2020 GAGE/SAGE SIG

Collecting Geophysical Observations from the Seafloor

Organizers: Kasey Aderhold (IRIS), Glen Mattioli (UNAVCO), David Schmidt (University of Washington), Monica Kohler (Caltech), John Collins (WHOI), Katrin Hafner (IRIS)

Goals of Collecting Geophysical Observations from the Seafloor SIG

- Inform community of current geophysical seafloor instrumentation available and recent/upcoming experiments
- Discuss future research targets and instrumentation requirements
- Encourage connections and collaboration between the marine seismic and marine geodetic community

Agenda

- 12:00 - 12:05 - Introductions and Welcome
- 12:05 - 01:00 - Informational Presentations
  - Seafloor geodesy instrumentation - Andy Newman and David Schmidt
  - OBSIC - John Collins
  - Long-Term Seafloor Seismometers - Monica Kohler
  - SMART Cables Sensing the Pulse of the Planet - Bruce Howe
- 01:00 - 01:10 - Break
- 01:10 - 02:00 - Discussion of Synergistic Topics
  - Science drivers, instrument platform and testing, data, future geophysical facility, new technology
- 02:00 - Concluding Thoughts

Informational Presentations

10 minutes each with ~2 minutes for Q&A

- Seafloor geodesy instrumentation - Andrew Newman & David Schmidt
- OBSIC - John Collins
- Long-Term Seafloor Seismometers - Monica Kohler
- SMART Cables Sensing the Pulse of the Planet - Bruce Howe

- Science Drivers
  - Where do we want both seafloor geodesy and seafloor seismic data to be collected? What scientific questions could be answered with joint observations?
- New Technologies
  - What new technologies are out there for making seafloor geophysical observations?
  - How about Distributed Acoustic Sensing and tapping into seafloor cables?
- Instrument Platform and Testing
  - What can be the same (or shared) about the instrument platform between seafloor seismic and seafloor geodetic? What has to be different, or separate?
- Data
  - Where is community seafloor geodesy data going to be stored?
  - What metadata needs to be stored? Data from collocated instruments (pressure, temperature)? Data products?
- Future Geophysical Facility
  - How do seafloor observations fit with the future geophysical facility?
  - Potential community experiments or larger initiatives?

Conclusion and Next Steps

Future opportunities to get involved… many links shared in the Google Doc, meetings/webinars announced in the slides

The Google Doc and notes will be compiled and posted on the UNAVCO SIG page along with the meetings slides (with presenters' permission)

Seafloor Geodesy Community Building Activities

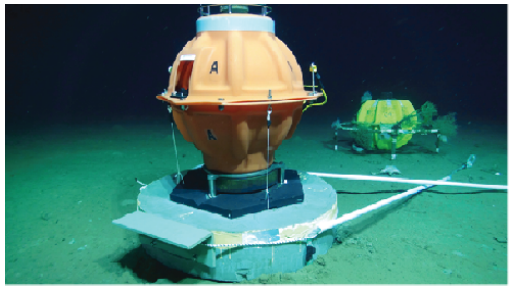
Andrew Newman, Georgia Tech
David Schmidt, University of Washington

Seafloor Geodetic Instrument Pool

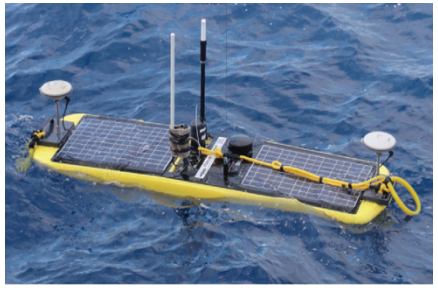
- 16 GNSS-Acoustic sites
  - Measure secular horizontal displacement at sub-cm/yr
  - APGs to measure transient vertical deformation (sub-cm)
- 3 Wave Gliders for data collection
- Commissioning to be completed by late 2021
- No funding for deployments, operations, or maintenance.

- NSF is seeking feedback on where and how to utilize the seafloor geodetic instrument pool.

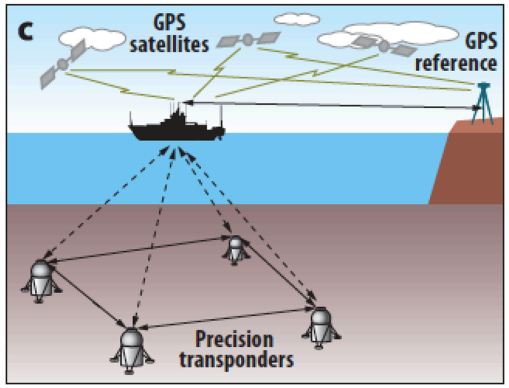
GNSS-A Transponder/Benchmark



Wave Glider



GPS-A positioning



Burgmann & Chadwell, AREPS 2014

Goals for Community Activities

- Inform and grow a diverse seafloor geodetic community
- Solicit community feedback to guide NSF
- Build consensus on how to utilize the pool
- Advance technologies for future development
- Seek feedback on community needs
  - training, resources, desired capabilities, inclusivity.

For more Information, go to **http://seafloorgeodesy.org**

Seafloor Geodesy Webinar Series

- Past Webinars
  - August 3rd, State of the Art in Seafloor Geodesy
  - August 11th, Capabilities of the Instrument Pool

- Future Events
  - Virtual Workshop, early 2021

For more Information, go to **seafloorgeodesy.org**

Seafloor Geodesy
Request for White Papers

Your whitepaper(s) could:

- include information on an existing or near-term project;
- describe specific existing, emergent, or nascent technologies;
- explain proposals for community experiments with the new instrument pool;
- discuss opportunities to grow a diverse, thoughtful and inclusive community;
- describe management structure and community development ideas for a stand-alone or integrated seafloor geodetic facility.

Due September 18th

For more Information, go to **seafloorgeodesy.org**

Results from 2019 Online Poll

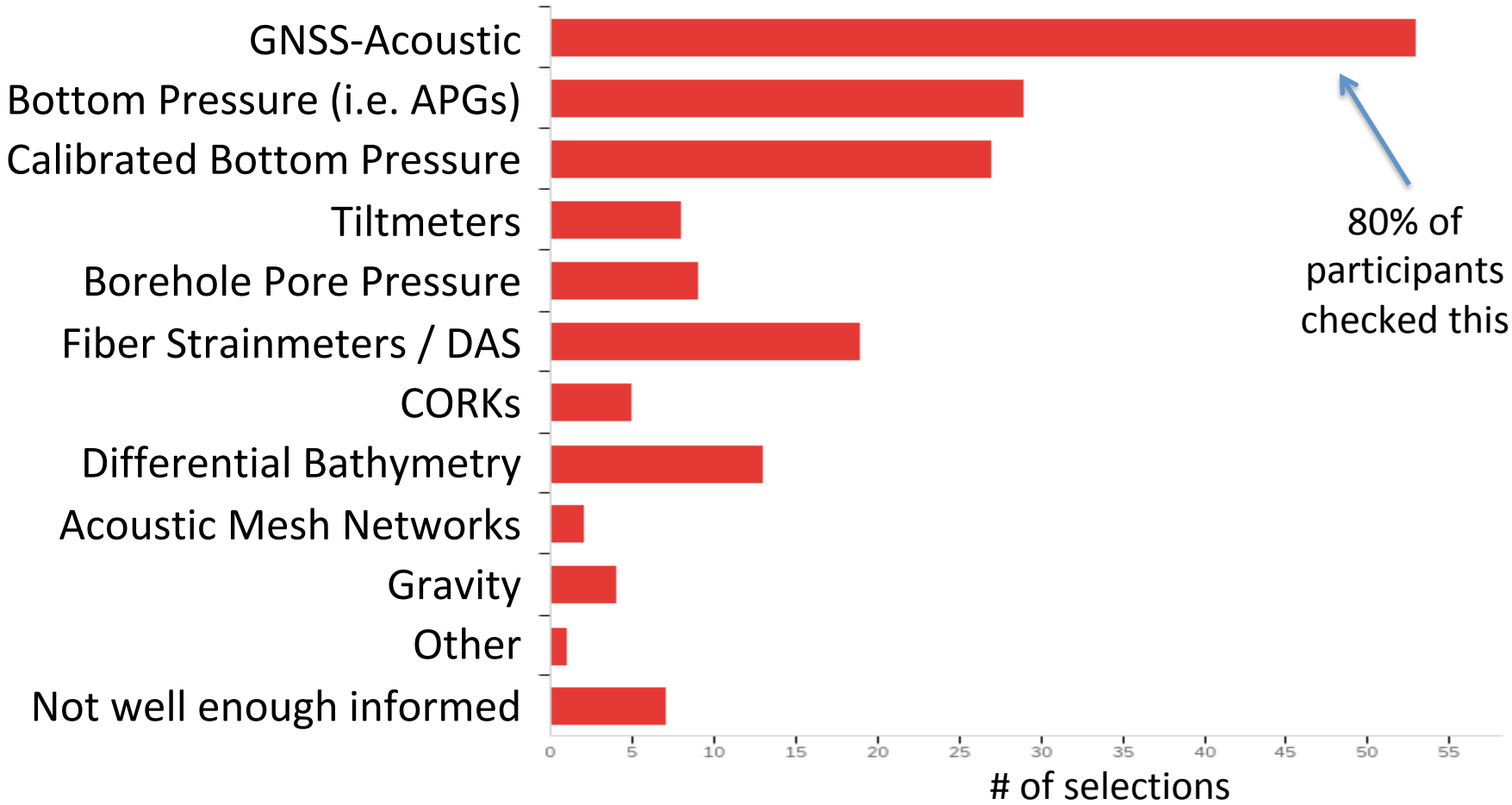
- Participation and Representation (67 Total)

Group	% of total
Senior Faculty	37%
Senior Researcher	16%
Junior Faculty	15%
Graduate Student	13%
Postdoc	8%
Technician/Engineer	5%
Junior Researcher	3%
Other	3%

Group	% of total
Seismology	25%
Terrestrial Geodesy	23%
Marine Geophysics	12%
Geodynamics	9%
Instrumentation	9%
Seafloor Geodesy	8%
Volcanology	6%
Geology	5%
Rock Physics	2%

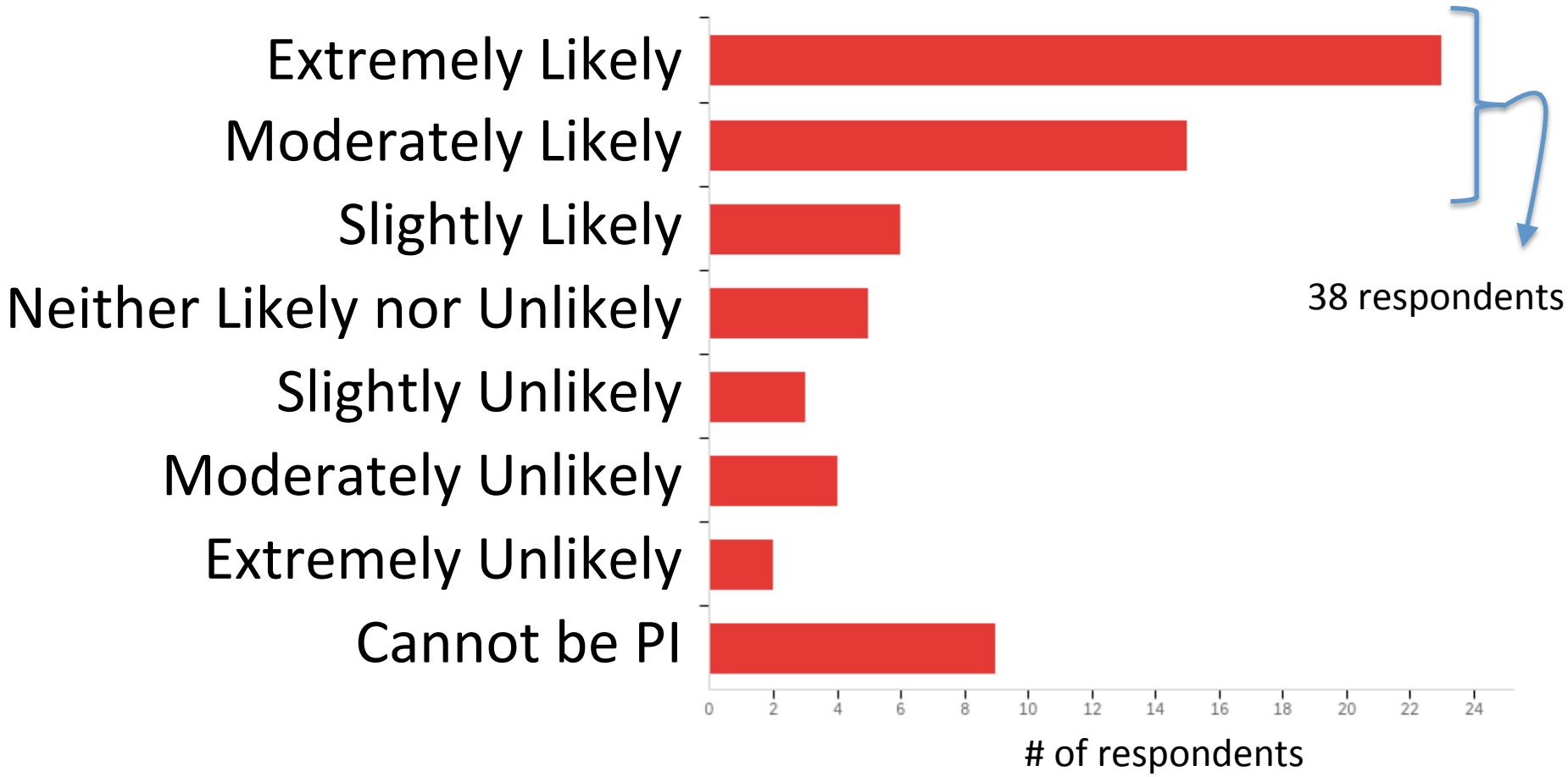
Results from 2019 Online Poll

- What seafloor geodetic equipment should be included in a community instrument pool? (Choose up to 3)



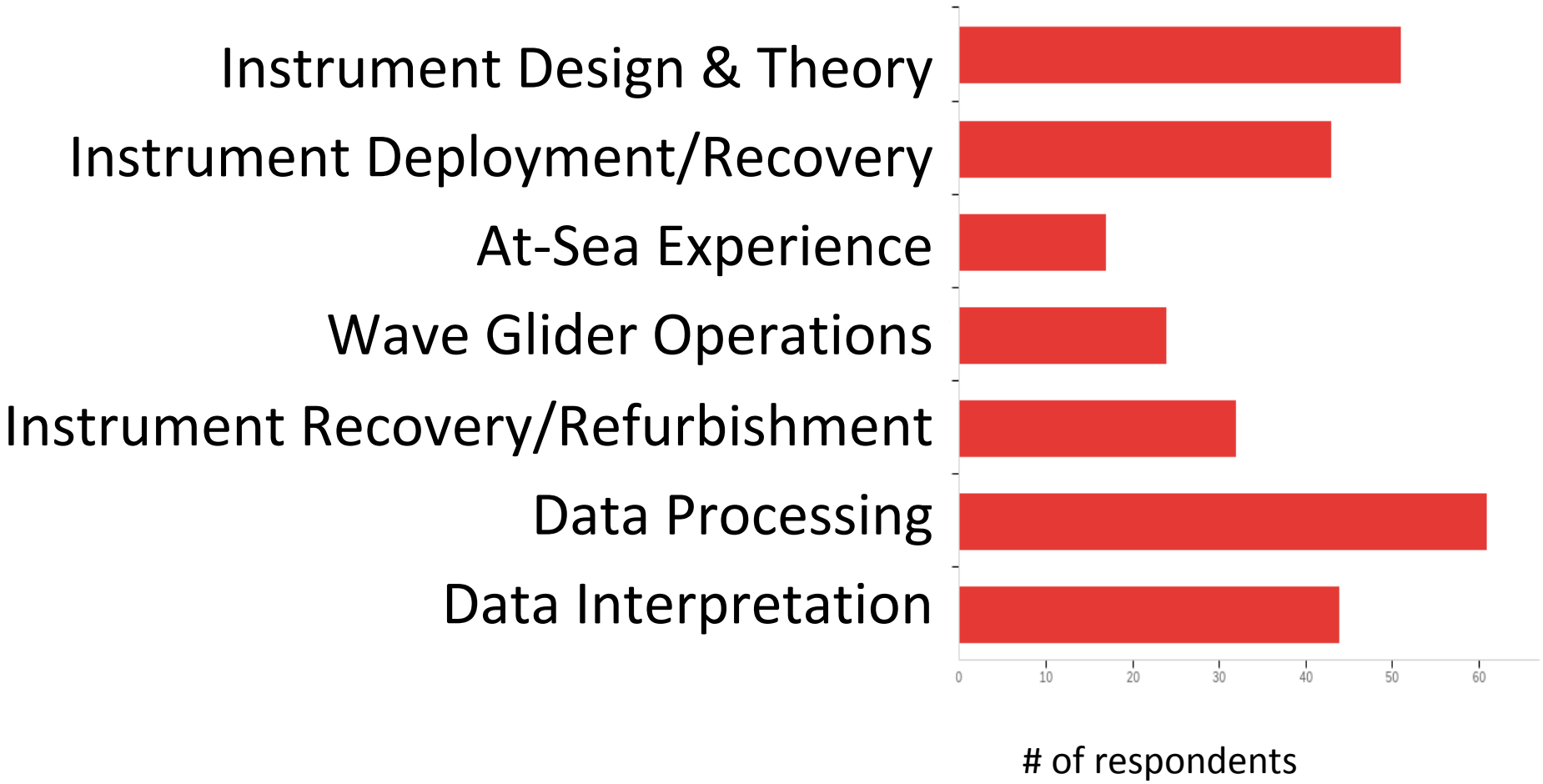
Results from 2019 Online Poll

- If available, how likely would you be to write a proposal that would utilize seafloor geodetic instrumentation from a community instrument pool in the next 5 years?



Results from 2019 Online Poll

- For a seafloor geodetic training workshop, what topics should be included? (Choose all that apply)



Results from 2019 Online Poll

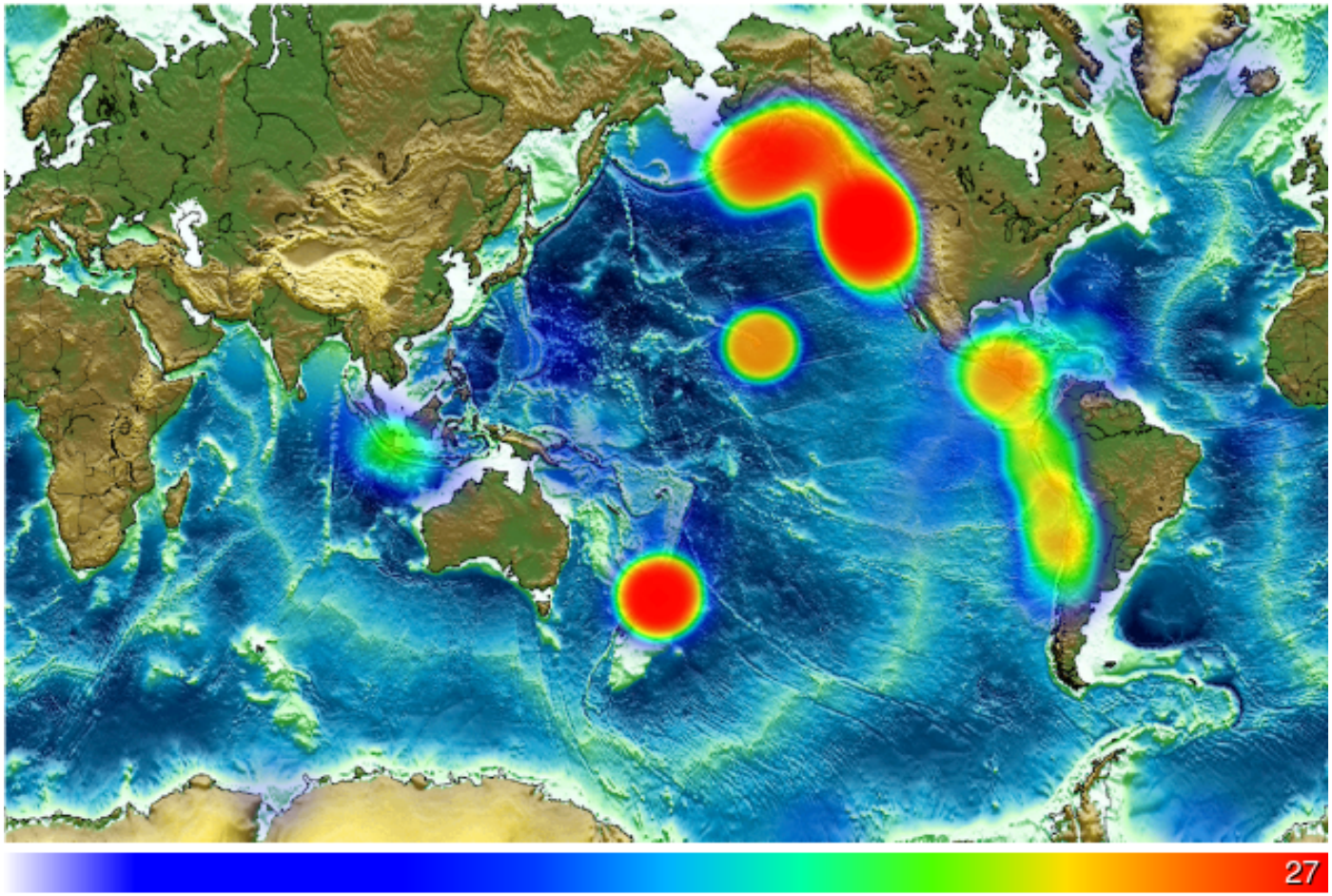
Instruments from a seafloor geodetic instrument pool should:

… only be used as part of a community experiment.

… be allocated through PI-driven competitive proposals (i.e. small PI teams) submitted to NSF.

Results from 2019 Online Poll

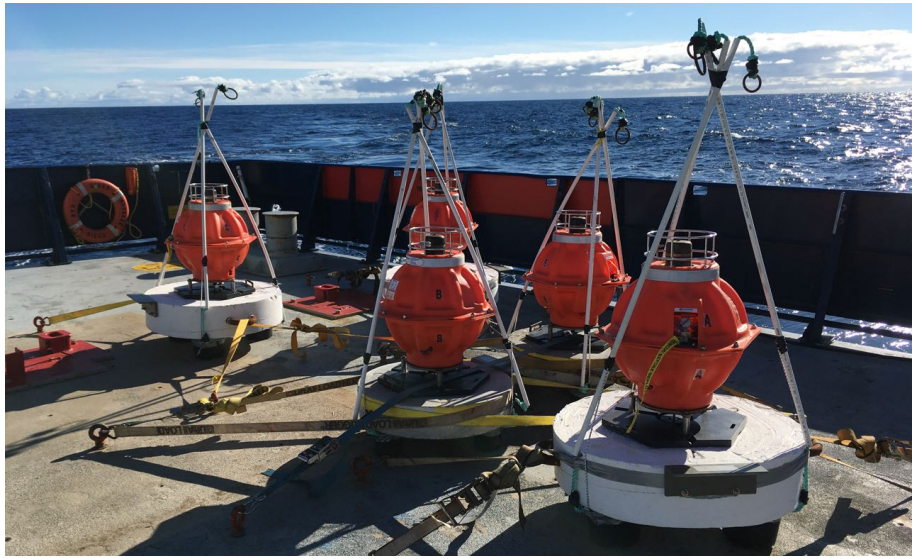
- Where do you think seafloor geodetic instruments should be deployed? (select up to 3 locations)



Next Steps

Future Timeline

- Fall 2020: Technical Webinars (?)
- Early 2021: Virtual Workshop
- Mid 2021: Provide feedback to NSF
- Late 2021: Follow-up workshops / webinars (unfunded)
- Late 2021: Seafloor Geodetic Pool available for deployment
- Summer 2022: possible deployments? (unfunded)



OBSIC

2020 GAGE/SAGE SIG

OBSIC — Ocean Bottom Seismic Instrument Center

- 5-Year Cooperative Agreement between WHOI and NSF-OCE
- Start Date: August 01, 2018
- Base Budget: $1.8M (OBS Maintenance; OBS Mobilization/De-Mobilization; Data Archiving; Regular (1st 8 hours) at sea; IT Support)
- Experiment Support: Expendables (batteries etc.); Shipping; Travel, O/T for techs and sea-pay for engineers
- FY-2021 Budget: 104 person-months

Cooperative Agreement with USGS Woods Hole Coastal and Marine Science Center

- USGS /WHOI Cooperative Agreement: ~$70K/year for facility support
- Nathan Miller (WHCMSC) and David Wilson (Albuquerque Seismo Lab) sit on the WHOI OBS Lab's Internal Advisory Council (IAC).
- USGS provides in-kind and direct funds to an OBSIC at WHOI by supporting:
- *Shared sea-going technical staff.* Two techs are available for use on NSF-funded projects in U.S. waters or on other projects of U.S. national interest for up to 1 month each per year. Salaries for these two technicians will be fully supported by the USGS.
- *Rapid-response OBS fleet.* The USGS currently maintains a pool of 16 WHOI "D2" short-period OBS for use on rapid-response experiments, as well as other short-period experiments., USGS is committed to improving and expanding this rapid-response OBS capability.
- *Instrument development.* USGS will work with the OBSIC to support new instrument development. Initially, this development work would be focused on continuing to improve the rapid-response capability and expanding long-term monitoring capabilities (e.g., longer endurance and *in situ* data recovery) for subduction zone science.
- *Continued funding of OBS experiments.* USGS will continue to fund OBS experiments through WHOI. As in the past, these data will be released through the IRIS DMC within two years of collection, as with NSF-funded OBS experiments

United States Department of the Interior

U. S. GEOLOGICAL SURVEY
12201 Sunrise Valley Drive
Reston, VA 20192
jhaines@usgs.gov
+1-703-648-6422

October 18, 2017

To the National Science Foundation:

If the proposal submitted by Dr. John Collins, entitled "An Ocean Bottom Seismic Instrument Center at Woods Hole Oceanographic Institution" is selected for funding by NSF, it is the USGS Natural Hazards Mission Area's intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal.

Sincerely,

John Haines
Associate Director (acting) for Natural Hazards
Program Coordinator, Coastal and Marine Geology Program

WHOI OBS Lab

- 3,712 square feet in new (2011) LOSOS (Laboratory for Ocean Sensors and Observing Systems) building on the WHOI Quissett campus.

Current Instrumentation Inventory

OBS Type	OBSIC Fleet
Short-Period OBS	29
Unshielded Broadband OBS with Guralp CMG-3T and DPG	30
Unshielded Broadband OBS with Guralp CMG-3T, Kinemetrics Episensor Strong-Motion Accelerometer and DPG	10
Unshielded Broadband OBS with Nanometrics Trillium Compact and DPG*	20
Unshielded Broadband OBS with Nanometrics Trillium Compact and APG**	8
Shielded Broadband OBS with Nanometrics Trillium Compact and DPG***	15
Shielded Broadband OBS with Nanometrics Trillium Compact and APG**	19

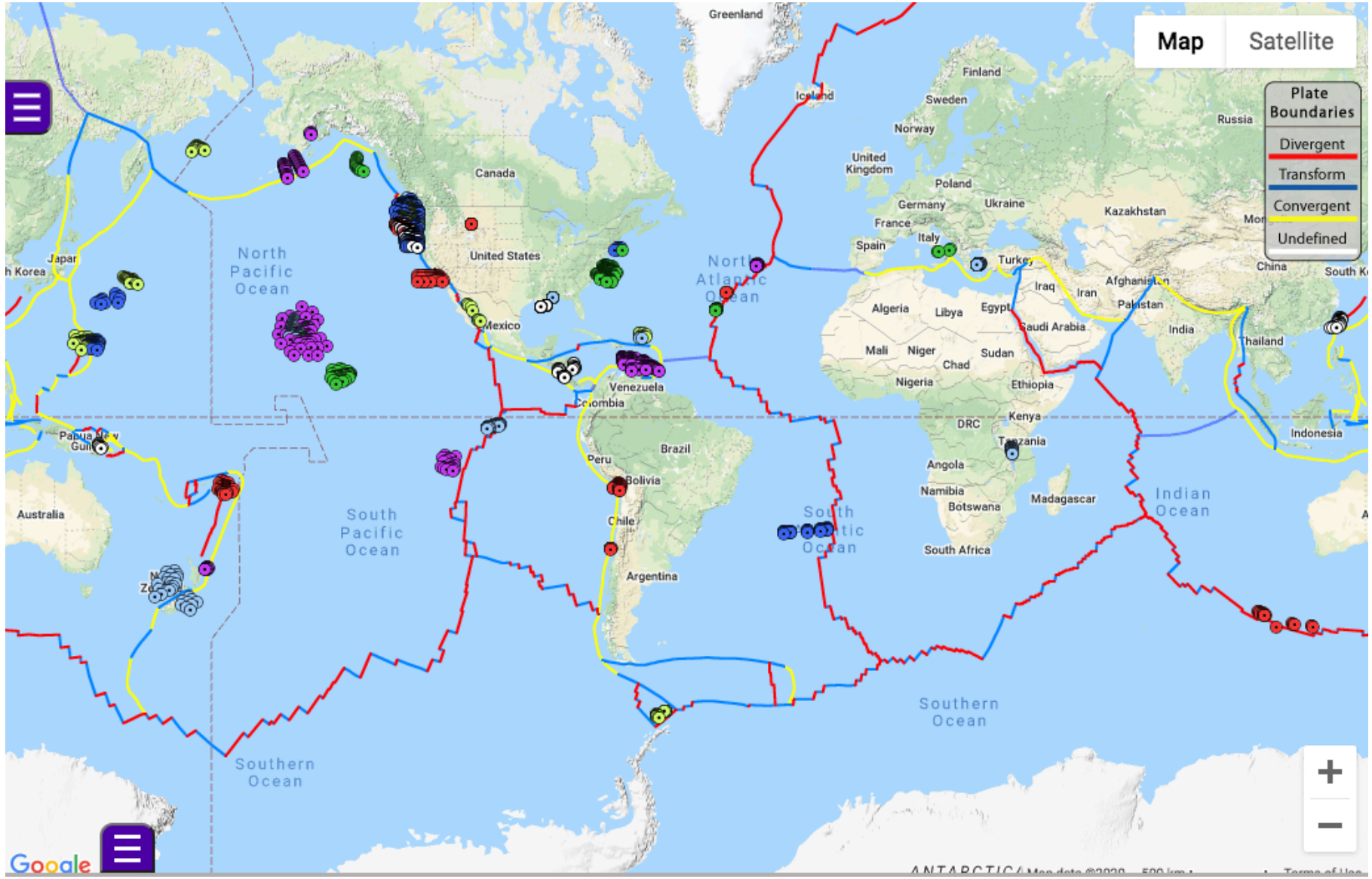
WHOI ARRA; **designed & formerly operated by LDEO; * designed & formerly operated by SIO*

OBSIC: 102 Broadband OBS (5+ variants); 29 short-period OBS (1 variant)

Other: 41 SIO broadbands (34 x T-240; 7 x T-40); 16 LDEO broadbands; 72 SIO short-period (63 x conventional, 2 x flips, 7 x LPSPs

OBSIC

- 1996 stations
- ~880 years of data
- Data from all passive (and ~50% of active-source) expts. archived in SEED format at IRIS DMC since 2001.
- Virtual Network is **_OBSIP**
- Data from all active-source expts. archived in SEGY format at DMC as Assembled Data



Requesting OBSIC Instrumentation

See https://obsic.whoi.edu/policies-and-procedures/

- For NSF-funded projects, all OBS costs are supported through a cooperative agreement between NSF-OCE-MGG and OBSIC.
- OBS costs for MGG-supported experiments are not included in the PI's proposed budget, but do come out of the MGG science budget and thus, an Informational Budget that summarizes the anticipated costs of supporting the experiment, both ashore and at sea, must be included in the proposal.
- PIs submitting to NSF programs other than MGG should contact a program officer in MGG for information on how to include the OBSIC costs in their proposals
- The PI submits an instrument request to OBSIC, and OBSIC provides the PI with a 1-page Informational Budget.
- The Informational Budget must be included in the "Supplementary Documentation" section of the proposal.
- Make a ship-time request (www.unols.org)

APPENDIX 1. An Example of Informational Budget

This form is generated based on PIs Instrument Request

U.S. National Ocean Bottom Seismic Instrumentation Center

This is an informational budget provided to prospective users of instruments in the U.S. National Ocean Bottom Seismic Instrumentation Center. OBSIC will provide complete engineering and technical support for OBS operations at sea. The cost of providing this support (e.g., instrument charges, personnel support, shipping and travel) will be funded directly through the Center; these costs do not need to be included in individual NSF science proposals. NSF does, however, require PIs to provide an informational budget estimating these costs in any proposal requesting OBSIC instruments. For more information on OBSIC, see https://obsic.whoi.edu.

Project Title: *Western Pacific Old Crust and Mantle Structure*

Principal Investigator(s): *John Collins*

Funding Agency: *NSF/OCE/MGG*
Submission deadline: *April 30th, 2019*

Instruments:			
	18	*Short Period*	*1 deployments*
	0	*Short Period Long Deployment*	*0 deployments*
	20	*Long Period*	*1 deployments*
	0		*0 deployments*

Date of prop. experiment: *12/1/2020; 11/1/2021*

The cruise dates and durations in the Instrument Request should be consistent with the PI's ship-time request (typically UNOLS).

Logistics:		
	1 -	*45 day leg*
	1 -	*14 day leg*
	0 -	*0 day leg*
	0 -	*0 day leg*

Ports: Guam *to* Guam

The following is an estimate of the cost of supporting the OBS operations requested in this proposal. These costs are subject to change depending on factors such as the scheduling of this project, and the lengths and ports of the deployment and recovery legs. This budget includes inflationary costs for experiments scheduled in outlying years. A final budget for OBS support operations for this project will be negotiated as part of the annual cooperative agreement between NSF and OBSIC.

Baseline Facility Costs		
On-Shore Labor		$xxx,xxx
At-Sea Regular Labor		$xxx,xxx
	Total Baseline Facility Costs	**$X**
Experiment Specific Costs		
At Sea Labor Uplift		$yyy,yyy
Instrument Costs		$yyy,yyy
Shipping		$yyy,yyy
Travel		$yy,yy
Instrument Modifications		$0
	Total Experiment Specific	**$Y**
	Total:	**$X+Y**

OBSIC provides these numbers based on PIs Instrument Request

Notes:

OBSIC Management Office
January 20th, 2019
OBSIP Experiment Estimate Number: - 24014.xx_John Collins western Pacific expediment

Slide Redacted

Delayed Experiments => Busy OBSIC Schedule for 2021

Cruise dates and vessels subject to change.

Gaherty ORCA Year 2 Recovery: 11/03/2020 – 12/20/2020	SIO; 30 BBOBS R/V Revelle, San Diegou to Honolulu
Boettcher Gofar Year 2 Deployment/Recovery: 01/16/2021 – 03/42/2021	WHOI and SIO ; 13 BBOBS; 10 SMOBS; 28 SPOBS R/V Thompson, San Diego to Port Everglades, FL
Laske NE Pacific Deployment April 2021; ????????	SIO; 25 BOBS R/V Kilo Moana; Honolulu to Honolulu
Wilcock Axial Seamount Year-1 Deployment May 2021; ????????	WHOI; 10 SPOBS and 5 BBOBS R/V Oceanus, Newport to Newport
Canales Cascadia Active-Source (2-ship): May/June 2021;	WHOI and SIO; 60 SPOBS; 115 drops R/V Oceanus , Newport to Newport
Worthington Queen Charlotte Fault Broadband Deployment July/August 2021; ????????	WHOI, 28 BBOBS (1-year); Sikuliaq(?), Ketchikan to Ketchikan (?)
Worthington Queen Charlotte Fault Active-Source (2-ship): July/August 2021; ????????	WHOI and SIO; 35 SPOBS; 149 SPOBS drops Canadian Coastguard Vessel Tully(?) , Ketchikan to Ketchikan(?)
Boettcher Gofar Leg 3 Recovery: January 2022 ???????	WHOI and SIO; 13 BBOBS; 10 SMOBS; 28 SPOBS Ship:?; San Diego to San Diego (?)

OBSIC Governance

- OBSIC is funded by NSF Ocean Sciences
- Governance is under UNOLS (University-National Oceanographic Laboratory System)
- Marine Seismic Research Oversight Committee
- Ocean-Bottom Seismometer Instrument Center Operations Sub-Committee (OBSIC-OS)
- https://www.unols.org/committee/marine-seismic-research-oversight-committee-msroc
- **OBSIC-OS Members:**

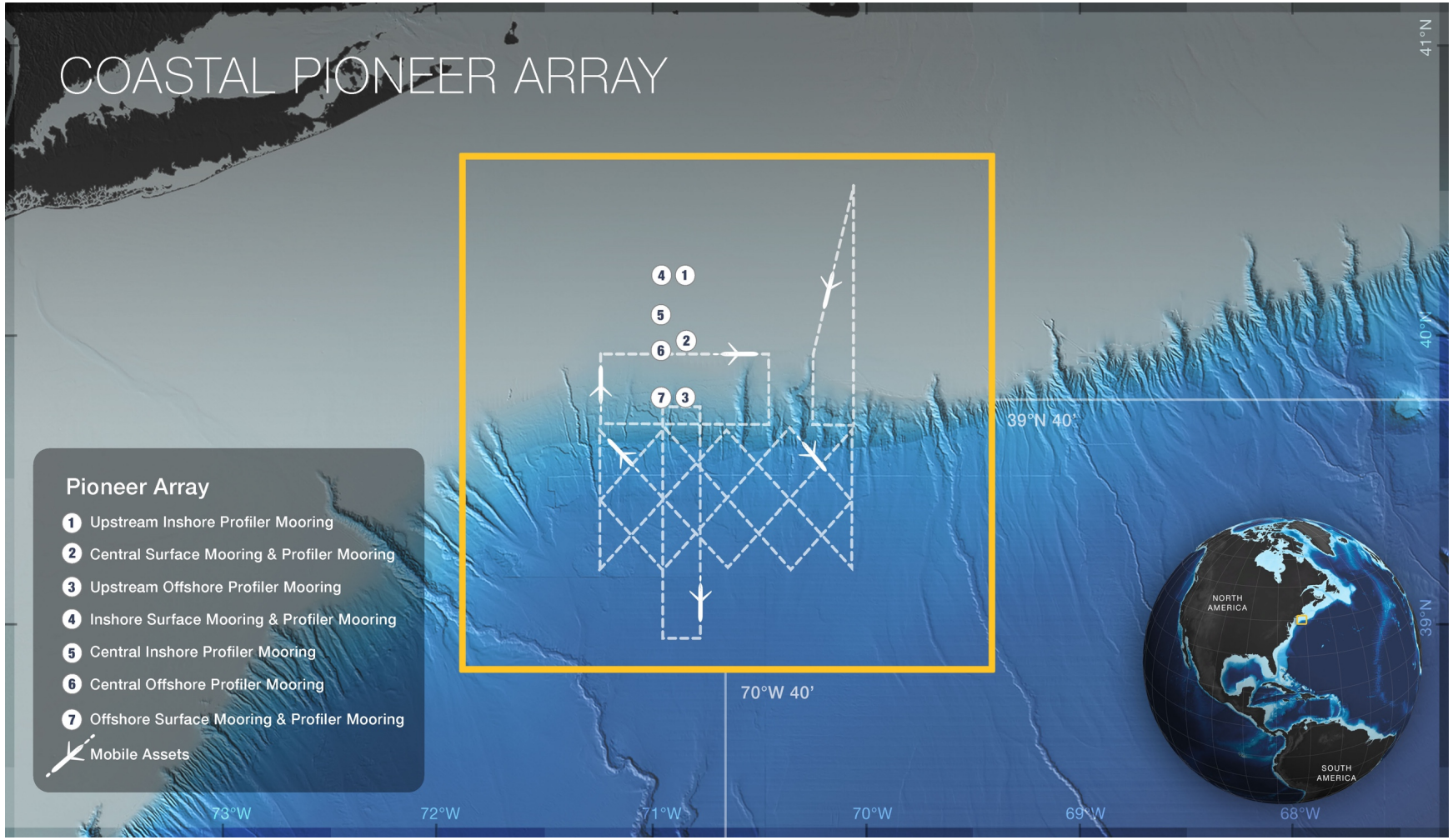
Jim Gaherty (NAU – Chair)
Kasey Aderhold (IRIS)
Jackie Caplan-Auerbach (WWU)
Zach Eilon (UCSB)
Emilie Hooft (UO)
Ross Parnell Turner (UCSD)
Lindsay Worthington (UNM)

OBSIC Challenges

- OBSIC fleet is old with large percentage of OBS dating from early 2000s
- OBSIC fleet is very heterogeneous
- Need to recapitalize
- NSF-OCE is aware and supportive but no specific plan yet
- OBSIC is an operational entity, i.e. no development
- Now is the time to consider a program to test and compare new instrumentation (COTS OBS, sensors, data-loggers, clocks) and operational procedures, e.g. TA approach.

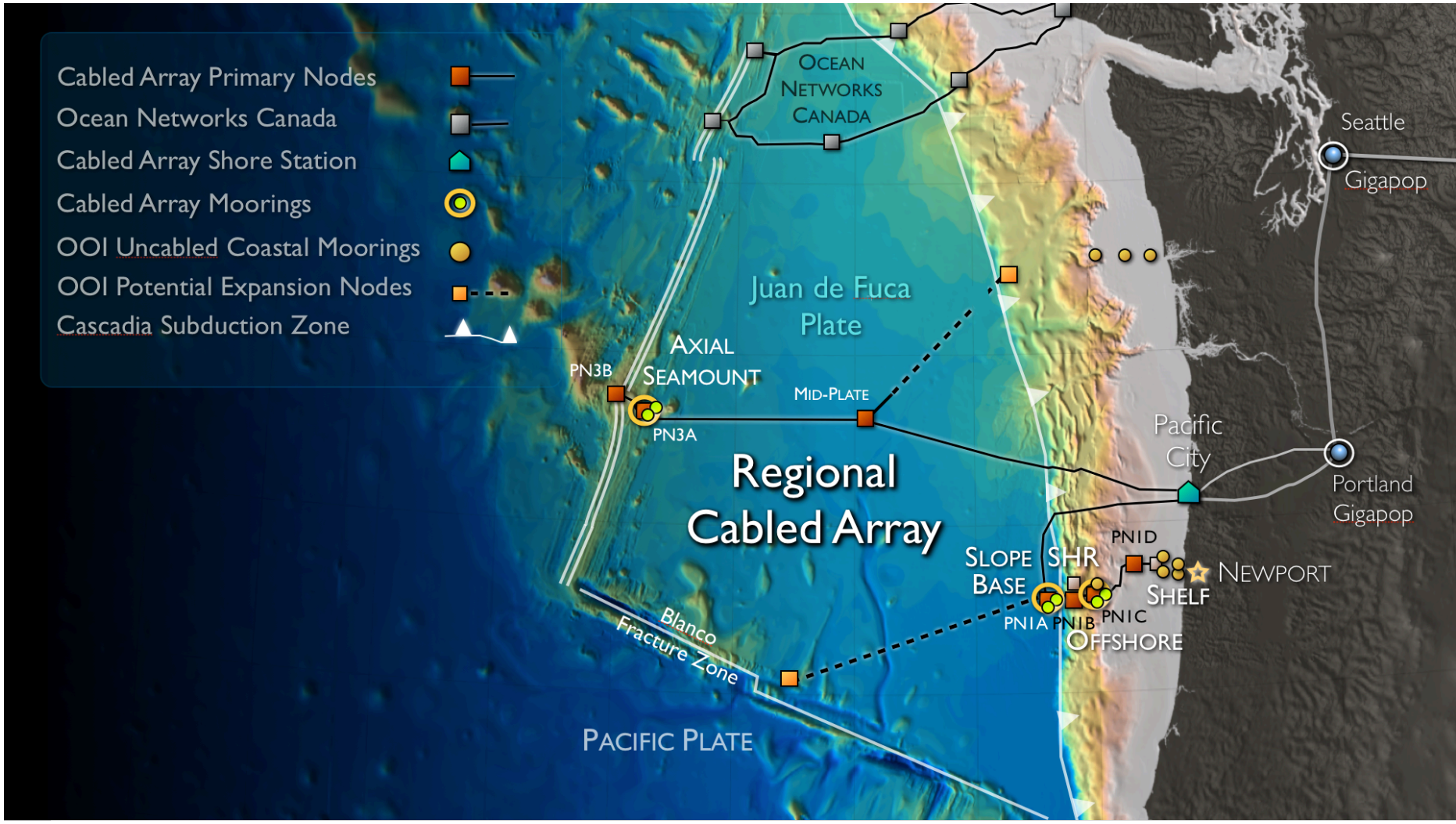
Ocean Observatories Initiative Pioneer Array

- ~100 nm south of Woods Hole, i.e. a 10-hour steam.
- Multiple surface and water-column moorings; glider profiles.
- WHOI-Keck-3D Acoustic Telescope (6 phased hydrophone arrays) for isolating and recording natural and anthropogenic ambient sound.
- Data telemetered ashore in real-time.
- Shelf, slope, and ocean basin environments.

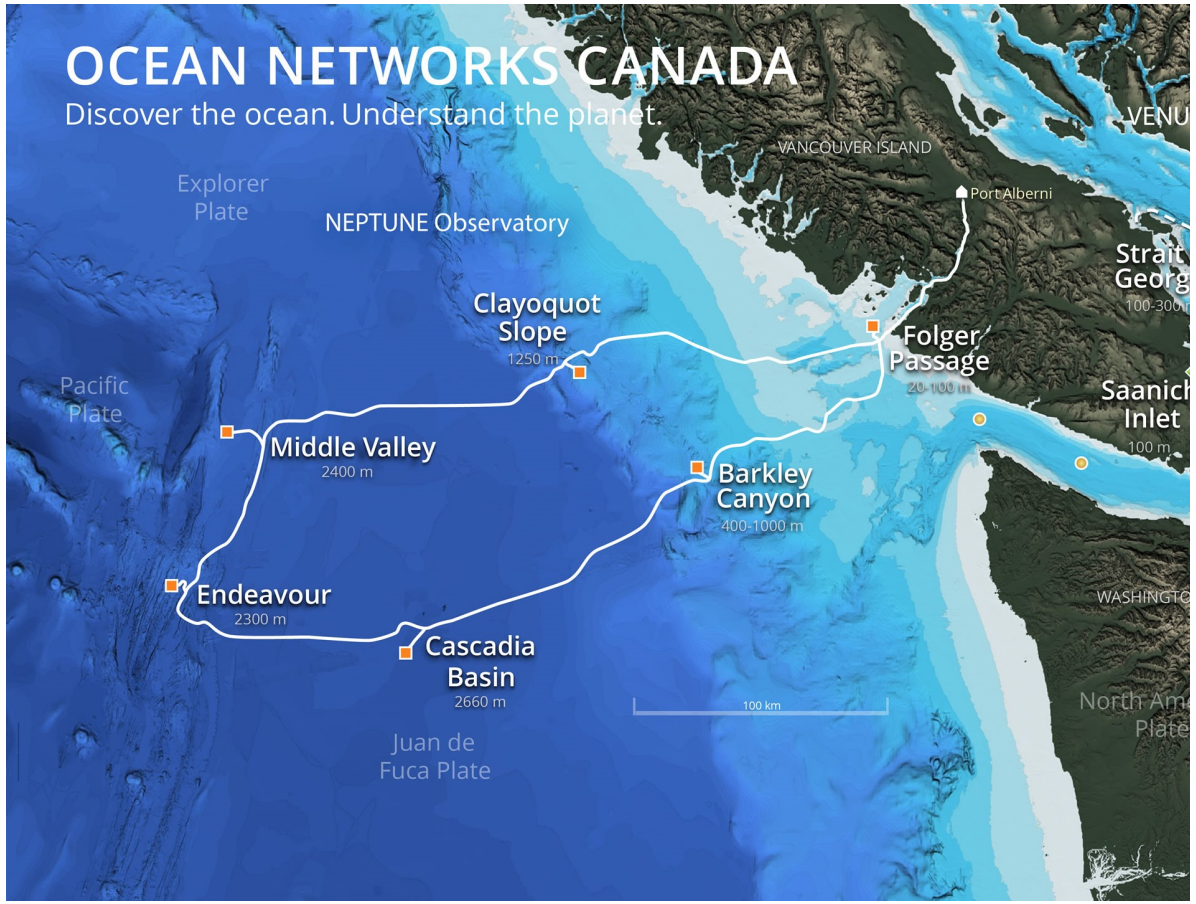


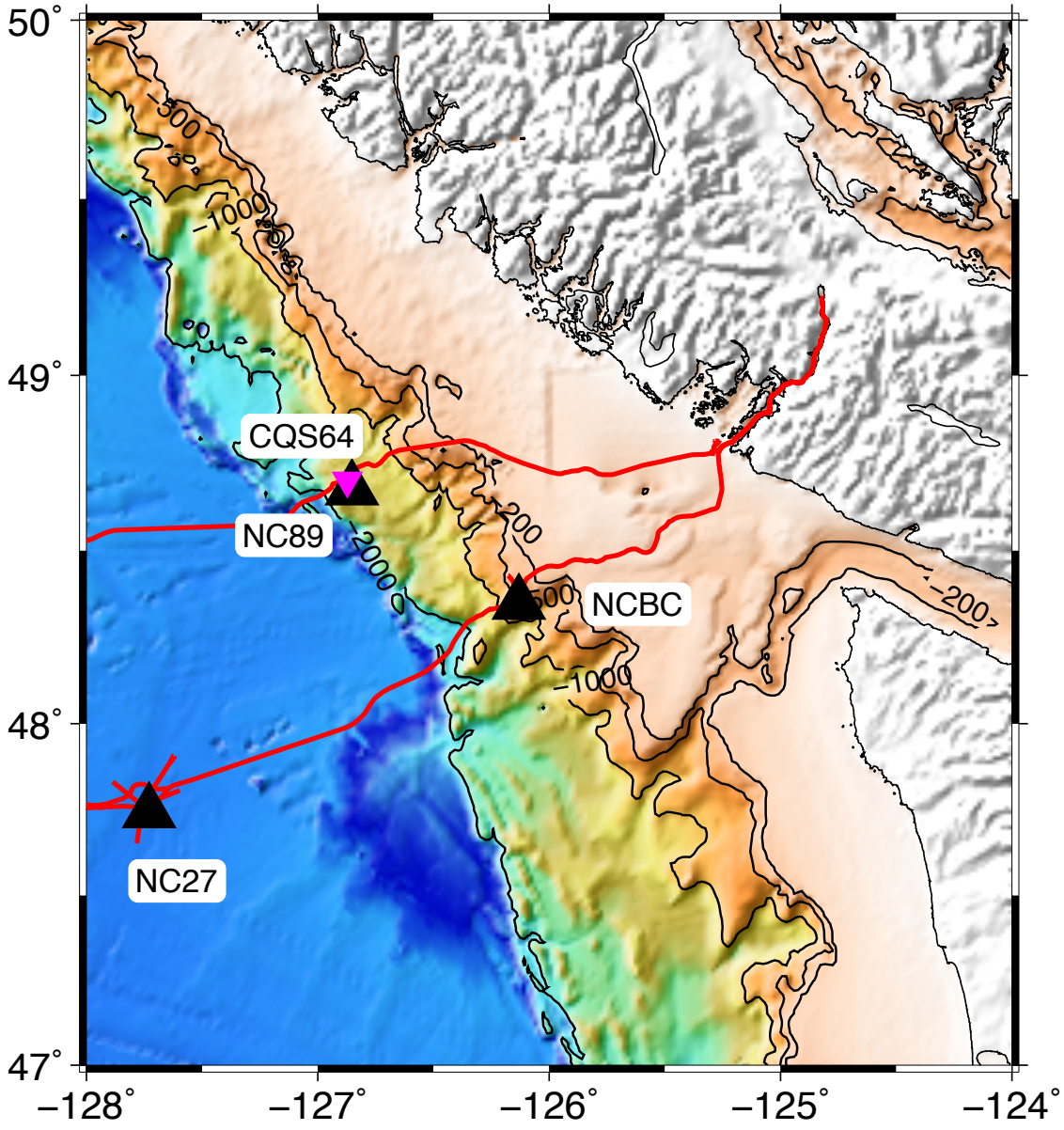
Ocean Observatories Initiative Regional Cabled Array

- Realtime data from broadband seismometers, APGs, hydrophones, and a multitude of oceanographic sensors.
- Continental shelf, slope, deep ocean basin, and mid-ocean ridge.
- ~1 day steam from Newport, OR



Ocean Networks Canada (ONC) Seafloor Cabled Network





- Realtime data from broadband seismometers, APGs, hydrophones, and a multitude of oceanographic sensors.
- Continental shelf, slope, deep ocean basin, and mid-ocean ridge.
- < 1 day steam from Sydney, BC

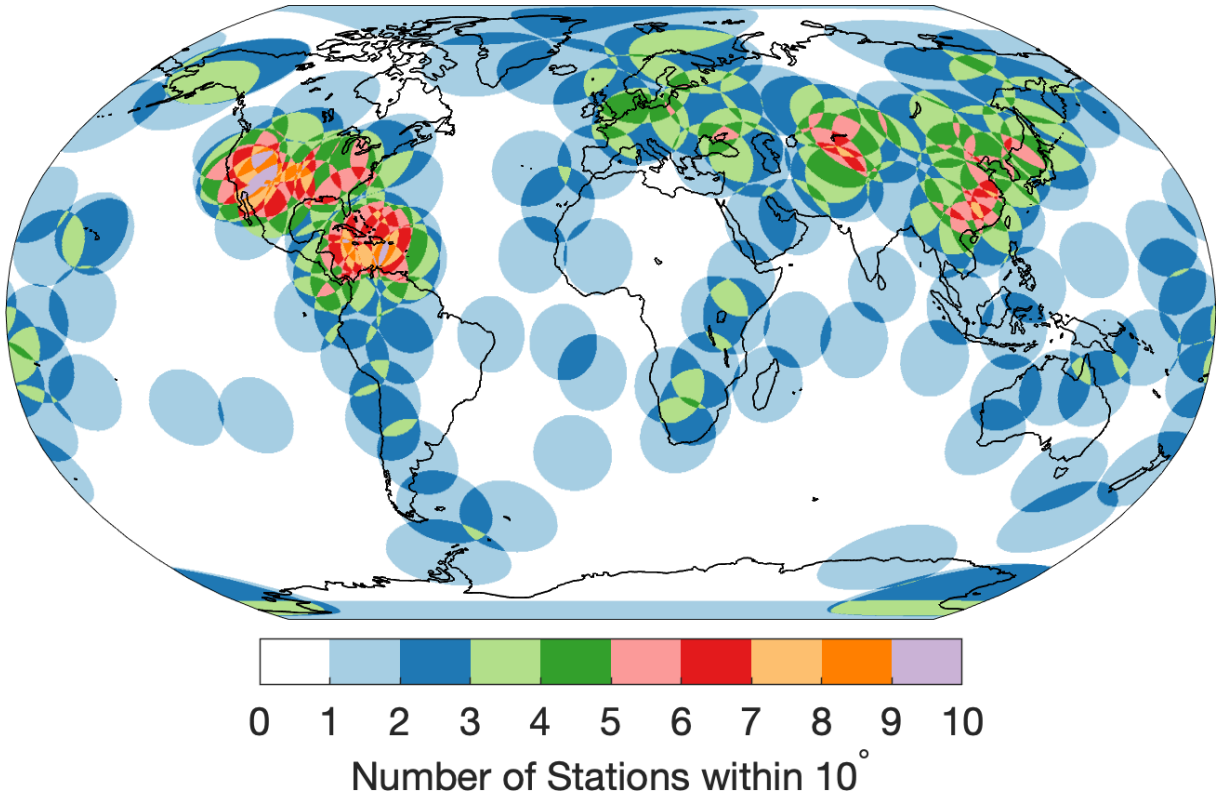
2020 GAGE/SAGE Science Workshop
Virtual Special Interest Group:
Collecting Geophysical Observations from the Seafloor

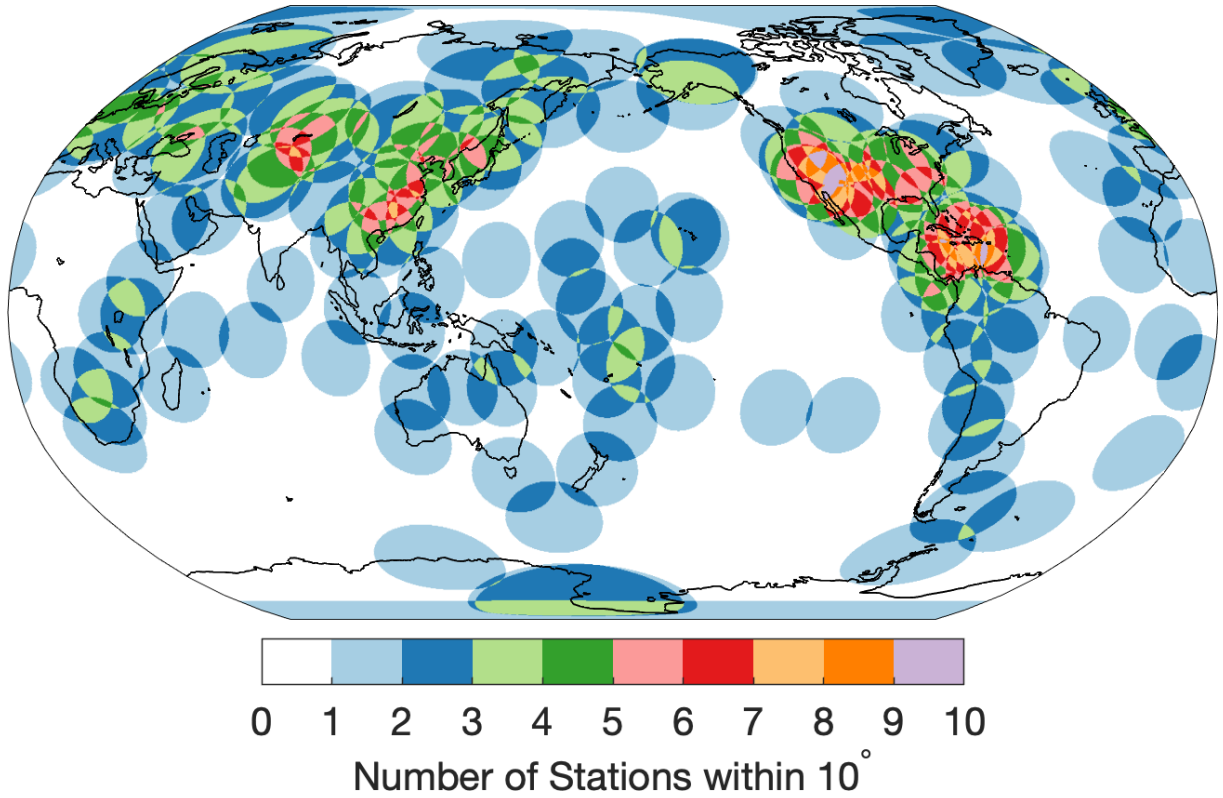
Long-Term Seafloor Seismometers

Monica Kohler, IRIS WGLTSS Chair, 2017-2019

Kohler, M. D., K. Hafner, J. Park, J. C. E. Irving, J. Caplan-Auerbach, J. Collins, J. Berger, A. M. Trehu, B. Romanowicz, B. Woodward, "**A Plan for a Long-Term, Automated, Broadband Seismic Monitoring Network on the Global Seafloor,**" *Seis. Res. Lett., 91* (3), 1343–1355, doi:10.1785/0220190123, 2020.

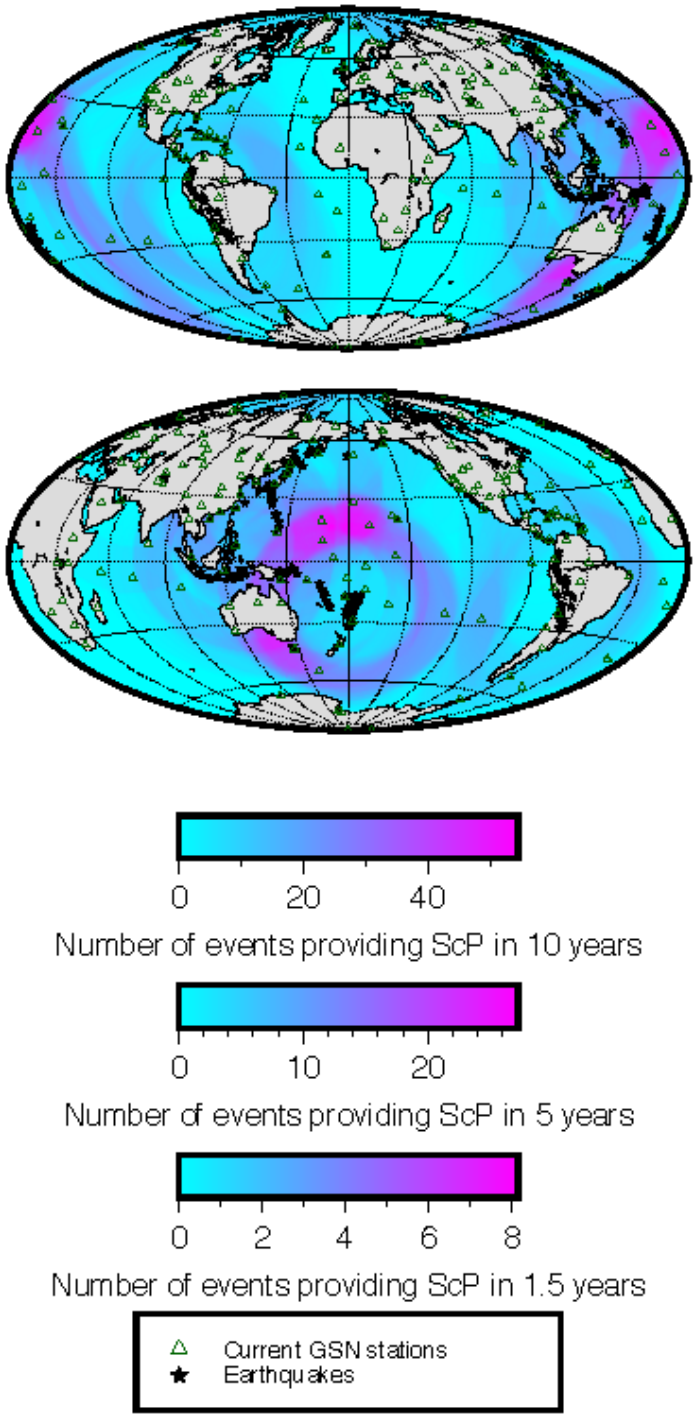
Global Seismographic Network (GSN) station coverage represented through geographical density of stations





Scientific Needs/Motivations – see Supplementary Materials of SRL paper

- Global Earth seismic tomography
  - Inner core, Outer core, Lower mantle, Mid-mantle, Asthenosphere, Lithosphere structure
  - Anisotropy, attenuation
  - Subduction zones, plumes, ULVZs, transition zone, discontinuities
  - To infer mantle and core dynamics, rheology, temperature, composition, internal boundaries.
- Teleseismic earthquake, slow-slip event source physics.
- Non-seismic source characterization (explosion, landslides, tsunamis, global microseismic: infragravity, storms)
- Data types
  - Teleseismic body waves
  - Surface waves, dispersion
  - Shear-wave splitting, receiver functions
  - Low-frequency acoustic
- Real-time/near-real-time applications



An example:
ScP coverage

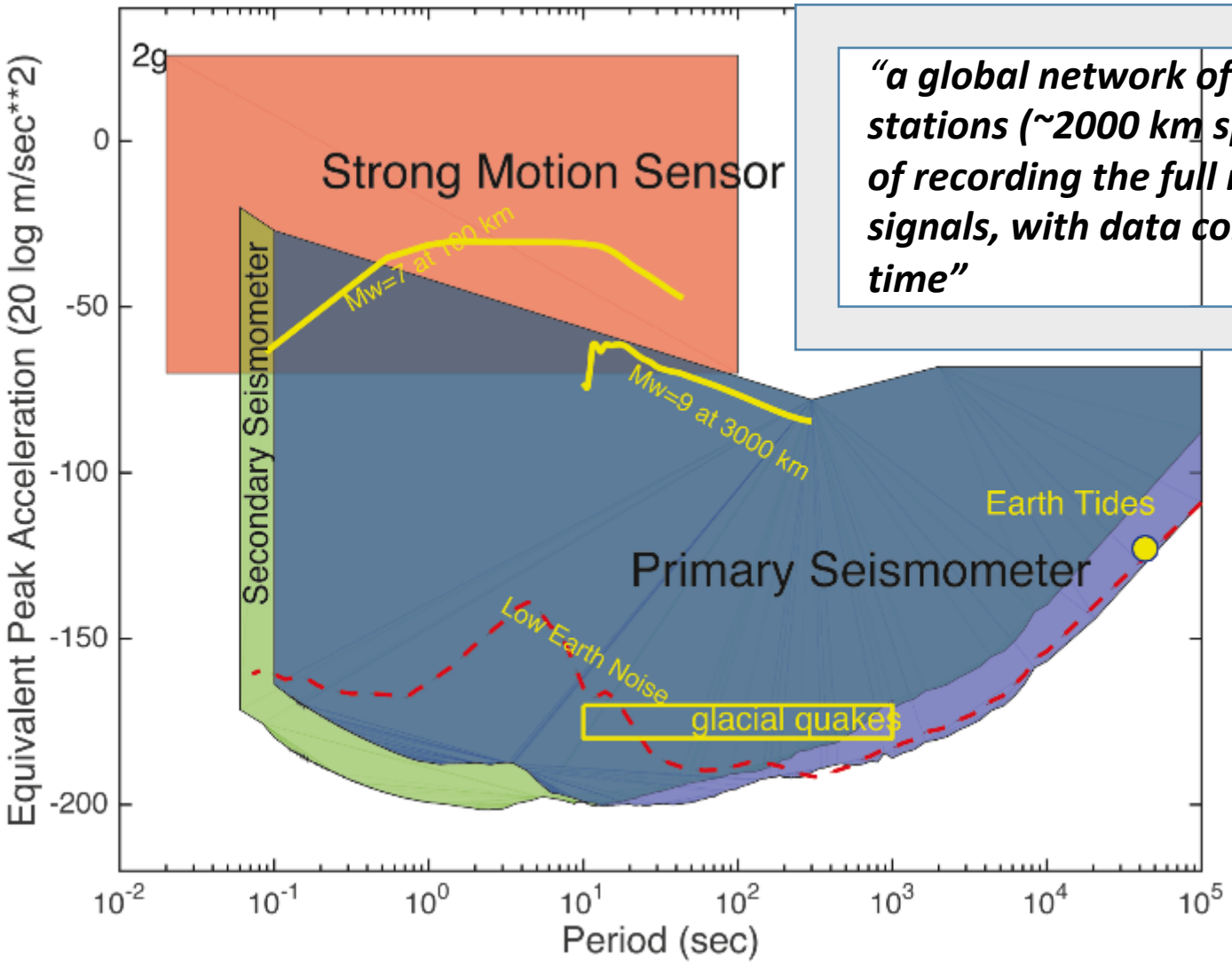
receiver function
Sp receiver function
MTZ
PP
SS
ULVZ
ScP
ScS
Sdiff
SmKS
SPdKS
PKPbc-PKIKP
PKiKP-PKIKP

See Supplementary Materials of SRL paper

Working Group on Long-Term Seafloor Seismometer pilot station recommendations:

- Occupation of site for at least four years
- Real-time not as high a priority. Minutes-Days OK.
- Sensitivity to a broad spectrum of seismic wave frequencies – 1000 s to 25 Hz
- Each seafloor station consist of at least five closely-spaced seismometers for redundancy and noise reduction
- Buried sensors
- Two regions are promising arenas for prototype seafloor seismic station:
    - Central North Atlantic Ocean
    - Central-Southern Pacific Ocean

GSN Design Goals



"a global network of uniformly spaced stations (~2000 km spacing"), capable of recording the full range of seismic signals, with data collection in real time"

High dynamic range installations

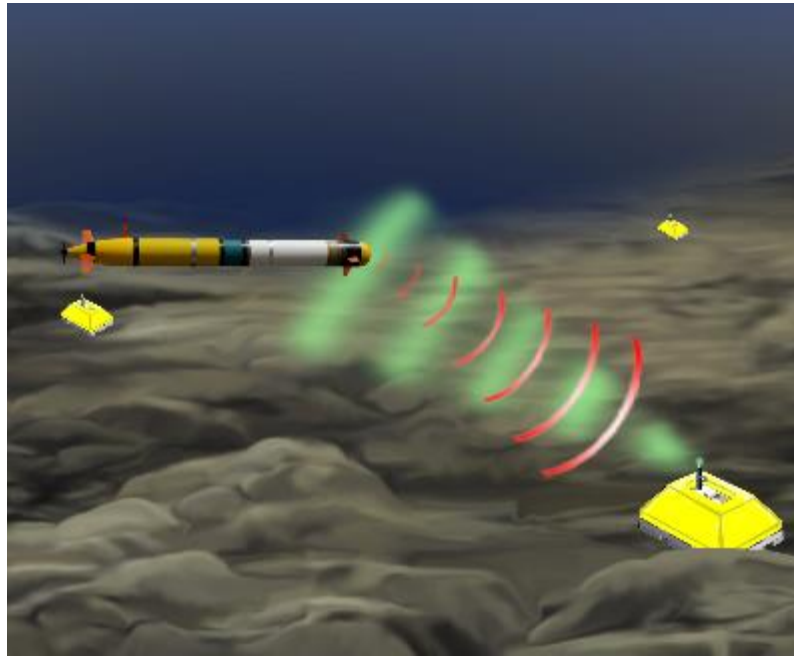
Broadband (hrs to ~ 25 Hz)

Quiet instruments / sites /

Real-time telemetry

Hardware developments

Two-Year Capable Shielded OBS with Integrated Optical and Acoustic Modems



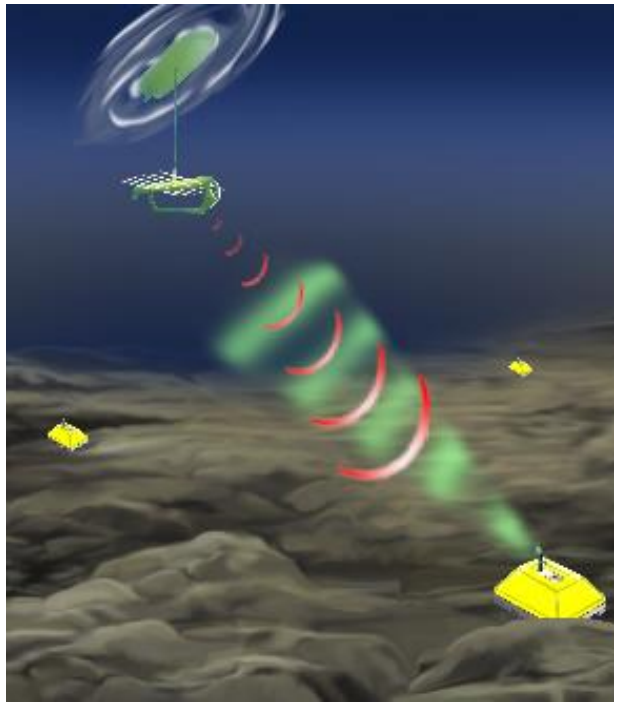
Optical modem can be used from a variety of platforms to communicate with shielded OBS. It can:

- Use an AUV (REMUS-600)
  - Endurance: 70 Hours at 3 knots
  - Range: 286 nautical miles
  - Depth: 600 meters
  - Communications: OTH Iridium

	Optical	***Acoustic***
Data rate:	10-20 Mbits/sec	5 kbits/sec
Range:	150 meters	kilometers
Latency:	micro sec	msec to sec
Efficiency:	300k bits/J	1k bits/J

Slide credit: John Collins, WHOI

Two-Year Capable Shielded OBS with Integrated Optical and Acoustic Modems

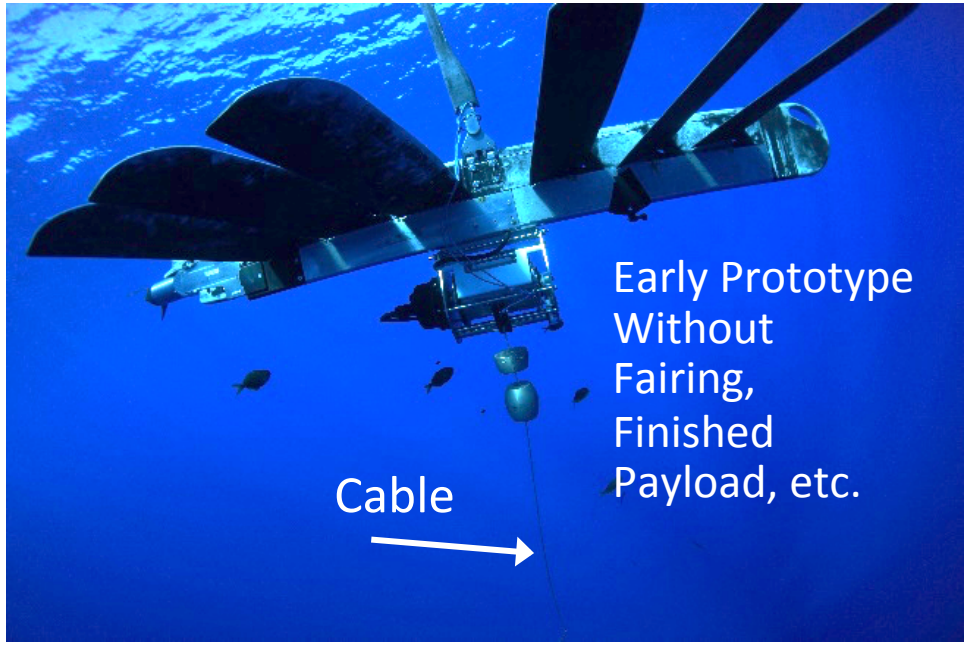


Liquid Robotics® Winch

1. ~150 m depth
   - Armored, 3 mm cable
   - 10 W power
   - 10 Mbps Ethernet
   - Active feedback based on pressure readings of sensor package
   - Currently in durability/longevity testing
2. 500 m+
   - Acoustic comms
   - No Power
   - Details still being worked out

Optical modem can be used from a variety of platforms to communicate with shielded OBS. It can:

- Use Liquid Robotics®-developed winch system for their glider. It will be capable of lowering the modem to ~150 m depth providing Ethernet at the end of the wire.

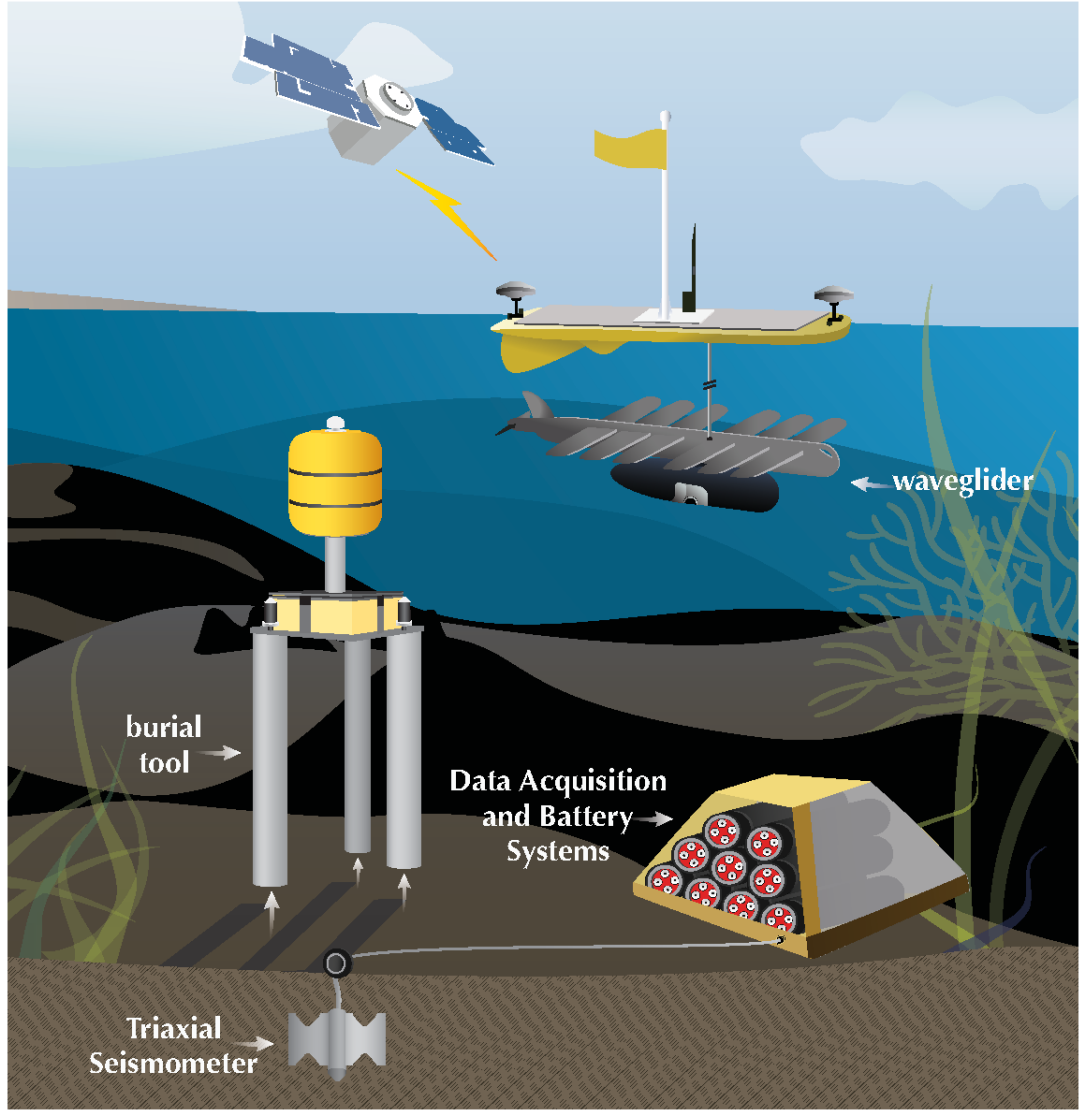


Slide credit: John Collins, WHOI

Seismic Seafloor Observatory

- Data offload method involving use of Liquid Robotics® wave glider AUV; data are then transferred to an ocean surface communications gateway.
- The gateway transmits data via satellite to shore while it holds station over the OBS using acoustic communication modems.
- Near-real time data, streaming at 1 sps with latency of a few minutes.
- Higher sample rates upon request.
- Remotely installed sensors. Use wave glider to tow out the OBS, to eliminate ship time.
- Operate 2 years without servicing.

System components developed but now requires building and testing on remote seafloor site.



Slide credit: Jon Berger, John Orcutt, Scripps

Working Group on Long-Term Seafloor Seismometers paper:

Kohler, M. D., K. Hafner, J. Park, J. C. E. Irving, J. Caplan-Auerbach, J. Collins, J. Berger, A. M. Trehu, B. Romanowicz, B. Woodward, "**A Plan for a Long-Term, Automated, Broadband Seismic Monitoring Network on the Global Seafloor**," *Seis. Res. Lett., 91* (3), 1343–1355, doi:10.1785/0220190123, 2020.

SMART Cables Sensing the Pulse of the Planet

***S**cience **M**onitoring **A**nd **R**eliable **T**elecommunications*

submarine telecommunications cables
for ocean and climate monitoring and disaster warning

Bruce Howe

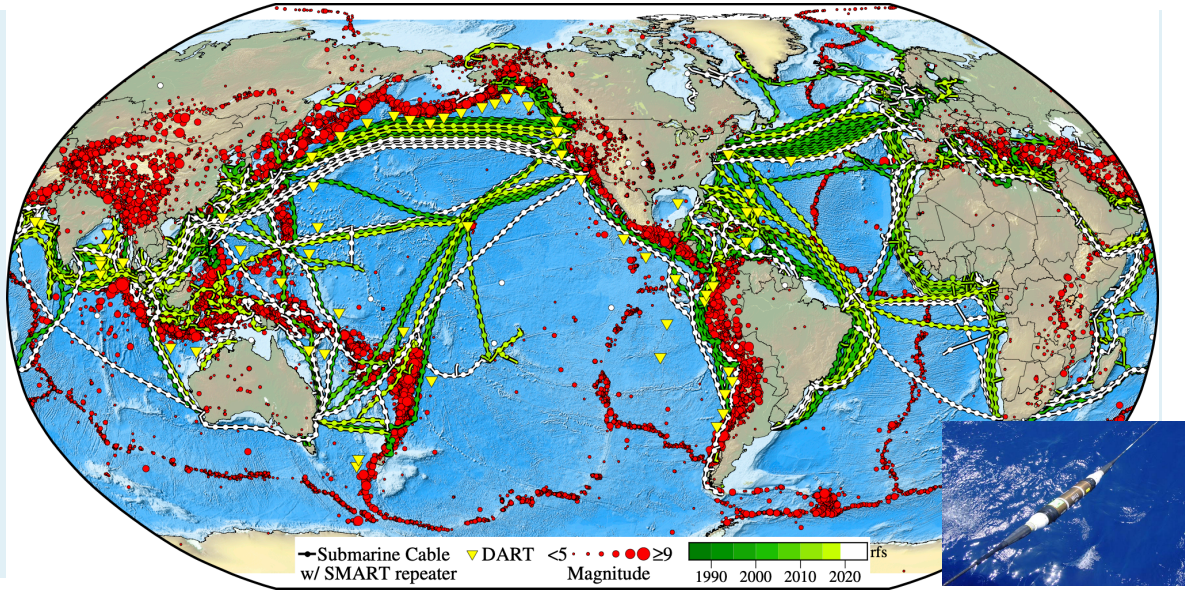
ITU/WMO/IOC Joint Task Force
and
University of Hawaii at Manoa

2020 Collecting Geophysical Observations from the Seafloor
UNAVCO
18 August 2018

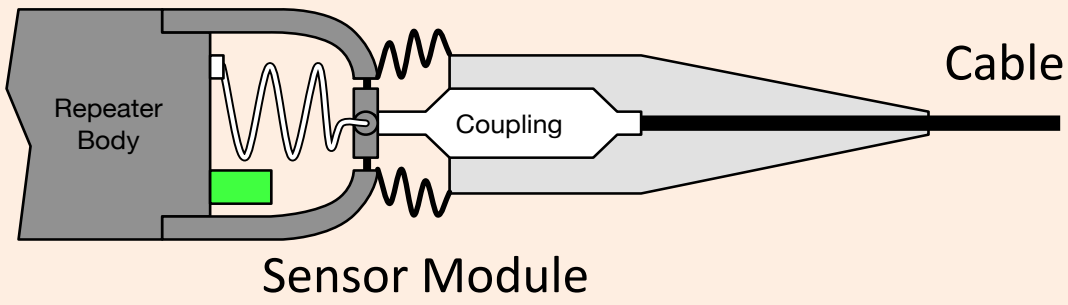
SMART Cables - Basic Concepts

Global Array: Tsunamis, Earthquakes, Climate, Oceans, Sea Level

SMART cables: 1st order addition to Ocean-Earth observing system, with unique contributions that will strengthen and complement in situ and satellite systems



One approach



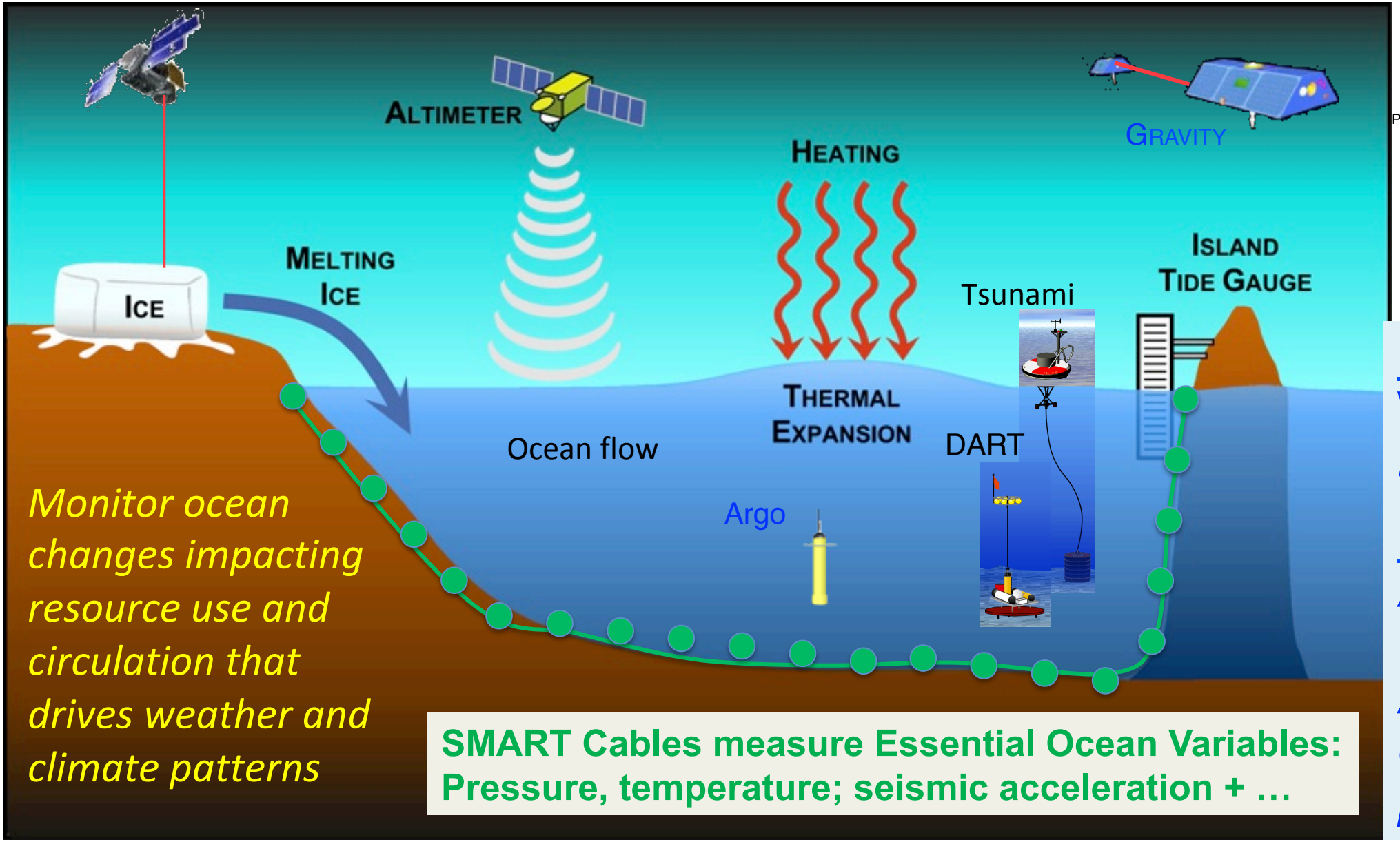
Install routinely on new cables
Deploy by cable ship, no maintenance

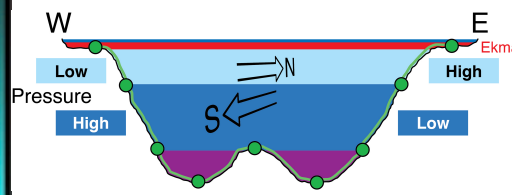
- **Telecom + science, shared infrastructure, $↓**
- Sensors in repeaters, no interference
- Reach: Global, trans-ocean, 1+ million km
  ~10,000+ repeaters (~100 km)
  10-25 year refresh cycle
- Initial: **bottom pressure, temperature and acceleration**; Later: supplement (fiber sensing…)

https://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx

John You, Nature, 2010 – Harnessing telecoms cable for science

Some Planet Observing Tools





Monitor ocean changes impacting resource use and circulation that drives weather and climate patterns

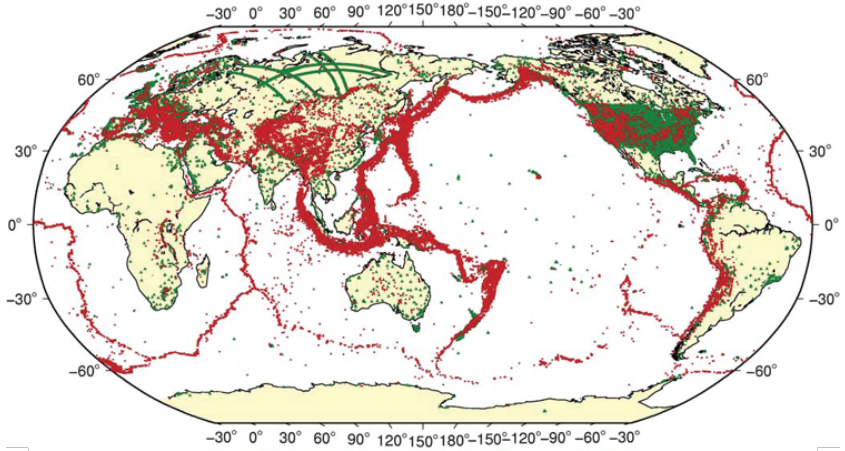
SMART Cables measure Essential Ocean Variables: Pressure, temperature; seismic acceleration + …

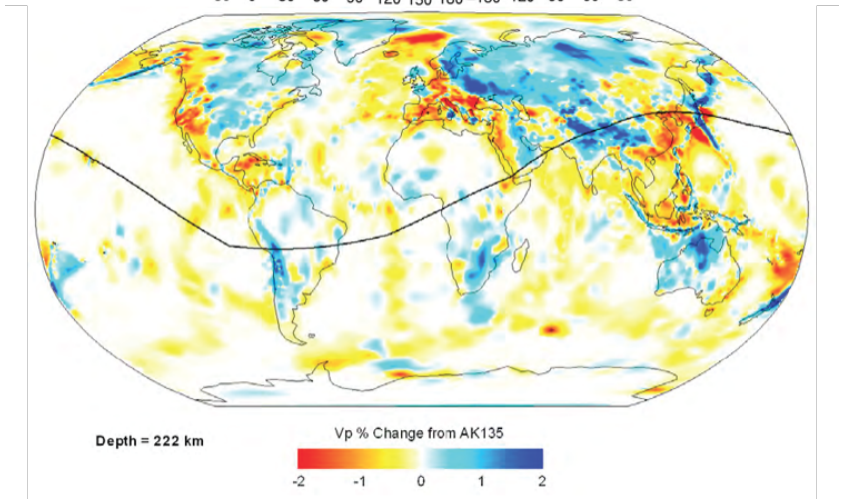
Now:
Very few bottom obs

Future:
Add SMART Cables Augment and complement present

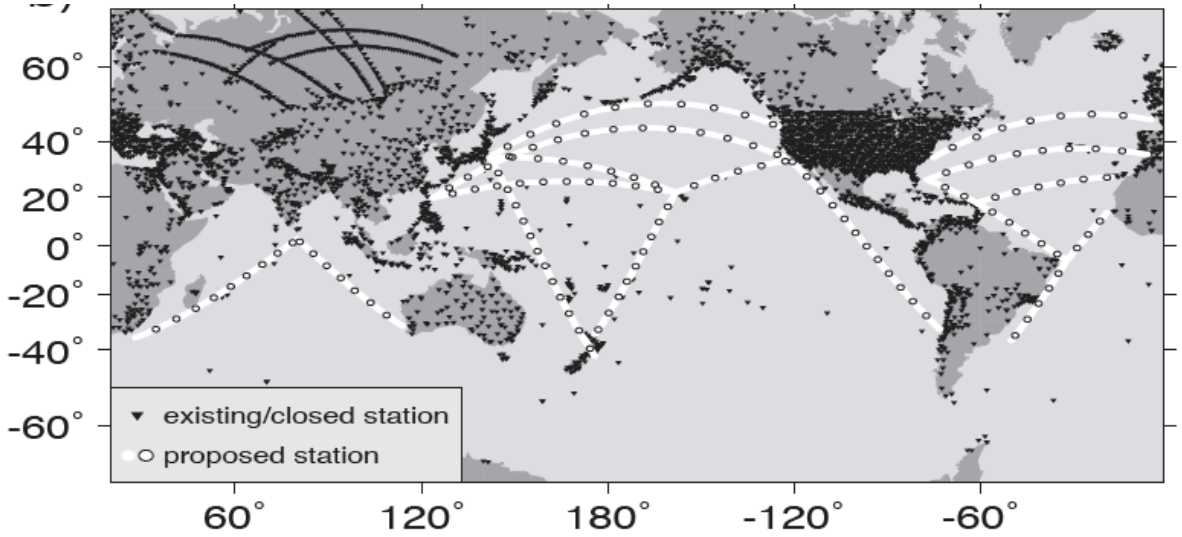
Adapted from Nerem, 2016

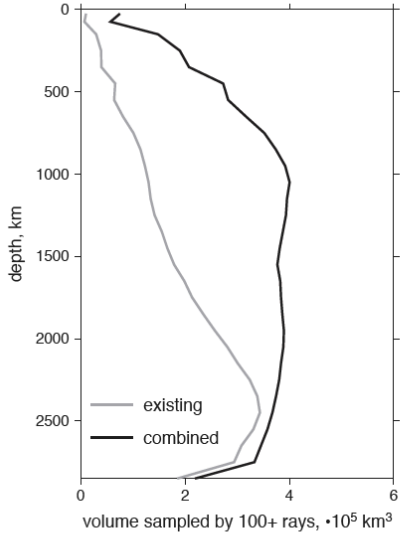
SMART Cables for seismology





- Earthquakes (red) and seismic stations (green) unevenly distributed around the globe.
- Oceans 70%, lack sensors – big gaps.
- Slice in SALSA3D model, after tomographic inversion.
- The white regions areas with no data.
- Additional sampling - SMART cables in Pacific



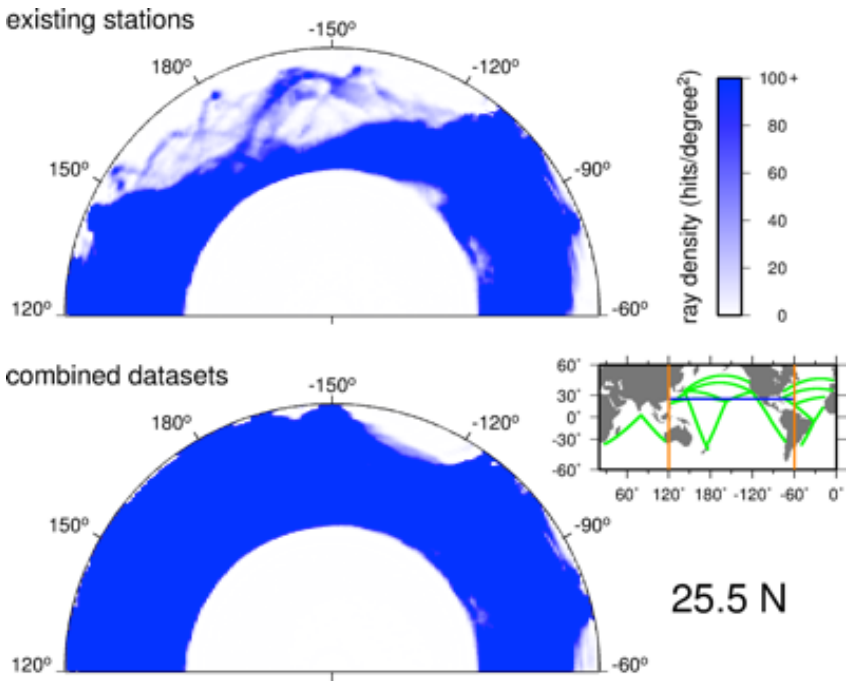


Ballard et al., 2016; Begnaud et al., 2011

N. Ranasinghe, C. Rowe et al., Enhanced global seismic resolution using transoceanic SMART cables, Seismol. Res. Lett., 2017.

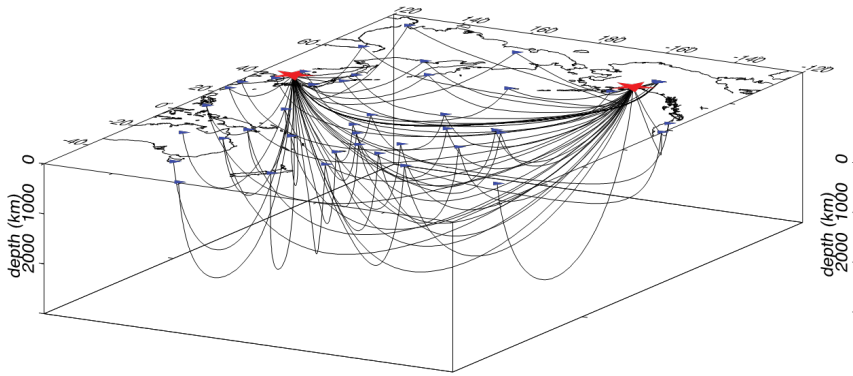
SMART Cables for seismology

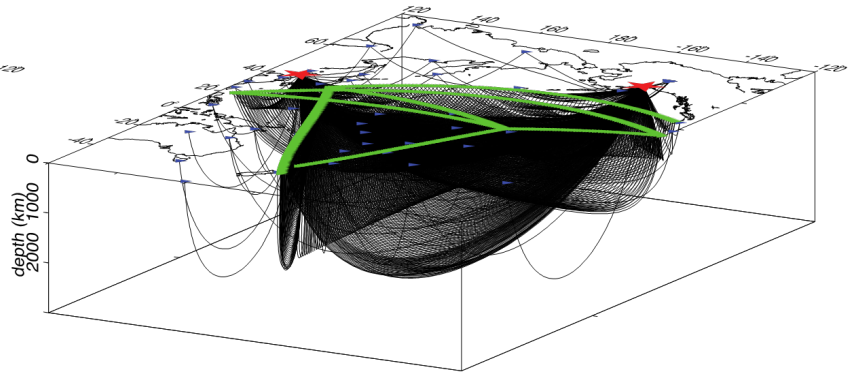
- **Better sampling** with SMART cables
- **Increased – global – coverage** -> **reduced location uncertainties, better magnitude calculations,** may provide reduced detection thresholds.



Current array (with 2 sources) sparsely samples the crust and upper mantle.

Rays to SMART Cable sensors provide improved coverage over large areas.





Additional sampling with SMART cables in Pacific, 20 y earthquake sources

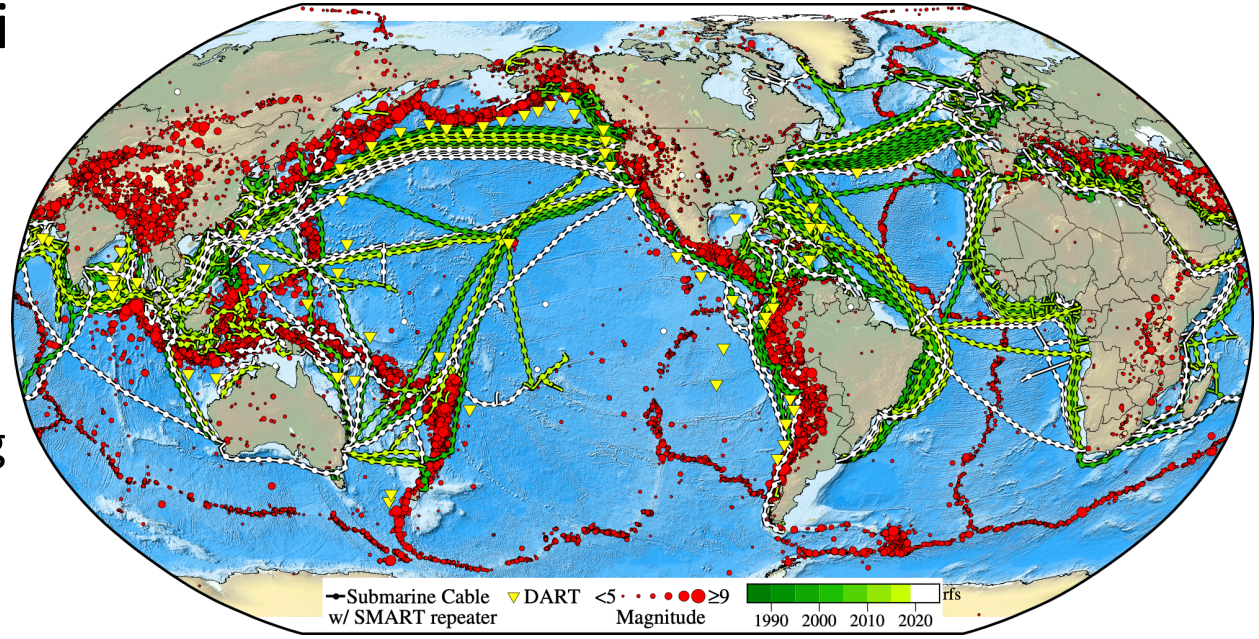
Modeling work continuing – P and S waves, …

N. Ranasinghe, C. Rowe et al., Enhanced global seismic resolution using transoceanic SMART cables, Seismol. Res. Lett., 2017.

Earthquakes and Tsunamis

Earthquake warning: time to “Drop, Cover, and Hold On!”
Survive to escape Tsunami

DART tsunami warning buoys
June 2020, 21/61 not working

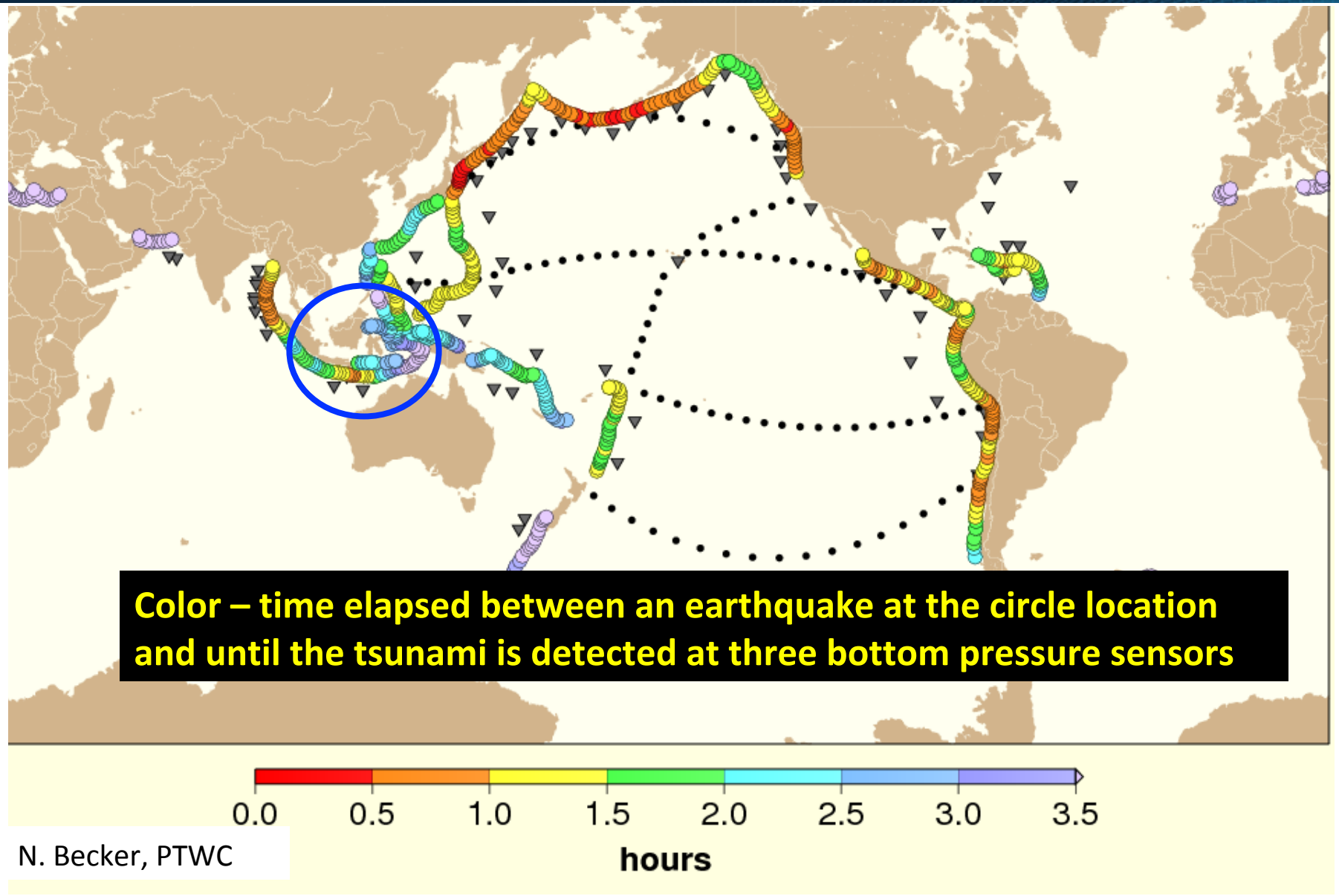


Place	Year	Mag	H (m)	Deaths
Chile	1960	9.5	25	6000
Alaska	1964	9.2	30	132
Mindinao	1976	7.9	9	7,800
Papua N. Guinea	1998	7.1	15	2200
Sumatra	2004	9.2	33	230,000
Samoa	2009	8.1	14	189
Maule, Chile	2010	8.8	3	525
Tohoku	2011	9.0	10	19,000
Palu	2018	7.5	7	2000

Place	Year	Mag	H (m)	Deaths	Cables cut
Algiers	2003	6.8	3	2,244	All Europe-Mid-East
Tohoku	2011	9.0	10	19,000	~10

Taiwan
Climate change increasing typhon number and intensity (e.g., Morakot 2009)
+ earthquakes trigger submarine turbidity currents - Cut 42 cables 2006-2013

Tsunami Detection Time at three bottom pressure recorders (2016)



N. Becker, PTWC

Add SMART

500 km spacing

Circles:
Simulated Earthquakes

Time to issue warning reduced from 2.1 to 1.6 hours – ***25% Important!***

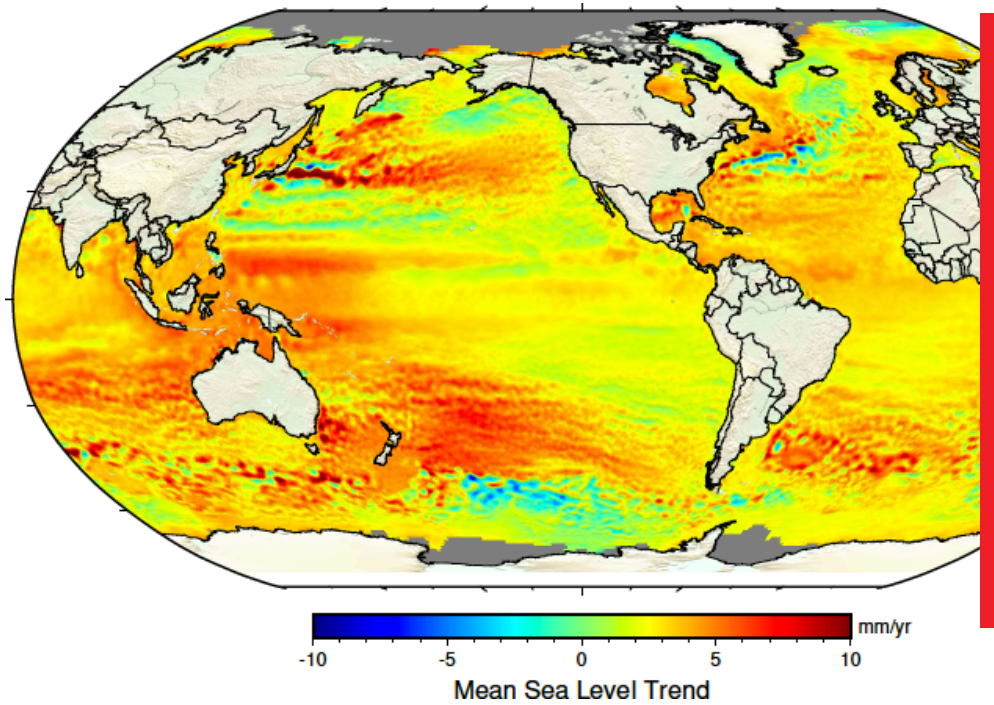
Better with 50 or 100 km spacing

Reduce cost

Sea level rise + ocean heat content

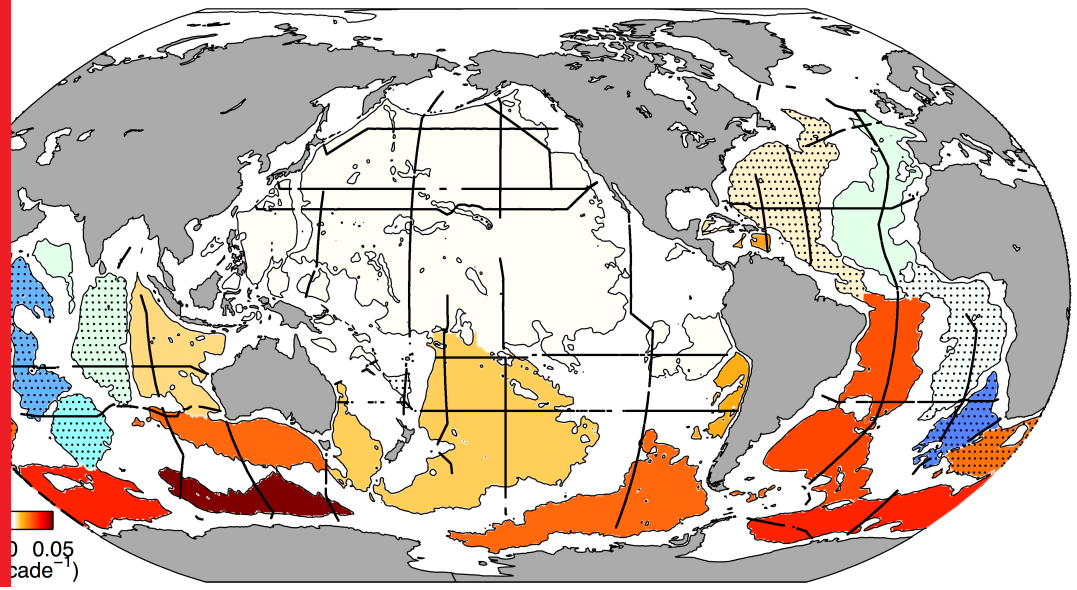
Sea level rise

Not uniform – time and space, accelerating



Ocean Temperature

Increasing, heat reservoir, water expanding



Islands disappearing
Coastal inundation
Changing ocean circulation
El Nino

Global 3.2 mm/y

2100: 8 mm/y, 1 m

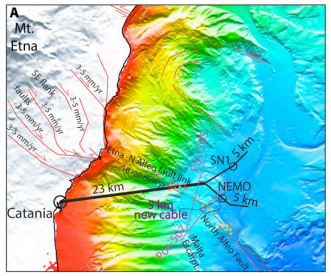
Growing coastal populations

In deep ocean (4000 m)
10s of mK / decade
Climate
Ecosystem impacts

Progress – SMART Cable Systems

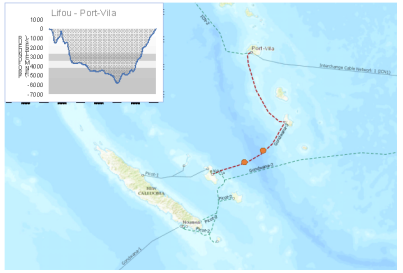
INGV–Italy–Sicily: InSea Project – wet demo

- Funded June 2019, install 2022, €2.4M, Guralp
- SMART prototype step (ground truth and fiber sensing nearby)



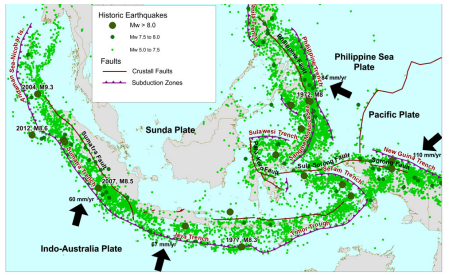
New Caledonia–Vanuatu – Gondwana-3

- Partial (€4M)funding, France, 2019; ADB, commercial
- Disaster warning, sea level
- 300 km, 2 SMART repeaters (DAS fiber funded already)



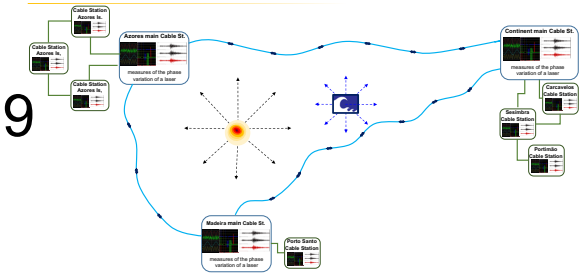
Indonesia (2019+)

- Tsunami Warning, ocean, climate, ITF
- Cable-based technology (incl fiber sensing), SMART phasing, 10-20 y
- Sustainable, reliable (minimal vandalism), good coverage

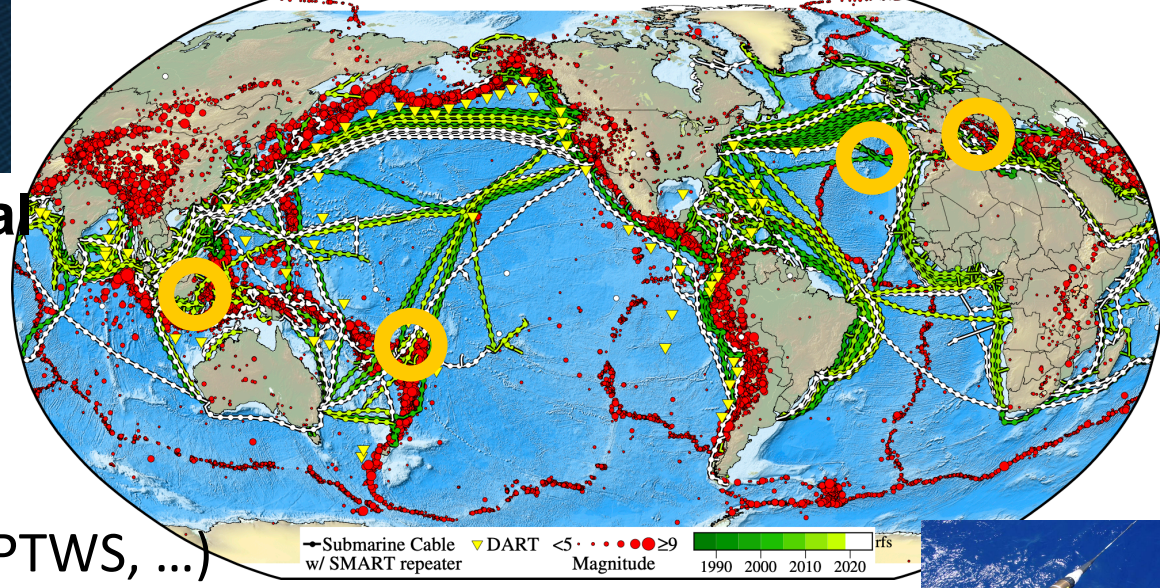


CAM2 – Continental Portugal-Azores-Madeira Ring

- Proposed 2019, approved by Gov't 2020, RFP 2021, in service 2024-29
- Explicitly SMART + fiber sensing + observatories, under current investigation of LEA (Listening to the Earth under the Atlantic).



Concluding Remarks



- **Transition – Sicily, Vanuatu, Indonesia, Portugal**
- Planning – Australia-Darwin-Singapore **EllaLink!**
  - LAm, Chile, Ecuador, Columbia, Arctic, …
- Support from
  - UN organizations (ITU, WMO, IOC, ESCAP, ESBN, PTWS, …)
  - Development Banks (ADB, IADB) positive
  - Research and Education Networks (RENs); US Ocean NOAA
- Need
  - Off-the-shelf SMART repeater
  - More Corporate Social Responsibility – via Gov’ts and UN …
  - Very early access to proposed systems to enhance the value proposition
  - Embed in UN Decade of Ocean Science for Sustainable Development
- ***Long Term Goals:***
  - ***Shared critical infrastructure, Gov’t + telecom working together***
  - ***Global scale, N ~ 2000 mini-observatories – climate, DRR, cable monitoring***

References

UN Sponsors
International Telecommunications Union
World Meteorology Organization
Intergovernmental Oceanographic Commission
150 members, 90 organizations

Bruce Howe
Chair, JTF SMART Subsea Cables
bhowe@Hawaii.edu

JTF SMART Cables web page
https://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx

SMART Cables white paper 2019

Howe, B. M., B. Arbic. J. Aucan, C. Barnes, N. Bayliff, N. Becker, R. Butler, L. Doyle, S. Elipot, G. C. Johnson, F. Landerer, S. Lentz, D. Luther, J. Mariano, K. Panayotou, C. Rowe, R. Scholl, Y. T. Song, M. Thomas, P. Thomas, F. Tillman, T. Weber, S. Weinstein, The SMART Cables Joint Task Force, **SMART Cables for Observing the Global Ocean: Science and Implementation**, *Frontiers in Marine Science*, OceanObs'19 Special Issue, doi: 10.3389/fmars.2019.00424, 2019.
https://www.frontiersin.org/articles/10.3389/fmars.2019.00424/full

Recent Total Telecom Webinar
Video of the session Post-webinar article Q&A article

Thanks to NASA for planning funding!