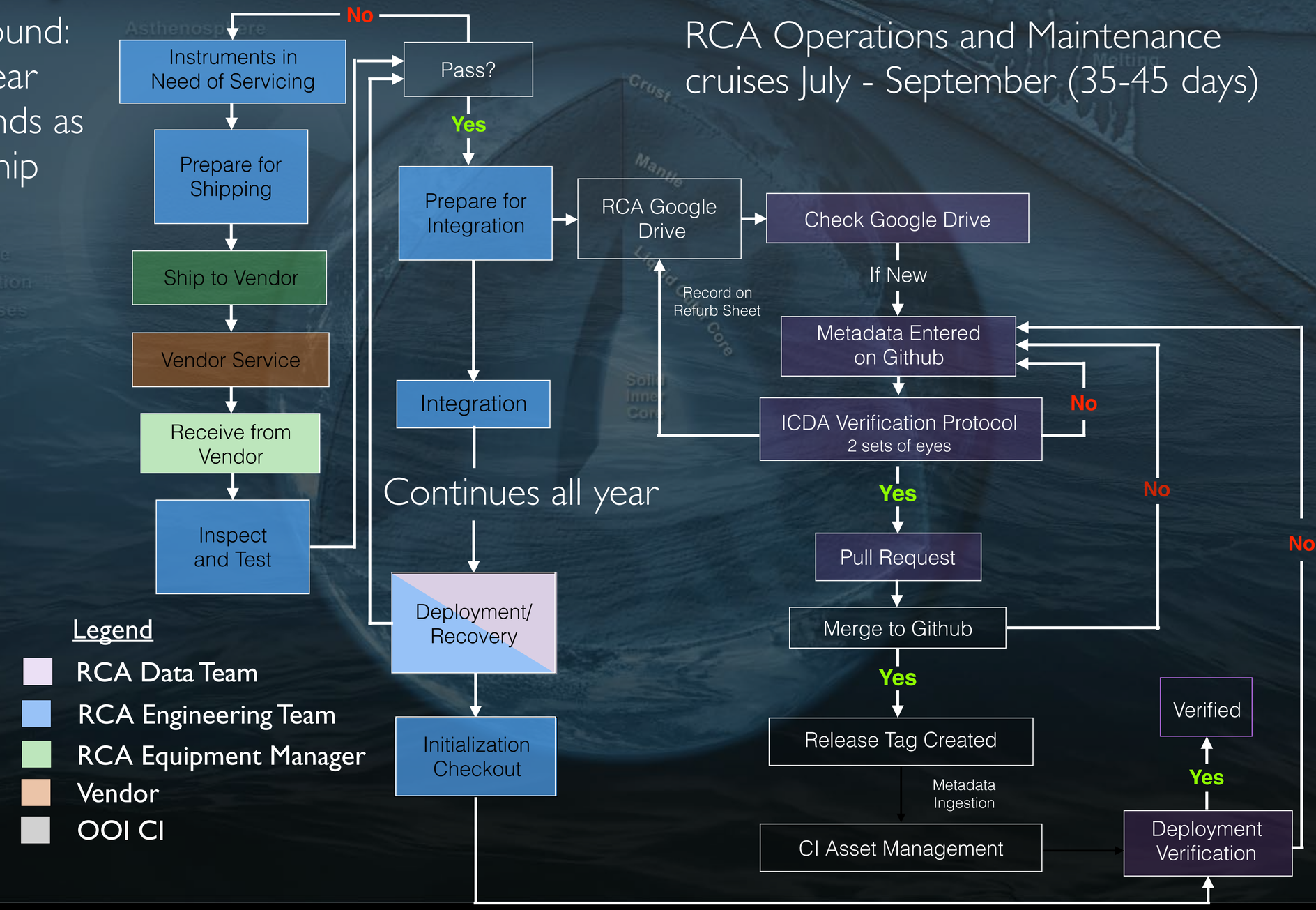
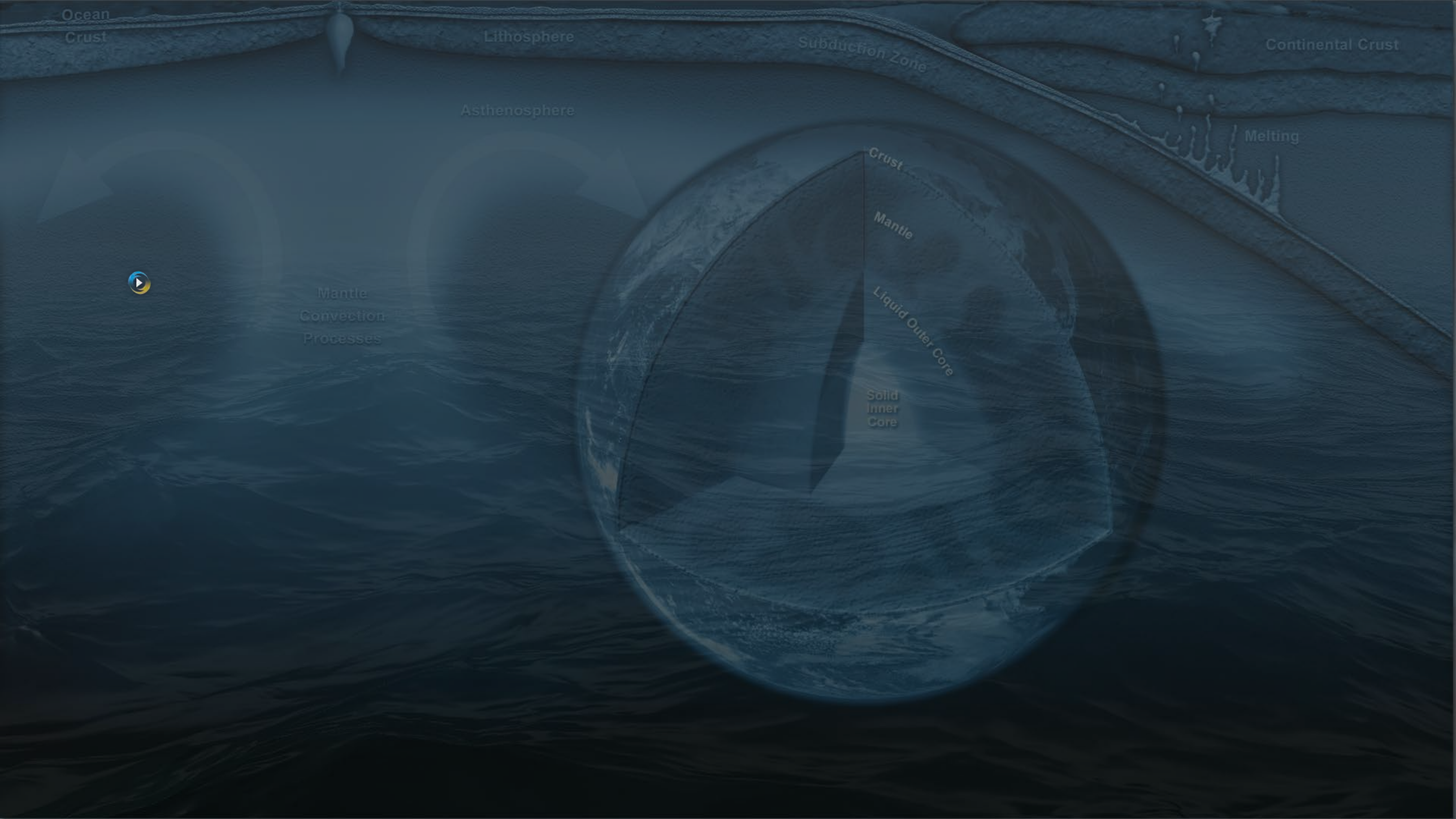
WASHINGTON
HUSKIES
SEATTLE, WA

RCA Quality Assurance: Instruments and Metadata

Out team is busy all year round: The process for the next year starts even before cruise ends as instruments come off the ship e.g. August 2022

RCA Operations and Maintenance cruises July - September (35-45 days)




Ocean
Crust
Lithosphere
Subduction Zone
Continental Crust
Asthenosphere
Melting
Crust
Mantle
Liquid Outer Core
Solid
Inner
Core
Mantle
Convection
Processes