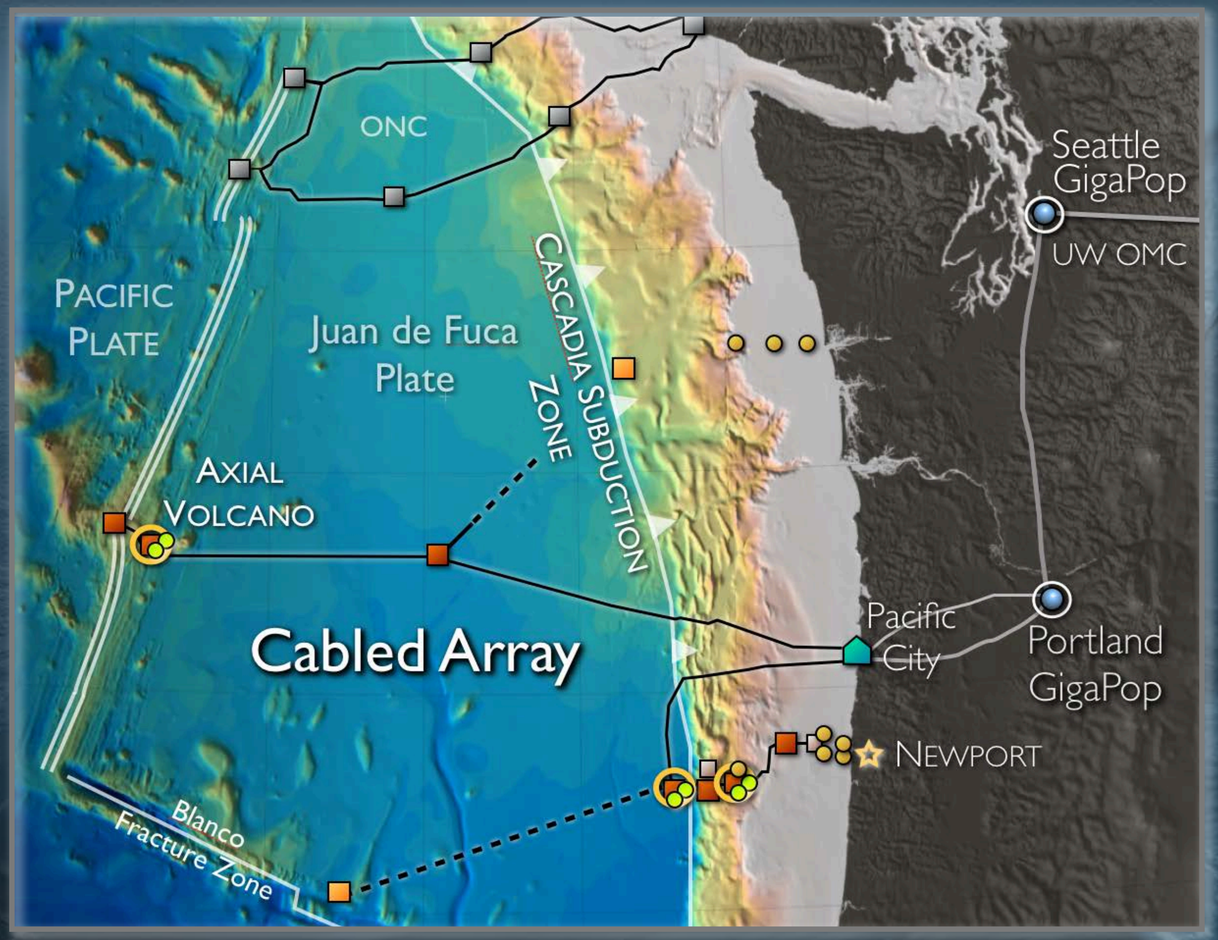
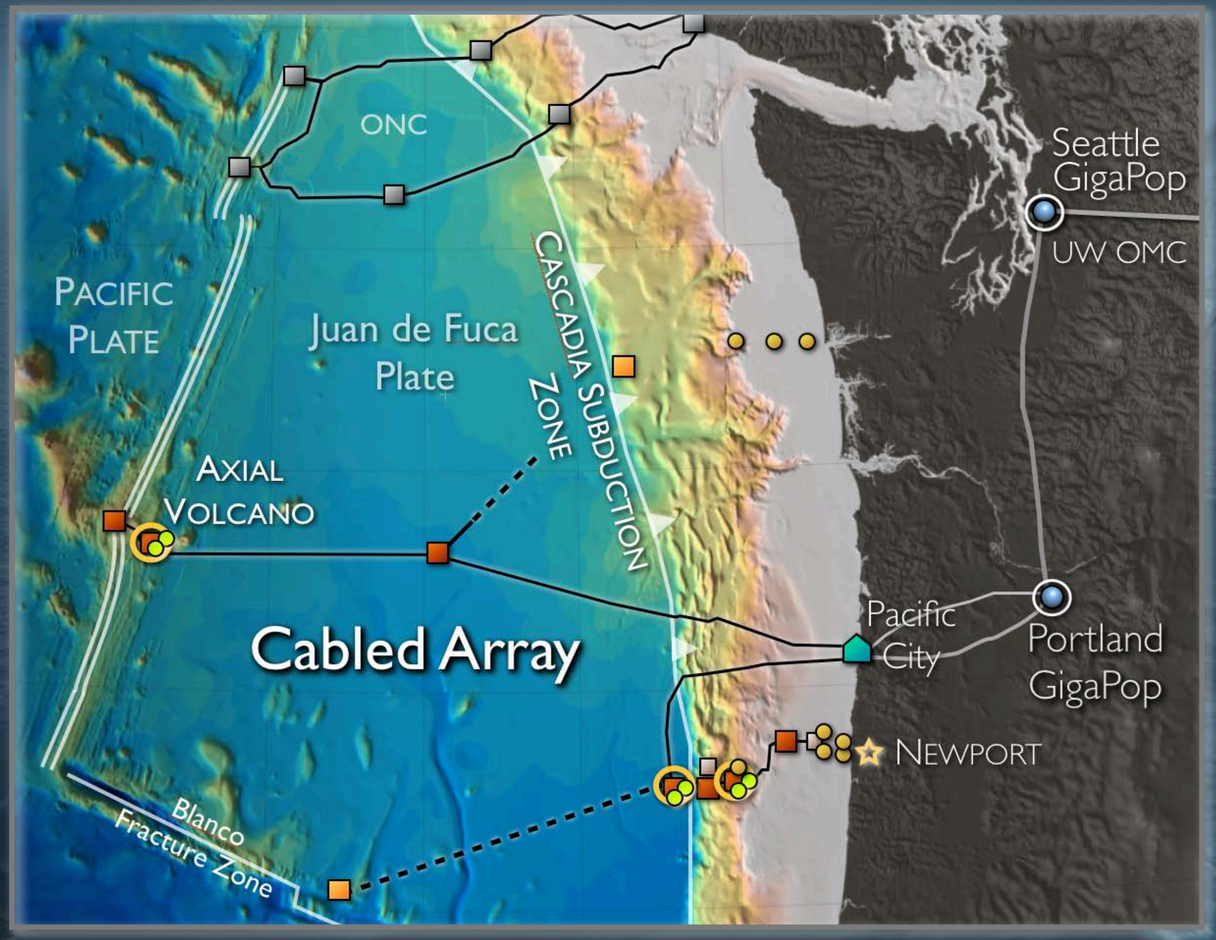
Regional Cabled Array



Installation completed on time and on budget

- 900 km of high bandwidth (10 Gbs) and high power (8 kW) primary cables
- 18 junction boxes providing 375W and 1 Gbs
- 6, up to 2700 m tall moorings with instrumented wire crawlers connected to the cable
- 140 instruments provide 24/7 real-time data with two way communication - response capabilities
- highly expandable for science, industry, education

Regional Cabled Array



Includes two types of infrastructure

- **Primary Infrastructure**

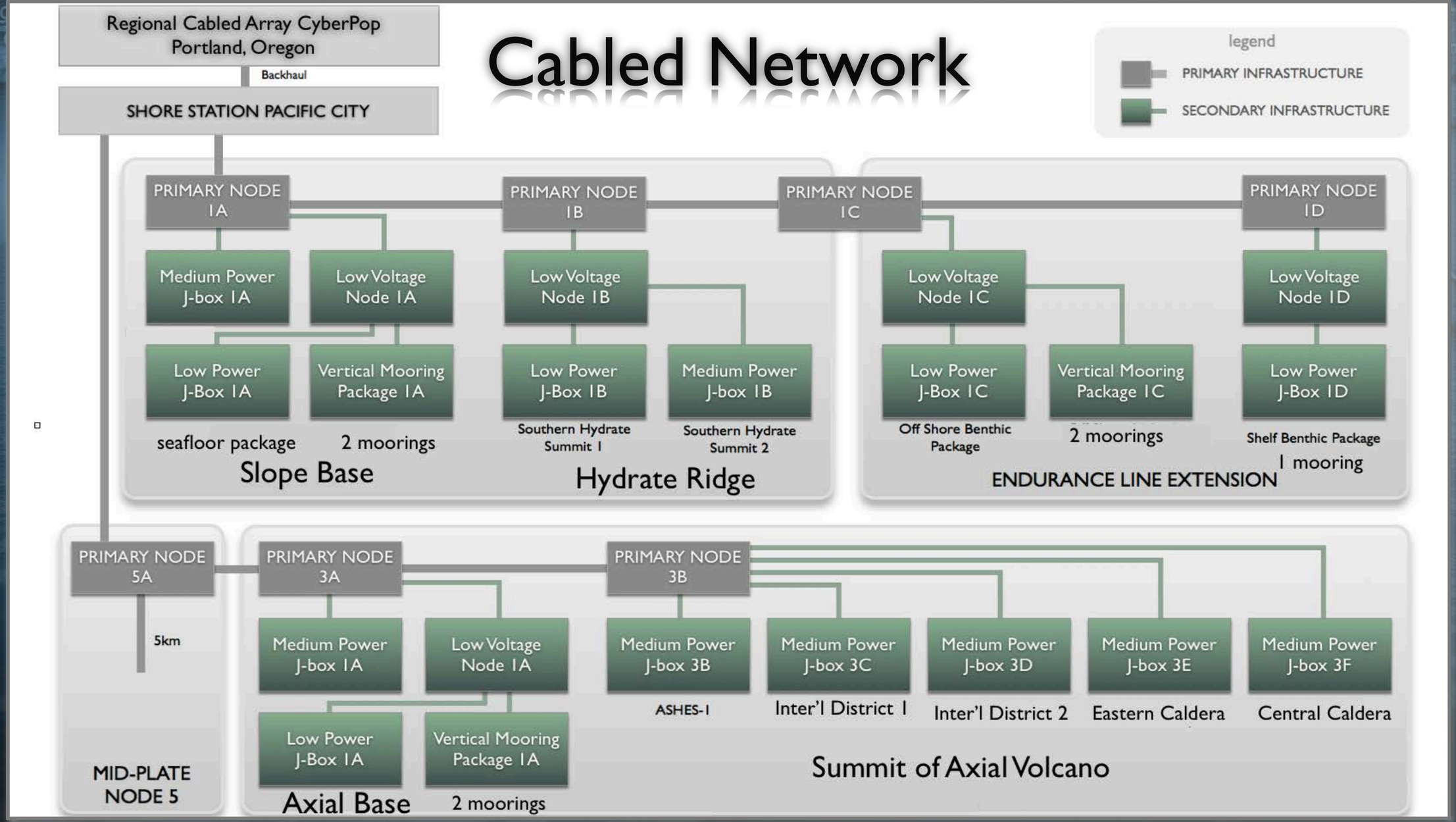
  Backbone cables, primary nodes, shore station, terrestrial backhaul

- **Secondary Infrastructure**

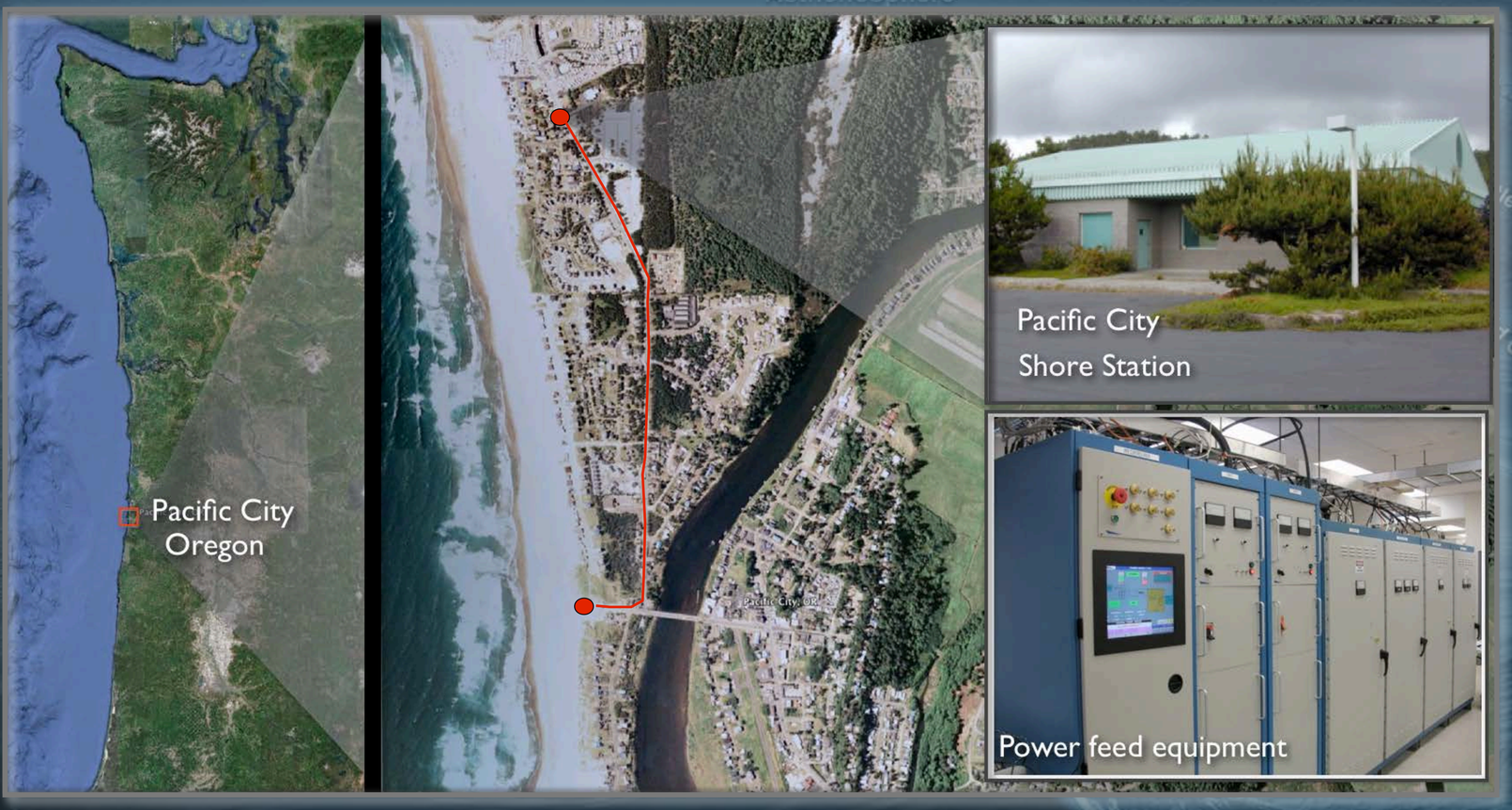
  Extension cables, junction boxes (secondary nodes), moorings, instruments (PI and COTS)*

* unique operational requirements e.g. >300°C black smokers

Cabled Network



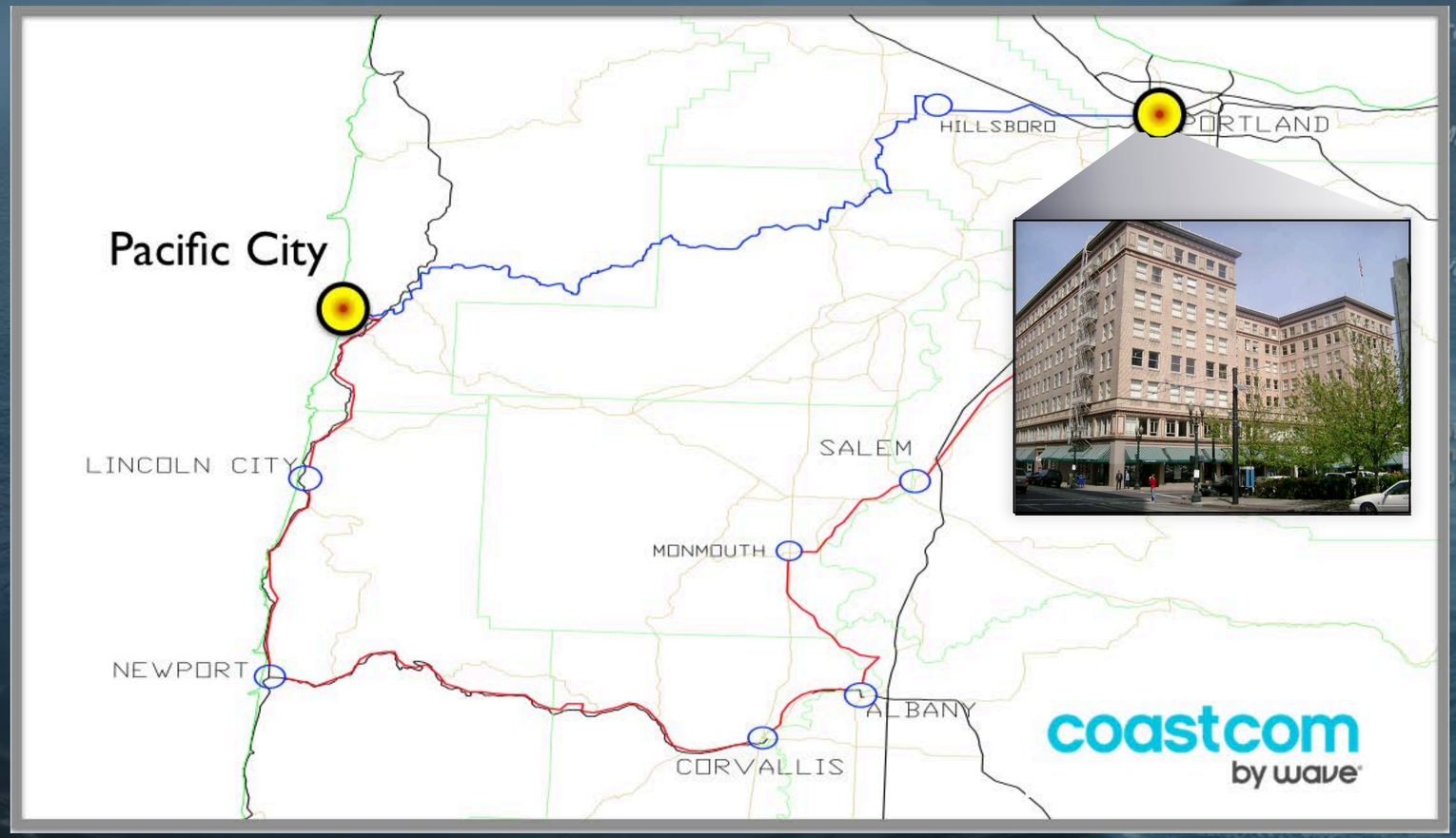
Shore Station Leased from Tillamook Lightwave



10,000 gallon fuel tank provide several weeks of power should land lines fail (utilized a couple times); station behind secured gate

- Manned during working hrs, 1.5 FTE, powering up/down of Primary Infrastructure is done at Shore Station
- Provides 10 kVdc, up to 8A, 8 kW power, and 10 Gbs communication to each cable line (upgradable to 40 Gbs)
- New telecommunications company will share space (Sept), lower cost; two new customers using shore conduit
- All seismic data and hydrophone data are routed to the NAVY from a secure site in the Shore Station; returned from Johns Hopkins to Pittock
- All raw data flow both to the Pittock Exchange Building and the UW Operations Center

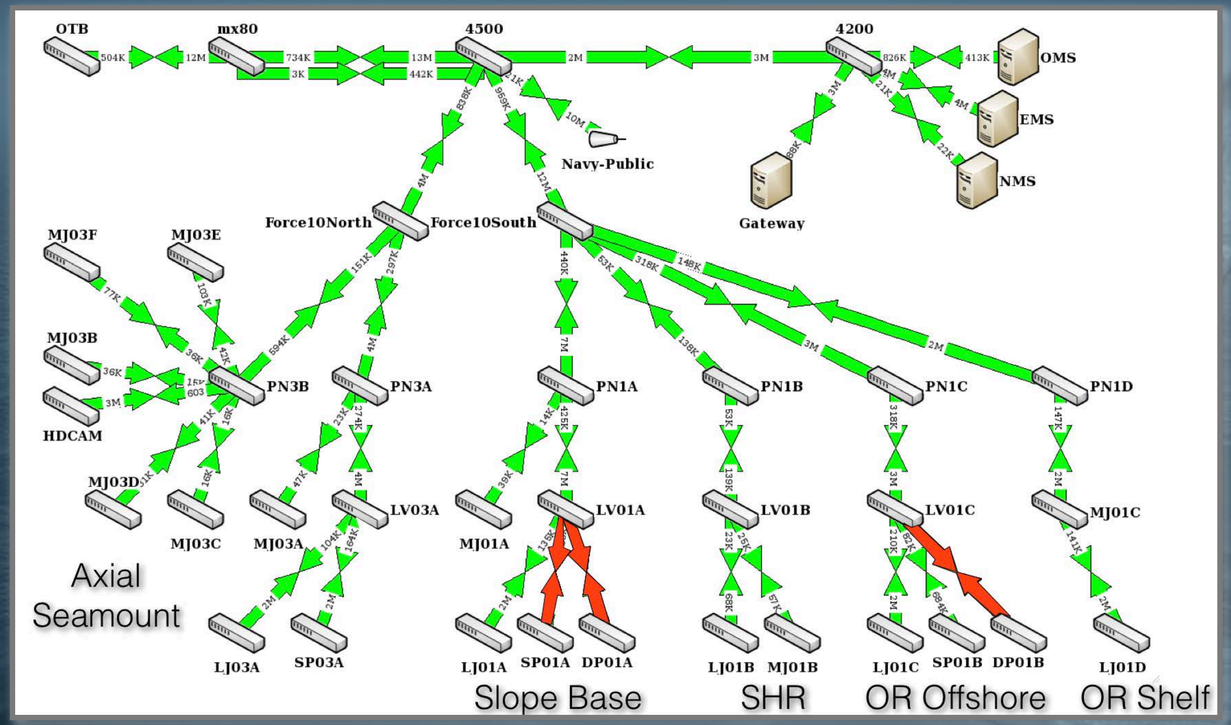
Backhaul (Portland, OR to Pacific City, OR)



- Terrestrial telecommunications fiber that connect the shore station in Pacific City, OR with the Portland Point of Presence (Cyberpop)
- Utilizes diverse routes from Pacific City to Portland, OR allowing maximum availability.

UW Observatory Management Center

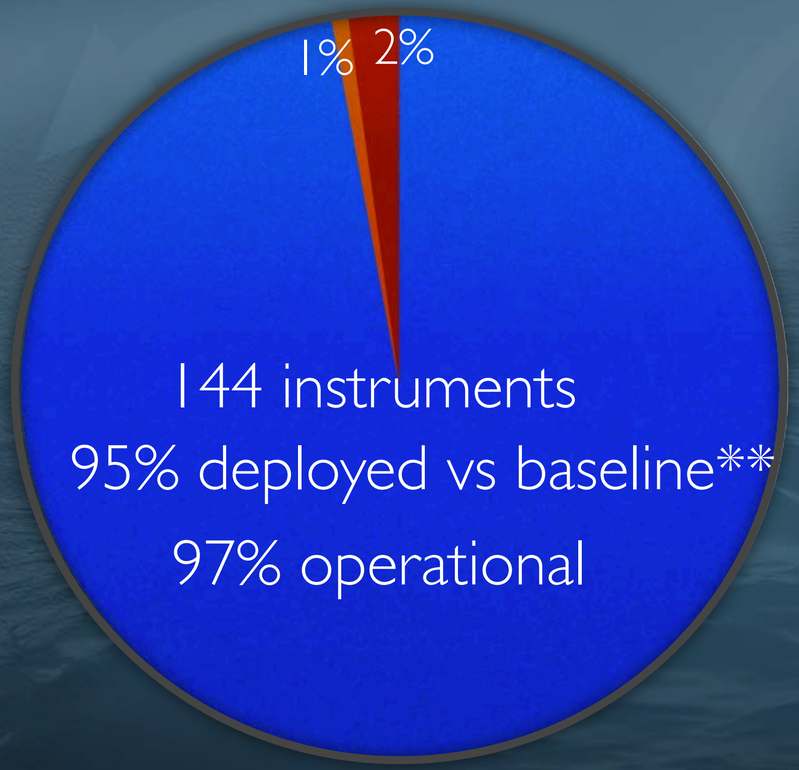
Provides Live Health Monitoring of Array



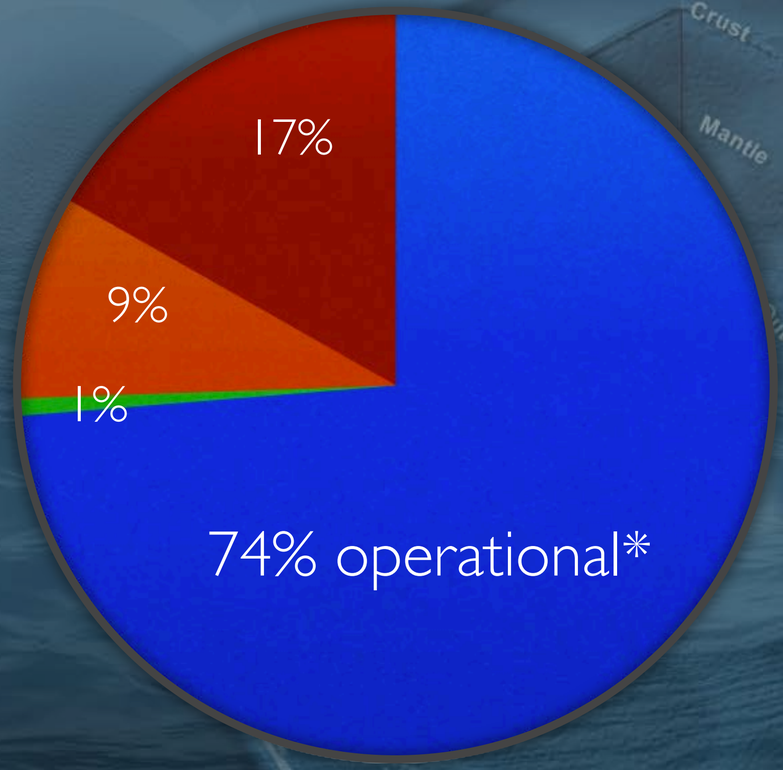
- The Observatory Management System (OMS)
  - Includes a collection of services implemented in software.
  - It is the primary control system for operation of the Cabled Array and a management system with complete observatory awareness (>1000 alerts and alarms).
  - It includes a
    - Network Management System (NMS) – L-3 MariPro; Primary Infrastructure
    - Element Management System (EMS) – Secondary Infrastructure

- Monitors the health of the networks
- Collects, stores and depicts engineering telemetry data from all network components
- Provides both a local and remote GUI for the OMS operator control
- Provides alarm capture, notification, management and propagation.

Instrument Operational Status



2016 Deployment



May 2017

- Operational
- Trouble shooting
- Failed
- Offline (Deep profiler, HD Camera, 1 Science Pod Shallow Profiler)

Failed:

OPTAA (7 - pump and lamp);
VADCP (1);
pCO2 (2 - no comms; ground faults);
Digital still camera (1 - PIA likely comms);
pH(1 - ROV pulled cable out on installation)
Resistivity-Tem sensor (ceramic likely cracked)

HD camera - ground fault, running every two weeks

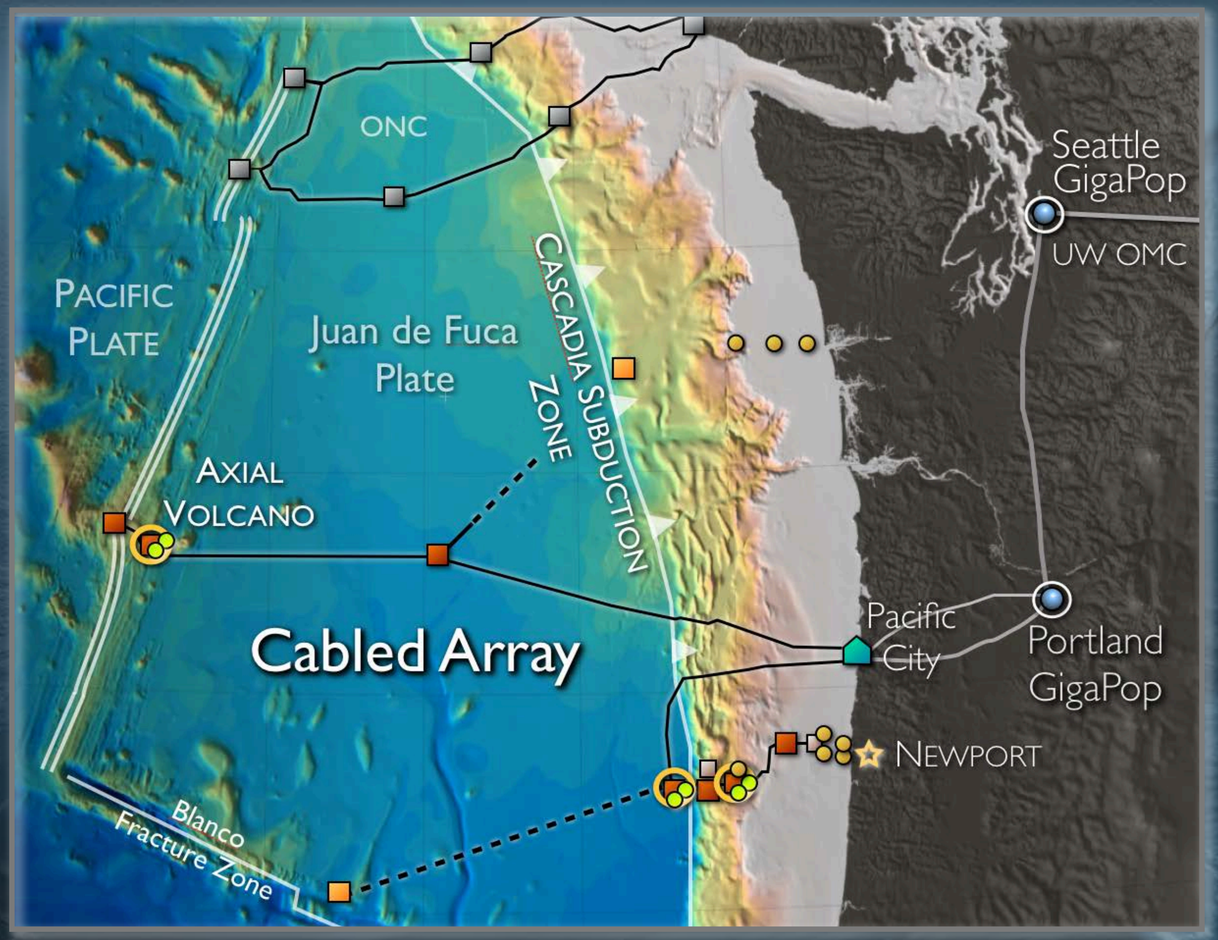
**1 DP and 1 THSPH sensor not installed

*Checking data quality on 8 instruments

Incorporating Operational Efficiencies

- Replacing drymate connectors with wet mates - don't have to turn/ refurbish some junction boxes annually.
- HD camera modified this year to include a cleaning brush for biofouling, will not need to turn annually
- Incorporating RAS/PPS and Mass Spectrometer into one frame saving dives and significant installation time
- Deploying pressure sensors 1 year before turns (uncabled) to equilibrate for follow-on years connection
- This year developed and implemented Mission Execution for HD camera, digital still camera and Shallow Profilers so missions are now automated

Regional Cabled Array



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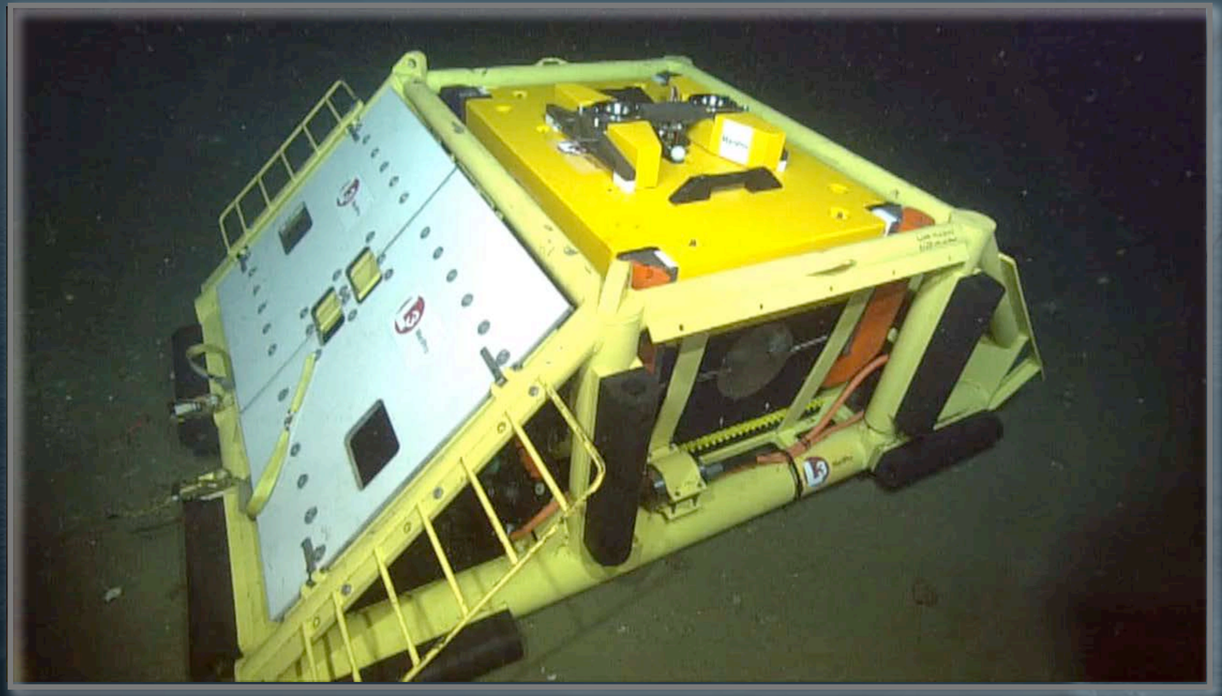
Primary Infrastructure: L-3 Mari Pro Inc. - UW Important Industry-Institution collaboration



Shallow Water Node

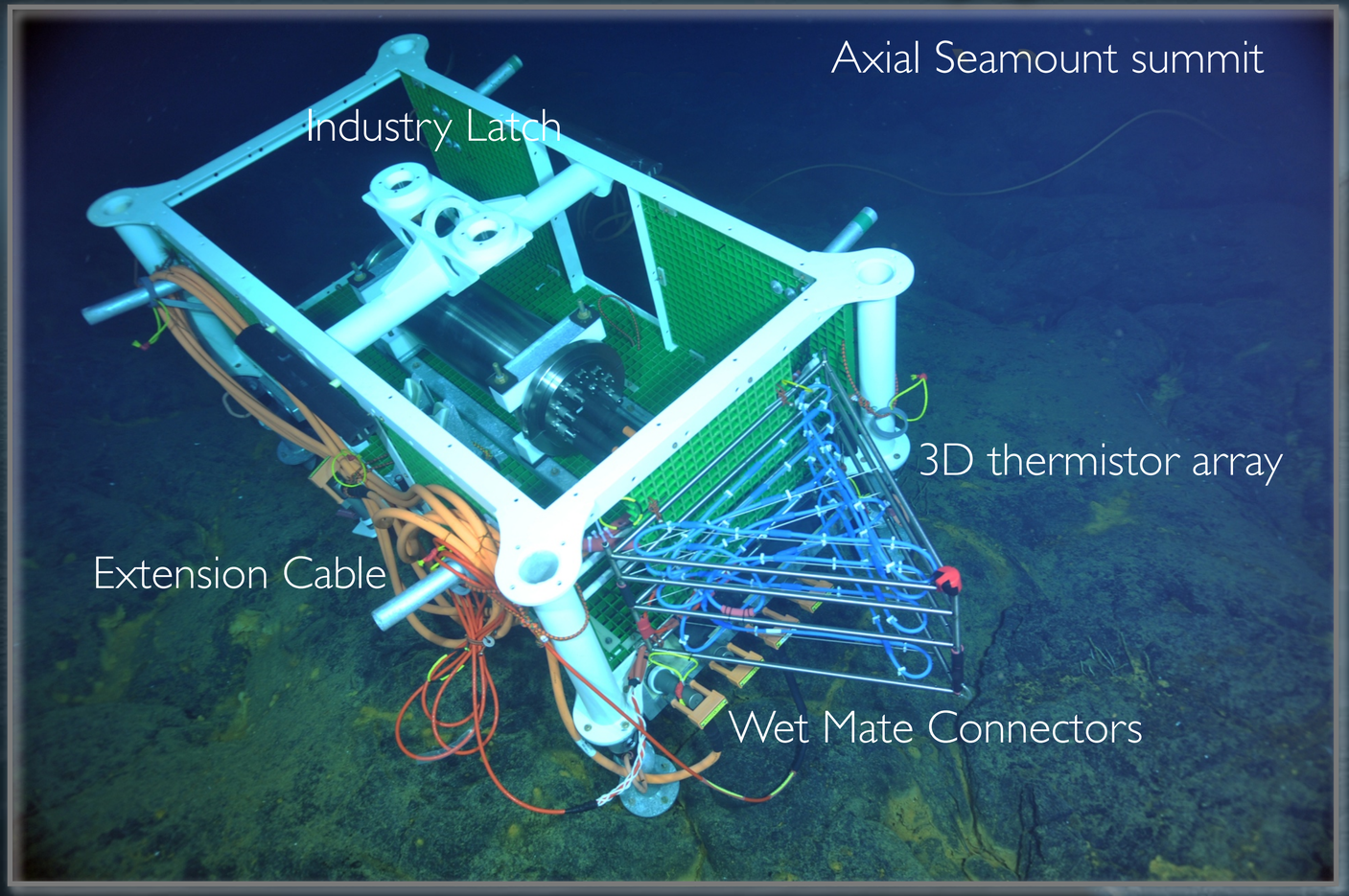
10 km south of Southern Hydrate Ridge

7 PRIMARY NODES

- Each Primary Node -10 GbE, 8 kW
  - 5 Science Ports (1 GbE, 375 V)
    - ROV Wet mate Connectors
  - 2 High Bandwidth Science Ports (10GbE, 375V)
    - ROV Wet mate Connectors
  - 2 Backbone Expansion Ports (10kV)
- Pulse per Second Timing
- Science Interface Assembly removable by ROV
- Primary cabled buried out to 1500 m water depth
- Route approved by OFCC, COL is a member

All fully operational science 2014 - virtually no issues

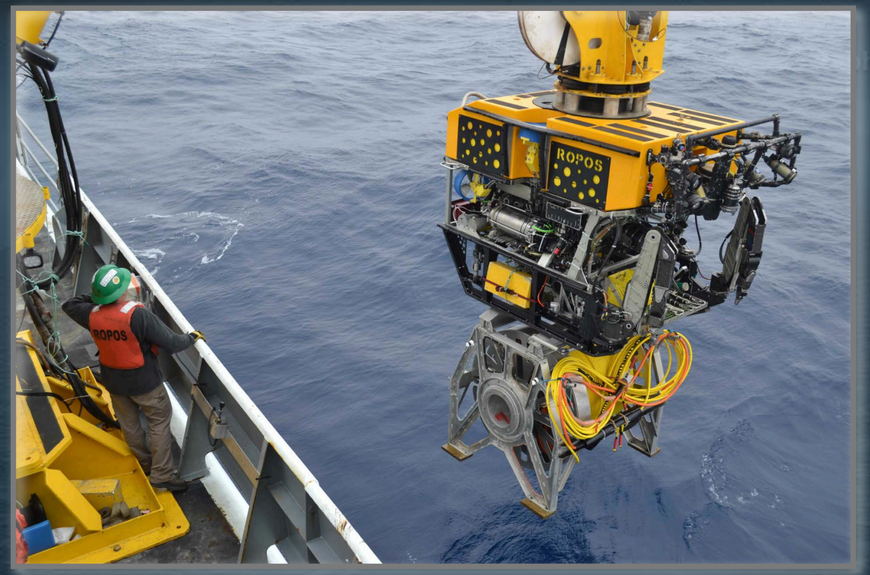
Secondary Junction Boxes

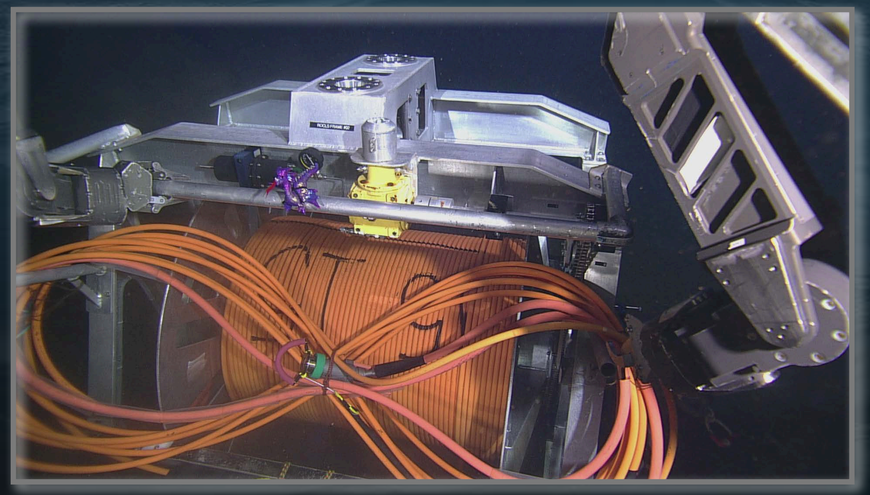


- Provides 8 configurable science ports with 1 Gbs bandwidth, up to 200W of power per port (±12/24/48 VDC), and one expansion port 10Amp, 375VDC), 10/100BASE-T, RS232 or RS485 data links
- Extend power and bandwidth to instruments and platforms
- Setup specifically for each platform/site; can easily be daisy chained for expansion
- Planned for 5 year O&M turns, phased
- Designed and built by Applied Physics Lab = easily modified and upgraded

18 now installed on Cabled Array - All are Operational with no issues since installed in 2014

Extension Cables





- Extension cables installed with ROPOS 2013-2014 using their ROCLS system
- 33,000 m installed with lengths up to ~ 5 km (Axial) and over very complicated terrane
- All are operational with no issues since powered up in 2014
- Longer cables installed by lowering ROCLS on a trawl wire, then latching into with vehicle (exceed 4,000 lb limit); < ~250 m installed with tool sled (elevator)
- Issue in future will be ROPOS is only vehicle with cable-laying capabilities

Operations and Maintenance Secondary Infrastructure

R/V Thompson and ROPOS 2015

R/V Sikuliaq and Jason 2016

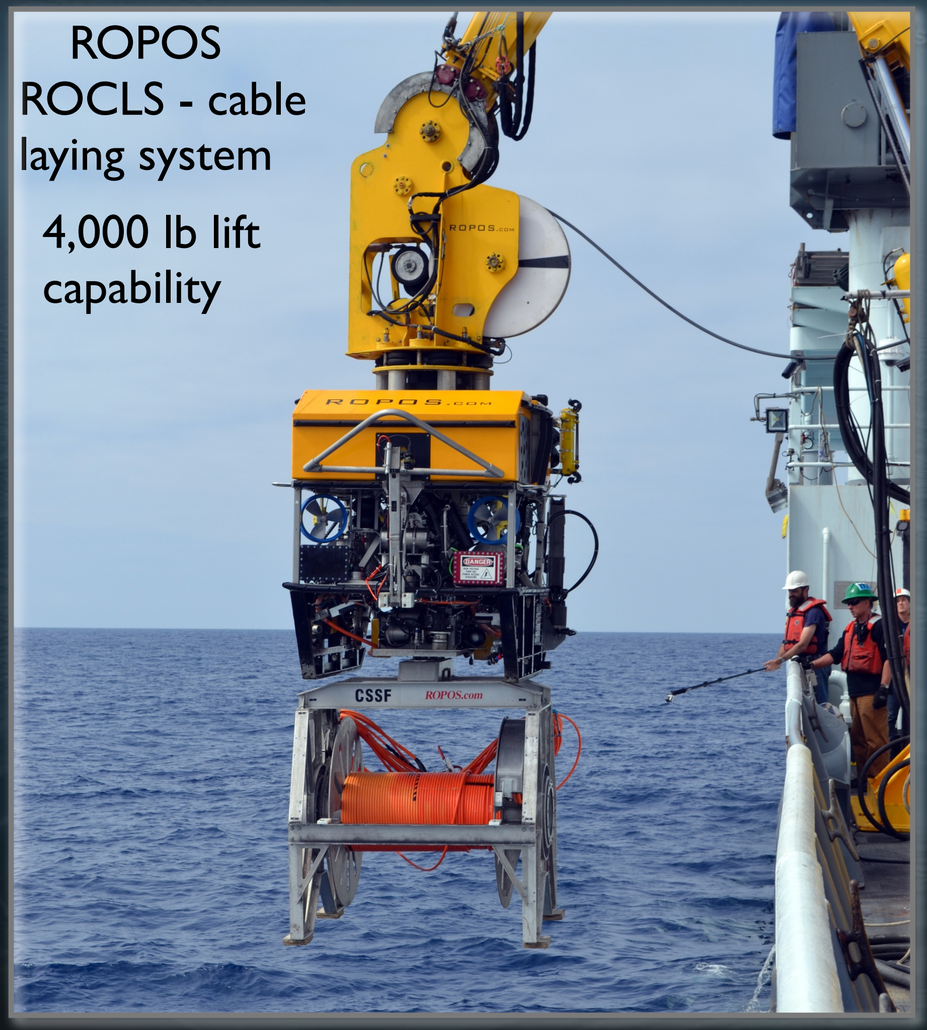
- 35-36 day cruises utilizing an ROV
- 24 hour ops with rapid ROV turn arounds
- 3 legs, ~2 days in port to switch out personnel and equipment
- Requires detailed and well planned deck layouts, dives, and logistics

Leg 1: Shallow profilers and associated j-boxes/instruments; verification CTD and sampling

Leg 2:Seafloor instruments and junction boxes all sites

Leg 3: Deep Profilers; verification CTD and sampling

ROV's ROPOS and Jason utilized for O&M

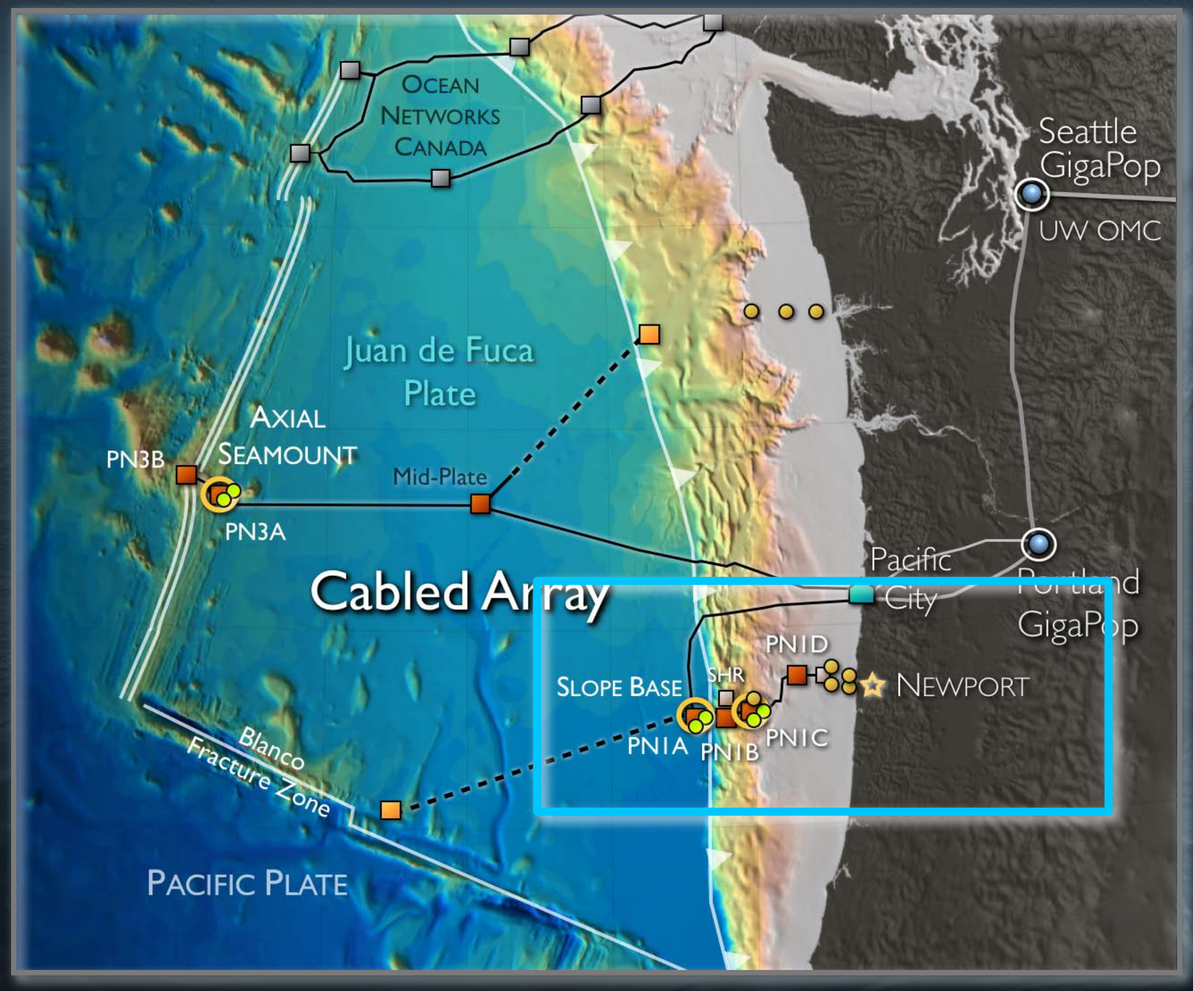


All install & 2015 first O&M cruise

Jason 2016 and forward

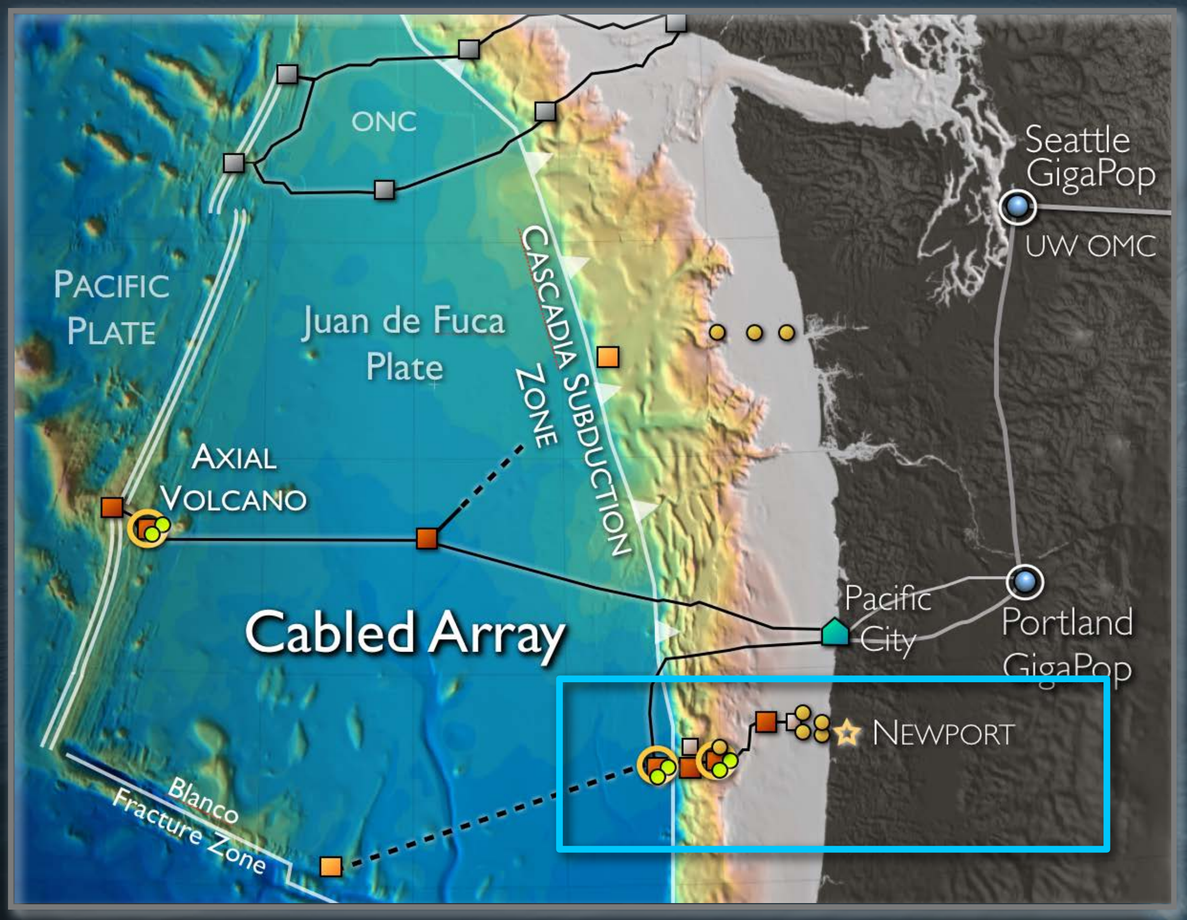
- 2015 = 35 day cruise
  2016 = 38 day cruise
  1-3 hr turn arounds
- Installed and turned
  130 instruments each cruise
  ~13 platforms each cruise
- 6 shallow profiler science "pods" turned each year; one set turned in 1 day
- 2 Deep profiler moorings recovered and installed

Cabled Array Margin Science

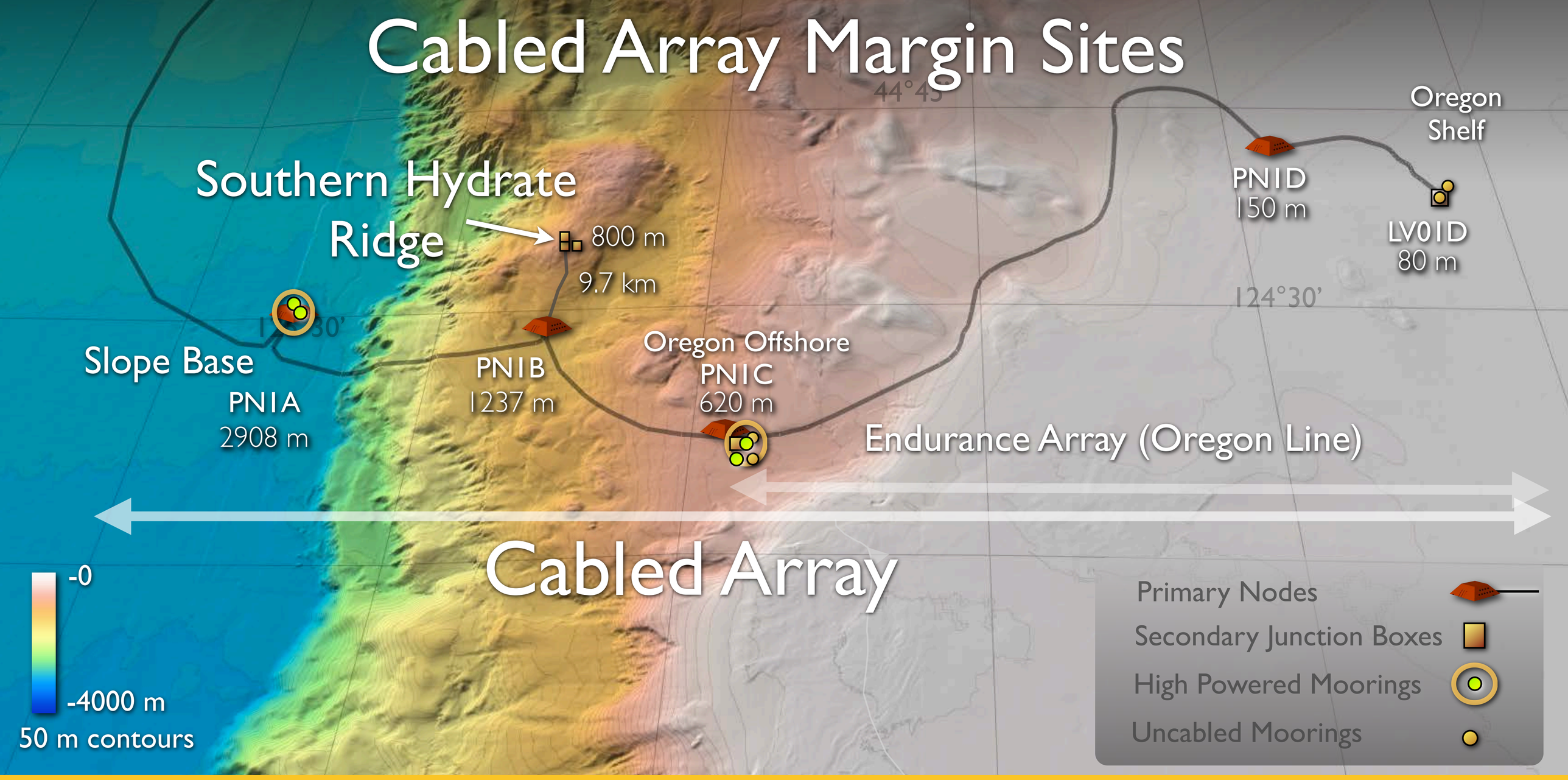


- Monitoring offshore seismic activity - Cascadia Subduction Zone
- Hypoxia events and ocean acidification
- Global biogeochemistry and carbon cycling
- Climate variability and ecosystems
- Coastal ocean dynamics and ecosystems
- Ocean circulation, mixing and ecosystems
- Methane seeps and novel microbial communities

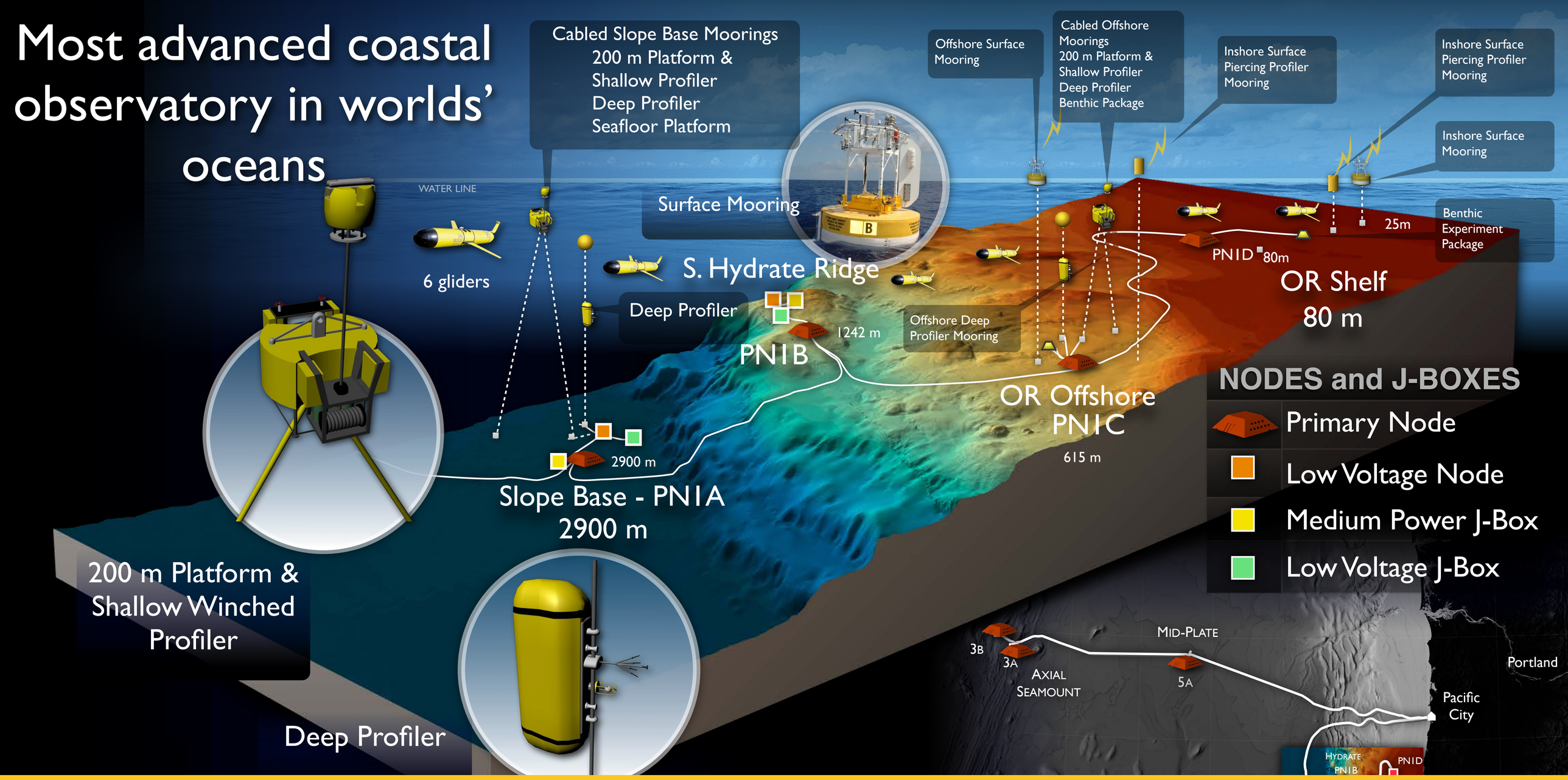
Cabled Array Margin Sites

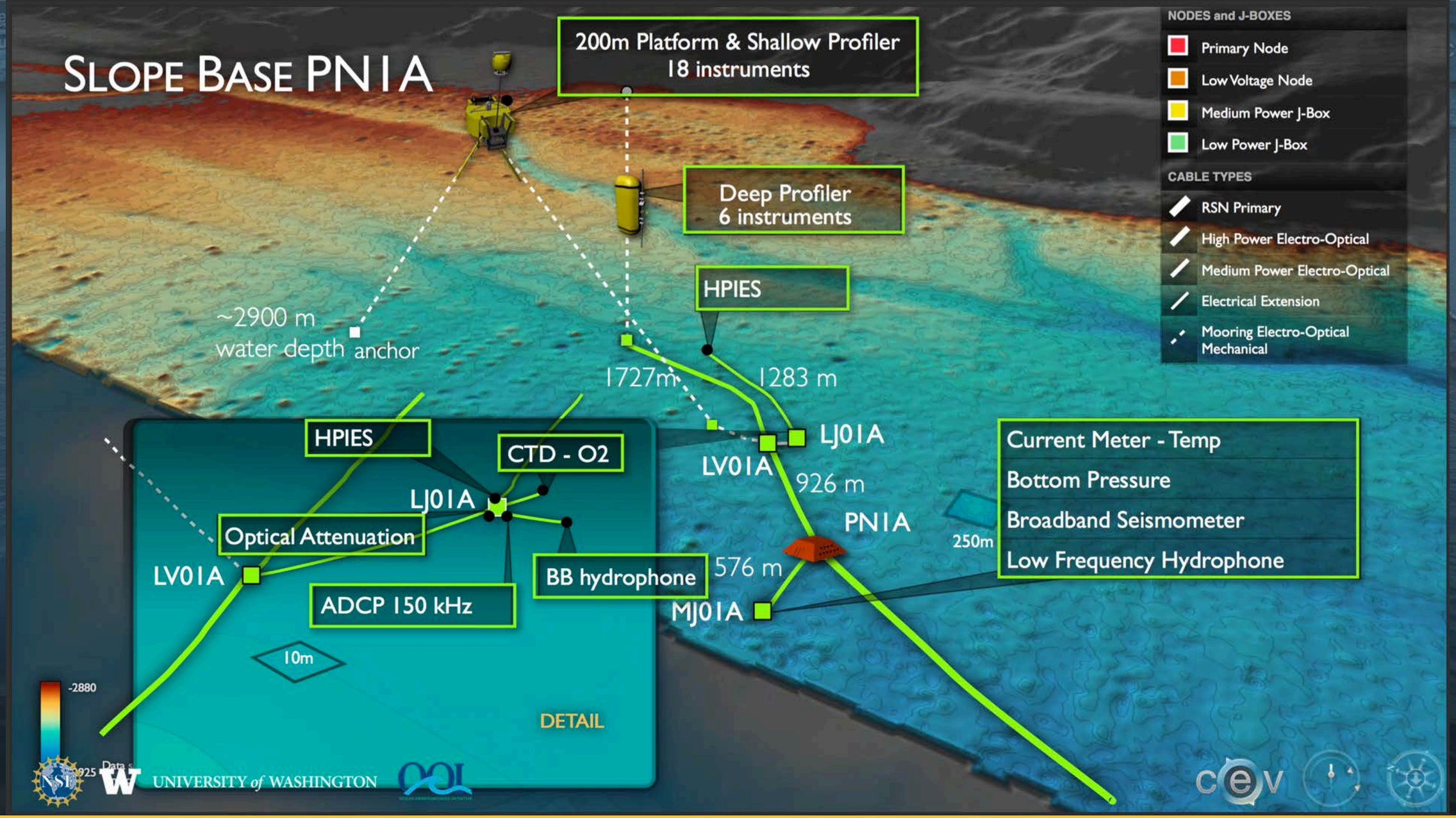


- Slope Base - PN1A (33 instruments)
  - Deep and Shallow Profiler
  - 2 junction boxes (geophysical & water column)
- Southern Hydrate Ridge - methane seep
  - 3 junction boxes
  - 12 instruments - geophysical, water column, seep
- Oregon Offshore (28 instruments)
  - Deep and Shallow Profiler
  - 1 junction box and 1 BEP (geophysical, water column, benthic)
- Oregon Shelf (10 instruments)
  - 1 junction box and 1 BEP (water column, benthic)


Cabled Array Margin Sites
44°45'
Oregon Shelf
Southern Hydrate Ridge
800 m
9.7 km
PNID
150 m
LV01D
80 m
124°30'
Slope Base
PNIA
2908 m
PNIB
1237 m
Oregon Offshore
PNIC
620 m
Endurance Array (Oregon Line)
Cabled Array
-0
-4000 m
50 m contours
Primary Nodes
Secondary Junction Boxes
High Powered Moorings
Uncabled Moorings

Most advanced coastal observatory in worlds' oceans



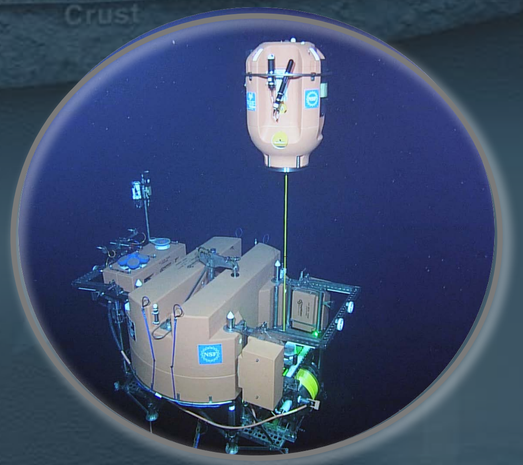

SLOPE BASE PN1A
200m Platform & Shallow Profiler
18 instruments
Deep Profiler
6 instruments
HPIES
~2900 m
water depth
anchor
1727m
1283 m
LJ01A
LV01A
926 m
PN1A
250m
576 m
MJ01A
HPIES
CTD - O2
LJ01A
Optical Attenuation
LV01A
BB hydrophone
ADCP 150 kHz
10m
-2880
DETAIL
UNIVERSITY of WASHINGTON
NODES and J-BOXES
Primary Node
Low Voltage Node
Medium Power J-Box
Low Power J-Box
CABLE TYPES
RSN Primary
High Power Electro-Optical
Medium Power Electro-Optical
Electrical Extension
Mooring Electro-Optical
Mechanical
Current Meter - Temp
Bottom Pressure
Broadband Seismometer
Low Frequency Hydrophone

Shallow Profilers Designed-built by APL

- 2 legs, 12 ft across 7 ton platform at 200 m designed with most efficient O&M in mind
- Supplied with 3 kW power, 1 Gbps communications
- Platform and Science Pod hosts 18 sensors
- Profiler makes 9 trips/day; stepped profiles on way down
- 2-way real-time communications allows adaptive sampling (thin layers, storms, megaplume events)
- Instruments sampling at 1 to 40 Hz (hydrophone)

At least 30% expansion capabilities

Since 2015, the three shallow profilers have completed >10,000 profiles

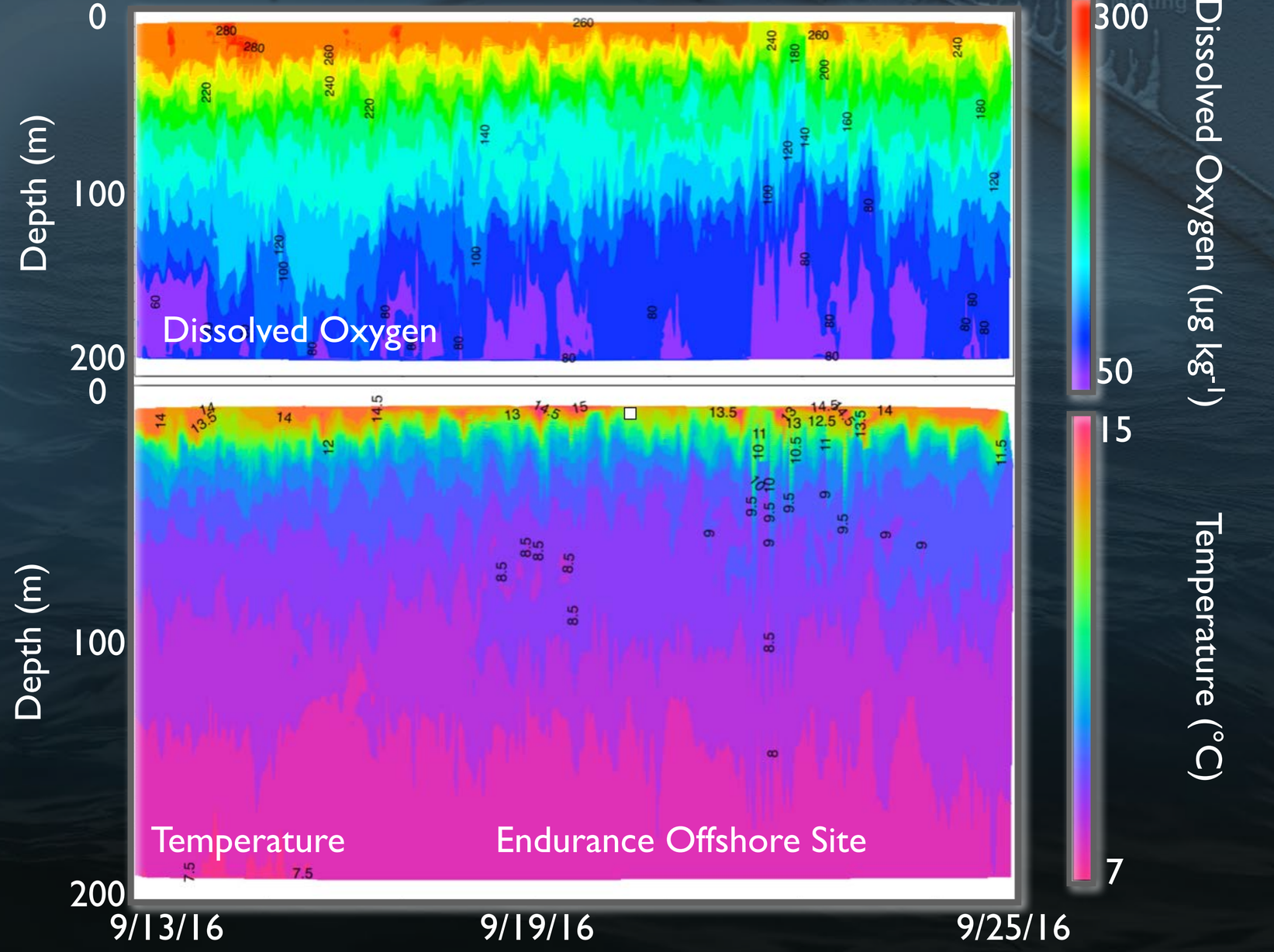


Platform Interface Controller (stationary science pod)

- 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

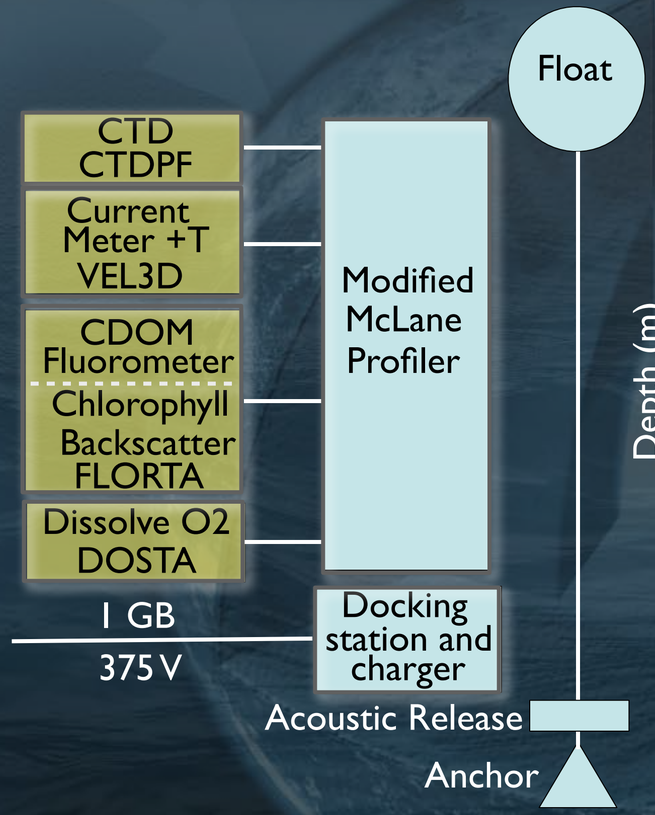


Cabled Array Deep Profiler

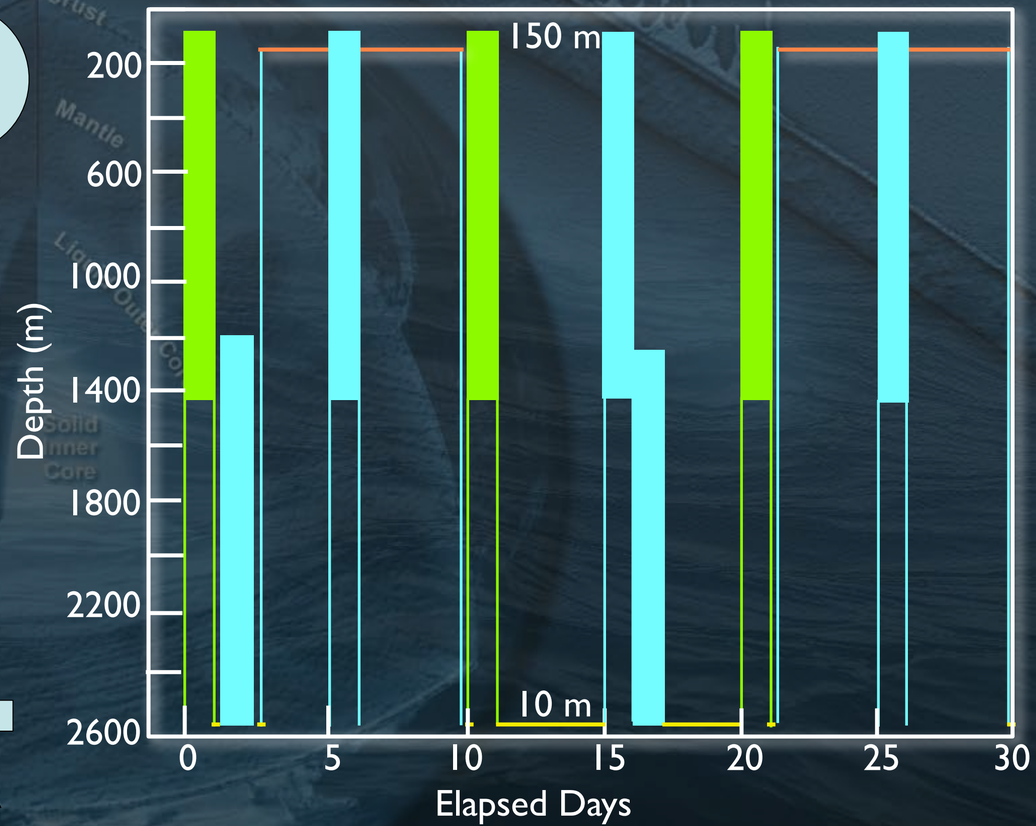
"clam shell" on ROV allows recovery and reinstallation of vehicle

4 months at Axial Seamount 2014

Slope Base, Oregon Offshore, Axial Base



- 9 Profiles required each day for high frequency phenomena, aliasing



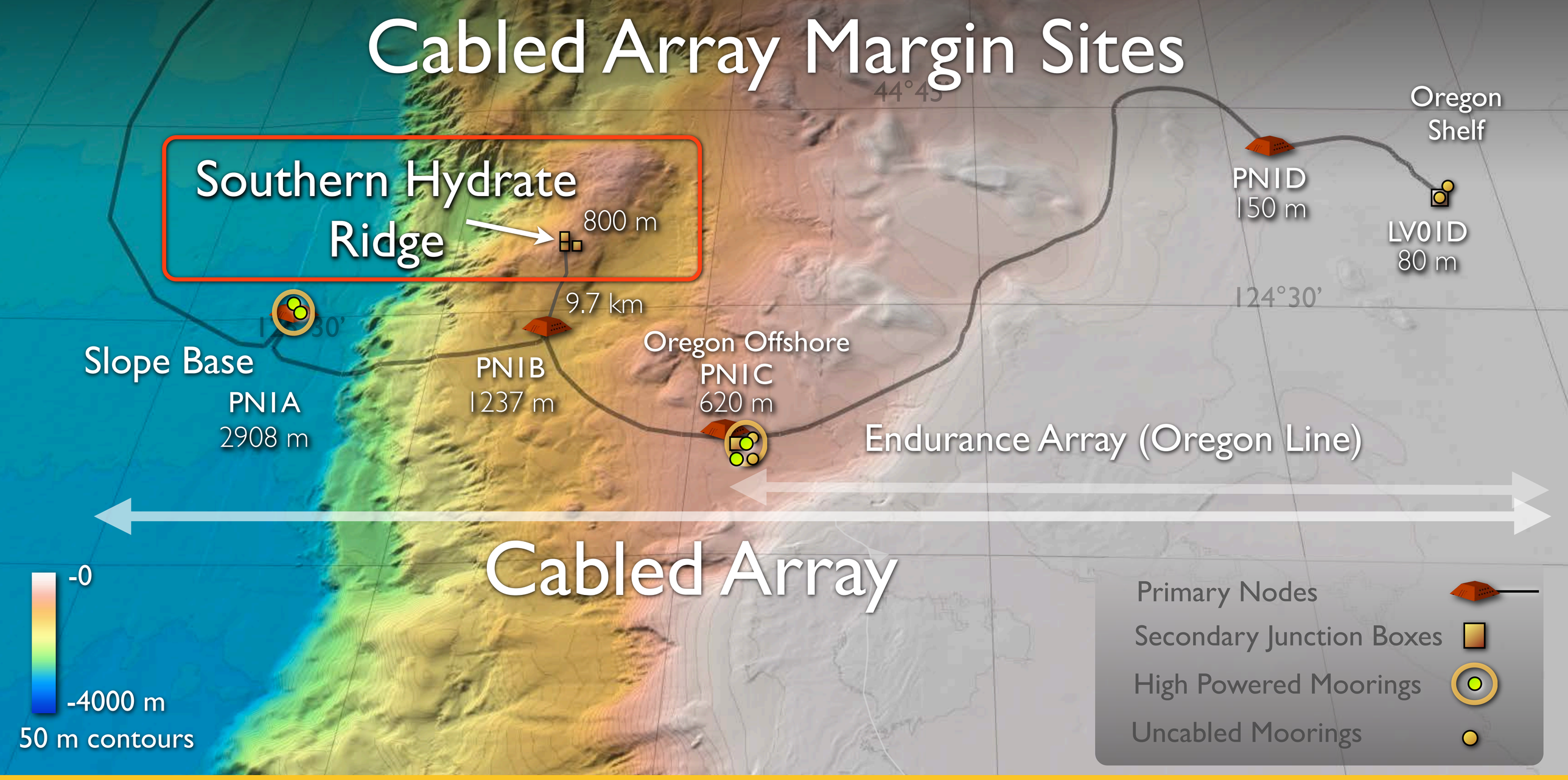
- Vehicles have had issues with firmware, communication and connector issues (Impulse connectors); intense APL team failure analyses 2016

Field Verification

FIELD VERIFICATION OF DATA

Instruments	Methods (Shipboard + Shore-based)
CTD and O_2 sensors (CTDBP, CTDPF, DOSTA, DOFST)	Ship CTD Cast + Water (Salinity, O_2); ROV CTD + Water (Salinity, O_2); T-S_Plot
Dissolved Nitrate (NUTNR)	Ship CTD Cast + Water (NO_3); ROV CTD + Water (NO_3)
Fluorometer (FLORT, FLORD, FLNTU)	Ship CTD w/ Fluorometer Cast + Water (Chlorophyll-a)
Water pH (PHSEN) and pCO2 (PCO2W)	Ship CTD w/ pH Sensor Cast + Water (Shipboard Spectrophotometric pH + Shore-based pCO_2 and Total CO_2)
PAR (PARAD)	Ship CTD w/ PAR Sensor Cast
Dissolved Gas Mass Spectrometer (MASSP)	In Situ Calibration Bags; Isobaric Gas-Tight (IGT) fluid samples using shipboard GC
Benthic Fluid Flow (FLOBN-M and FLOBN-C) Physical Samples	Samples recovered for shore-based chemical analysis; Comparison of flow rates determined by two series (M,C)
Vent Fluid Temp+Resistivity (TRHPH) and Temp+pH+H_2S (THSPH)	IGT samples for shipboard (gas) and shore-based chemical analyses. Data also used for in situ calibration.

- Vertical CTD casts taken before and after installation
- CTD and Niskin samples on remotely operated vehicle immediately adjacent to Deep and Shallow Profiler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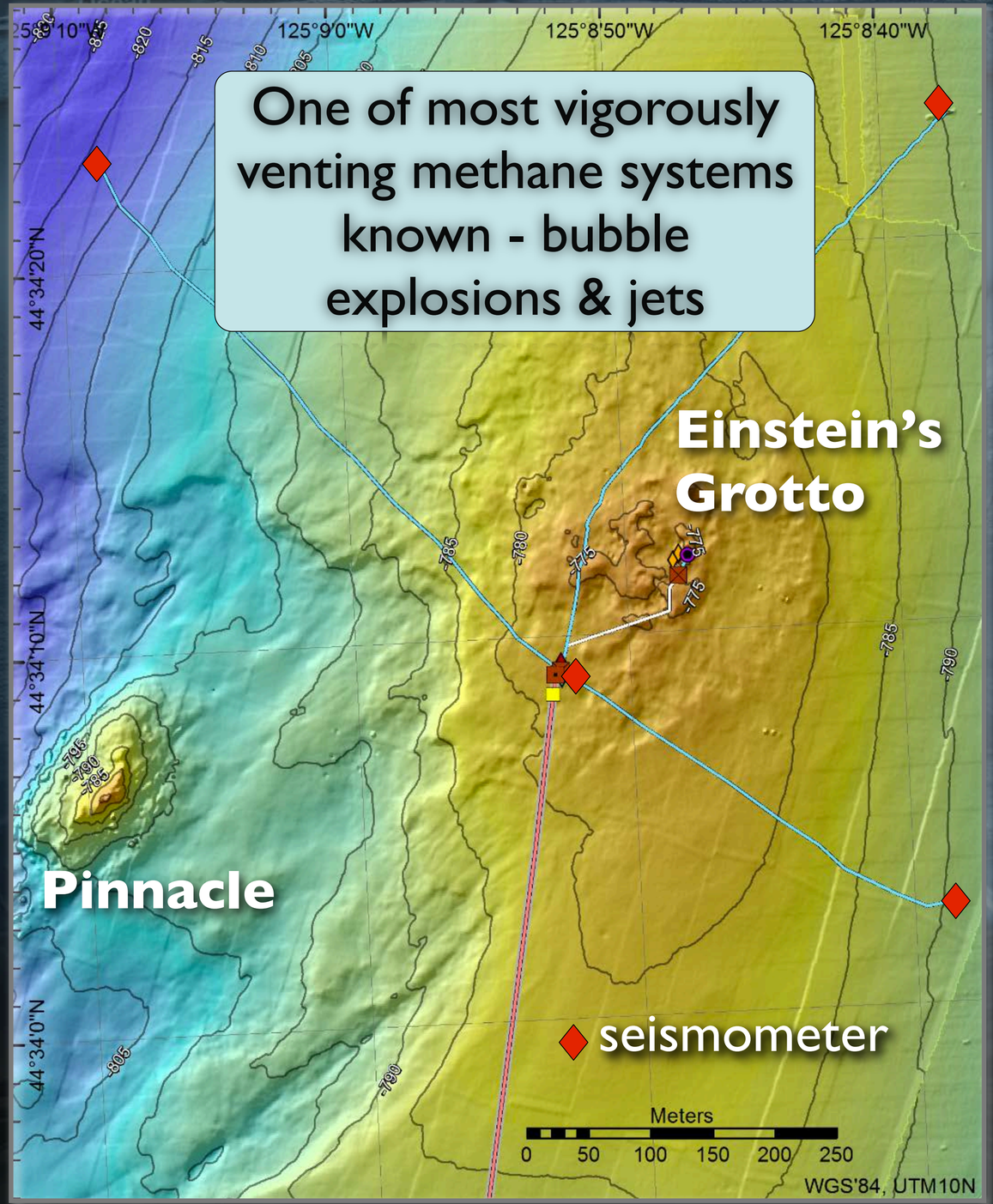
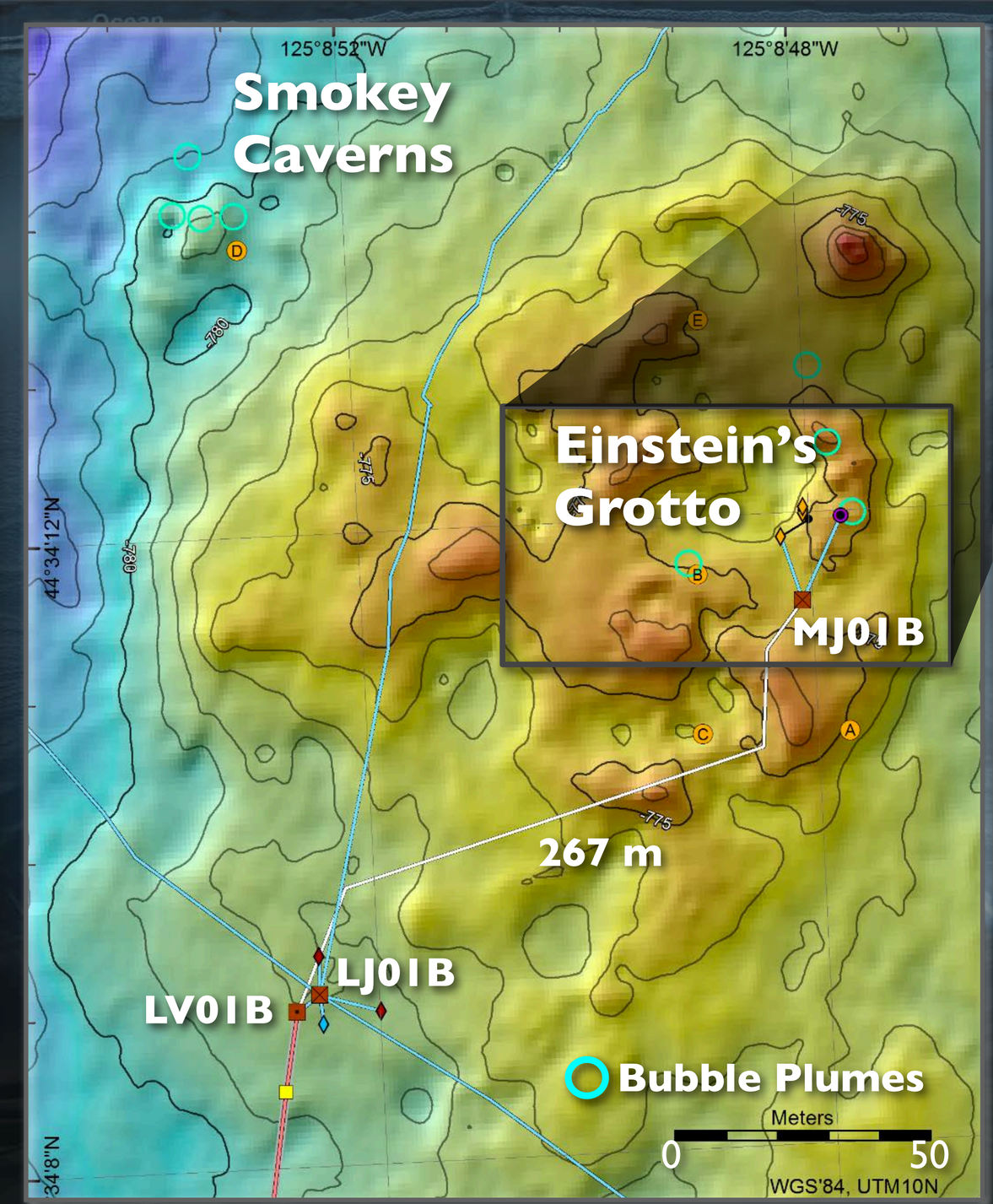
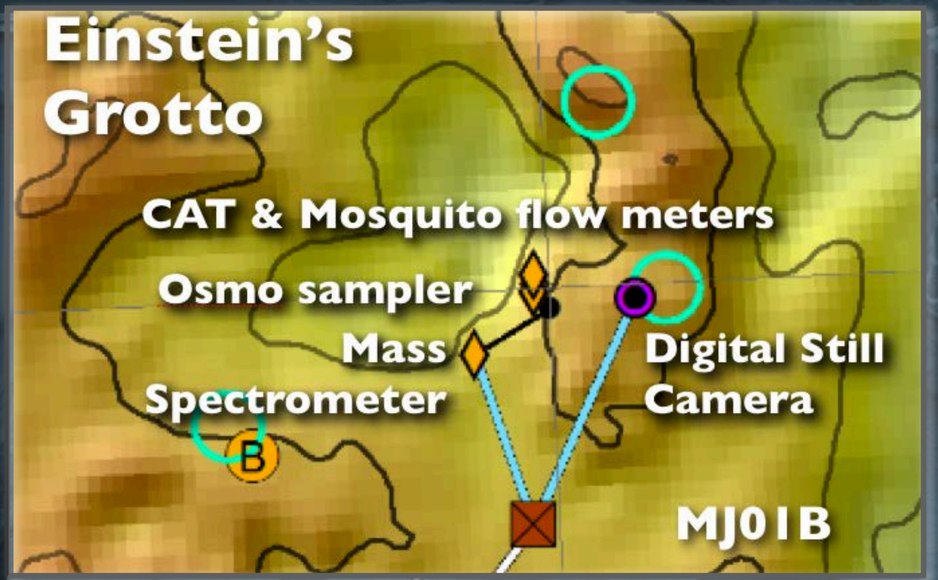
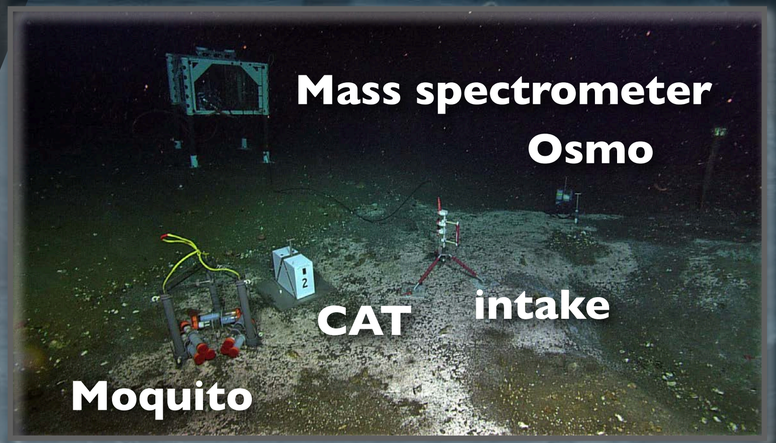


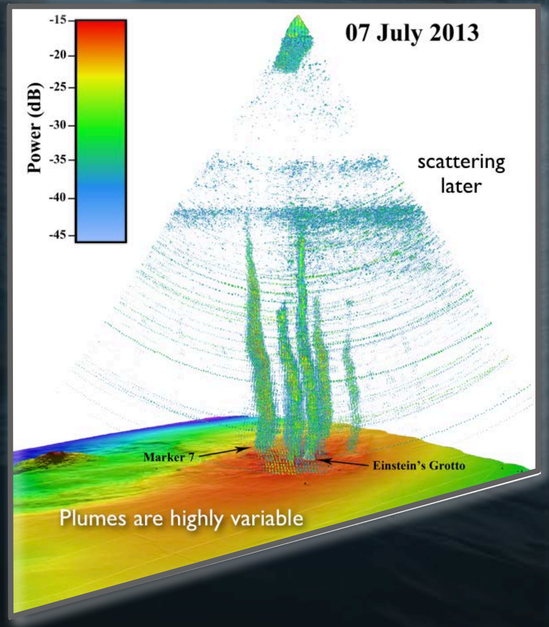
Southern Hydrate Ridge

- 3 Junction Boxes with a total of ~ 2 kW power available; 1 Gbs bandwidth each
- 10 cabled instruments, 3 uncabled
  - 3 short-period seismometers 1-100Hz
  - 1 broadband seismometers .3 m-10 Hz
  - 1 low frequency hydrophone 2 Hz to 20 K Hz
  - 1 Digital Still camera & lights
  - 1 75 kHz upward-looking ADCP
  - 1 Pressure sensor
  - 1 Current meter
  - 1 OSMO fluid sampler; 2 flow meters
- All operational
- MARUM Germany-OOI will add 2 cabled bubble plume sonars (full field and local), ± camera and CTD 2018-2019, 2020; 2019? Field program with Zonne and Quest ROV



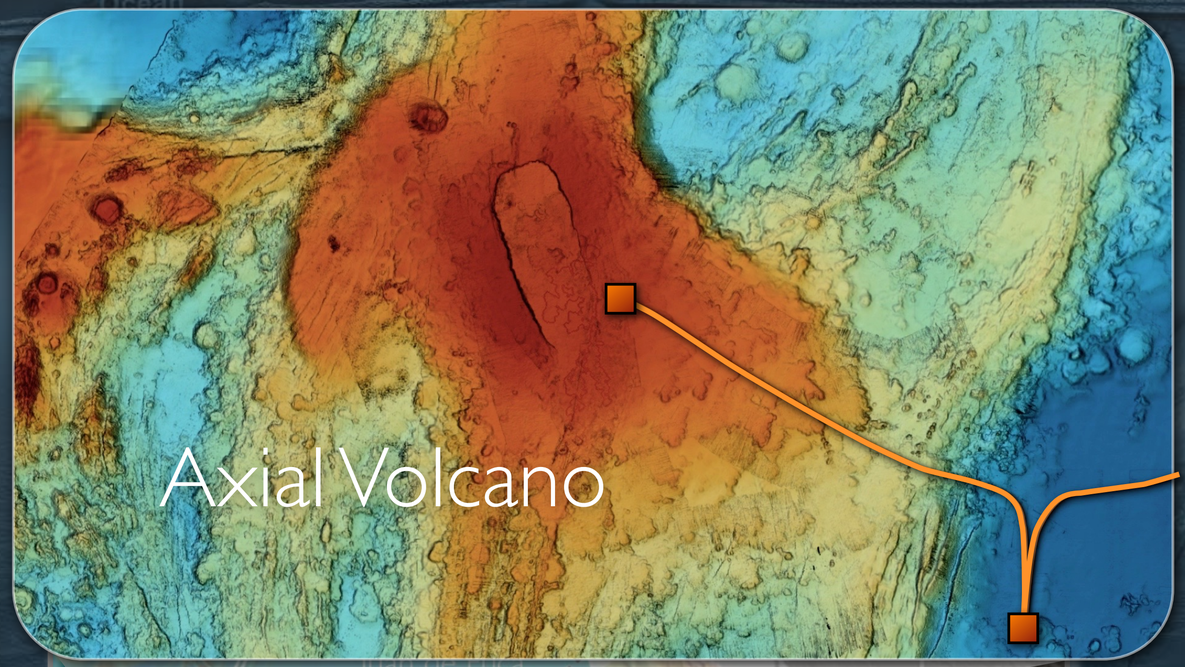


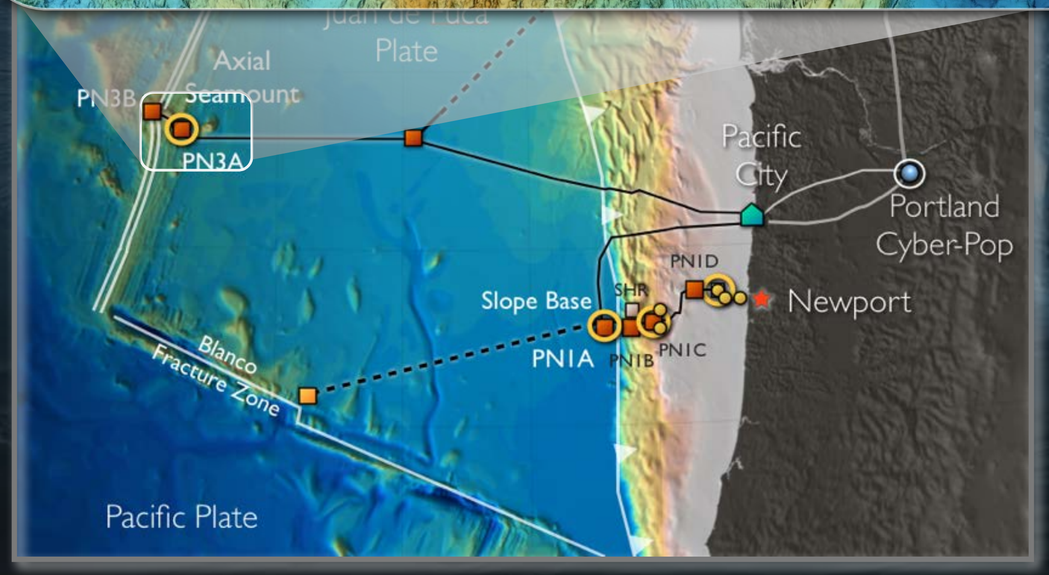




- What are the linkages among seismicity, fluid flow and gas hydrate-methane release
- What is the temporal-spatial evolution of methane release and biological communities?

Axial Seamount
The most advanced submarine volcanic observatory in World's Oceans

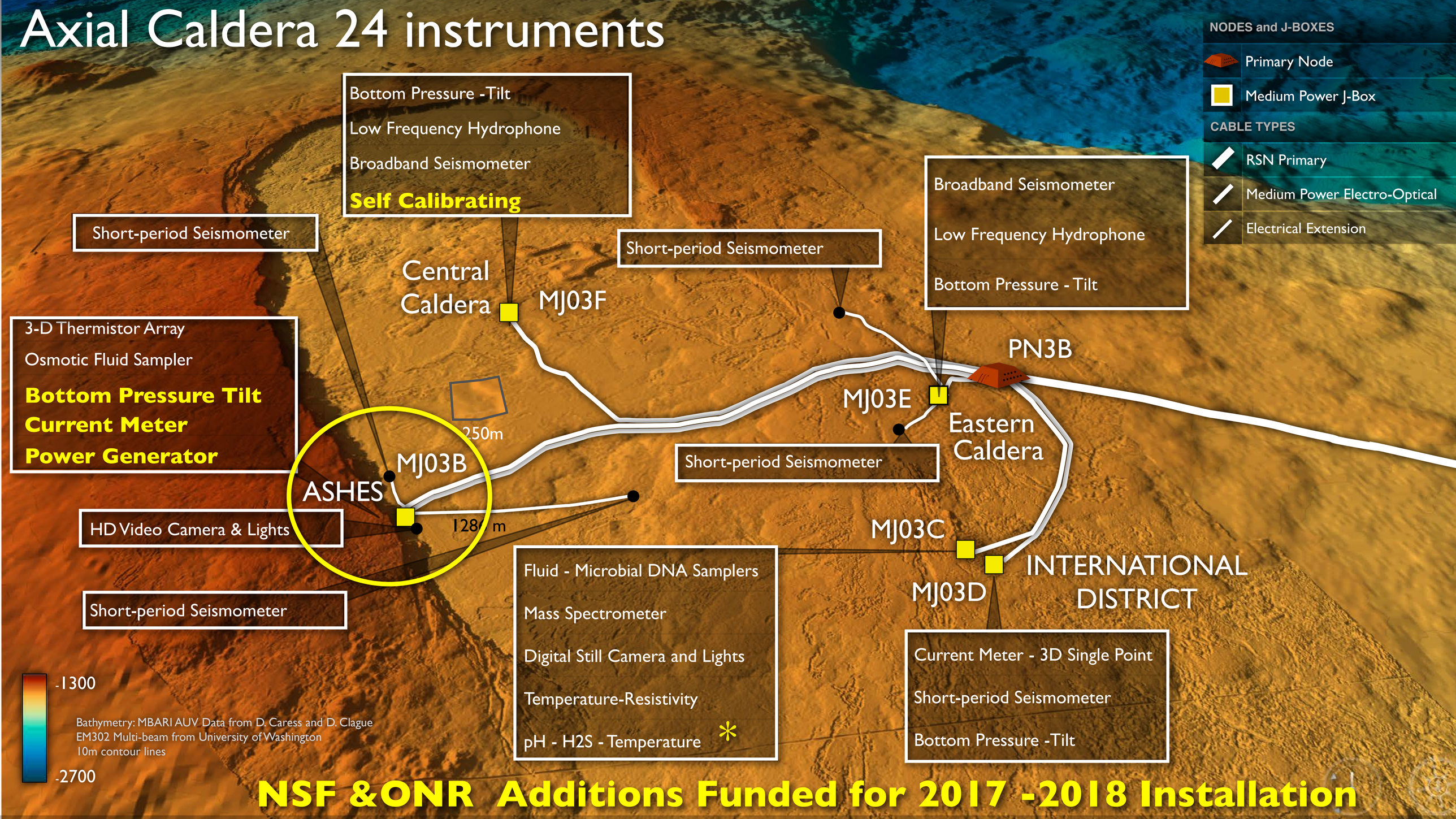




- The largest and most magmatically active volcano off the OR-WA coast
- What is the life evolution of underwater volcanoes, flux of heat, chemicals and biological material from the seafloor to the hydroshere, linkages among seismic, chemical and biological processes and how to they change with time?

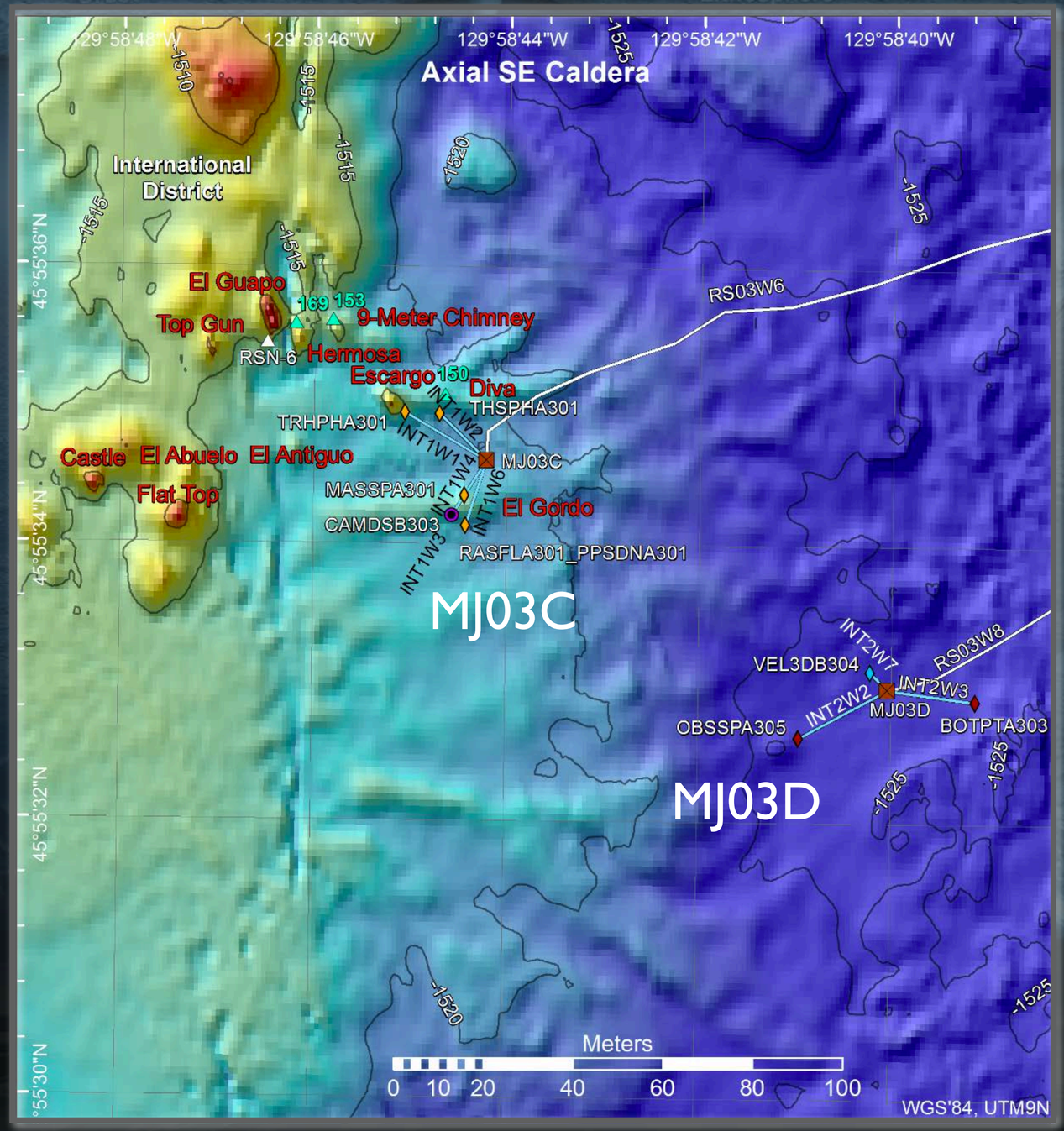
Erupted in 1998, 2011, and April 24, 2015

Axial Caldera 24 instruments



NSF &ONR Additions Funded for 2017 -2018 Installation

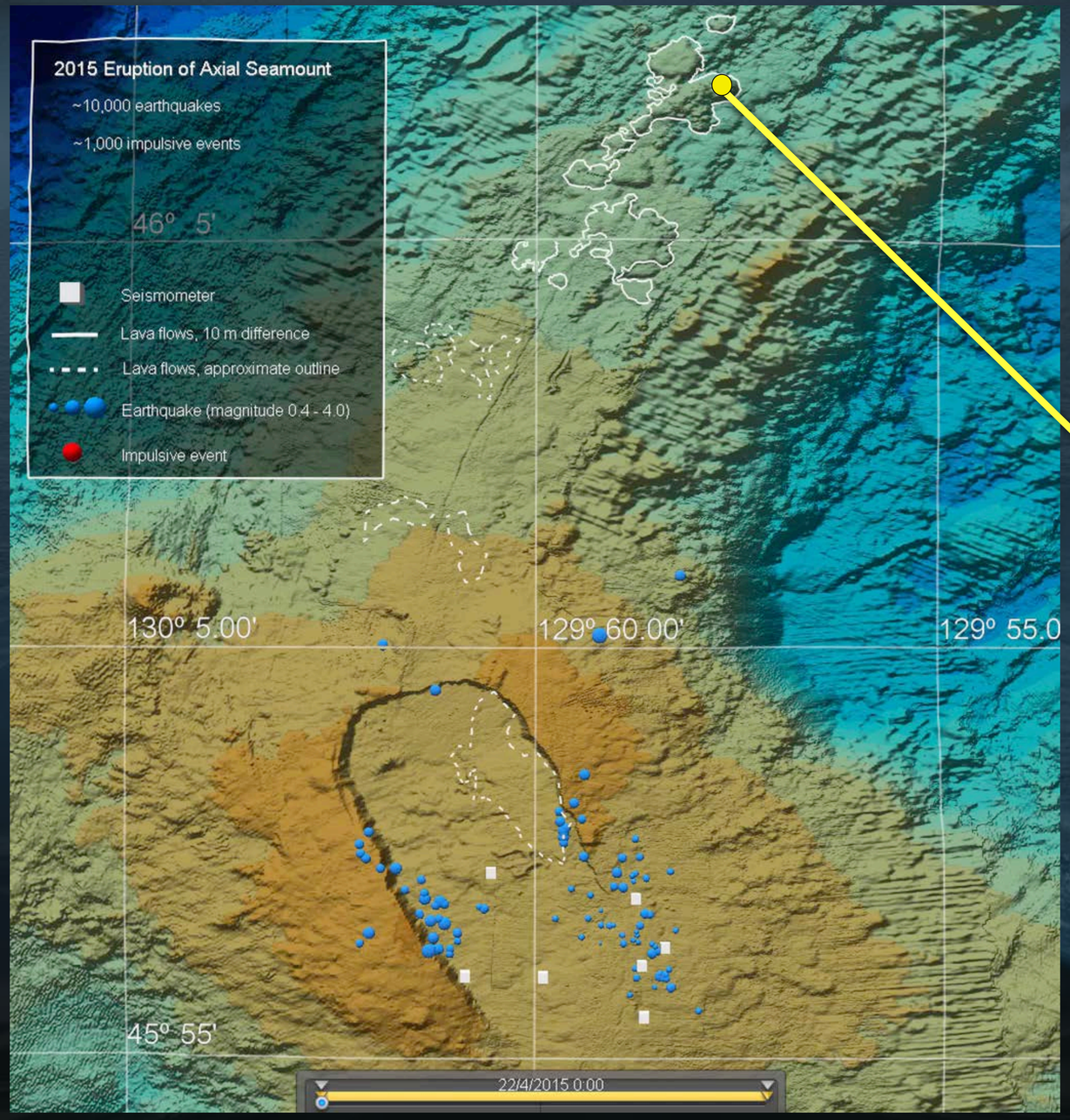
International District



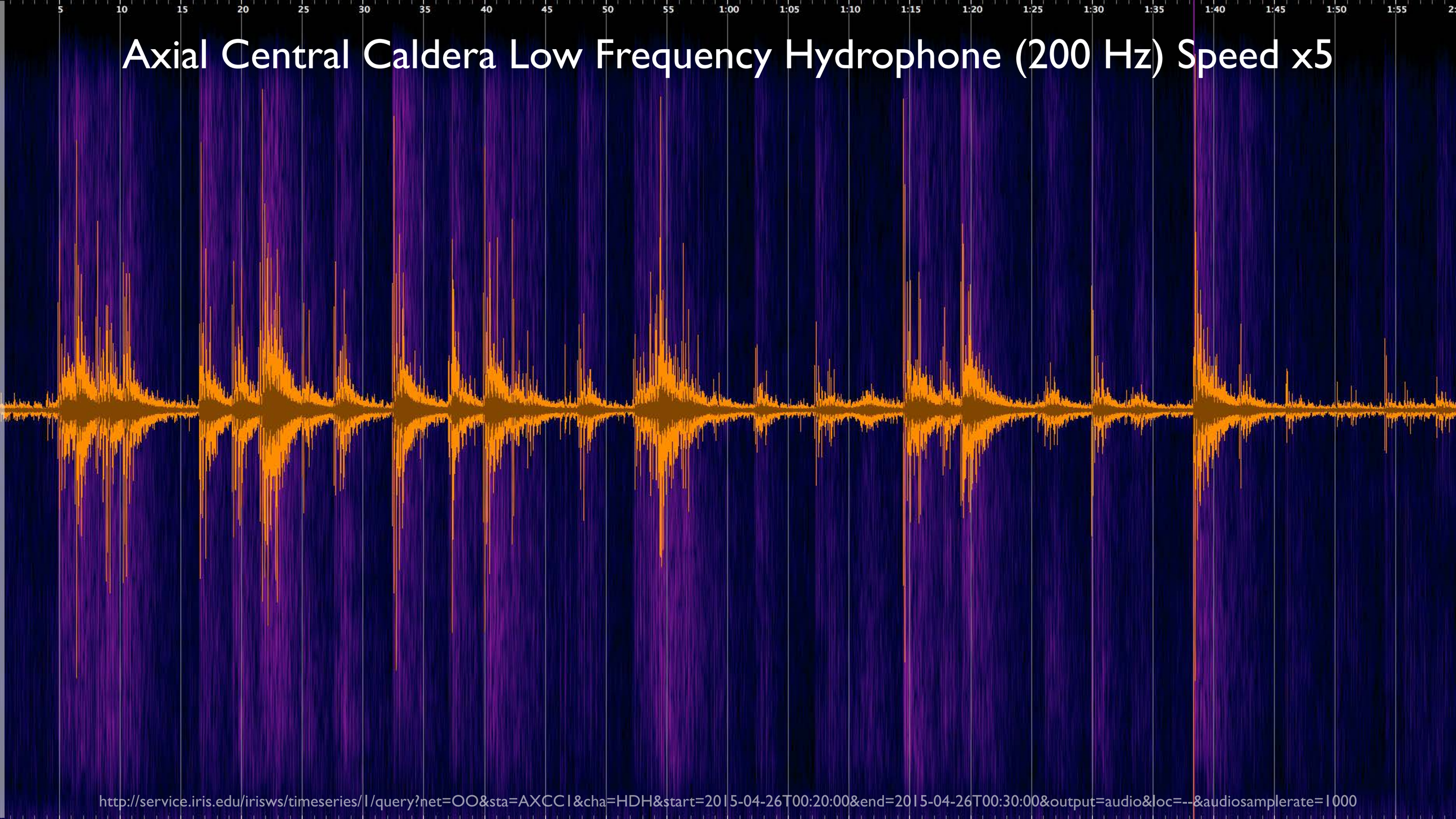
- Similar hydrothermal questions re ASHES, but additional focus on vent fluid chemistry - e.g. volatiles, boiling processes.
- How do microbiological communities evolve over time/respond to events?
- What is the nature of melt migration, seafloor deformation, seismicity pre, during, post eruption - how does the system evolve with time

- short-period seismometer
- bottom pressure-tilt
- mass spectrometer
- digital still camera
- temperature-resitivity
- temperature-pH-H_2S* 2017 installation
- RAS fluid sampler
- DNA sampler
- current meter

Earthquakes Explosions (Wilcock et al., 2016)



Axial Central Caldera Low Frequency Hydrophone (200 Hz) Speed x5



http://service.iris.edu/irisws/timeseries/1/query?net=OO&sta=AXCC1&cha=HDH&start=2015-04-26T00:20:00&end=2015-04-26T00:30:00&output=audio&loc=--&audiosamplerate=1000