# 2020 GAGE/SAGE SIG - Collecting Geophysical Observations from the Seafloor

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Delving into the oceans to record seismic and geodetic observations from the seafloor has remained a challenging frontier in geophysical research. Improving our understanding of structure and hazards at subduction zones, ocean basins, coasts, and islands will require improving coverage of the seafloor through development and deployment of specialized instrumentation. Different research targets and analysis techniques will have different requirements (e.g. duration, location/depth, timing quality, burial, etc.), however there is significant overlap in objectives for at-sea operations. This SIG will explore convergence of marine research targets between the geodetic and seismic communities and spark discussion on how current and future resources can be best leveraged for high-impact science.

## 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

**Seafloor Geodesy Instrumentation - Andy Newman and David Schmidt**

- Instrument pool under commissioning: 16 GNSS-Acoustic sites; 3 Wave Gliders for data collection
- Goals for community engagement activities
  - Develop and grow the seafloor geodetic community

    - Provide guidance to NSF on where and how to use the instrument pool.
- Summary of poll Results from Fall 2019; insights into preliminary community feedback
- 2-year timeline and milestones
    - Late 2021 - instrument pool ready for deployment
- For more information, go to the link: http://seafloorgeodesy.org/ and sign up for the seafloor geodesy listserv. Past webinars are posted on the website.
- Questions/Comments:
    - Ross Henderson - NASEM Nat'l Academies of Science, Engineering, and Medicine can lobby Congress. They are currently conducting their decadal survey in Ocean Sciences: https://www.nationalacademies.org/our-work/sustaining-ocean-observations-phase-2-workshop?mc_cid=6ff64d00fe&mc_eid=7f2525f1e9

**OBSIC - John Collins**

- Ocean Bottom Seismometer Instrument Center
    - 5-Year cooperative agreement between WHOI and NSF-OCE
    - WHOI and USGS have a cooperative agreement as well, particularly interested in advancing and developing a rapid response fleet of OBS (community interest in this capability as well, e.g. Cuba earthquake
- Current instrumentation - largely carried-on from previous OBSIP pool, varied designs
- Data is archived at IRIS DMC in SEED and sometimes SEG-Y
- Requesting OBSIC instrumentation - informational budget, ship time request (separate)
- Schedule - Many PI experiments including some very ambitious deployments, also some past community experiments supported
- Challenges - fleet is old, heterogeneous; need to recapitalize, NSF-OCE is aware and supportive
    - Development is not part of cooperative agreement
    - Commercial options for full OBS
    - Or develop independent design
- Potential site(s) - Ocean Observatories Initiatives Pioneer Array, OOI Regional Cabled Array - Newport, OR, ONC cabled network
- Questions/Comments:
    - Bruce Howe - What is the total PI related projects budget using OBSIC instruments? John Collins - Operations at OBSIC ~$6M
    - Bruce Howe - Testing of ocean bottom seismometers could be done at Station ALOHA with 8 ship visits/year, 1 with ROV, depth of 4728 meters.
    - Hector Mora - I would like to know, how non-US research institutions could benefit from this type of initiatives? I explicitly refer to the subduction zone of the Nazca plate beneath Colombia and Ecuador, and the Caribbean plate beneath northern Colombia. I understand that there is interest in these areas, but how any action could be coordinated together? John Collins - Partnering with a U.S. colleague is the easiest way, there are also community initiatives like SZ4D that may look at locations like this.

**Long-Term Seafloor Seismometers - Monica Kohler**

- SRL paper on this topic, includes results from a community survey:
    - https://pubs.geoscienceworld.org/ssa/srl/article-abstract/91/3/1343/583521/A-Plan-for-a-Long-Term-Automated-Broadband-Seismic?redirectedFrom=PDF
    - https://authors.library.caltech.edu/103033/3/SRL-2019123.pdf
    - Citation: Monica D. Kohler, Katrin Hafner, Jeffrey Park, Jessica C. E. Irving, Jackie Caplan−Auerbach, John Collins, Jonathan Berger, Anne M. Tréhu, Barbara Romanowicz, Robert L. Woodward; A Plan for a Long−Term, Automated, Broadband Seismic Monitoring Network on the Global Seafloor. Seismological Research Letters ; 91 (3): 1343–1355. doi: https://doi.org/10.1785/0220190123
- Recommendations from the Working Group
    - Occupation for at least 4 years, at least 5 closely-spaced seismometers, buried sensor emplacement
    - Real-time data is not as high of a priority, minutes to days is okay
    - Broad frequency range (1000s to 25 Hz)
    - Two main regions - Central North Atlantic Ocean and Central-Southern Pacific Ocean
    - Hardware developments - optical and acoustic modems for data telemetry, wave glider technology
- Overall observatory schematic - currently focused on seismic but could be integrated with GNSS
- Questions/Comments:
    - Bruce Howe - What is the estimated running cost of the proposed global array? and number of stations?
    - Helen Janiszewski - What plans are there for data processing to ensure seamless integration with the land-based GSN? Will this be the responsibility of the user?
    - Ross Henderson - I don't mean to advertise NASEM, but here's another fast-tracked working group chaired by Bill Brune at Penn State. They are also looking at the oceans and the Great Lakes: https://www.nationalacademies.org/our-work/future-use-of-nasa-airborne-platforms-to-advance-earth-science-priorities?mc_cid=3e5b994e10&mc_eid=7f2525f1e9

**SMART Cables Sensing the Pulse of the Planet - Bruce Howe**

- International Task Force
- Every 100 meters are repeaters
- Telecom is primary mission of the cables; sensors cannot affect that mission
- Bottom pressure, (Paros) acceleration, temperature initial measurements
- Drift issues for long-term measurements - esp. Pressure
- Questions/Comments:

- Tim Parker - What type of weak motion sensors are included? Bandwidth covered? Bruce Howe - Looking at two types, one is Silicon Audio
- WB Dickinson - Are you using any specific GIS technology in this project and how is it being used? Bruce Howe - None at this time.

- **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?
    - We can maximize the science by colocating seafloor geodetic and seismic instrumentation, when mutually beneficial to answer science questions and logistically feasible
    - Subduction zones ranging from ones we see as very locked to mostly slipping; recent megathrust history to late-stage seismic cycle
    - Large seismic gap in Central Peru - offshore Lima; before next megathrust earthquake cycle
    - One logistical challenge is that geodetic deployments need long term surveys (as for GNSS-A), but some seismic deployments are more short term.

- **New Technologies**
  - What new technologies are out there for making seafloor geophysical observations?
    - A-0-A for calibrated pressure to minimize instrument drift
    - Extending DAS to longer cable lengths
    - Novel ways to telemetry data and deal with data offload from seafloor instruments (optical modems, visits by Wave Gliders and AUVs).
    - Challenge: How to achieve real-time or near real-time telemetry from the sea floor (i.e. buoy systems w/ satellite link).
    - GOOGLE - state of polarization used to measure earthquakes
    - Bruce Howe - Maybe William Wilcock can comment on pressure sensor drift/absolute calibration? Spahr Webb (from Chat): Comment on calibrated pressure gauges- Will has shown impressive results on removing drift from pressure gauge signals. We deployed 5 sensors in AK and NZ with A-0-A and see drift removal at better than 1cm level from those deployments as well. That was over one year.
    - Glenn Mattioli - Can those self-cal p sensors be attached to SMART cables? Bruce Howe - With time the self-cal p sensors probably can be integrated (as they get smaller, and reliability is demonstrated).

  - How about Distributed Acoustic Sensing and tapping into seafloor cables?

        - A recent workshop and tutorial on DAS with recordings is available at https://www.iris.edu/hq/event/2020_DAS_Workshop

- **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?
        - Ross Henderson: One project being pursued by NSF is sustainable fishing (including fleets of on-ship processing commercial fleets); also aquaculture. Any thoughts on using seafloor studies for measuring appropriate zones for ecological stability?
        - Monumentation and power requirements vary depending on the instrumentation.
        - Bruce: hydrophones could be considered
        - John Orcutt (from Chat): With regard to the Navy, isolated sensors in the global ocean haven't been of real interest. They do want to know where these are deployed - this has been difficult in the past since the process is not defined.
        - Joann Stock (from Chat): What level of detail do we need for where the sensors are located? I think sometimes the commercial companies do not want to release information on the exact locations of their cables. For IODP we have to request clearance for drill sites, and it might be denied if there is a cable somewhere in the vicinity, but I do not think they tell us where it is exactly.
        - Bruce: there are ways to work out conflicting seafloor uses

    - How do we create a platform or resource to test new instruments side-by-side?

- **Data**
    - Where is community seafloor geodesy data going to be stored?
        - UNAVCO is a logical entity to develop an archive for seafloor geodetic data.
        - Glen: proposes that we may need to be aggressive about this if it is something people think should be part of the next geophysics facility solicitation
        - Andy Newman: this has been included in recent white paper; so he hopes NSF heeds this recommendation
        - If you are interested in Distributed Acoustic Sensing data, please get in touch with Jerry Carter (IRIS) who is leading the Data Working Group for the DAS RCN: https://www.iris.edu/hq/initiatives/das_rcn

- What metadata needs to be stored? Data from collocated instruments (pressure, temperature)? Data products?
    - Schmidt: There is currently no agreed upon data standards or formats for seafloor geodetic data. Data volumes are small for GNSS-A, but there can be significant metadata to curate. Seafloor pressure data can have greater samping (minutes to hours), but data volumes are still small compared to seismic. We will eventually need a small workshop or working group for this.
    - Helen Janiszewski (from Chat): Continue conversations with community to improve metadata consistency standards for the same types of instruments deployed on land and at sea.

- **Future Geophysical Facility**
    - How do seafloor observations fit with the future geophysical facility?
        - Andy N. - scientific questions asked across the coastline; subduction zone processes; merging data sets between offshore and onshore; still working out if instruments (example geodetic) should be housed by a geophysics facility OR maybe just the data - still open question
        - Glen M. - it remains to be seen what the future geophysical facility will look like; current funds that support SAGE/GAGE are EAR/OPP; if the community feels it is essential that community makes the argument that marine observations are critical, then contributions from OCE and MG&G of NSF would be needed for the facility support - because otherwise the guidance from NSF seems to be that we will be doing less with less (i.e. no adding seafloor observations) - Maybe we need a workshop on seafloor data?
        - Harold Tobin (from Chat): the divide between land and sea (EAR and OCE) at NSF has greatly hampered sub zone science, among many other things. It's critical to address this, and the geophysical facility would be a great place to start. We should advocate for this through community initiatives such as SZ4D.
          The NSF program managers are aware of this.
            - John Orcutt - NSF OCE does provide funds to the current data center (IRIS/seismic for OBSIC data)

    - Potential community experiments or large initiatives
        - SZ4D
        - Has Marra et al., Science 361, 486–490 (2018) 3 August 2018 been discussed? Obtaining Global scale observations economically
        - https://cloud.google.com/blog/products/infrastructure/using-subsea-cables-to-detect-earthquakes