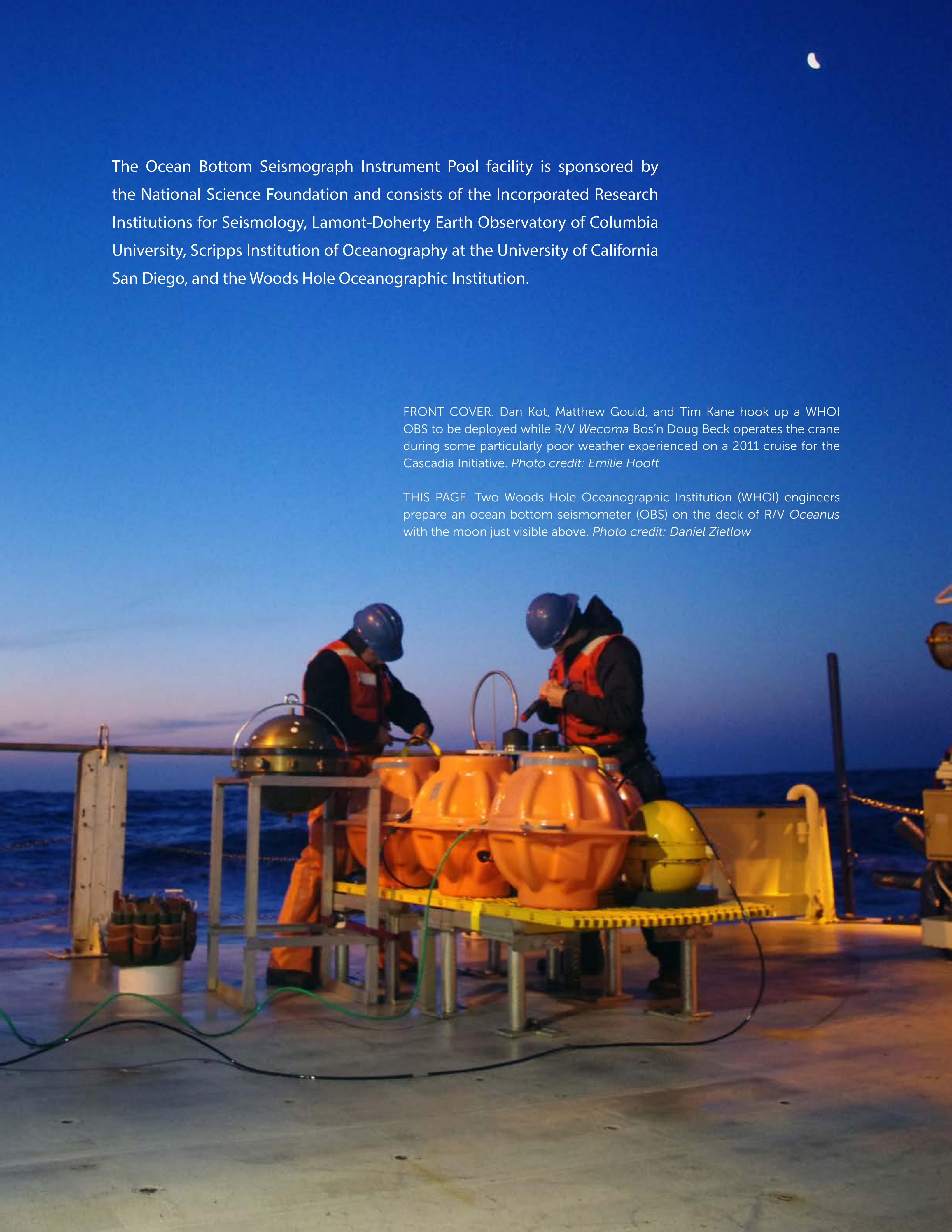
Ocean Bottom Seismograph Instrument Pool
FINAL REPORT

Prepared for the National Science Foundation

Prepared by the IRIS OBSIP Management Office

IRIS
Lamont-Doherty Earth Observatory
Columbia University | Earth Institute
Scripps Institution of Oceanography UCSD
Woods Hole Oceanographic Institution 1930

The Ocean Bottom Seismograph Instrument Pool facility is sponsored by the National Science Foundation and consists of the Incorporated Research Institutions for Seismology, Lamont-Doherty Earth Observatory of Columbia University, Scripps Institution of Oceanography at the University of California San Diego, and the Woods Hole Oceanographic Institution.



FRONT COVER. Dan Kot, Matthew Gould, and Tim Kane hook up a WHOI OBS to be deployed while R/V *Wecoma* Bos'n Doug Beck operates the crane during some particularly poor weather experienced on a 2011 cruise for the Cascadia Initiative. *Photo credit: Emilie Hooft*

THIS PAGE. Two Woods Hole Oceanographic Institution (WHOI) engineers prepare an ocean bottom seismometer (OBS) on the deck of R/V *Oceanus* with the moon just visible above. *Photo credit: Daniel Zietlow*

Ocean Bottom Seismograph Instrument Pool

FINAL REPORT

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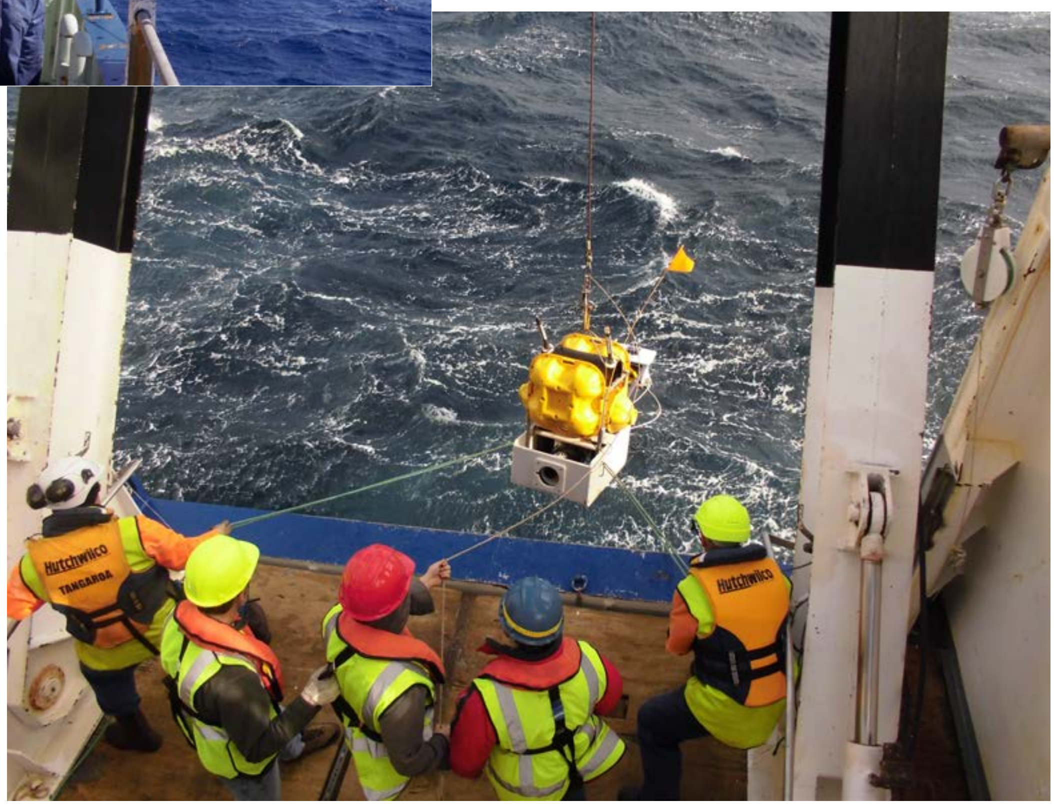
IRIS Lamont-Doherty Earth Observatory COLUMBIA UNIVERSITY | EARTH INSTITUTE SCRIPPS INSTITUTION OF OCEANOGRAPHY UCSD WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

One of the WHOI ARRA OBSs is pulled aboard R/V *Oceanus* during a Cascadia Initiative cruise. *Photo credit: Daniel Zietlow*



Scientists deploy an Lamont-Doherty Earth Observatory (LDEO) OBS offshore Gisborne, New Zealand, from R/V *Tangaroa* as part of the HOBITSS experiment. *Photo credit: Takeo Yagi*

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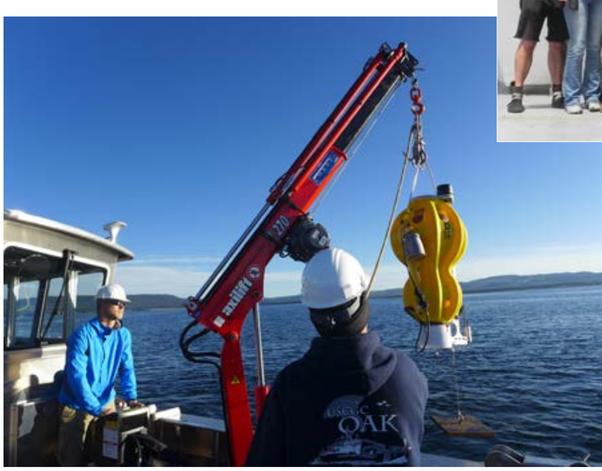
The majority of the ship's party for the CREST experiment on board R/V *Langseth*. *Photo credit: Tom Spoto*



A WHOI short-period OBS modified for use in fresh water is lowered into Yellowstone Lake aboard R/V *Annie*. *Photo credit: Robert Sohn, Woods Hole Oceanographic Institution*

1. Introduction

Established in 1999 as a National Science Foundation (NSF) instrument facility, the Ocean Bottom Seismograph Instrument Pool (OBSIP) provides ocean bottom seismometers to support research and further our understanding of marine geology, seismology, and geodynamics. The instruments in the pool were built, maintained, and deployed by three institutional instrument contributors (IICs): Lamont-Doherty Earth Observatory (LDEO), Scripps Institution of Oceanography (SIO), and Woods Hole Oceanographic Institution (WHOI). To address myriad research questions, the OBSIP facility has supported a wide range of scientific investigations in environments ranging from fresh to salt water and shallow to deep water, as well as brief to extended deployments and high frequency to long-period data collection. NSF support of the OBSIP structure provides access to ocean bottom seismic instrumentation for any interested and capable principal investigator (PI), thus democratizing the field of ocean bottom seismology.

In 2011, the Incorporated Research Institutions for Seismology (IRIS) was selected to manage the OBSIP facility after a competitive selection conducted by NSF. IRIS assumed management responsibilities for OBSIP in 2012, via a cooperative agreement with NSF. IRIS brought full-time, professional project management to OBSIP to more fully implement OBSIP as a community-governed, transparent, efficient facility serving the Earth sciences community.

The IRIS-managed OBSIP facility aimed to fulfill the goals of enabling frontier research, developing more effective instrumentation, and increasing data quality. The facility also aimed to achieve key broader impacts with the overall goal of making opportunities available to a wider community, including through international collaboration. Fulfilling these goals took a variety of forms through the IRIS OBSIP Management Office (OMO), other IRIS programs, PI-driven experiments, large-scale community experiments, and community science initiatives such as Cascadia and GeoPRISMs. Community and PI experiments were targeted at grand challenges in the geosciences and frontier research, with a focus on student and early career participation in cruises, workshops, and symposia. Instrumentation developments targeted improved data quality, safer deployment, more accurate timing, and extended recording duration. Efforts were made to upload data in a timely manner, with fewer errors and in accessible formats that could utilize the request and analysis tools at the IRIS Data Management Center (DMC). Communication to and from the community was strengthened to address questions, to distribute information about available data sets and opportunities, and for governance.

IRIS operated the OBSIP facility from early-2012 through 2019. In the rest of this document, references to OBSIP are generally referring to this period of the IRIS-managed OBSIP. In late 2017, NSF released a solicitation for an Ocean Bottom Seismograph Instrument Center (OBSIC) as a successor to OBSIP. IRIS did not compete for the OBSIC facility, which was ultimately awarded to WHOI. OBSIC commenced operations in 2018. The NSF-IRIS OBSIP Cooperative Agreement concludes on September 30, 2019.

Figure 1. A Scripps Institution of Oceanography (SIO) Abalone OBS is moved into position for deployment aboard R/V *Oceanus* by SIO OBS crew Phil Thai and Martin Rapa, Marine Tech Erik Arnesen, and Bos'n Doug Beck. *Photo credit: Cruise OC1208B*

2. Facility Information

The OBSIP facility was composed of the following organizations (Figure 2):

- National Science Foundation Division of Ocean Sciences (NSF OCE)
- Institutional Instrument Contributors (IICs)
    - Lamont-Doherty Earth Observatory
    - Scripps Institution of Oceanography
    - Woods Hole Oceanographic Institution
- OBSIP Management Office (OMO)
    - Incorporated Research Institutions for Seismology (IRIS)
- OBSIP Oversight Committee
    - Committee chair and six additional volunteer members from marine seismology and the broader research community

Additional OBSIP stakeholders included the NSF Division of Earth Sciences (NSF EAR) and the University-National Oceanographic Laboratory System (UNOLS).

Principal investigators could request the use of instruments as part of the NSF standard proposal process. Other private and public organizations, as well as industry, had access to use of the instruments upon request and depending upon availability. The coordinated efforts of OBSIP were focused on providing instrumentation and science support to all interested scientists conducting geophysical experiments.

OBSIP work can largely be categorized into five main areas of effort: Management and Governance, Quality, Base Operations, Experiment-Specific Support, Engineering, and Community. OBSIP was structured for efficient operations by taking advantage of the key capabilities and contributions of each of the participants. IRIS provided overall management via the OMO, while operational activities were executed via subawards to the three IIC institutions (see Tables 1 and 2).

Figure 2. This chart, from the OBSIP communications plan, summarizes the relationships and communications between the elements of the OBSIP facility.

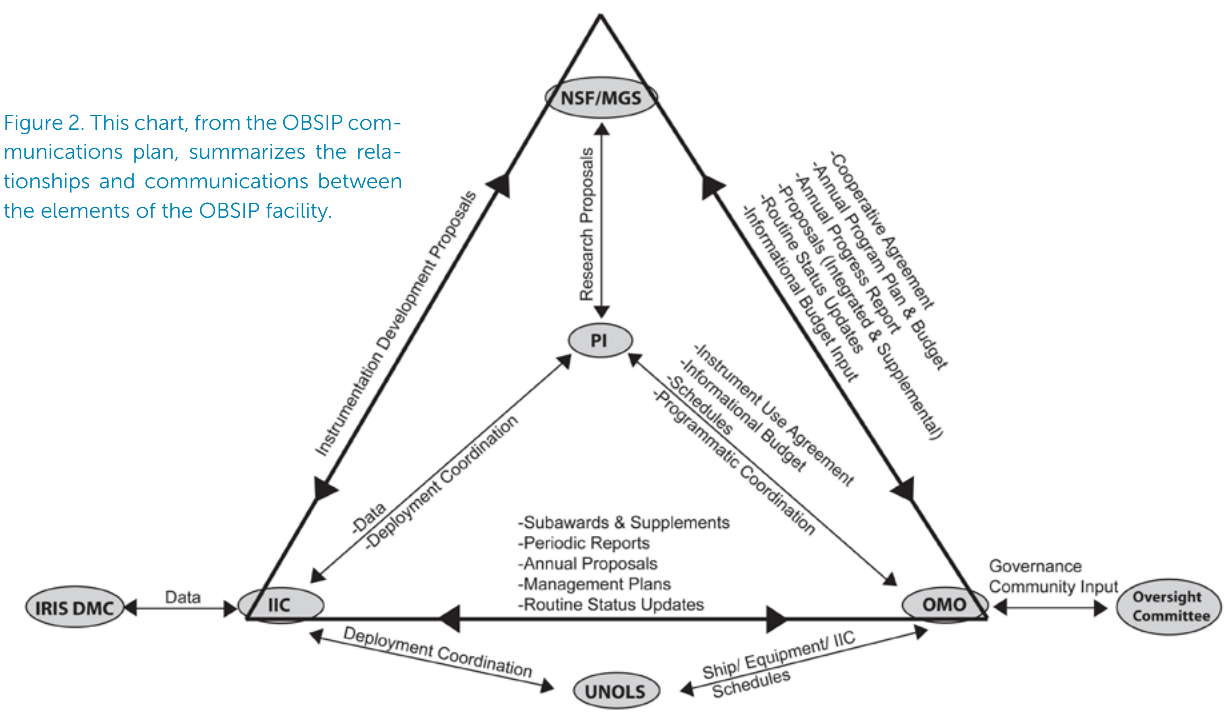


Table 1. Key OBSIP Locations

Facility	Activity	Location
OBSIP Management Office	Overall project management, data quality assurance and quality control, and outreach activities	IRIS Headquarters, Washington, DC
Data Management Center	Archiving and distribution of all OBSIP seismic data	IRIS Data Management Center, Seattle, WA
Lamont-Doherty Earth Observatory	Instrument provider/operator	Columbia University, Palisades, NY
Scripps Institution of Oceanography	Instrument provider/operator	University of California, San Diego, La Jolla, CA
Woods Hole Oceanographic Institution	Instrument provider/operator	Department of Geology and Geophysics, Woods Hole, MA
NSF	Funding agency	NSF Headquarters, Alexandria, VA

Table 2. OBSIP Award PIs and Co-Investigators

Name	Affiliation	Role
David Simpson	IRIS	IRIS OBSIP award PI (2012–2014)
Bob Detrick	IRIS	IRIS OBSIP award PI (2014–)
Bob Woodward	IRIS	IRIS OBSIP award Co-Investigator
Brent Evers	IRIS	IRIS OBSIP award Manager
Andrew Barclay	LDEO, Columbia University	Subaward Co-Investigator
James Gaherty	LDEO, Columbia University	Subaward PI
Maya Tolstoy	LDEO, Columbia University	Subaward Co-Investigator
Jeff Babcock	SIO, UCSD	Subaward PI
John Orcutt	SIO, UCSD	Subaward Co-Investigator
John Collins	WHOI	Subaward PI

2.1. MANAGEMENT OFFICE

The OBSIP Management Office was operated by the Incorporated Research Institutions for Seismology.

Founded in 1984 with support from the National Science Foundation, IRIS is a consortium of over 100 US universities dedicated to the operation of science facilities for the acquisition, management, and distribution of seismological data. IRIS programs contribute to scholarly research, education, earthquake hazard mitigation, and verification of the Comprehensive Nuclear-Test-Ban Treaty. IRIS is a 501 (c) (3) nonprofit organization incorporated in the state of Delaware with its primary headquarters office located in Washington, DC.

The mission of the IRIS Consortium, its members, and affiliates is to:

- Facilitate and conduct geophysical investigations of seismic sources and Earth properties using seismic and other geophysical methods
- Promote exchange of geophysical data and knowledge, through use of standards for network operations, data formats, and exchange protocols, and through pursuing policies of free and unrestricted data access
- Foster cooperation among IRIS members, affiliates, and other organizations in order to advance geophysical research and convey benefits from geophysical progress to all of humanity

IRIS membership comprises virtually all US universities with research programs in seismology, and includes a growing number of Educational Affiliates, US Affiliates, and Foreign Affiliates. A Board of Directors and several standing committees provide IRIS with advice on managing its facilities. Support for IRIS comes from the National Science Foundation (including the EAR Instrumentation and Facilities Program, EarthScope, and Office of Polar Programs), other federal agencies, universities, and private foundations.

OBSIP was integrated into the Instrumentation Services (IS) directorate of IRIS—the umbrella for all IRIS instrumentation activities (Figure 3). The IS directorate supports the use and/or operation of thousands of seismological instruments worldwide.

The OBSIP Project Manager was an integral part of the IRIS team, drawing on a broad range of IRIS resources, including professional business services, outreach resources, web resources, and data management. The OBSIP Project Manager reported to the IRIS Director of Instrumentation Services and, for governance oversight, to an OBSIP Oversight Committee consisting of OBSIP research community members. The OBSIP Oversight Committee provided advice to the IRIS Board of Directors, which has the ultimate authority over all activities of the corporation.

The OBSIP Management Office was responsible for the following activities as part of the OBSIP facility:

- Developing subaward agreements with each of the IICs and assumed responsibility for oversight and funding
- Monitoring the scientific, technical, and fiscal performance of all subawards (including the IICs), ensuring that all NSF requirements were observed
- Utilizing the IRIS governance model to provide a mechanism for timely feedback by the user community to the IRIS Board of Directors and OMO Oversight Committee
- Establishing an OBSIP Management Council and ensured that it was involved in OBSIP management
- Establishing the OBSIP Oversight Committee to assess OBSIP and OMO operations
- Facilitating effective communications among the OBSIP stakeholders
- Coordinating experiment schedules, instrument and IIC staff availability, and ship schedules in cooperation with NSF/UNOLS

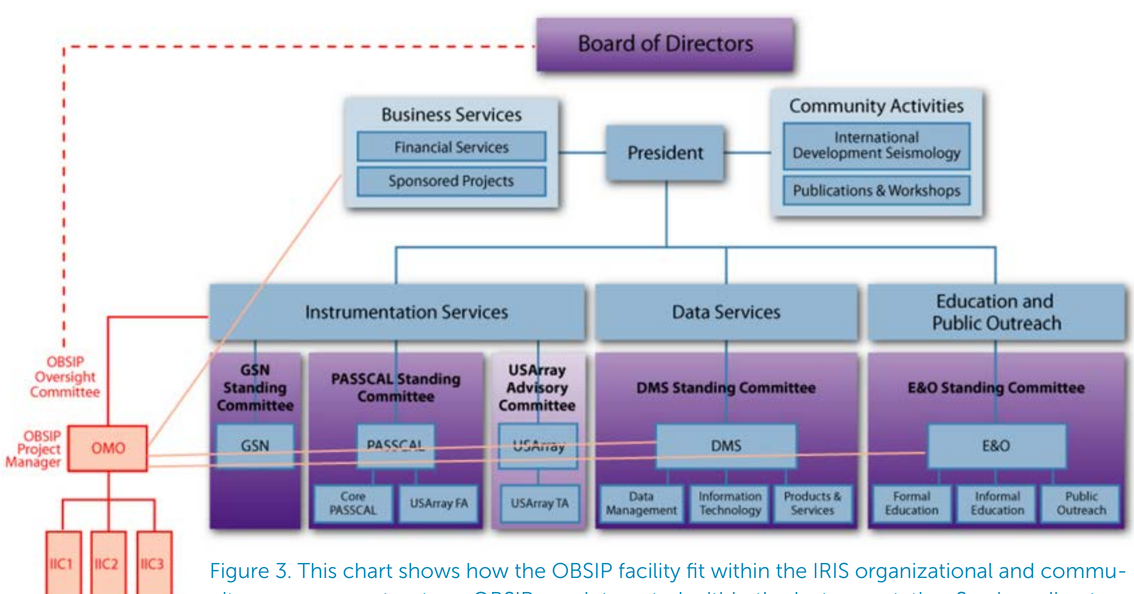


Figure 3. This chart shows how the OBSIP facility fit within the IRIS organizational and community governance structure. OBSIP was integrated within the Instrumentation Services directorate, with interactions between the Data Services and Education and Public Outreach directorates as well as Financial Services facilitated by the OBSIP Management Office.

- Encouraging collaboration and coordination of IIC activities to minimize duplication of efforts
- Working with the IICs to ensure high and consistent data quality by monitoring compliance with NSF OBSIP data policies, establishing and reviewing data quality metrics, and assisting in answering questions related to data usage and access
- Maintaining an OBSIP website to inform the community about OBSIP services and instruments and OBS deployment schedules and availability
- Helping coordinate access to ocean bottom seismometers (OBSs) and other Earth and ocean science data collected with support from other national and international organizations and facilitating effective communications among the OBSIP stakeholders
- Ensuring that OBS data were entered into the IRIS Data Management Center in a timely fashion
- Engaging in appropriate programs to inform the Earth and ocean science community about the potential uses of the OBSIP facility and to keeping the community informed about its accomplishments

IRIS's OBSIP management activities were reviewed by an NSF-convened external review panel in January 2015. The panel found strengths in community engagement, data delivery, quality control, and communication.

In addition to management through the OMO, all data obtained through OBSIP experiments were archived at the IRIS DMC based in Seattle, Washington. The DMC continues to ensure that all OBSIP data are readily available to the seismological research community and the public around the world.

2.2. INSTITUTIONAL INSTRUMENT CONTRIBUTORS

Three Institutional Instrument Contributors—Lamont-Doherty Earth Observatory of Columbia University, Scripps Institution of Oceanography of the University of California San Diego (UCSD), and Woods Hole Oceanographic Institution—each contributed both instruments and technical support to the pool, via subawards from IRIS. The subaward activities were directed by one or more subaward PIs at each IIC institution. These PIs collectively have well over 100 person-years of management experience. The PIs were responsible for all aspects of maintaining their OBS fleets in good working order, overseeing deployment and recovery activities, archiving data, and participating in community activities.

The IIC's "base operations" activities as part of the OBSIP facility included:

- Management – direct all cruise preparations, prepare detailed estimates and budgets for experiments, handle staffing, implement Quality Plan, attend management and governance meetings
- Experiment preparations – test, repair, calibrate, pack, and ship all OBSIP instrumentation and equipment
- Data processing and delivery – process and upload OBSIP data for storage at the IRIS DMC
- Engineering development – modernize and improve the fleet of instruments
- Quality Plan support – implement Quality Plan for continuous improvement of processes and procedures
- OMO and community support – provide support to OMO and the user community by answering questions or investigating potential data problems

Experiment-specific support covered by the IICs included:

- Field operations – organize engineers and technicians for experiment cruises to deploy and recover OBSIP instrumentation and ensure high quality recovery of data
- Coordinate shipping, travel, and materials and supplies purchases
- Data archiving

2.3. MANAGEMENT COUNCIL

The OBSIP Management Council (MC) was comprised of the three IICs and the OMO, and provided a forum for collaboration, discussion, and planning. The MC convened monthly (most often by conference call) to review the status and schedule of all operational activities, technical issues, reports, and budgets. The MC was also the forum to discuss other issues of mutual interest, including management improvements, OBSIP strategy and tactics, responses to the Oversight Committee, Quality Plan initiatives and deliverables, schedules and outreach activities, efficiencies, and opportunities. The MC served as a collaborative body to ensure nimble and coordinated operations of OBSIP.

2.4. SHIPS AND SCHEDULING

The OBSIP Management Office provided professional, dedicated support for maintaining the complex and rapidly evolving OBSIP instrument and ship schedules in consultation with NSF, UNOLS, and the IICs. The OMO would typically meet with UNOLS in June or July of each year to schedule experiments for the following calendar year. Experiments with confirmed funding and ship time would be entered into the schedule. Scheduling priorities are set in the following order:

1. Programs funded by the NSF Division of Ocean Sciences
2. Programs funded by other NSF divisions
3. Programs funded by other US government agencies
4. Other funded programs

Instruments were allocated on a "first funded–first priority" basis. All other conditions being equal, the highest scheduling priority would go to experiments with the earliest funding dates, then to the earliest request dates. The goal of the scheduling was to optimize the use of the instruments and to accommodate as many experiments as possible. It was sometimes necessary to negotiate with the PI the exact type and number of instruments, or to move the scheduled time of an experiment.

The OBSIP Management Office allocated projects among the three IICs based on instrument requirements and availability, and made the final decision on which IIC supported a given experiment. In some cases, especially for work in remote areas, ship scheduling would drive OBS scheduling. Requests were accepted for OBSIP instruments at any time of the year, and instruments were made available to users for rapid response studies as the schedule permitted.

The research vessel *Marcus G. Langseth*, operated by Lamont-Doherty Earth Observatory, played a key role in executing active source OBSIP experiments. R/V *Langseth* is the only US research vessel specifically equipped to perform advanced multichannel seismic studies. OBSIP short-period instruments were often deployed in conjunction with R/V *Langseth* to allow scientists to record refraction responses from its active source airgun array. A significant effort to fulfill the capabilities of R/V *Langseth* is ongoing in the marine seismic community.

2.5. OBSIP OVERSIGHT COMMITTEE

The OBSIP Oversight Committee advised the Board of Directors and the OMO Project Manager to assess the appropriateness of staffing levels and budgets, the adequacy and responsiveness of service and instrumentation to the community, whether instrument developments were adequate to meet future needs, the quality of the data, and whether each IIC continued to meet the IIC definition and criteria.

The OBSIP Oversight Committee was charged by the IRIS Board of Directors to:
- Set guidelines for the use of the OBSIP facility, including the use of equipment and services provided by the Institutional Instrument Contributors
- Set guidelines for archiving data collected in OBSIP experiments
- Provide guidance for scheduling instrument use and advise on issues
- Establish procedures that define PI responsibilities
- Provide guidance on effective communication with the scientific community
- Develop and evaluate strategies for the continued maintenance and procurement of OBSIP instrumentation so as to best serve the needs of the community
- Develop new initiatives to enhance the effectiveness of the OBSIP program
- Advise the Project Manager and the IRIS President on program planning and annual budgets
- Perform an annual review of instrumentation usage, data return, and quality of data
- Prepare an annual report on OBSIP, including assessments of the OMO and each of the IICs

The OBSIP Oversight Committee consisted of seven volunteer members of the marine seismology and broader research communities, with one serving as chair (Table 3). Members served staggered three-year terms. The Oversight Committee met twice a year, once in the spring and once in fall and at least one of these meeting would be in person. The OBSIP Project Manager and IIC representatives attended Oversight Committee meetings but were not members of the committee.

Table 3. Historical OBSIP Oversight Committee Membership

Name	Institution	Role	Since	Until
Gail Christeson	The University of Texas at Austin	Member	2011	2012
Robert Dunn	University of Hawai'i at Mānoa	Member	2011	2012
Doug Toomey	University of Oregon	Member	2011	2012
David Okaya	University of Southern California	Member	2011	2013
Doug Wiens	Washington University in St. Louis	Member	2011	2013
Don Forsyth	Brown University	Chair	2011	2014
Anne Trehu	Oregon State University	Member	2011	2014
Monica Kohler	California Institute of Technology	Member	2013	2015
Harm Van Avendonk	The University of Texas at Austin	Member	2013	2015
William Wilcock	University of Washington	Member	2013	2015
Richard Allen	University of California, Berkeley	Chair	2014	2015
DelWayne Bohnenstiehl	North Carolina State University	Member	2014	2019
Heather DeShon	Southern Methodist University	Member	2014	2019
Anne Sheehan	University of Colorado Boulder	Chair	2015	2019
Jackie Caplan-Auerbach	Western Washington University	Member	2016	2019
Wayne Crawford	Institut de Physique du Globe de Paris	Member	2016	2019
Robert Reece	Texas A&M University	Member	2016	2019
Yang Shen	University of Rhode Island	Member	2016	2019

3. Instruments

The OBS labs at LDEO, SIO, and WHOI designed, built, maintained, and operated the entire fleet of instruments that formed the Ocean Bottom Seismograph Instrument Pool.

The instruments that comprised the pool were configured for either brief duration or extended duration deployments (Table 4). Short-period instruments are primarily designed for use in experiments involving an active source (e.g., airguns) or for recording signals from natural sources at frequencies greater than 1 Hz. Long-period instruments were designed for extended-length deployments that record low frequency (<1 Hz) seismic energy from natural sources (e.g., earthquakes). However, instruments within the instrument pool were not confined to a particular type of experiment and, subject to availability, were used for any field program envisioned.

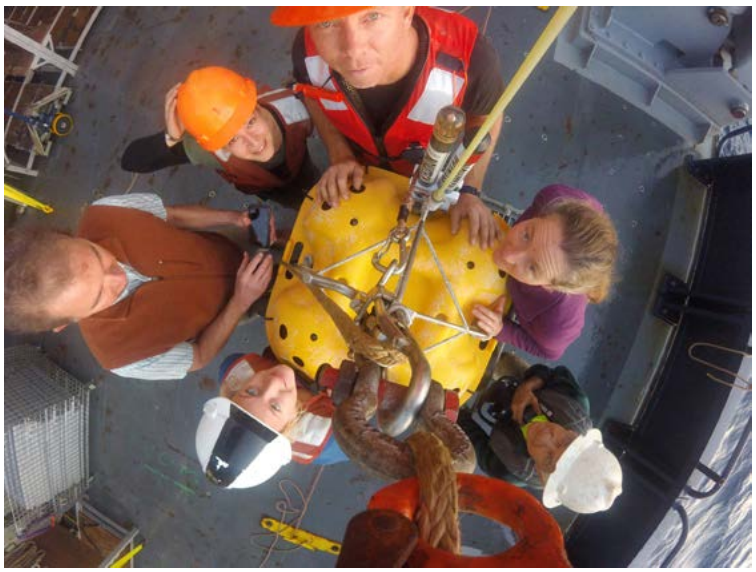


Figure 4. The PI, research team, and OBSIP personnel prepare an instrument for the Santorini deployment. *Photo credit: Emilie Hooft*

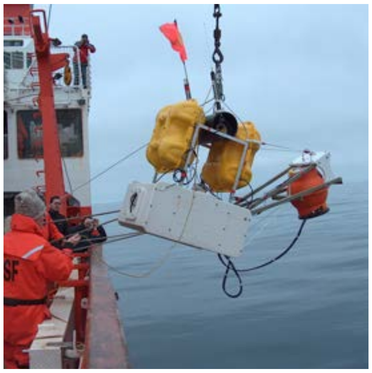
All instruments had a seismic sensor augmented with a differential or absolute pressure gauge, hydrophone, and/or a strong motion sensor. Other common components are a digitizer, precision clock, a large capacity memory device, and batteries in arrangements that enable continuous recording from few days up to 15 months. The most common deployment/recovery configuration is to attach a heavy weight to the OBS that detaches using acoustic and burn wire releases, leaving the anchor on the seafloor. Modifications have been made to be able to deploy OBSs in freshwater and to recover the anchor in sensitive or protected environments.

Table 4. Ocean Bottom Seismometers in the OBSIP Fleet at the Time of this Report, by Type and Operating institution

Institutional Instrument Centers	LDEO	SIO	WHOI
LP OBS	30	39	30
SP OBS		59	30
Cascadia LP OBS	10	15	14 (+ 6)
Cascadia TRM OBS	19		
Total OBSIP Instruments	**59**	**113**	**80**

OBS = ocean bottom seismometer. LP = long-period. SP = short-period.
TRM = trawl resistant mount.

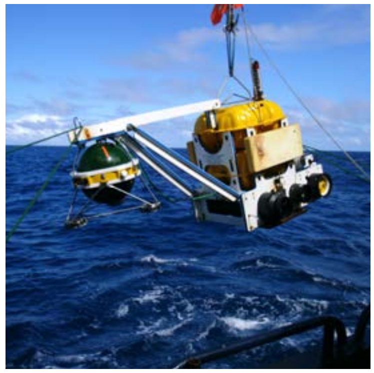
3.1. LONG-PERIOD OBS



ChilePEPPER cruise. *Photo credit: Anne Trehu and Cruise MV1206*

LDEO broadband

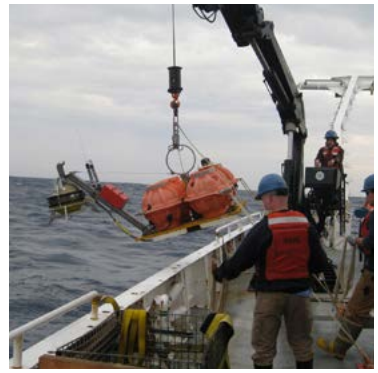
Sensor: Nanometrics Trillium Compact
Datalogger: LDEO custom
Flotation: Glass spheres
Air weight: 750 lbs



On NoMelt cruise. *Photo credit: Martin Rapa*

SIO broadband

Sensor: Nanometrics T-240
Datalogger: SIO custom
Flotation: Glass spheres
Air weight: 1000 lbs

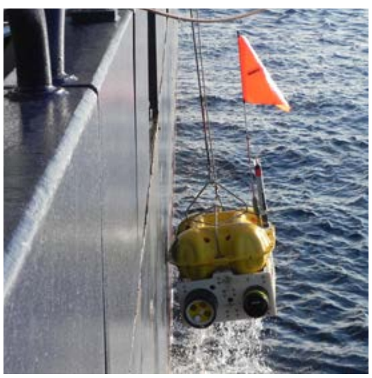


On ENAM cruise. *Photo credit: Jim Gaherty*

WHOI broadband

Sensor: Guralp CMG-3T
Datalogger: Quanterra Q330
Flotation: Glass spheres
Air weight: 530 lbs

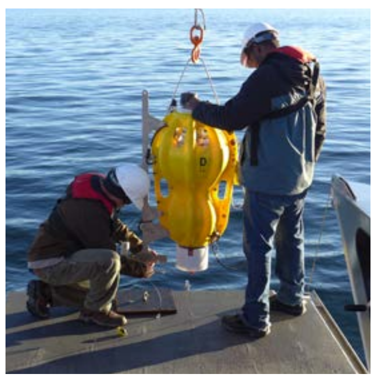
3.2. SHORT-PERIOD OBS



Santorini. *Photo credit: Emilie Hooft*

SIO short-period instrument

Sensor: 4.5 Hz Geophone
Datalogger: SIO custom
Flotation: Glass spheres and optional syntactic foam
Air weight: 400 lbs



Yellowstone Lake. *Photo credit: Robert Sohn, Woods Hole Oceanographic Institution*

WHOI short-period instrument

Sensor: 4.5 Hz Geophone
Datalogger: Quanterra Q330
Flotation: Glass spheres
Air weight: 140 lbs

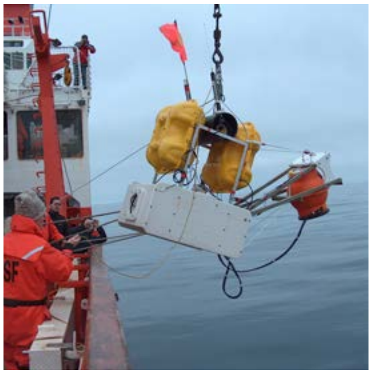
3.3. CASCADIA INSTRUMENTS

The Cascadia Initiative funded the construction of a total of 60 OBS by the three IICs. The group at LDEO built 30 OBSs, and the groups at SIO and WHOI built 15 each.

All 60 OBSs are equipped with Nanometrics Trillium Compact seismometers. In addition to the seismometers, the SIO and WHOI OBSs are equipped with differential pressure gauges (DPGs) while the LDEO OBSs carry absolute pressure gauges (APGs). All 60 instruments are equipped with 12-month (minimum) battery packs.

Twenty of the LDEO OBSs are installed in trawl-resistant enclosures and were available for deployments in water depths extending from the shelf down to 1,000 m (Figure 5). In these units the sensors are protected by a smooth, low profile steel shield so that trawl fishing nets (which are typically used in waters up to about 1 km depth and that are dragged across the seafloor) will slip over the instrument and not catch it or move it. These 20 OBSs have been deployed via the ship's wire and recovered using a remotely operated vehicle (ROV), but are now equipped with pop-up buoys for recovery without ROVs. These instruments are not deployable in water depths greater than 1,000 m.

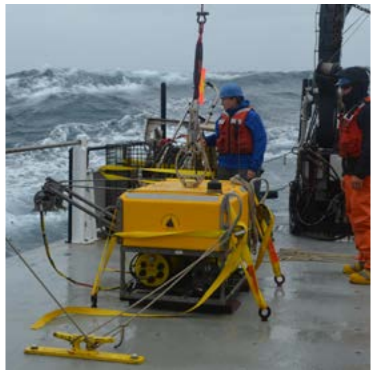
Figure 5. Two watches converge to quickly deconstruct a trawl-resistant OBS. From left to right: Melodie Elmer, Nick Benz, Sam Bell, Rose Wade, and Blake Parris. *Photo credit: Erik Fredrickson*



On ChilePEPPER cruise. *Photo credit: Anne Trehu and Cruise MV1206*

LDEO BB

Sensor: Nanometrics Trillium Compact
Datalogger: LDEO custom
Flotation: Glass spheres
Air weight: 750 lbs



Cascadia 2014 deployment cruise. *Photo credit: Aubreya Adams*

WHOI ARRA

Sensor: Nanometrics Trillium Compact
Datalogger: Quanterra Q330
Flotation: Syntactic foam
Air weight: 1000 lbs

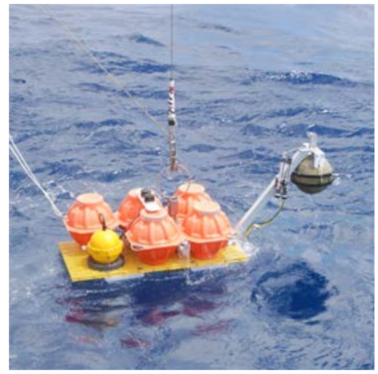


Photo credit: Jeff McGuire

WHOI Keck

Sensor: Guralp CMG-3T
Datalogger: Quanterra Q330
Flotation: Glass spheres
Air weight: 745 lbs

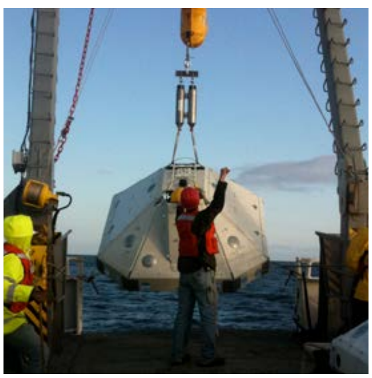
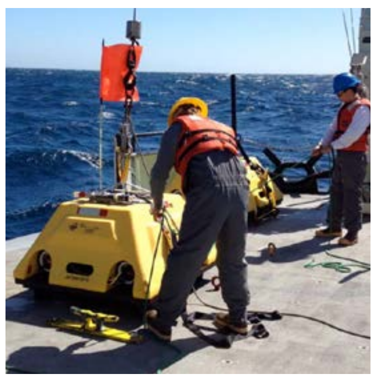


Photo credit: Maya Tolstoy

LDEO TRM

Sensor: Nanometrics Trillium Compact
Datalogger: LDEO custom
Flotation: None, recovered using pop-up buoys or by remotely operated vehicle
Air weight: 1400 lbs



Martin Rapa and Phil Thai on the 2012 Cascadia deployment cruise. *Photo credit: Doug Toomey*

SIO ABALONE

Sensor: Nanometrics Trillium Compact
Datalogger: SIO custom
Flotation: Syntactic foam
Air weight: 850 lbs

3.4. DEVELOPMENT INITIATIVES

The OMO was able to allocate some operations and maintenance savings (achieved through careful management of NSF operational funds) toward improvements in technical capability. Project initiation forms (PIFs) were used to develop and evaluate engineering projects. The PIFs were presented to the OBSIP Oversight Committee, and the development plan for the selected projects was reviewed by NSF. Progress made on these projects and their results was reviewed during site visits and through conference calls with the IICs, and were presented during OBSIP Oversight Committee meetings and technical interchange calls.

Engineering development projects that were initiated to advance OBS fleet capabilities included:

- Line spool elevator – provided the ability to more efficiently and safely retrieve the trawl-resistant OBS units that must be brought up via line, rather than self-buoyant Flotation.
- Trillium Compact conversion – updated the fleet to replace aging and non-standard sensors.
- Syntactic foam upgrades – systematically replaced glass ball flotation in some portions of the fleet to increase reliability and to standardize instrument configuration.
- Long-duration extension – The packaging of the batteries was modified and updated to enable the use of larger battery pack, thus increasing the bottom time of the instruments. This modification was made in response to research community requests for more data days with less ship time. In particular, carefully timed 15-month deployments could now record two quiet summers with a single deployment.
- Clock and controller upgrades – improved timing quality and controller (and thus instrument) reliability.

When significant instruments issues or failures occurred, they were reviewed and investigated by the IICs. A report was written by the relevant IIC and distributed to the PI of the experiment. NSF and the OBSIP Oversight Committee were briefed on these reports during the regular meetings.

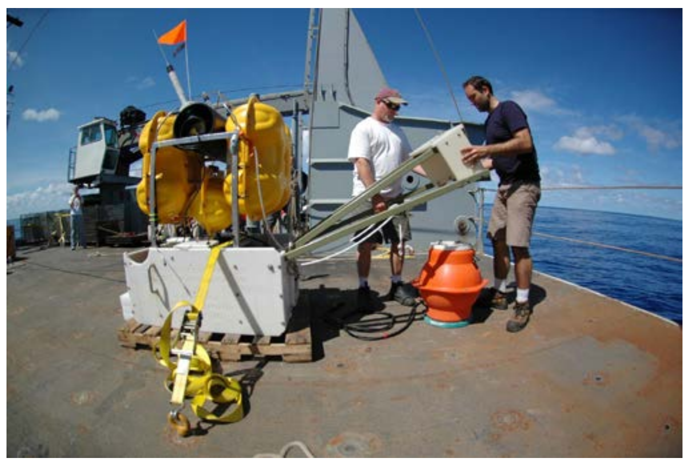


Figure 6. As part of OBSIP's integrated operations, WHOI and LDEO engineers jointly prepare an LDEO broadband OBS for deployment in the Western Pacific Ocean. *Photo credit: Doug Wiens and Cruise RR0915*

3.5. INSTRUMENT REQUESTS

Requests for OBSIP instruments were submitted using an online instrument request form available on the OBSIP website. The contents of a submission using this form was automatically forwarded to the OBSIP Management Office. The OMO would generate a one-page informational budget and send it to the PI. The informational budget would include a summary of instrument mobilization and demobilization costs, instrument drop charges, technical and engineering support costs, and travel and shipping costs. The informational budget was required to be included with the PI's science proposal and uploaded to FastLane in the "supplementary documentation" section. Instrument requests were handled as efficiently as possible in order to comply with proposal deadlines and scientific opportunities.

The instrument request form included all information required for generating an informational budget, including instrument types, numbers, and configurations. Other special circumstances (e.g., simultaneous land deployments, hazardous location) were also included in the request. OBSIP previously suffered instrument losses as a result of deployment in risky locations. PIs planning OBS operations were requested to include any anticipated unusual risks such as severe weather, currents or seas, unusually shallow or deep water depths, intensive bottom trawling activity, ice, foreign waters in areas of political unrest, probable volcanic activity, or debris flows. The OBSIP Management Office and IICs would advise on proposed high-risk instrument locations and worked with the PIs to identify and mitigate these risks.

The OBSIP costs identified in the informational budget were not included in the PI's NSF science proposal budget. The PI's proposal budget would include all costs for non-OBSIP personnel and any other costs not specifically covered in the OBSIP informational budget, such as miscellaneous cruise fees or communications charges. Upon acceptance of the PI's proposal, NSF provided OBSIP the necessary direct funding to provide instrumentation and technical support for the experiment, and the OMO would begin planning for and scheduling the project in conjunction with UNOLS.

Between 11 and 21 instrument requests and informational budgets were handled every year during OBSIP.

3.6. SCIENCE SUPPORT PLANS

Science Support Plans, or SSPs, were developed by the OMO for all experiments, beginning in 2015. This procedure was initiated in response to feedback from the IICs and PIs to better establish and coordinate experiment plans. These documents were circulated in draft form among the OMO, PIs, the IIC, vessel operators, and NSF until a final version was approved by all parties. SSPs included an overview of the experiment; contacts; the schedule, including shipping, travel, and cruises; instrumentation and configurations; known risks; data delivery; vessel information; expected post-cruise evaluations and acknowledgments; and any outstanding issues or areas of concern.

Nine SSPs were completed during OBSIP operations. During the process of developing and reviewing the SSPs, it was agreed among all parties that these documents were able to establish the expectations of an experiment beyond the NSF proposal and budget, helping to limit significant last-minute alterations to the plans and to improve the planning and execution of OBSIP experiments.

3.7. CRUISE EVALUATION FORM

Cruise evaluations were completed within days or months of a cruise by the PI via a form on the OBSIP website. This form requested feedback about the performance of the OBSIP instruments; the performance of personnel, including IIC staff, scientific party, and ship's crew; pre-cruise communication; safety issues; and the success of the overall cruise. When PIs responded, the feedback was compiled in order to track improvement or decline. Any safety concerns were addressed and PI suggestions related to instrumentation and metadata were incorporated where possible in future OBSIP operations. All OBSIP IIC OBS crews aboard the cruises were highly praised across the board as hard-working, personable, and helpful when working with the rest of the science crew, ship crew, and the ROV *Jason* crew.

3.8. SITE VISITS

The OMO would visit the instrument laboratories of each IIC once or twice a year (Figure 7). Visits would take a half or full day and included discussion of status and plans, review of ongoing or completed engineering projects, and meeting new and continuing employees. When possible, site visits were arranged around other meetings and travel opportunities. The majority of the time on site was spent meeting with the lab managers to discuss operations, budgets, completed or future experiments, and project concerns. These in-person meetings were valuable for the OBSIP program, enabling a level of dialogue and review not possible with teleconference and e-mail communication.

Figure 7. Jeff Babcock of SIO shows instrument components during a spring 2015 site visit to Scripps Institution of Oceanography. From left to right: NSF Program Manager Candace Major, SIO Lab Manager Jeff Babcock, OMO Program Manager Brent Evers, WHOI Lab Manager John Collins, NSF Program Manager Jim Holik. Photo credit: *Bob Woodward*

3.8.1. Calibration Rodeo

The availability of Nanometrics Trillium-240 (T-240) seismometers from the EarthScope Transportable Array initiated a project affectionately called the "calibration rodeo" at OBSIP. These spare broadband sensors were earmarked to be installed as high-quality reference sensors at the IIC locations (Figures 8 and 9). One T-240 was sent to each of WHOI and SIO, and two were sent to LDEO because they had two concrete piers to occupy. These seismometers at LDEO and WHOI were installed in collaboration with staff from the Albuquerque Seismological Laboratory's (ASL) Global Seismographic Network (GSN) project team and staff from the IRIS PASSCAL Instrument Center at New Mexico Tech. The seismometer at SIO was installed in collaboration with staff from GSN Project IDA team at SIO.

Figure 8. Left to right: PASSCAL Director Bruce Beaudoin, WHOI Lab Manager John Collins, WHOI Engineer Alan Gardner, ASL Engineer Jared Anderson, and PASSCAL Staff Scientist Cathy Pfeifer during the installation of a reference seismometer at the WHOI OBS lab. *Photo credit: Kasey Aderhold*

Figure 9. LDEO Engineer Carlos Becerril and ASL Engineer Jared Anderson mark new north lines on the LDEO instrument testing pier using an Octans. *Photo credit: Kasey Aderhold*

Prior to deployment, the IRIS PASSCAL staff performed full pier calibrations of the four T-240 sensors before shipping them to the IICs. Once the sensors were installed at the IIC sites, the ASL and IDA GSN teams demonstrated the full in situ calibration protocol used by the GSN, and later the results were compared to the full pier calibration results. An Octans fiber optic gyroscope was also utilized to verify or establish north lines on the piers at the IIC locations.

The calibration rodeo was an opportunity to develop technical interchange on the best practices for calibration techniques and procedures, standardizing this technique across OBSIP, the GSN, and PASSCAL programs in order to avoid potential inconsistencies in the future.

The title to these reference sensors will be transferred to the IICs and the sensors will remain at each IIC beyond the OBSIP award so that they may be used for instrument testing and the regular calibration of other seismometers for future field deployments.

3.8.2. Technical Interchange

Technical interchange calls were organized by IRIS once or twice a year with participation from technical staff across the IRIS Instrumentation Services directorate. Each of these calls would include three to four brief presentations from representatives of IRIS facilities or subawardees on recent seismological engineering or testing projects specific to their group. The OMO and IICs joined these calls and would occasionally present on topics of mutual interest such as testing of clocks.

IRIS organized in-person Technical Interchange Meetings (TIMs) in April of 2015 in Albuquerque, New Mexico, and April 12–13, 2016, in Palm Springs, California (Figure 10). There were about 35 attendees at each TIM, with representatives from the OBSIP OMO, the three IICs (LDEO, SIO, and WHOI), as well as the two elements of the GSN at the Albuquerque Seismological Laboratory and Project IDA, the magnetotelluric facility at Oregon State University, IRIS PASSCAL and Polar programs, and the EarthScope Transportable Array. Presentations were heard from all groups on technical aspects of seismic instrumentation, including power, equipment testing, connectors and cables, and data and data storage media. The meetings concluded with field trips to the ASL (2015) and Piñon Flat Observatory (2016) where participants were given guided tours of the facilities.

Figure 10. Attendees of the Technical Interchange Meeting in 2016 tour a vault at Piñon Flat, California (left), and participate in a demonstration of a lithium ion battery system (right). *Photo credit: Kasey Aderhold*

3.9. QUALITY PLAN

Each aspect of OBSIP facility operations, from engineering to data dissemination, affected OBSIP's success in delivering timely and accurate data, and the quality of each step was therefore central to every aspect of facility operations. OBSIP's approach to delivering a quality end product—data—was therefore to incorporate quality into every aspect of the OBSIP facility, from engineering to operations to data processing, with the ultimate goal of providing timely and accurate OBS data uploaded to the IRIS Data Management Center for use by the scientific community.

A comprehensive Data Quality Plan was developed and evolved over time. The OMO and the IICs reported at each OBSIP Oversight Committee meeting on their six-month accomplishments and objectives with respect to the Quality Plan. While the demands of an often intense operational schedule always drove OBSIP, much good work was accomplished as part of the quality initiative. In particular, a more formalized design review process was started, operational procedures were enhanced and shared, and performance issues were documented.

Figure 11. LDEO's Ted Koczynski and students Nick Benz and Blake Parris pry open the hatch to a TRM OBS on the final Cascadia Initiative cruise. *Photo credit: Erik Fredrickson*

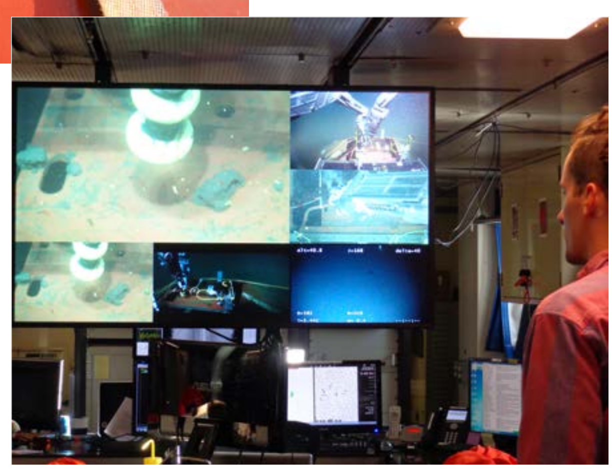


Figure 12. Student Erik Fredrickson watches the ROV *Jason* cameras from the safety and comfort of the R/V *Thompson* computer lab. *Photo credit: Erica Emry*

4. Experiments

Many of the frontier research goals of the seismology community involve crossing coasts and reaching into the oceans. Marine seismic work is challenging, and the reward for such work is ground breaking and impactful science that provides greater understanding of earthquake and faulting behavior and Earth's structure and dynamics, particularly in areas of significant societal impact such as the Cascadia subduction zone.

Since its inception in 1999, the OBSIP facility has supported 59 experiments in every part of the world (Table 5). Scientific targets have ranged from subduction zones, hotspots, mid-ocean ridges, and rift zones (e.g., Figure 13). During 2012-2019, OBSIP supported or was involved in 21 experiments, 55 cruises, and 1200 deployments of individual sensors. OBSIP has deployed both broadband and short-period seismometers, differential and absolute pressure gauges, and hydrophones. Additional instrument modifications have been made to accommodate instruments needed by specific experiments.

Table 5. Experiments Supported by the OBSIP Facility

Year	Experiment	PI	IIC	Start Date	End Date	Network Code
2019	Bransfield Strait	Wilcock	WHOI	1/3/19	2020	ZX 18-017
2018	Alaska Amphibious Community Seismic Experiment (AACSE)	Community	LDEO, WHOI	5/9/18	2019	XD
2018	Hawaiian-Emperor Seamount Chain	Shillington	SIO, WHOI	9/12/18	10/21/18	ZU 18-015
2018	Pacific Array	Gaherty	SIO	4/7/18	2019	XE
2016	Yellowstone Lake	Sohn	WHOI	7/13/16	8/17/18	YL
2016	Pisagua/Iquique Crustal Tomography to Understand the Region of the Earthquake Source (PICTURES)	Trehu	SIO	10/26/16	12/9/16	_PICTURES XW Z7 16-005
2016	Crustal Reflectivity Experiment Southern Transect (CREST)	Reece	WHOI	1/4/16	2/25/16	YB 16-003
2015	Santorini	Hooft	SIO, WHOI	11/17/15	12/12/15	1E 15-008
2015	Study of Extension and maGmatism in Malawi aNd Tanzania (SEGMeNT)	Shillington	SIO	2/21/15	10/10/15	YQ 16-010
2014	Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS)	Wallace	LDEO	5/10/14	5/12/15	YH 8F
2014	Eastern North America Community Seismic Experiment (ENAM)	Community	SIO, WHOI	4/2/14	4/6/15	YO 14-005
2013	Gorda	Nabelek	LDEO, SIO	11/17/13	12/12/15	Z5
2013	Gulf of Mexico Hydrates	Haines, Hart	WHOI	4/18/13	5/2/13	XZ 13-010
2013	MARINER	Canales	SIO	4/16/13	1/9/14	X3 13-007
2012	Juan de Fuca	Carbotte	SIO, WHOI	6/7/12	7/23/12	X6 12-015
2012	East Coast Submarine Landslides	Collins, Uri ten Brink, McGuire	WHOI	7/6/12	12/7/12	ZS
2012	Blanco Transform	Nabelek	SIO, WHOI	9/18/12	10/6/13	X9

Table continues next page...

Table 5. Continued

Year	Experiment	PI	IIC	Start Date	End Date	Network Code
2012	Mariana	Wiens	LDEO, SIO, WHOI	1/26/12	2/10/13	XF 12-008
2012	ChilePEPPER	Trehu	LDEO	5/1/12	3/22/13	Z4
2011	Gulf of Alaska (GoAlaska)	Christeson	WHOI	6/16/11	6/22/11	1B 11-017
2011	Bering Sea	Barth, Wood	WHOI	8/20/11	8/29/11	2B 11-016
2011	Alaska Langseth Experiment to Understand the megaThrust (ALEUT)	Shillington	SIO	7/2/11	7/12/11	ZF XM 11-024
2011	Gulf of Mexico Hydrates	Gerstoft	WHOI	4/3/11	4/8/11	XJ 11-018
2011	NoMelt	Gaherty	SIO, WHOI	11/30/11	1/7/13	ZA 12-001
2011	Cascadia	Community	LDEO, SIO, WHOI	7/25/11	10/10/15	7D _CASCADIA
2011	Salton Sea (SSIP)	Driscoll	SIO	3/1/11	3/31/11	11-025
2010	CD-Papua	Gaherty	SIO	3/1/10	1/31/11	ZN
2010	Cascadia Keck	Community	WHOI	7/13/10	6/28/11	7A
2010	Lōʻihi Volcano	Caplan-Auerbach	WHOI	9/15/10	8/2/11	9A
2010	Shatsky Rise	Korenaga	WHOI	7/26/10	9/2/10	ZL 10-022
2010	ALBACORE	Kohler	SIO	8/15/10	9/16/11	2D
2009	Lau Basin	Wiens	LDEO, SIO, WHOI	1/22/09	12/3/10	YL 09-012
2009	Endeavor (ETOMO)	Toomey	SIO, WHOI	8/22/09	9/16/09	YN 09-014
2009	Pacific Lithosphere Anisotropy and Thickness Experiment (PLATE)	Forsyth	LDEO, SIO	10/19/09	11/1/10	Z6
2009	Marine Observations of Anisotropy (MOANA)	Sheehan	SIO	1/31/09	2/14/10	ZU
2008	Costa Rica (TICO-CAVA)	Holbrook	SIO, WHOI	2/16/08	4/18/08	XB 08-012 08-003
2007	Central Oregon Locked Zone Array (COLZA)	Trehu	SIO	9/9/07	9/11/09	07-030
2007	GEOPRICO	Uri ten Brink	WHOI	3/9/07	9/6/07	YI
2007	Seismicity of Quebrada-Discovery-Gofar Transforms (QDG)	McGuire	SIO, WHOI	12/23/07	1/26/09	ZD 08-014
2007	TAIGER	McIntosh	LDEO, SIO	11/13/07	6/30/09	YM 08-022 08-002
2006	Augustine Volcano	Uri ten Brink	WHOI	2/8/06	3/27/06	ZV
2005	TOMODEC	Wilcock	LDEO	1/7/05	1/13/05	XU
2005	GEOPRICO	Uri ten Brink	WHOI	3/28/05	11/15/05	YF
2005	Plume Lithosphere Undersea Melt Experiment (PLUME)	Laske, Orcutt	SIO, WHOI	1/5/05	12/14/07	YS
2005	Sea of Cortez Ocean Bottom Array (SCOOBA)	Gaherty	SIO	10/16/05	10/10/06	ZL
2005	Atlantis Massif	Smith, McGuire	WHOI	6/5/05	3/25/06	ZM
2004	Development and Testing of a Deep-Water, Acoustically-Linked, Moored-Buoy Seafloor Observatory (Nootka)	Collins	WHOI	5/16/04	7/5/05	X1

Table continues next page…

Table 5. Continued

Year	Experiment	PI	IIC	Start Date	End Date	Network Code
2004	Broadband Onshore-offshore Lithospheric Investigation of Venezuela and the Antilles arc Region (BOLIVAR)	Levander, Collins	SIO, WHOI	4/20/04	5/31/04	XT 06-009
2004	Calabria-Apennine-Tyrrhenian/ Subduction Collision Accretion Network (CATSCAN)	Tolstoy	LDEO	10/1/04	8/24/05	YD
2003	Development and Testing of a Deep-Water, Acoustically-Linked, Moored-Buoy Seafloor Observatory (ALST)	Collins	WHOI	11/19/03	1/18/04	ZT
2003	Seismicity, Structure, and Fluid Flow of the TAG Hydrothermal System (STAG)	Sohn	LDEO, WHOI	6/25/03	3/31/04	XI 07-002
2003	Multi-Scale Seismic Imaging of the Mariana Subduction Factory	Wiens	LDEO	6/12/03	5/12/04	YY
2003	East Pacific Rise 9°N (EPR 9N)	Tolstoy	SIO	9/1/03	3/31/07	ZK 04-020
2002	Hydrate Ridge	Pecher	WHOI	8/16/02	8/30/02	ZU 03-003
2002	Premiere Experiment, Sea of Cortez, Addressing the Development of Oblique Rifting (PESCADOR)	Lizarralde	SIO	9/16/02	10/30/02	04-018
2001	Southeast Indian Ridge	Cochran	WHOI	12/11/01	1/18/02	ZM 02-011
2001	Gravity Lineations, Intraplate Melting, Petrologic and Seismic Expedition (GLIMPSE)	Forsyth	LDEO	12/1/01	11/25/02	2A
2001	Far-offset Airgun Imaging of the Mantle (FAIM)	Gaherty	SIO	6/3/01	6/27/01	03-006
2001	Exmouth and Cuvier Margins	Driscoll	SIO	11/2/01	11/28/01	04-003

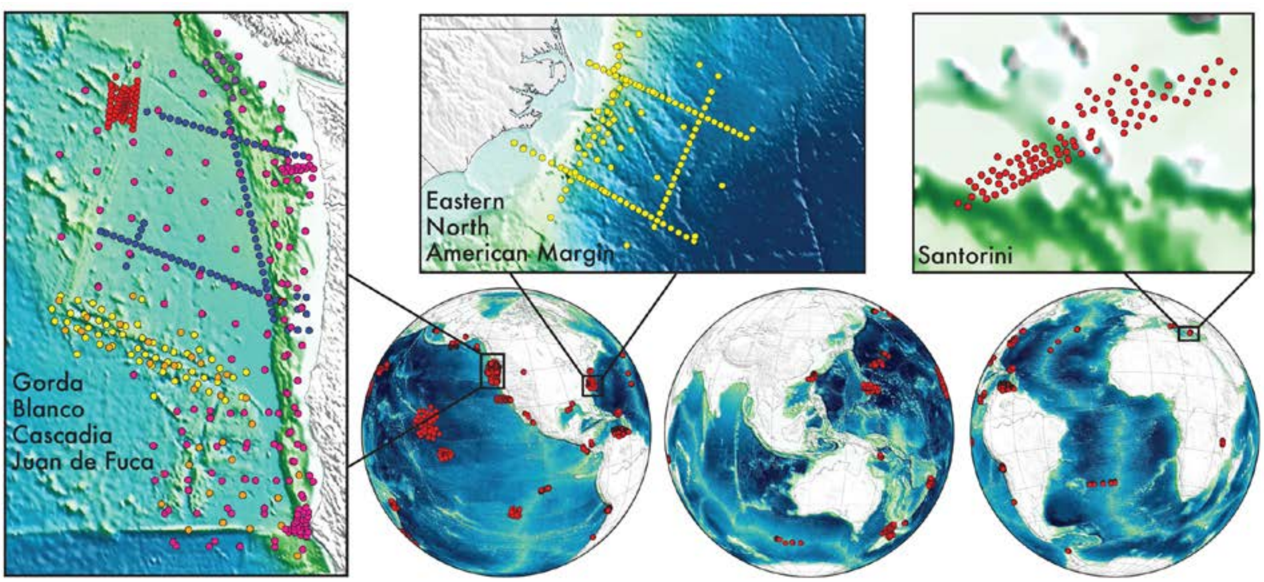


Figure 13. The OBS deployments as part of OBSIP, with map insets for several key experiments and focus regions. Not shown on the maps are early experiments with data only archived in SEG-Y format and the recent experiments that were deployed under OBSIP and will be recovered under OBSIC (Bransfield Strait, Pacific Array, and AACSE).

4.1. CASCADIA INITIATIVE

The Cascadia Initiative was an onshore/offshore seismic and geodetic experiment deployed in the Pacific Northwest to study questions ranging from megathrust earthquakes to volcanic arc structure to the formation, deformation, and hydration of the Juan De Fuca and Gorda Plates (Toomey et al., 2014).

With funds from the 2009 American Recovery and Reinvestment Act (ARRA), NSF's Earth Sciences and Ocean Sciences divisions funded the three IICs to construct an amphibious array of 60 OBSs for OBSIP.

Figure 14. LDEO Engineer Carlos Becerril modifies an instrument's circuits before it is deployed at sea aboard R/V *Oceanus*. *Photo credit: Cascadia Initiative Expedition Team*

Twenty of the LDEO OBSs were installed in trawl-resistant enclosures and were available for deployments in water depths extending from the shelf down to 1,000 m. These 20 OBSs were deployed via the ship's wire and recovered using an ROV. LDEO also built 10 instruments following their standard broadband OBS design, while SIO built 15 following their broadband ABALONE design, and WHOI built 15 following their broadband ARRA design. The existing WHOI Keck OBSs were also utilized.

The OBSs were sent out in four one-year deployments, with minimal turnaround time between the annual recovery and redeployment cruises. This experiment provided an offshore extension of the EarthScope Transportable Array (~70 km spacing) on land, and allowed three denser deployments focused on either imaging various properties of the offshore subduction thrust interface and forearc or recording local seismicity (Figure 15).

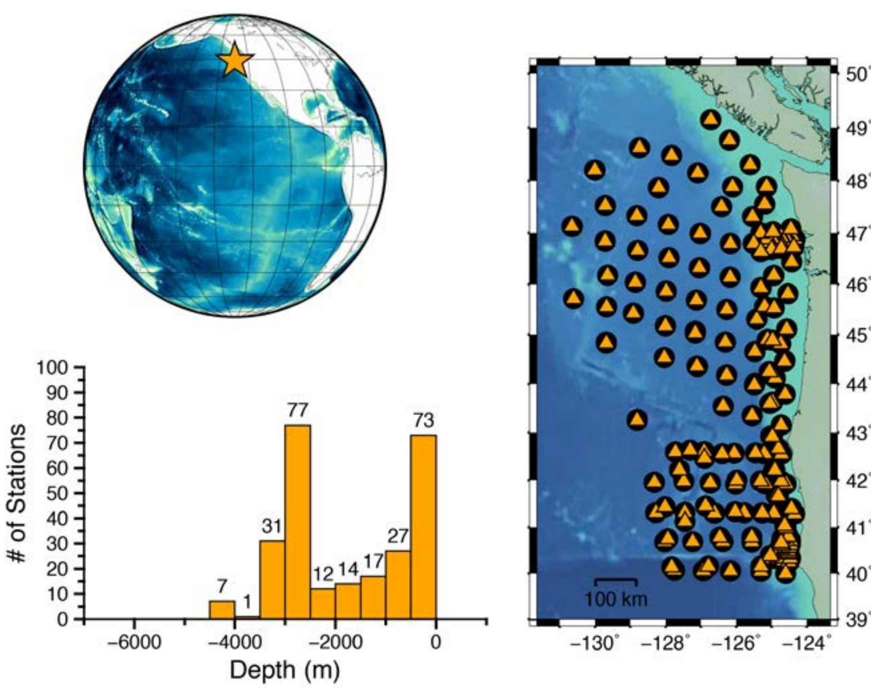


Figure 15. Cascadia Initiative deployments.

The four-year-long Cascadia Initiative was a particularly demanding effort and demonstrated the capacity and innovation of the OBSIP facility. While the facility did see some failures early on in these rapidly developed instruments, instrument performance improved throughout the four years, and instrument recovery was very high. The elevated operational tempo of the Cascadia effort was a testament to the capability and capacity of the IICs. This one experiment alone included 25 cruises and 266 instrument drops (40 of these were with WHOI Keck instruments).

4.1.1. 2011 Cascadia Cruises

- LDEO cruise via R/V *Wecoma* (7/24/2011–8/2/2011) – Original plan was for 20 instruments, but not all instruments were ready to be deployed and one overturned and was recovered. Fourteen LDEO trawl resistant module (TRM) OBSs deployed.
- SIO/LDEO cruise via R/V *Wecoma* (10/15/2011–10/21/2011) – Fifteen SIO broadband OBSs and 10 LDEO broadband OBSs were deployed.
- WHOI cruise via R/V *Wecoma* (11/15/2011–11/30/2011) – Original plan was for 25 instruments, but had bad weather. Thirteen WHOI broadband OBSs and 10 WHOI Keck OBSs were deployed.

4.1.2. 2012 Cascadia Cruises

- WHOI cruise via R/V *Oceanus* (5/12/2012–5/21/2012) – All 13 WHOI broadband OBSs and 10 WHOI Keck OBSs recovered.
- LDEO cruise via R/V *Thompson* (7/10/2012–7/24/2012) – All 14 LDEO TRM OBSs and 10 LDEO broadband OBSs recovered. Six LDEO TRM OBS deployed.
- SIO cruise via R/V *New Horizon* (7/13/2012–7/18/2012) – All 15 SIO broadband OBSs recovered.
- WHOI cruise via R/V *Oceanus* (8/22/2012–8/30/2012) – Fifteen WHOI broadband OBSs and 10 WHOI Keck OBSs deployed. One site had an unresponsive OBS so a second OBS was deployed there.
- SIO cruise via R/V *Oceanus* (8/31/2012–9/6/2012) – Fifteen SIO broadband OBSs deployed.
- LDEO cruise via R/V *Oceanus* (9/10/2012–9/22/2012) – Fourteen LDEO TRM OBSs and 10 LDEO broadband OBSs deployed.

4.1.1. 2013 Cascadia Cruises

- WHOI cruise via R/V *Oceanus* (6/3/2013–6/14/2013) – Thirteen WHOI broadband OBSs and 10 WHOI Keck OBSs were recovered, two WHOI broadband OBS not recovered (one later recovered – G36B remains lost).
- SIO cruise via R/V *Oceanus* (6/17/2013–6/22/2013) – Fifteen SIO broadband OBSs recovered.
- LDEO cruise via R/V *Atlantis* (6/25/2013–7/9/2013) – Twenty LDEO TRM OBSs recovered, 10 LDEO broadband OBSs recovered.
- WHOI cruise via R/V *Oceanus* (8/1/2013–8/10/2013) – Thirteen WHOI broadband OBSs and 10 WHOI Keck OBSs were deployed.
- SIO cruise via R/V *Oceanus* (8/18/2013–8/22/2013) – Fifteen SIO broadband OBSs deployed.
- LDEO cruise via R/V *Oceanus* (8/29/2013–9/6/2013) – Twenty LDEO TRM OBSs and 10 LDEO broadband OBSs deployed.

4.1.4. 2014 Cascadia Cruises

- WHOI cruise via R/V *Oceanus* (5/13/2014–5/21/2014) – Eleven WHOI broadband OBSs and 10 WHOI Keck OBSs were recovered, two WHOI broadband OBSs were not recovered (later recovered on LDEO cruise).
- SIO cruise via R/V *Oceanus* (5/28/2014–6/2/2014) – Fifteen SIO broadband OBSs recovered.
- LDEO cruise via R/V *Thompson* (6/22/2014–7/6/2014) – Nineteen LDEO TRM OBSs recovered, 10 LDEO broadband recovered, two WHOI broadband recovered, one LDEO TRM FN15C not recovered.
- WHOI cruise via R/V *Oceanus* (7/10/2014–7/18/2014) – Fourteen WHOI broadband OBSs and 10 WHOI Keck OBSs deployed.
- SIO cruise via R/V *Oceanus* (7/24/2014–8/5/2014) – Fourteen SIO OBSs deployed. Some overlap with the Gorda deployment, so broadband OBSs were swapped between sites. One fewer Cascadia site for one more Gorda site. Gorda OBSs also recovered and some deployed.
- Gorda cruise via R/V *Oceanus* (8/9/2014–8/14/2014) – Some of the SIO Cascadia instruments deployed. One of the SIO Cascadia took the place of one SIO Gorda.
- LDEO cruise via R/V *Oceanus* (9/7/2014–9/21/2014) – 19 LDEO TRM OBSs and nine LDEO broadband OBSs deployed. Gorda OBSs also recovered and one LDEO deployed in a Gorda site.

4.1.5. 2015 Cascadia Cruises

- WHOI cruise via R/V *Oceanus* (8/26/2015-9/2/2015) – Fourteen WHOI broadband OBSs and 10 WHOI Keck OBSs recovered.
- SIO cruise via R/V *Oceanus* (9/8/2015-9/18/2015) – All SIO OBSs recovered from Cascadia and Gorda, two SIO OBSs did not release but were later recovered by LDEO cruise.
- LDEO cruise via R/V *Thompson* (10/1/2015-10/15/2015) – Nineteen LDEO TRM OBSs and 10 LDEO broadband OBSs recovered. One data logger leaked and was discarded overboard for safety reasons. One of the LDEO OBSs recovered was in the Gorda deployment.

4.1.6. Cascadia Data Return

- # of OBSs retrieved / # of OBSs deployed: 264 / 266
  - 2011 – 62 OBSs deployed / 62 OBSs recovered in 2012
  - 2012 – 70 OBSs deployed / 69 OBSs recovered in 2013
  - 2013 – 68 OBSs deployed / 67 OBSs recovered in 2014
  - 2014 – 66 OBSs deployed / 66 OBSs recovered in 2015

- # of OBSs that returned possibly useful data on any channel for some time / # of OBSs deployed: 236 / 266
  - 2011 – 50 OBSs out of 62
  - 2012 – 63 OBSs out of 69
  - 2013 – 62 OBSs out of 67
  - 2014 – 58 OBSs out of 66

- # of OBSs that returned good data on all channels for near full intended recording duration / # of OBSs deployed: 175 / 266
  - 2011 – 42 OBSs out of 62
  - 2012 – 35 OBSs out of 69
  - 2013 – 52 OBSs out of 67
  - 2014 – 47 OBSs out of 66

4.2. OTHER EXPERIMENTS

The following experiments were deployed and/or recovered during the 2012–2019 period.

4.2.1. Mariana

The Mantle Serpentinization and Water Cycling Through the Mariana Trench and Forearc experiment led by PI Doug Wiens consisted of 15 broadband LDEO OBS, 10 broadband SIO OBSs, 32 short-period SIO OBSs, and 28 short-period WHOI OBSs deployed from R/V *Thompson* in an area located along the Mariana Trench in the Western Pacific Ocean (Figure 16). The experiment aimed to image the distribution of serpentinite in the upper mantle and explore the relationships between serpentinization and seismicity in a subduction zone. R/V *Langseth* was employed to shoot airguns over the short-period OBS array of the active seismic portion of the experiment. The broadband OBSs were recovered a year later in 2013, and data are archived in miniSEED under temporary network code XF.2012-2013 and SEG-Y under assembled data set ID# 12-008 at the IRIS DMC.

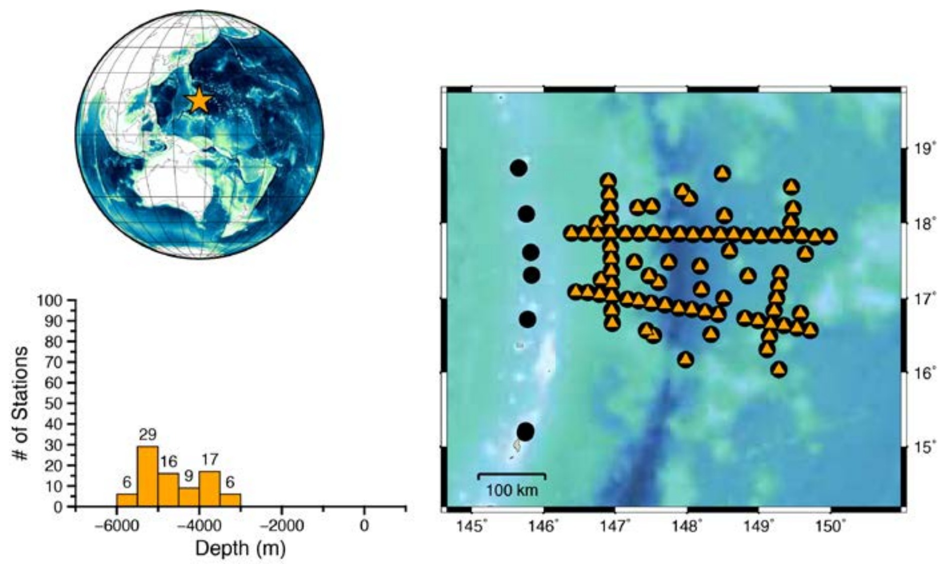


Figure 16. Mariana deployments.

4.2.2. ChilePEPPER

The 2010 Maule, Chile Earthquake: Project Evaluating Prism Post-Earthquake Response (Chile-PEPPER) experiment led by PI Anne Trehu consisted of 10 LDEO broadband OBSs deployed with integrated flow meters from R/V *Melville* in 2012 in the zone of greatest slip during the 27 February 2010 Maule earthquake (Figure 17). The OBSs were recovered a year later in 2013 and data are archived in miniSEED under temporary network code Z4.2012-2013 at the IRIS DMC.

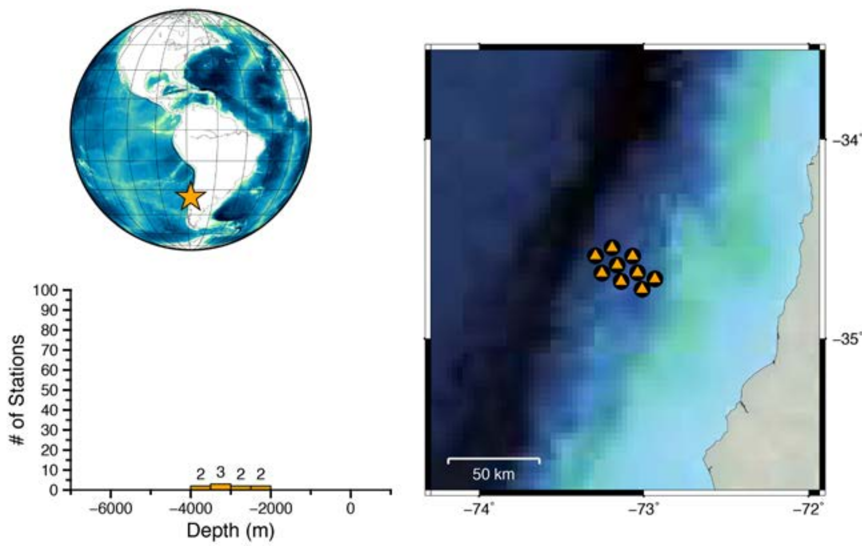


Figure 17. ChilePEPPER experiment deployments.

4.2.3. Juan de Fuca

The 2012 Juan de Fuca experiment led by PI Suzanne Carbotte consisted of 30 SIO short-period and 17 WHOI short-period OBSs deployed in three transects from R/V *Oceanus* and airgun shooting from R/V *Langseth* offshore the Cascadia region (Figure 18). The experiment aimed to characterize crustal and shallow mantle velocities and distinguish the distribution of faulting in this region. This two-ship active source cruise had two ridge-perpendicular transects across the full width of the Juan de Fuca Plate as well as one trench-parallel line. Data are archived in miniSEED under temporary network code X6.2012 and SEG-Y under assembled data set ID# 12-015 at the IRIS DMC.

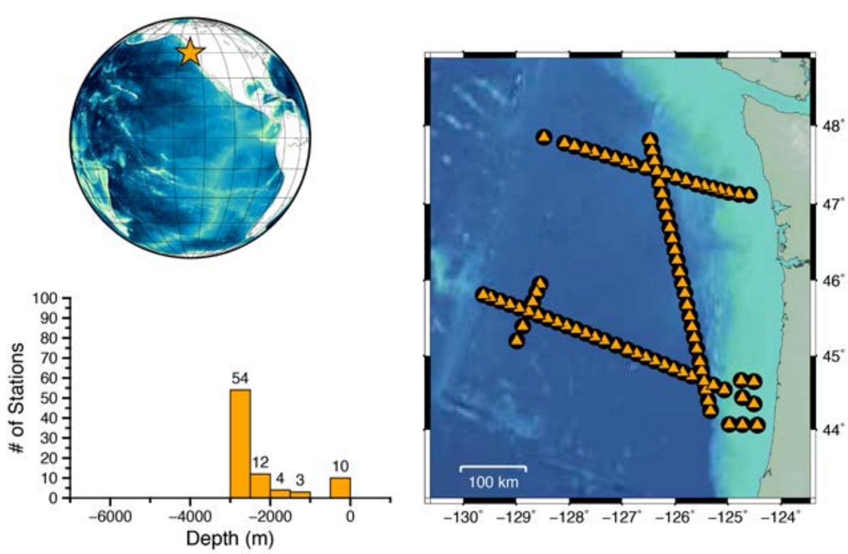


Figure 18. Juan de Fuca experiment deployments.

4.2.4. Blanco Transform

The Blanco Transform experiment led by PIs John Nabelek and Jochen Braunmiller consisted of 25 SIO broadband and 30 WHOI broadband OBSs deployed from R/V *Melville* in 2012 off the Oregon coast (Figure 19). The OBSs were recovered a year later in 2013 and data are archived in miniSEED under temporary network code X9.2012-2013 at the IRIS DMC.

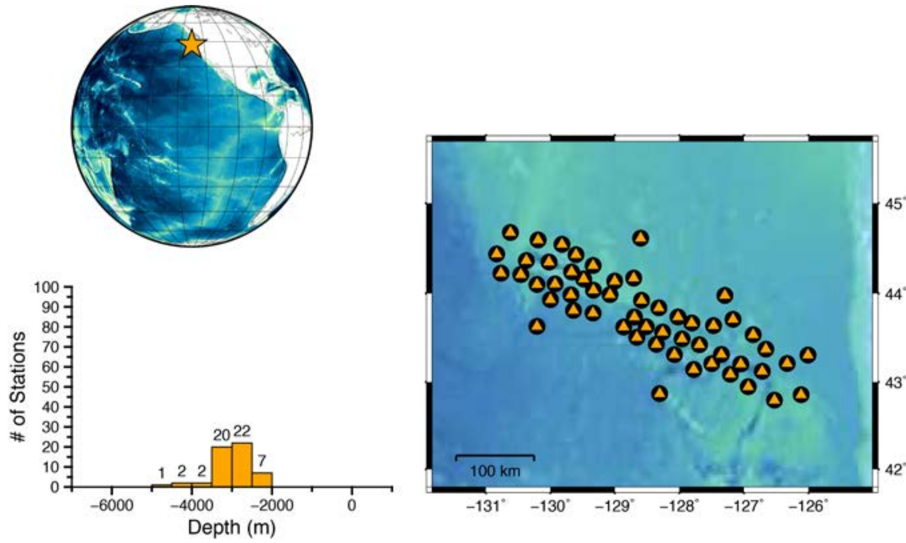


Figure 19. Blanco Transform experiment deployments.

4.2.5. NoMelt

The 2012 NoMelt experiment led by PI James Gaherty consisted of 27 SIO broadband OBSs recovered from R/V *Melville* on 70 million year old seafloor in the central Pacific Ocean (Figure 20). Deployment of these broadband OBSs along with 10 SIO short-period and 24 WHOI short-period OBSs was done in 2011 prior to the OBSIP award. Data are archived in miniSEED under temporary network code ZA.2011-2013 and assembled data set ID# 12-001 at the IRIS DMC.

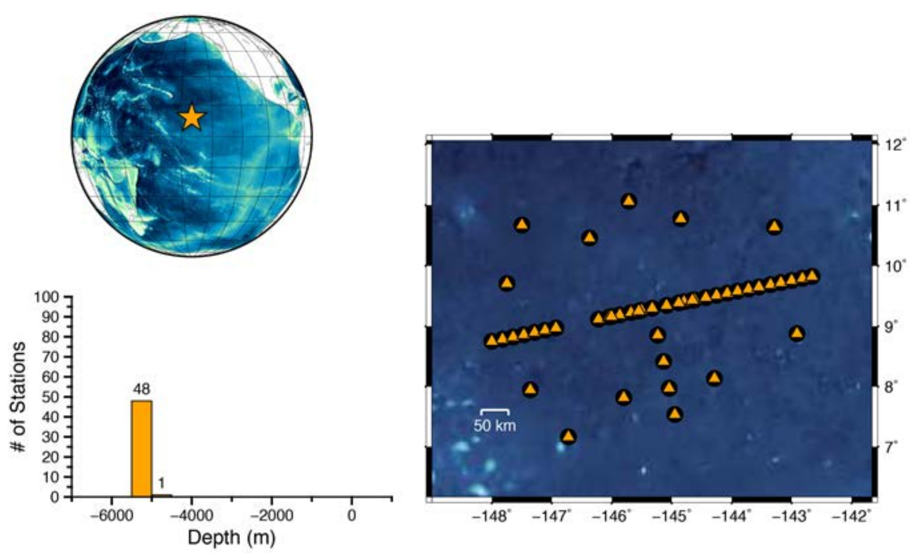


Figure 20. NoMelt experiment deployments.

4.2.6. East Coast Submarine Landslides – US Geological Survey

The East Coast Submarine Landslides experiment led by PIs Uri ten Brink, John Collins, and Jeff McGuire consisted of 16 WHOI short-period OBSs deployed in 2012 along the Atlantic continental margin (Figure 21). The OBSs were recovered five months later and data are archived in miniSEED under temporary network code ZS.2012 at the IRIS DMC. This experiment was done for the US Geological Survey and not under the OBSIP award.

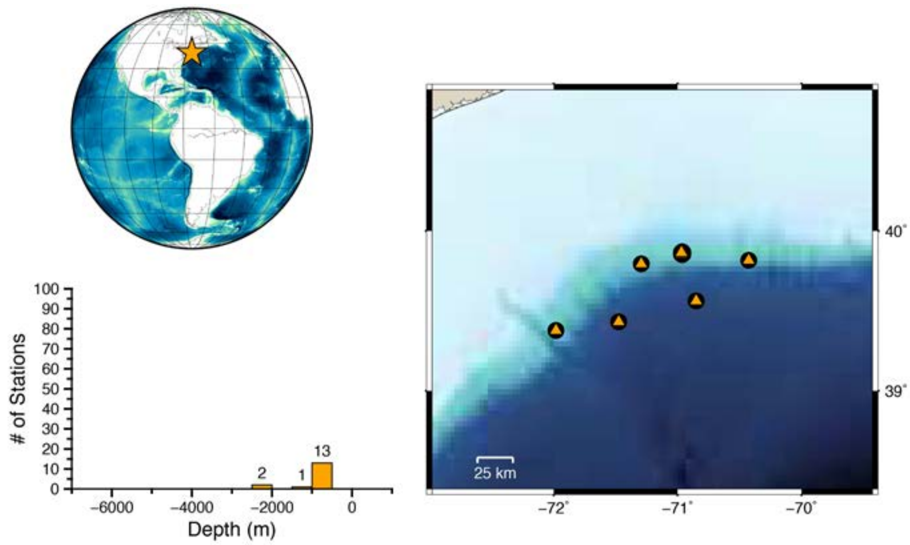


Figure 21. East Coast Submarine Landslides experiment deployments.

4.2.7. MARINER

The Seismic Investigation of the Rainbow Hydrothermal Field and its Tectono/Magmatic Settings, Mid-Atlantic Ridge 36°14'N experiment led by PI Juan Pablo Canales consisted of 46 SIO short-period OBSs deployed from R/V *Langseth* in 2013 in the Rainbow hydrothermal field (Figure 22). Fifteen of the OBSs were redeployed and left for six months then recovered in 2014. Data are archived in miniSEED under temporary network code X3.2013-2014 and SEG-Y under assembled data set ID# 13-007 at the IRIS DMC.

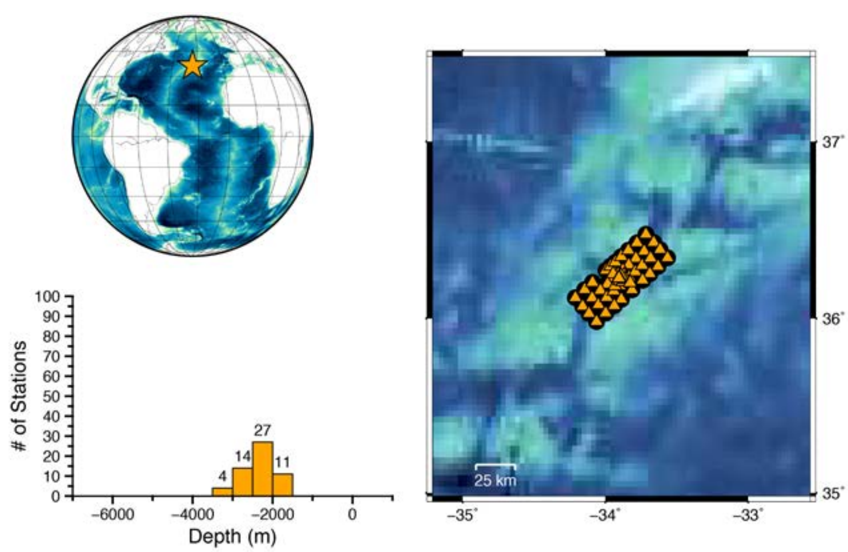


Figure 22. MARINER experiment deployments.

4.2.8. Gulf of Mexico Hydrates – US Geological Survey

The 2013 Gulf of Mexico Hydrates experiment led by PIs Seth Haines and Patrick Hart consisted of 21 WHOI short-period OBSs deployed in the Green Canyon site and 25 WHOI short-period OBSs deployed in the Walker Ridge site from R/V *Pelican* (Figure 23). Two-dimensional seismic data were collected over a combined area of ~850 km at tight spacing of 50–250 m and source offsets of less than 10 km. Data are archived in miniSEED under temporary network code XZ.2013 and SEG-Y under assembled data set ID# 13-010 at the IRIS DMC. This experiment was done for the US Geological Survey and not under the OBSIP award.

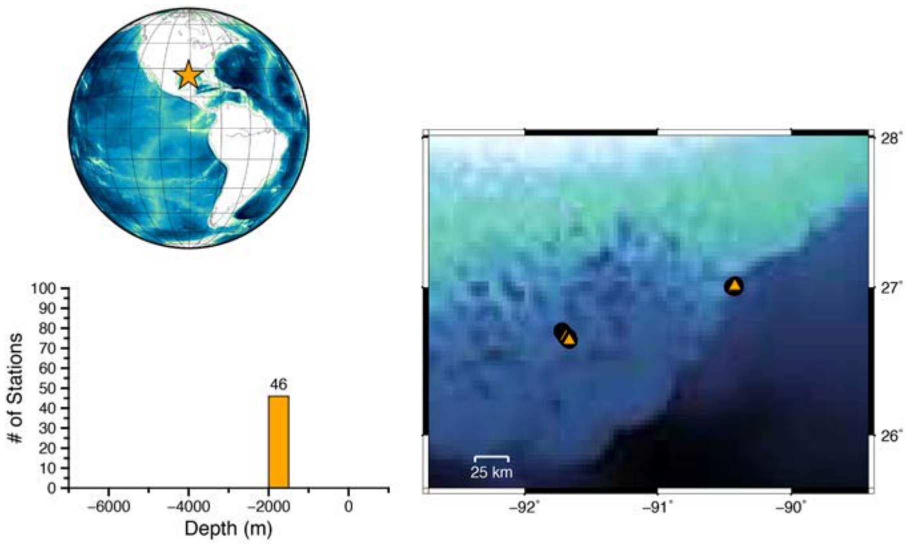


Figure 23. Gulf of Mexico Hydrates experiment deployments.

4.2.9. Gorda

The Seismicity, Structure, and Dynamics of the Gorda Deformation Zone experiment led by PI John Nabelek as a community seismic experiment consisted of two one-year deployments in 2013–2014 and 2014–2015 (Figure 24). In the first year, 15 LDEO broadband OBSs, 15 SIO broadband OBSs, and 25 SIO short-period OBSs were deployed from R/V *Oceanus*. In the second year, one LDEO broadband OBS, 15 SIO broadband OBSs, and 10 SIO short-period OBSs were deployed from R/V *Oceanus*. Data are archived in miniSEED under temporary network code Z5.2013-2015 at the IRIS DMC.

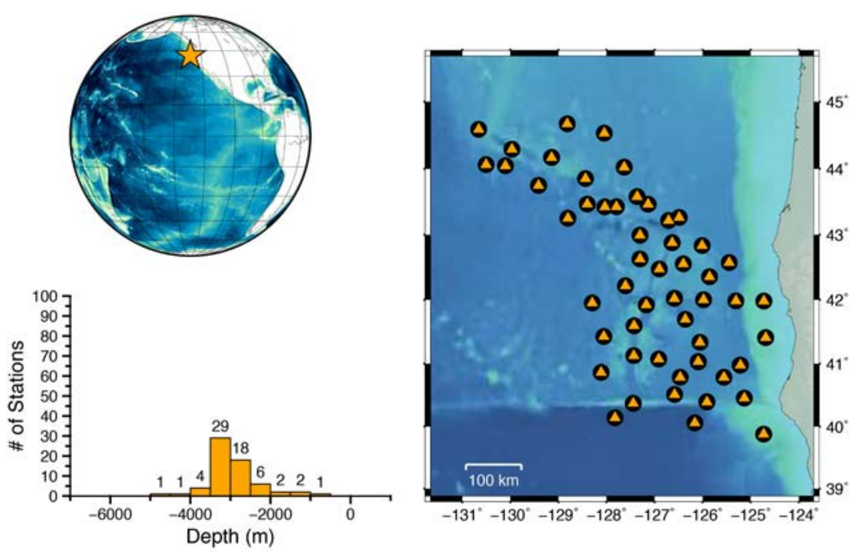


Figure 24. Gorda experiment deployments.

4.2.10. ENAM

The Eastern North American Margin (ENAM) community seismic experiment consisted of 30 WHOI broadband OBSs deployed from R/V *Endeavor* in April 2014 along the east coast of North America (Figure 25). On a later cruise in September 2014, 48 SIO and 47 WHOI short-period OBS deployments were performed as the active source component of the experiment and R/V *Langseth* shot airguns over the array in October 2018. The short-period OBSs were recovered, and the broadband OBSs were recovered a year later in 2015. Data are archived in miniSEED under temporary network code YO.2014-2015 and SEG-Y under assembled data set ID# 14-005 at the IRIS DMC.

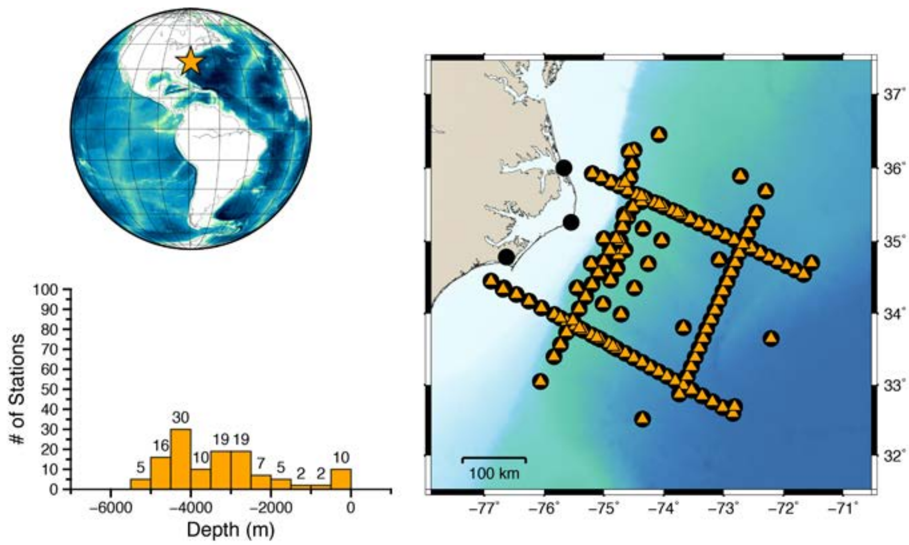


Figure 25. ENAM experiment deployments.

4.2.11. SEGMeNT

The Study of Extension and maGmatism in Malawi aNd Tanzania (SEGMeNT) experiment led by PI Donna Shillington consisted of 27 SIO short-period OBSs and seven SIO broadband OBSs deployed from R/V *Ndunduma* in 2015 in Lake Malawi (Figure 26). The broadband OBSs were recovered seven months later. Data are archived in miniSEED under temporary network code YQ.2015 and SEG-Y under assembled data set ID# 16-010 at the IRIS DMC.

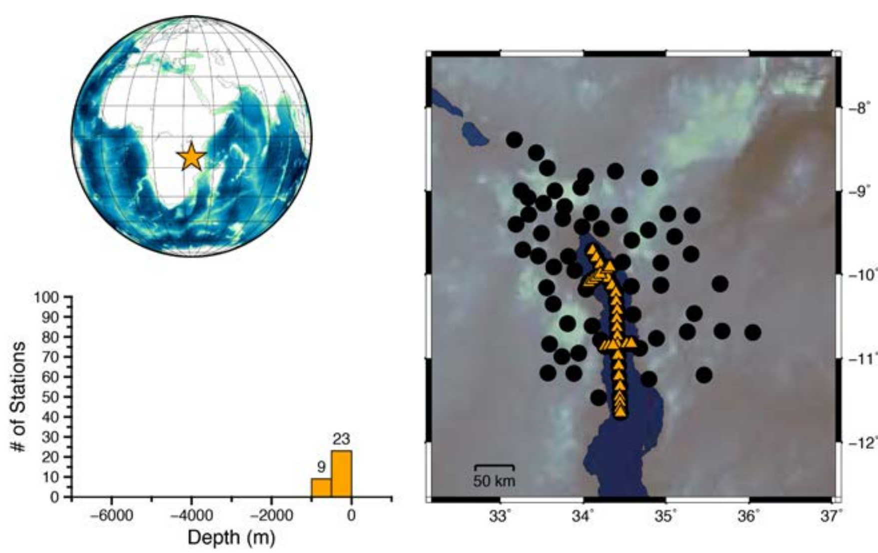


Figure 26. SEGMeNT experiment deployments.

4.2.12. HOBITSS

The Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS) experiment led by PI Laura Wallace consisted of 10 LDEO trawl resistant mount OBSs deployed from R/V *Tangaroa* in 2014 along with additional instruments in the Hikurangi portion of the subduction zone off the North Island of New Zealand (Figure 27). The OBSs were recovered a year later in 2015 and data are archived under miniSEED under temporary network code YH.2014-2015 at the IRIS DMC.

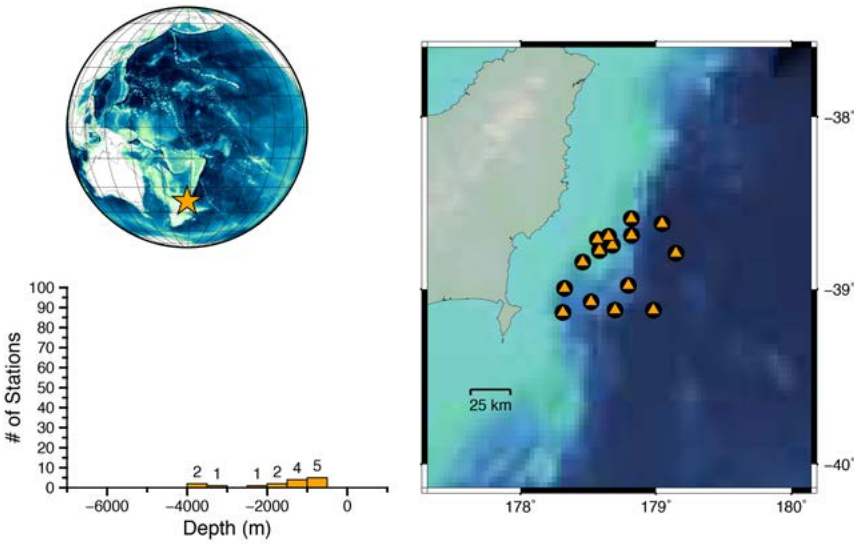


Figure 27. HOBITSS experiment deployments.

4.2.13. PROTEUS

The Plumbing Reservoirs of The Earth Under Santorini (PROTEUS) experiment led by PI Emilie Hooft consisted of 61 SIO short-period and 30 WHOI short-period OBSs deployed from R/V *Langseth* in 2015 in and around the island of Santorini (Figure 28). Airgun shots were performed from R/V *Langseth*. Data are archived in miniSEED under temporary network code 1E.2015 and in SEG-Y under assembled data set ID# 15-008 at the IRIS DMC.

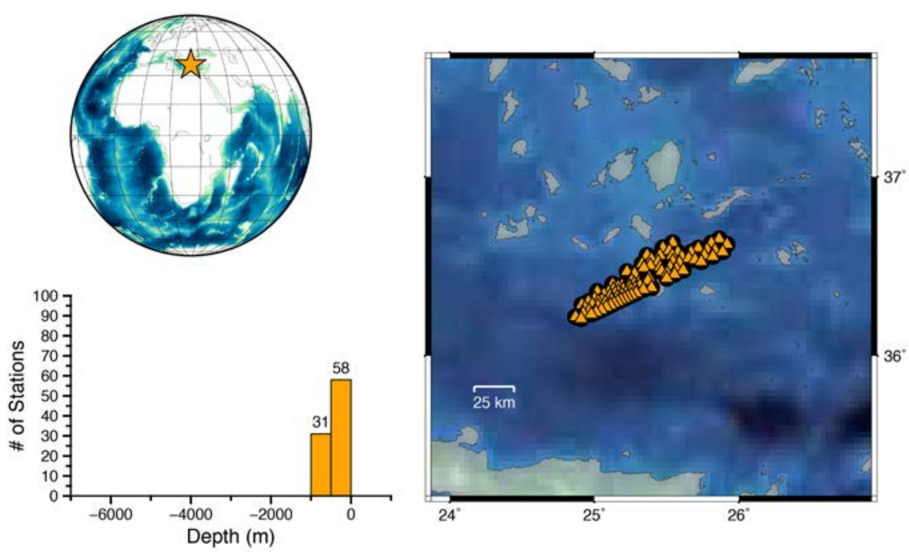


Figure 28. PROTEUS experiment deployments.

4.2.14. CREST

The 2016 Crustal Reflectivity Experiment Southern Transect (CREST) experiment led by PI Robert Reece consisted of 35 WHOI short-period OBS deployments in five sets of seven transects along the southern Mid-Atlantic Ridge from R/V *Langseth* (Figure 29). Data are archived in miniSEED under temporary network code YB.2016 and SEG-Y under assembled data set ID# 16-003 at the IRIS DMC.

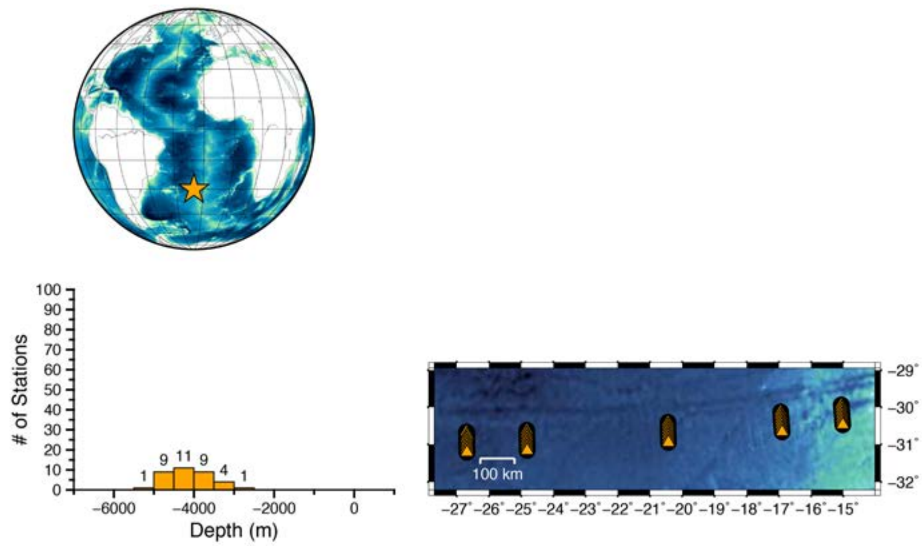


Figure 29. CREST experiment deployments.

4.2.15. PICTURES

The Pisagua/Iquique Crustal Tomography to Understand the Region of the Earthquake Source (PICTURES) experiment led by Anne Trehu consisted of 50 SIO short-period OBSs deployed from R/V *Sonne* in 2016 in the 1 April 2014 Pisagua earthquake source region (Figure 30). Airgun shots were performed from R/V *Langseth*. Data are archived in miniSEED under temporary network code XW.2016 and under assembled data set ID# 16-005 at the IRIS DMC.

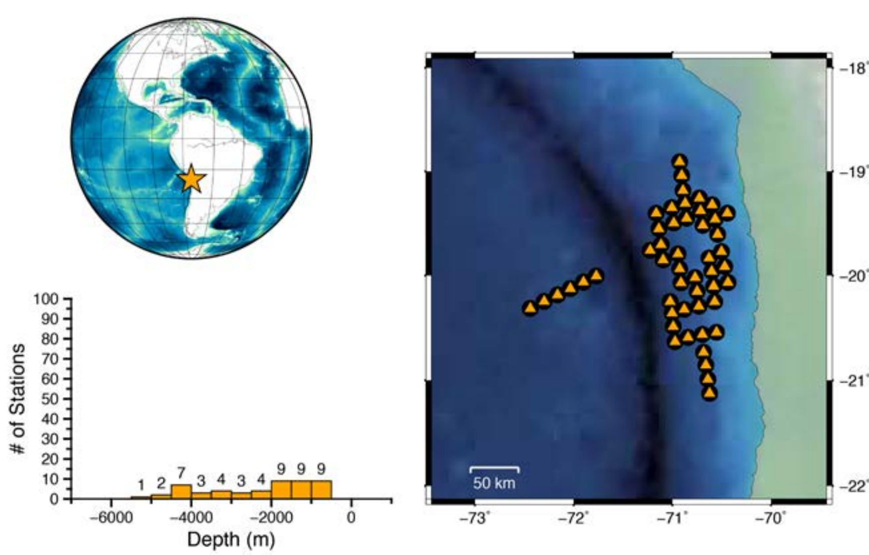


Figure 30. PICTURES experiment deployments.

4.2.16. Yellowstone Lake

The Hydrothermal Dynamics of Yellowstone Lake (HD-YLAKE) experiment led by Robert Sohn consisted of 10 WHOI short-period OBS deployed from the R/V *Annie* in 2017 in Yellowstone Lake (Figure 31). The OBS were recovered a year later in 2018 and data are archived in miniSEED under temporary network code YL.2016-2018 at the IRIS DMC. One test OBS was deployed for three days to test the recovery system that was modified for freshwater use, and two test OBS were deployed for a month in 2016.

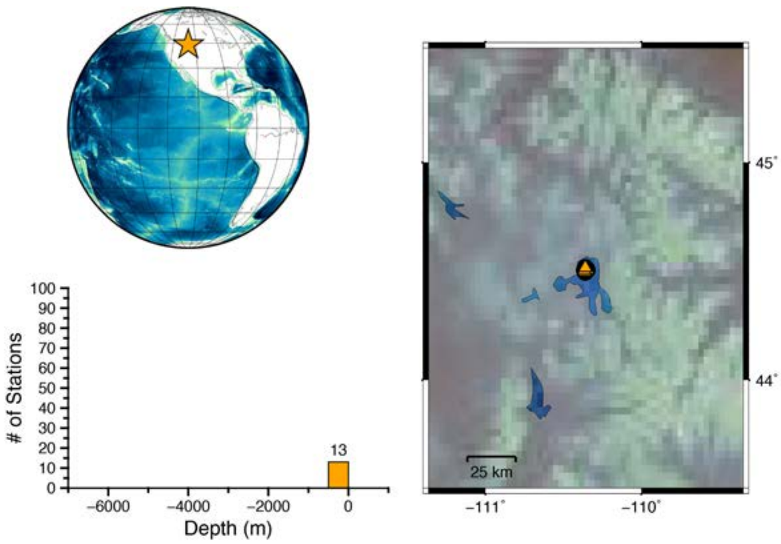


Figure 31. Yellowstone Lake experiment deployments.

4.2.17. Pacific Array

The Pacific OBS Research into Convecting Asthenosphere (Pacific ORCA) experiment led by PI James Gaherty consisted of 30 SIO broadband OBSs deployed from R/V *Kilo Moana* in 2018 over a 500 × 500 km region on 30 million-year-old seafloor east of the Marquesas islands in the central South Pacific (Figure 32). The OBSs will be recovered a year later in 2016 and data will be archived in miniSEED under temporary network code XE.2018-2019 at the IRIS DMC.

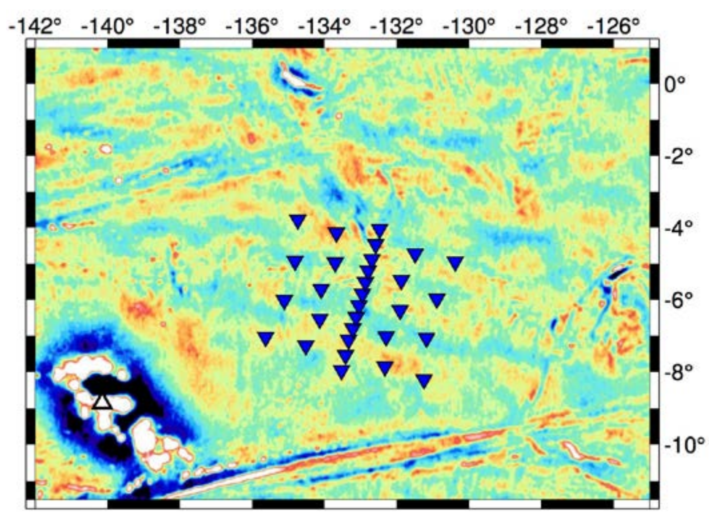


Figure 32. Pacific Array experiment deployments.

4.2.18. AACSE

The Alaska Amphibious Community Seismic Experiment (AACSE) consisted of 25 LDEO broadband, 20 LDEO trawl resistant mount, and 30 WHOI broadband OBSs deployed from R/V *Sikuliaq* in 2018 in the Alaska Peninsula subduction zone (Figure 33). The OBSs will be recovered a year later in 2019 and data will be archived in miniSEED under temporary network code XD.2018-2019 at the IRIS DMC.

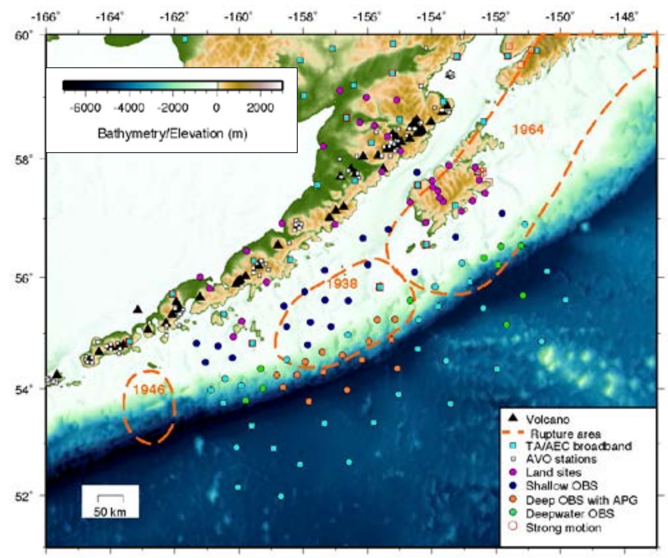


Figure 33. AACSE experiment deployments.

4.2.19. Hawaiian-Emperor Seamount Chain

The Hawaiian-Emperor Seamount Chain experiment led by PI Donna Shillington consisted of 55 SIO short-period and 15 WHOI short-period OBSs deployed from R/V *Langseth* in 2018 along two transects of the Hawaii section of the seamount chain. Airgun shots were performed from R/V *Langseth* (Figure 34) Data will be archived in miniSEED under temporary network code ZU.2018 and under assembled data set ID# 18-015 at the IRIS DMC. A second leg of this experiment is planned for the Emperor section of the seamount chain.

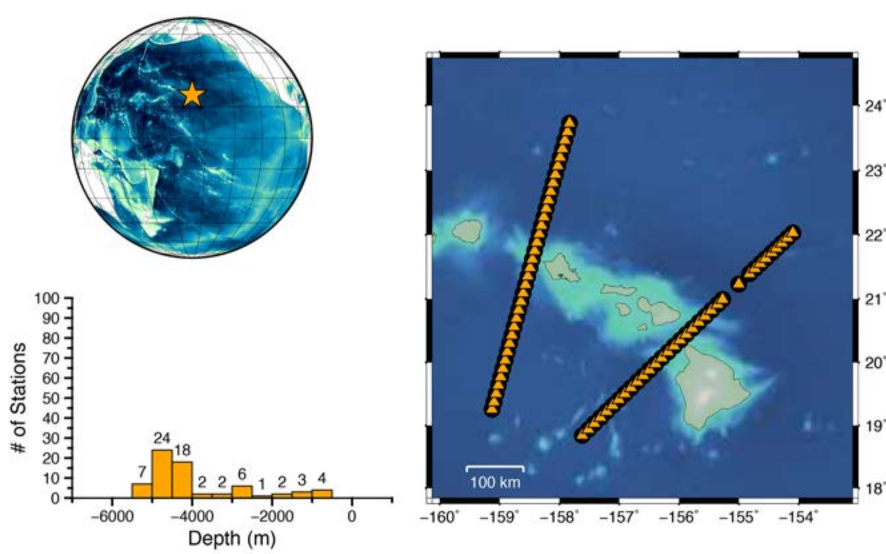


Figure 34. Hawaiian-Emperor Seamount Chain experiment deployments.

4.2.20. Bransfield Strait

The Bransfield Strait experiment consisted of 15 WHOI short-period OBSs deployed from R/V *Hesperides* in 2019 between the West Antarctic Peninsula and the South Shetland Islands (Figure 35). The OBS will be recovered a year later in 2020 and data will be archived in miniSEED under temporary network code ZX.2019-2020 and under assembled data set ID# 18-017 at the IRIS DMC.

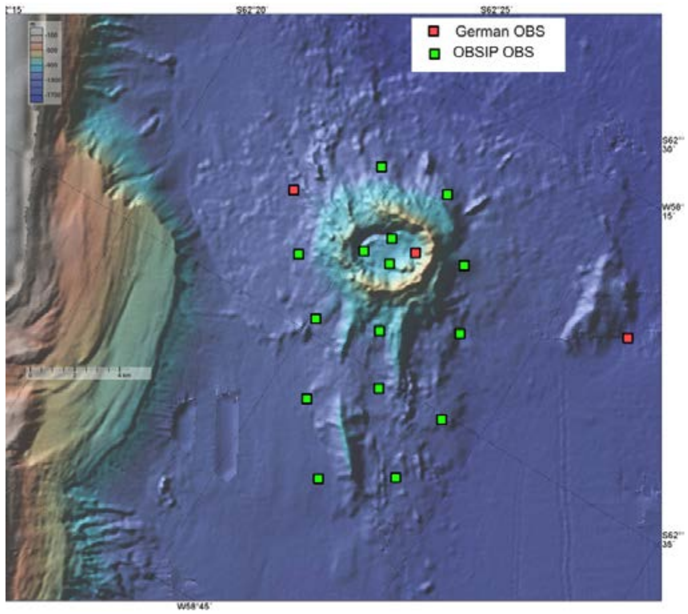


Figure 35. Bransfield Strait experiment deployments.

5. Citations

Exceptional scientific results were OBSIP's ultimate goal. As stated in the OBSIP Instrument Use Policies and Procedures, all users of OBSIP Instrumentation were requested to cite the use and support of the OBSIP facility, by incorporating the following acknowledgment in any publications or reports resulting from the use of OBSIP instruments:

> *Data used in this research were provided by instruments from the Ocean Bottom Seismograph Instrument Pool (http://www.obsip.org) which is funded by the National Science Foundation. OBSIP data are archived at the IRIS Data Management Center (http://www.iris.edu).*

Citations of publications, reports, dissertations, and theses that were aided or enabled through the use of the OBSIP facility are included at the end of this report.

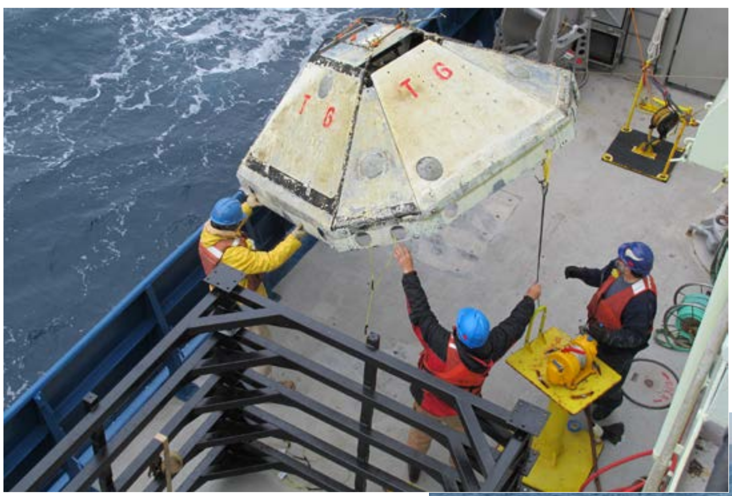


Figure 36. Repositioning an LDEO TRM as it is recovered aboard R/V *Atlantis*. *Photo credit: Cruise AT26-02*

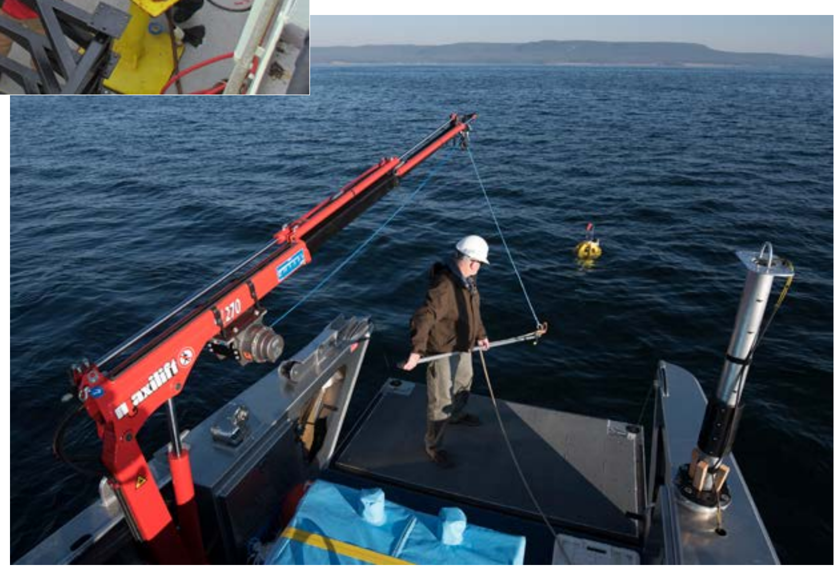


Figure 37. WHOI engineer Tim Kane stands ready to hook and recover an OBS from Yellowstone Lake. In compliance with the research permit, the anchor needed to be recovered as well as the instrument. *Photo credit: Chris Linder, Woods Hole Oceanographic Institution*

6. Data

6.1. DATA RELEASE PROTOCOL

All OBSIP experiment data were (and still are) stored and distributed by the IRIS Data Management Center (Figure 38). Data were checked for completeness by the OMO after being uploaded to the DMC by the IICs, and any subsequent changes to the data were announced via the OBSIPtec e-mail listserv. Changes made to SEED metadata can be reviewed using the DMC's Metadata Change Web Service. Data were typically embargoed for use by the experiment PI and became open to the public after two years. Some experiments, such as the Cascadia Amphibious Array community experiment, became available to all researchers immediately. Other underway geophysical data sets such as gravity and bathymetry were also submitted to analogous geophysical data repositories and portals, such as the Marine Geoscience Data System, and are publicly available in many cases with cross links between related data sets.

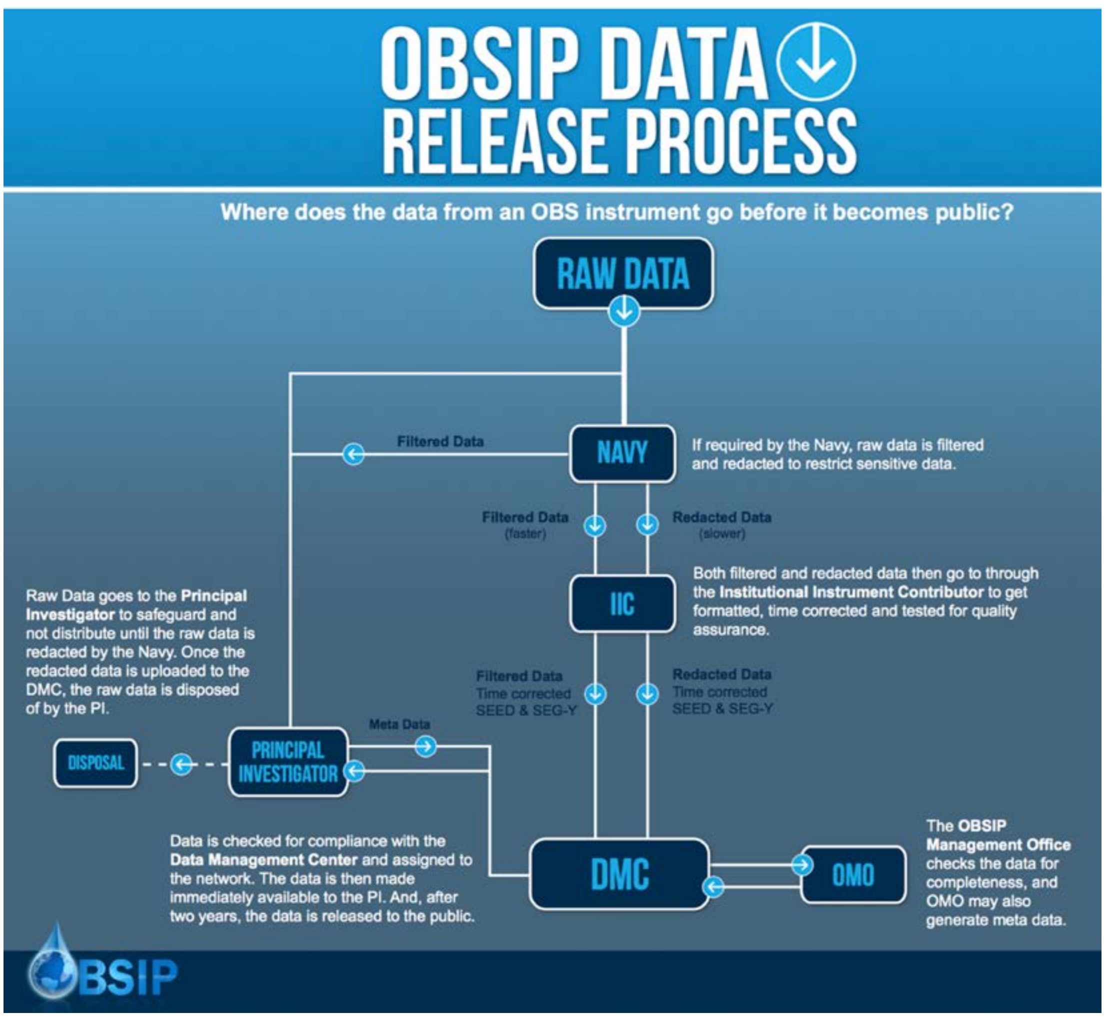


Figure 38. The process that OBSIP data would go through before being released to the public through the IRIS DMC. These steps limited most errors from propagating and ensured that data were as high quality as possible.

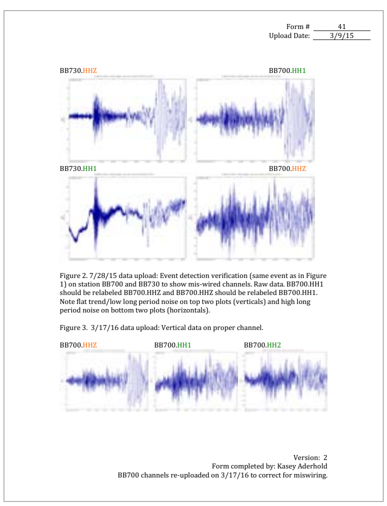
The DMC holds data from both passive and active experiments in SEED and SEG-Y formats, respectively. Some data sets are also archived as PH5. Data are most easily accessed using the DMC Metadata Aggregator, and are grouped within the OBSIP virtual network. The station listing of the virtual network can be found at http://ds.iris.edu/mda/_OBSIP.

OMO worked routinely with the DMC in applying and further developing software tools to ensure the highest possible data quality in OBS data sets before they were disseminated to the public. The IRIS (in general) and OMO (in particular) data management efforts addressed the goal of expanding the broad use of OBS data and lowering the hurdle to accessibility.

6.2. DATA UPLOAD VERIFICATION

Data from OBSIP experiments were reviewed upon archival by the OBSIP Management Office Data Quality analyst. The review was summarized in a Data Upload Verification Report (Figure 39).

Instruments that were not recovered or did not record were noted first, as were any missing channels. Station names, locations, and depths were compared to any available cruise reports, deployment or recovery tables, and other communications from Management Council meetings or e-mails with PIs. Instrument responses were reviewed for each station and channel. Samples of data were also reviewed at each station and channel, both from a period of time shortly after deployment as well as during a known earthquake and/or airgun shot during the experiment. If the experiment occurred during a leap second, the one second timing corrections were confirmed along with the method used. Anything unusual noted by the deployment or recovery crew in the cruise report as well as anything discovered during the data upload verification process was noted in the upload verification form and brought to the attention of the IIC to confirm or correct. Examples of errors that were found and corrected prior to the release of the data to users included incorrect responses, duplicate channels, swapped channels, sign errors on longitude, repeated station locations, and incorrect station depths.



Form # 41
Upload Date: 3/9/15

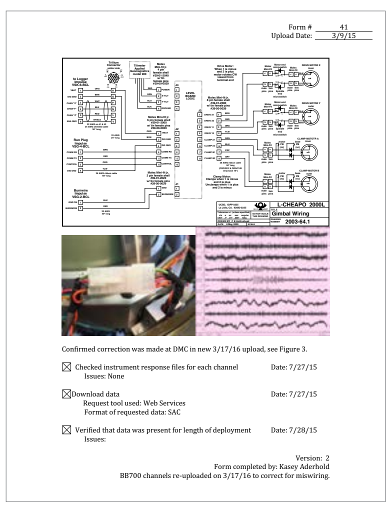
BB730.HHZ
BB700.HH1
BB730.HH1
BB700.HHZ

Figure 2. 7/28/15 data upload: Event detection verification (same event as in Figure 1) on station BB700 and BB730 to show mis-wired channels. Raw data. BB700.HH1 should be relabeled BB700.HHZ and BB700.HHZ should be relabeled BB700.HH1. Note flat trend/low long period noise on top two plots (verticals) and high long period noise on bottom two plots (horizontals).

Figure 3. 3/17/16 data upload: Vertical data on proper channel.

BB700.HHZ
BB700.HH1
BB700.HH2

Version: 2
Form completed by: Kasey Aderhold
BB700 channels re-uploaded on 3/17/16 to correct for miswiring.



Form # 41
Upload Date: 3/9/15

Confirmed correction was made at DMC in new 3/17/16 upload, see Figure 3.

☒ Checked instrument response files for each channel — Date: 7/27/15
Issues: None

☒ Download data — Date: 7/27/15
Request tool used: Web Services
Format of requested data: SAC

☒ Verified that data was present for length of deployment — Date: 7/28/15
Issues:

Version: 2
Form completed by: Kasey Aderhold
BB700 channels re-uploaded on 3/17/16 to correct for miswiring.

Figure 39. Example of a Data Upload Verification Report where it was discovered that the vertical and horizontal channel had been swapped. Data for this station were corrected at the IIC and the change was confirmed at the DMC before the data were released.

Any subsequent data uploads with corrections were reviewed again. When all outstanding issues were resolved, the data were released if it was a community experiment or the PI was notified if the data were restricted.

This independent review of data by the OMO was performed from a "user's view" of the data, as archived at the DMC—meaning all data were accessed from the same archive, and using the same tools, as any external data user would see. This was helpful for identifying the occasional mis-types of station latitude or longitude and, even rarer, incorrect timing corrections. Perhaps more importantly, this review identified problems that would not have been found by an in-house review of the data at an IIC. One example is a bug identified at the DMC that was truncating the responses of stations as the dataless SEED file was read. There was no issue with the dataless file that was sent in by the IIC. The problem could only be identified after the data were archived at the DMC, and it would have propagated on to the user without an independent review.

The OMO also reassessed data availability from experiments prior to this OBSIP award. Significant effort was made to ensure that the archive at the DMC was complete and comprehensive for all facility experiments from the beginning of OBSIP to present. This required many additional data sets to be uploaded during the time period that IRIS managed the OBSIP facility. For active source experiments, IICs were encouraged to archive in both SEG-Y and miniSEED when possible. Any additional data sets that were uploaded for these experiments were reviewed, with any issues or errors resolved and documented in the same manner as with new data set uploads.

Figure 40. A WHOI short-period instrument is hoisted on board R/V *Langseth* during the Santorini experiment. *Photo credit: Emilie Hooft and Cruise MGL1521*

6.3. HORIZONTAL ORIENTATIONS

Ocean bottom seismometers are deployed remotely and without intervention—therefore, their actual horizontal orientation on the seafloor is unknown. OBSIP instruments did not carry orientation devices (e.g., magnetic compasses, gyros). Therefore, horizontal orientation of the OBS needed to be determined from measured data. The ambient noise inherent in OBS data can make this process difficult, along with the short recording duration.

There are several viable methodologies for determining OBS orientation. OBSIP has used the process outlined by Stachnik et al. (2012) to orient instruments deployed in the Cascadia Initiative. Calculated orientations were distributed via Horizontal Orientation Reports prepared by the OMO and posted to the OBSIP website. A subsequent analysis by Doran and Laske (2017) included orientations of all four years of Cascadia instruments and can now be used by all researchers.

6.4. COMMUNITY QUESTIONS

In addition to reviewing new data sets being archived, the OMO was responsible for following up on outstanding community questions regarding data issues. Certain errors found in newer data sets led to the identification of errors in older data sets, such as a crossed datalogger wire that resulted in swapped channels on an SIO instrument deployed for both the NoMelt experiment in 2011 and the Gorda experiment in 2013. Regardless of whether the experiment occurred during or before the OBSIP award, community questions were documented, tracked, and in most cases resolved.

Known or reported issues with OBSIP data that reside in the DMC archive are documented in the metadata folders at the DMC. These user-accessible folders contain information such as data issue descriptions, e-mail correspondence, and cruise reports. When possible, data issues were also flagged with Data Problem Reports.

6.5. DATA ASSESSMENT FORM

Data assessment evaluations were completed a year or more after a recovery cruise by the experiment's PI via a form on the OBSIP website. This form requested feedback about the instrument return date, data return rate, timeliness of data archiving, post-cruise communications, provision of supplementary information about the data and instrument responses, and how well the data met the objectives of the PI's work. Information about the data was sometimes included in cruise evaluations.

Many PIs did not fill out a data assessment form, often stating that they required more time to work with the data in order to better understand how well it met their needs. Due to the multiple year delay between a recovery cruise and submitted science manuscripts, consistent feedback about the data from OBS experiments was not often acquired. This kind of standardized feedback may be more easily obtained with a twofold approach: a highly quantitative assessment of data return shortly after the recovery cruise, including instrumentation losses or failures, and a later more qualitative assessment of the overall usefulness of the data in scientific research, including which data were left out of analysis and why.

Feedback about OBSIP data from the PIs was very helpful for identifying recurring issues and for measuring progress on areas needing improvement. Feedback was provided primarily via e-mails, calls, cruise reports, and published papers, but also through in-person conversations at scientific conferences and meetings.

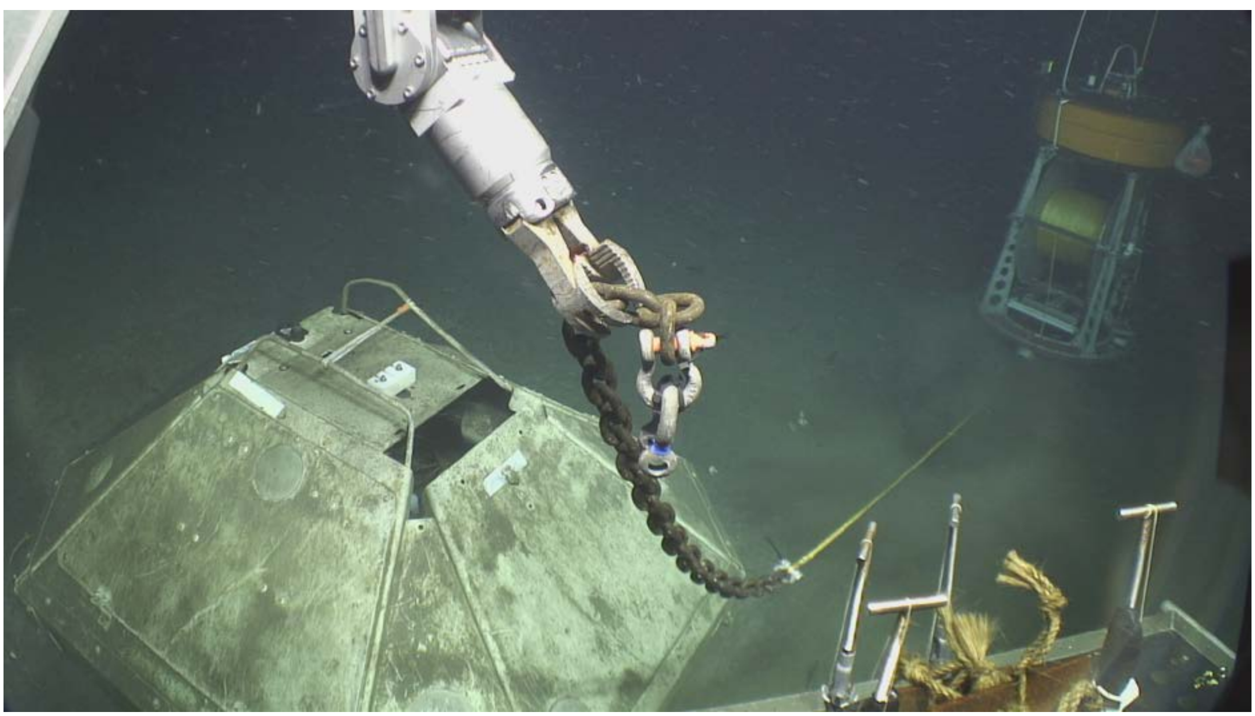


Figure 41. The view from ROV *Jason* while attaching the line spool elevator for recovery of an LDEO trawl resistant mount OBS deployed for the Cascadia Initiative. *Photo credit: ROV* Jason *crew*

7. Media and Outreach Activities

Communication activities had the goal of bringing in members of the broader community through listservs, a publicly available website that featured OBS related information for researchers and the general public, and organized events.

7.1. OBSIPtec MAILING LIST

The IRIS OBSIPtec mailing list provided a forum for the discussion of technical and operational issues relating to ocean bottom seismographs, in particular, the instruments operated by and data produced by the Ocean Bottom Seismograph Instrument Pool.

The goal of this mailing list was to encourage collaboration between the OBS operators and researchers and to provide a public discussion forum for the complex issues and challenges of using OBS data. There were 164 subscribers to the OBSIPtec mailing list, which has now been transferred to the OBSIC facility to continue to inform the community.

7.2. OBSIP WEBSITE

A website was maintained at www.obsip.org to inform the research community about the OBSIP facility, recent press coverage, upcoming opportunities, past experiments, instrument use policies, and other relevant ocean bottom seismology issues (Figure 42). It also served as a reference for all experiments undertaken as part of OBSIP.

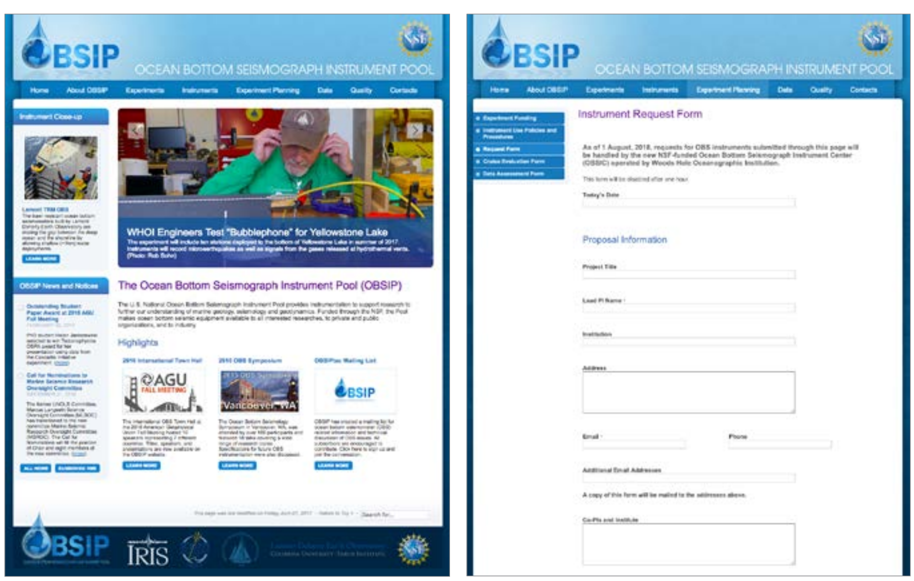


Figure 42. OBSIP website home and instrument request form pages.

7.3. AGU, SSA, AND IRIS WORKSHOPS

OBSIP had a growing presence at annual IRIS workshops, since they are viewed as effective opportunities to expand the OBS user base and to encourage use of OBS data through presentation of OBS experiments. These IRIS-led meetings attract a large contingent of land-based seismologists, many of who have not worked with OBS data. At the biennial IRIS Workshop held in 2014, a Special Interest Group was organized and held that focused on soliciting input from the seismology community to identify the key concerns and services that OBSIP should provide in the future. A new users course was also held to promote the community of new OBS data users.

The OMO also had a presence at the American Geophysical Union (AGU) and Seismological Society of America (SSA) conferences each year to advertise facilities and resources, attract new users, and foster international collaboration (Figure 43). Posters and presentations were regularly prepared and presented by the OMO.

Figure 43. An ABALONE instrument on display at the IRIS booth during the 2013 AGU Fall Meeting in San Francisco, California. *Photo credit: Raspberry Shake (@raspishake)*

The OMO organized an International OBS Town Hall at the 2016 AGU Fall Meeting in San Francisco, California. Sixteen presentations were made with speakers representing seven different countries. Speakers included:

- Vala Hjörleifsdóttir – Universidad Nacional Autónoma de México, Mexico
- Francisco Javier Núñez Cornú – Universidad de Guadalajara, Mexico
- Lukas Joeressen – K.U.M. Umwelt- und Meerestechnik Kiel GmbH, Germany
- Frauke Klingelhoefer – Ifremer, France
- Yann Hello – Géoazur, France
- Guust Nolet – Géoazur, France
- Yoshihiro Ito – Kyoto University, Japan
- Ching-Ren Lin – Academia Sinica, Taiwan
- PeiYing Patty Lin – Taiwan Ocean Research Institute, Taiwan
- Heiner Igel – Ludwig-Maximilians-University, Germany
- Hisashi Utada – University of Tokyo, Japan
- Guilhem Barruol – Université de La Réunion, France
- Juan José Dañobeitia – Unidad de Tecnología Marina, Spain
- Katrin Hafner – IRIS GSN, USA
- Shuichi Kodaira – JAMSTEC, Japan
- Brent Evers – IRIS OBSIP, USA

This event was well attended and likely contributed to the increased participation of international researchers and instrument providers at the 2017 OBS Symposium.

7.4. PHOTO REQUEST AND ARCHIVE

The OBSIP Management Office implemented a photo request in 2015 in order to better promote OBSIP activities through reports, educational materials, presentations, and the OBSIP website. The photo request was incorporated into subsequent science support plans. Twenty-five or more high quality photos were requested in the month prior to the cruise and instructions were sent that could be handed over to one or more cruise participants to complete. Included in the instructions was a one-pager describing the photo request and explaining the additional metadata needed, a pre-formatted Excel spreadsheet for recording the photo metadata, and a photo release form to collect signatures. Also welcomed in the request was any video footage, blogs/written documentation, preliminary figures, and other materials in addition to the photos.

The photo request was satisfied in a subset of experiments, and the high-quality photos that were supplied greatly improved the archive available to the OBSIP Management Office. Photos were used on the OBSIP website, posters presented at conferences, as well as this and other reports.

7.5. OTHER OUTREACH

IRIS has (or works together with community initiatives) programs that enable students to take advantage of resources connected with OBS research (Figure 44). This includes participation in OBS deployment and data analysis related activities including special student and community forums at AGU, focused workshops, and opportunities to apply for student prizes based on work using OBS data sets. The IRIS intern program makes it possible for students to participate in OBS-related research activities, including research cruises where students are part of watch standing crews. For many undergraduates this is the beginning of a career in the ocean sciences, marine seismology, or interdisciplinary geophysical fields. Cruise blogs with photos, videos, and results of student work are made available through the intern website. Expanding student participation through programs similar to that offered by the Cascadia Initiative that enabled community college student participation in OBS experiments, including placing them onboard cruises, would be worthwhile to continue.

The very successful IRIS Education and Public Outreach (EPO) Active Earth kiosk content was expanded to include pages specific to marine seismology topics and observation techniques. Kiosk interactions are measured in the many tens of thousands per year. The kiosk program is just one example of how IRIS EPO took advantage of the public interest in exploring the ocean to bring ocean sciences to a much larger audience.

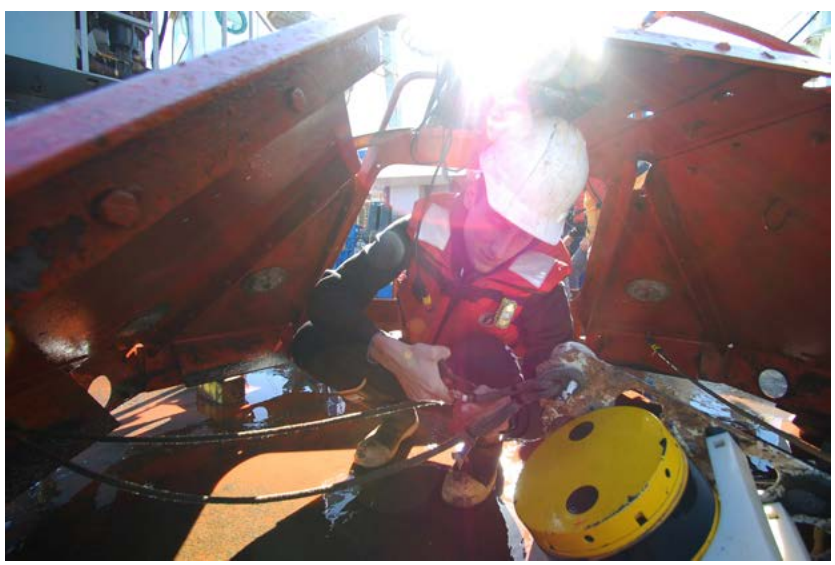


Figure 44. Student Erik Fredrickson detaching an OBS sensor from within the trawl-resistant module on a 2015 Cascadia recovery cruise. *Photo Credit: Charles Garcia*

8. Symposia and Workshops

The OBSIP Management Office carried out the logistical planning to hold informative and exciting OBS symposia to promote the science and applications of ocean bottom seismographs for geophysics research. Symposia were organized every two years and held in 2013, 2015, and 2017 (Figure 45). The agenda included sessions on OBS experiment results, OBS technology and development efforts, international OBS development efforts, and active source waveform inversion technology development. In addition to speakers, all symposia included a poster session. The symposia participants were a mix of marine seismologists, land seismologists, students, hardware developers and engineers, and industry. There was a strong international and early career scientist presence, which strengthened and increased over time along with overall attendance.

The symposia became popular, focused venues to share scientific results related to OBS research, to present new ideas for hardware development, and to involve community discussion on long-term needs for future instrumentation and instrument specifications. Some international speakers were invited with the goal of having representation from an array of OBS instrument and research centers around the world. In addition, international participation was strongly encouraged as the symposia were seen as a good place to foster the germination of ideas for international cooperation, collaboration, and resource sharing.

Figure 45. The 2017 OBS Symposium in Portland, Maine. *Photo Credit: Kasey Aderhold*

8.1. 2013 OBS SYMPOSIUM

The 2013 OBS Symposium was held at the Portofino Hotel in Redondo Beach, California, on October 21–22. Over 100 people attended the 2013 OBS Symposium.

Speakers for the symposium included Shuichi Kodaira, Joanna Morgan, Satish Singh, Weisen Shen, Spahr Webb/Andrew Barclay, Anne Sheehan, Jeff McGuire, Emilie Hooft, Gabi Laske, Nick Harmon, Hitoshi Kawakatsu, James Gaherty, Don Forsyth, Mechita Schmidt-Aursch, Frederik Simons, Haijime Shiobara, Del Bohnenstiehl, Philippe Charvis, and Monica Kohler.

The Steering Committee who planned and organized the symposium included Monica Kohler, John Nabelek, Harm Van Avendonk, and Doug Wiens.

On the Sunday afternoon and evening prior to the symposium, there was a half-day mini-workshop on the ocean bottom seismometer portion of the Cascadia Initiative. The objectives of this meeting were to (1) update the community on the status of the deployments, (2) discuss the data quality, (3) provide a forum for short presentations on the initial results and plans for data analysis, and (4) discuss the motivation and priorities for the fourth year of the deployments.

8.2. 2015 OBS SYMPOSIUM

The 2015 OBS Symposium was held at the Hilton Vancouver Washington hotel in Vancouver, Washington, on October 5–6. The 2015 OBS Symposium had approximately 110 participants.

Speakers for the symposium included Laura Wallace, Anne Trehu, Gaye Bayrakci, Seth Haines, Chuck Keller, Wayne Crawford, John Nabelek, Haiying Gao, Rob Sohn, Huajian Yao, Justin Ball, Shawn Wei, Vedran Lekic, Susan Bilek, Maya Tolstoy, Jeff Babcock, Donna Shillington, and Harm Van Avendonk.

The Steering Committee who planned and organized the symposium included Del Bohnenstiehl, Heather DeShon, Monica Kohler, and Harm Van Avendonk.

8.3. 2017 OBS SYMPOSIUM

The 2017 OBS Symposium was held at the Holiday Inn By The Bay hotel in Portland, Maine, on September 18–19. The 2017 OBS Symposium had about 120 participants representing academia and industry, early career to tenured faculty, and coming from 11 different countries (United States, Canada, China, Japan, South Korea, Taiwan, France, United Kingdom, Mexico, Spain, Australia).

Speakers for the symposium included Emilie Hooft, Paul Johnson, Catherine Rychert, Ross Parnell-Turner, Anne Sheehan, Gail Christeson, Xiaowei Chen, Suzanne Carbotte, Natalie Accardo, Karin Sigloch, Jennifer Harding, Uri ten Brink, William Wilcock, Anne Trehu, Haiying Gao, Dara Merz, Monica Kohler, Emily Roland, Colton Lynner, and Brandon Shuck.

The Steering Committee who planned and organized the symposium included Jackie Caplan-Auerbach, Robert Reece, Yang Shen, Del Bohnenstiehl, and Heather DeShon.

9. Facility Results

9.1 OPERATIONAL RESULTS

During the past seven years, OBSIP moved toward a more unified and seamless facility whose ultimate goal was to provide timely and high quality OBS data for the scientific community. The IICs and their staffs worked closely with PIs to provide support before, during, and after the cruises for every experiment listed in Section 4 of this report. OBS instruments were serviced thoroughly and quickly in order to make tight turnarounds necessitated by ship schedules, particularly during the Cascadia Initiative. Repairs, maintenance, and calibration testing were undertaken with care even during very narrow windows so that OBS fleets were ready for the next experiment. IIC crews demonstrated extraordinary ability to adapt to different ship facilities in order to execute operations, including non-UNOLS vessels. The amassed experience of IIC crews was an invaluable resource for navigating international ports and complex shipping logistics, ultimately ensuring that vital equipment arrived on time while keeping costs downs.

9.2. MANAGEMENT RESULTS

A key achievement under IRIS management has been to improve the funding stability to the IICs by restructuring the OBSIP subaward funding model. IRIS also implemented improved financial management of NSF funds through task-based accounting and tracking and this, in part, led to the cost savings that launched some technical improvements to instrumentation, as well as enabling IRIS to offset well over$1M in new NSF funding.

IRIS strengthened community governance of OBSIP by incorporating a community-based Oversight Committee that reviewed the performance and funding of both OMO and its IIC subawardees. Interaction within the ocean bottom seismology community was increased by holding three highly successful OBS science and technology symposia (each attracting over 100 researchers), holding an international OBS town hall at the fall AGU meeting, and increasing the presence of OBS science in the biennial IRIS workshops.

9.3. QUALITY RESULTS

The OMO, in collaboration with the IICs, developed and began implementation of a facility-wide Quality Plan aimed at addressing quality throughout the facility. The quality plan increased coordination between OBSIP IICs in addressing issues and working together, by regularizing meetings, planning, and reporting. As noted earlier, progress against Quality Plan objectives was reported to the Oversight Committee at six-month intervals. The process of holding inter-IIC design reviews (previously only performed within each institution) was acknowledged by all participants as being very valuable, but it was also challenging to be sufficiently thorough while still respecting each organization's intellectual property.

Developing metrics to quantify improvements in quality would have been a next step in the evolution of OBSIP, had it continued. However, it was clear to the OBSIP managers and staff that, if nothing else, the OBSIP quality plan efforts were helping to organize and systematize diverse quality activities underway at the IICs and this was having a positive impact.

9.4. TECHNICAL RESULTS

Careful management of NSF funding resulted in accumulated savings of operations and maintenance funds during the seven years of OBSIP. With NSF approval, these funds were used to initiate reviewed and prioritized engineering projects to advance the OBS fleet capabilities. Projects included upgrading sensors for fleet uniformity and quality, developing a line spool elevator for quicker and safer retrieval of the LDEO TRM OBSs, replacing glass ball flotation with syntactic foam for fleet uniformity and reliability, improving clocks and controllers, and extending the power capacity of instrumentation for longer, 15-month deployments. Each of these projects addressed specific instrumentation needs for the community.

9.5. DATA RESULTS

The OBSIP data archive volume and requested use has seen unprecedented growth in recent years. There are now a total of 56 OBSIP experiments archived at the IRIS DMC. The growth in the number of OBSIP data users, heavily driven by the widely used Cascadia data set, has been significant (Figure 46).

OBSIP implemented tool and techniques to identify and correct (or avoid) errors in data uploaded to the DMC. The OMO responded to all user inquiries regarding data access or real or perceived data issues, and implemented a tracking system to follow up on any issues that were identified. Further, through significant effort and tracking, the backlog of outstanding data sets (i.e., data sets that were never uploaded to the DMC, due to various problems) was eliminated.

Development of high-level data products and data quality analyses including horizontal orientation analysis of all Cascadia Initiative data was also pursued.

The OBSIP user community has grown significantly over recent years, particularly as a result of the highly successful Cascadia Initiative, which introduced ocean bottom seismic data to a whole community of geophysicists who previously only worked with land-based data. The OMO also worked hard to grow and strengthen the national and international OBS community via the OBS symposia, IRIS workshops, publications, and mailing lists, as well as visibility at a variety of scientific meetings. Broadening the marine seismic research community helps achieve the ultimate goal of OBSIP—exceptional scientific results.

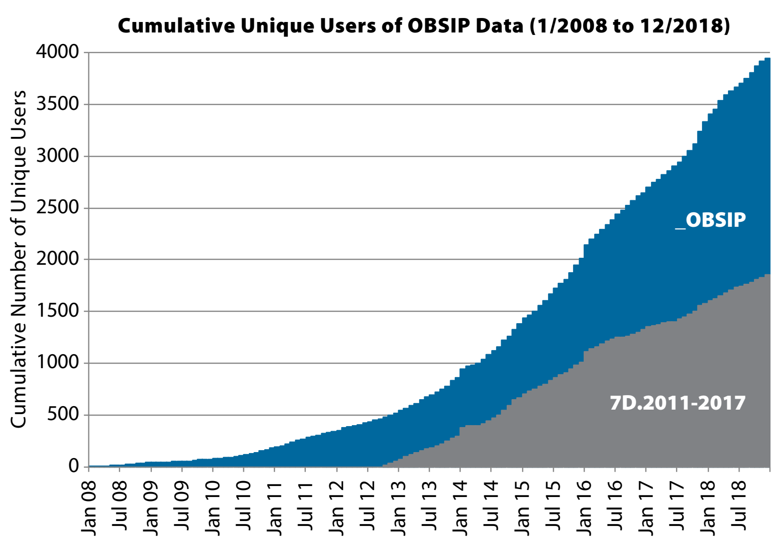


Figure 46. Data users from January 2008 to December 2018, showing the cumulative total unique data users of all OBSIP data (blue) and solely the Cascadia data set (gray). Note that the Cascadia data set drove an increase in OBSIP data use that continues even after the Cascadia data use tapers off.

10. Community Engagement and Transparency

As part of the IRIS-managed OBSIP activities, there was a substantial increase in community engagement in marine seismology. The IRIS community's strategic plan has, for many years, emphasized the need for increased availability of observations in the ocean basins. IRIS engagement in OBSIP exposed many members of the terrestrial seismology community to marine seismology, through participation in the OBS symposia, through direct service on the OBSIP oversight committee, through visibility of OBSIP within the IRIS governance structure, and as a result of IRIS outreach in scientific venues (e.g., AGU) and to the general public.

Implementation of the OBSIP Oversight Committee, in the same model as other long-standing IRIS Standing Committees (e.g., the PASSCAL Standing Committee), provided transparency into OBSIP operations. Annual budgets, including subaward budgets to the IICs, were reviewed by the Oversight Committee. These budgets were also reviewed by the IRIS Board of Directors. OBSIP performance and plans were reviewed by the Oversight Committee and shared IRIS-wide via the IRIS Coordinating Committee. High-level OBSIP performance was reviewed multiple times per year by the IRIS Board of Directors.

The OBSIP Oversight Committee highlighted the following as key positive aspects of the IRIS-operated OBSIP:

- Inclusive community governance, including outreach to a broad user community
- Improvement in data quality as a result of the combined IIC and OMO reviews of data
- Biannual OBS symposia that illuminated future directions, facilitated information exchange, and broadened the community
- Community governance that provided diverse and balanced guidance to the facility

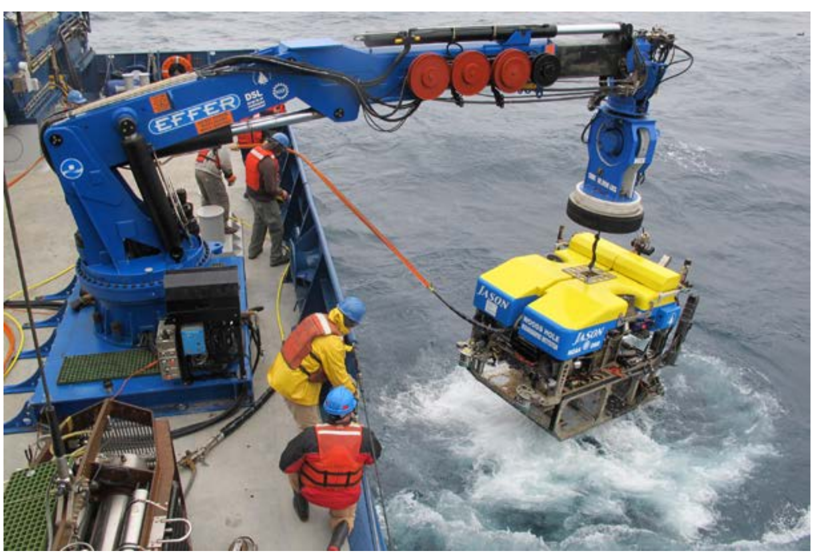


Figure 47. ROV *Jason* being used during the 2013 cruise aboard R/V *Atlantis* to recover LDEO TRM instruments. *Photo credit: Cruise AT26-02*

The OBSIP facility has now been replaced by the OBSIC facility, operated by Woods Hole Oceanographic Institution, which will continue to provide ocean bottom seismographic equipment as a resource to the scientific community. OBSIC will have the legacy of OBSIP, in both its 1999–2011 and 2012–2019 incarnations, to build upon.

Acknowledgments

The work performed at the OBSIP facility and summarized here would not have been possible without funding from the National Science Foundation under award OCE-1112722. We greatly appreciate the collaborative oversight throughout the years by NSF Program Directors, including Rodey Batiza, Rick Carlson, Donna Blackman, Candace Major, and Jim Holik.

The Institutional Instrument Contributors and their teams of extraordinarily dedicated engineers, technicians, and staff were tireless in their careful execution of experiment tasks. Their enthusiasm and expertise was truly the beating heart of OBSIP and enabled researchers to push the boundary of our knowledge forward:

Lamont-Doherty Earth Observatory

Andrew Barclay, Carlos Becerril, Walt Masterson, John Clapp, Ted Koczynski, Peter Liljegren,
Maya Tolstoy, and Jim Gaherty

Scripps Institution of Oceanography

Jeff Babcock, John Orcutt, Martin Rapa, Sean McPeak, Ernie Aaron, Mark Gibaud, Juan Reyes, and Rita Bauer

Woods Hole Oceanographic Institution

John Collins, Alan Gardner, Tim Kane, Dan Kot, Peter Lemmond, Maryanne Ferriera, Dan McCorkle,
Dan Lizarralde, and Jeff McGuire

The OBSIP Management Office was led by Brent Evers, with the assistance over the years of staff members Jessica Lodewyk and Kasey Aderhold. IRIS management, including Instrumentation Services Director Bob Woodward and IRIS Presidents Dave Simpson and Bob Detrick, served as the OBSIP award PIs and provided high-level guidance and advice. The staff at the IRIS Data Management Center were extremely helpful in all aspects of OBSIP data archiving and distribution, with special thanks to Mea Edmunds and Un Joe.

We especially wish to thank all the members of the seismology community who served as chairs or members of the OBSIP Oversight Committee, OBS Symposium organizing committees, and the Cascadia Initiative Expedition Team.

Figure 48. Student Melodie Elmer sprays down the data logger of an LDEO TRM before removal. *Photo credit: Charles Garcia*

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Toomey, D. R., R. M. Allen, A. H. Barclay, S. W. Bell, P. D. Bromirski, R. L. Carlson, X. Chen, J. A. Collins, R. P. Dziak, B. Evers, D. W. Forsyth, P. Gerstoft, E. E. E. Hooft, D. Livelybrooks, J. A. Lodewyk, D. S. Luther, J. J. McGuire, S. Y. Schwartz, M. Tolstoy, A. M. Tréhu, M. Weirathmueller, and W. S. D. Wilcock (2014). The Cascadia Initiative: A sea change in seismological studies of subduction zones, Oceanography 27(2): 138–150, DOI: 10.5670/oceanog.2014.49.

Appendix A
Financial Summary of OBSIP

These tables represent actual spending reported up to August 2019. Final invoicing and closeout of this award will occur after this report is completed, and numbers may differ from those reported here.

Table A1. OBSIP Funding by Award, 2012–2019

	LDEO	SIO	WHOI	OMO	
Base Funding 2012–2019	$4,338,059	$6,088,387	$5,610,143	–	
Experiments 2012–2019	$3,066,070	$4,438,852	$2,636,856	–	
Instrument Refurbishments	$307,524	$745,126	$507,548	–	
Engineering	$245,718	$200,132	$131,961	–	
Management	–	–	–	$2,298,679	
Operations	–	–	–	$613,564	
Community Activities	–	–	–	$429,960	
Subtotals	**$7,957,371**	**$11,472,497**	**$8,886,507**	**$3,342,203**	**TOTAL $31,658,578**

Table A2. OBSIP Funding Broken Down by Year and Award

	2012	2013	2014	2015	2016	2017	2018	2019	Subtotals
LDEO Base Funding	$285,498	$739,045	$712,485	$729,518	$763,143	$678,498	$429,283	$590	**$4,338,059**
SIO Base Funding	$278,555	$1,032,431	$973,805	$1,123,806	$1,069,398	$1,175,616	$389,341	$45,435	**$6,088,387**
WHOI Base Funding	$93,924	$898,281	$1,099,393	$970,657	$1,043,526	$883,312	$618,989	$2,061	**$5,610,143**
LDEO Experiments[1]	$99,052	$780,610	$783,840	$239,552	–	$1,003,376	–	$159,639	**$3,066,070**
SIO Experiments[1]	$159,816	$968,057	$912,177	$617,127	$331,351	–	$1,443,136	$7,186	**$4,438,852**
WHOI Experiments[1]	–	$345,375	$654,913	$336,303	$161,200	$805,313	$256,147	$77,606	**$2,636,856**
LDEO Refurbishment	–	$94,676	$46,383	$166,466	–	–	–	–	**$307,524**
SIO Refurbishment	–	$325,781	$191,096	$228,250	–	–	–	–	**$745,126**
WHOI Refurbishment	–	$125,329	$101,238	$280,981	–	–	–	–	**$507,548**
LDEO Engineering	–	$30,564	–	$215,154	–	–	–	–	**$245,718**
SIO Engineering	$12,004	–	–	$188,129	–	–	–	–	**$200,132**
WHOI Engineering	–	–	–	$127,966	–	–	–	$3,995	**$131,961**
OMO Management[2]	$466,813	$342,394	$345,876	$385,871	$390,997	$269,547	$70,450	$26,731	**$2,298,679**
OMO Operations	$19,933	$101,286	$141,078	$105,817	$99,348	$82,592	$54,166	$9,344	**$613,564**
OMO Community Activities	$21,411	$116,212	$17,693	$110,157	$25,950	$126,157	$5,442	$6,938	**$429,960**
Subtotals	**$1,437,006**	**$5,900,040**	**$5,979,977**	**$5,825,753**	**$3,884,913**	**$5,024,410**	**$3,266,954**	**$339,525**	**TOTAL** $31,658,578

[1] Not all experiment-specific funding was used in the year awarded.
[2] Includes costs for governance committee meetings.

Appendix B
A Brief Analysis of OBSIP Deployments

By Andy Frassetto, Bob Woodward, and Kasey Aderhold, all at IRIS

B1. INTRODUCTION

The US Ocean Bottom Seismograph Instrument Pool (OBSIP) has addressed diverse scientific objectives through the deployment of instruments in different subsea environments and at different scales, durations, and water depths. This history provides insight into overall usage and performance of the OBSIP resource. Here, we examine the characteristics and performance of OBSIP deployments in order to help inform future directions of this important capability.

B2. INSTRUMENT USAGE

We investigate several aspects of how OBSIP instruments have been used to help address key questions regarding future developments to the facility:

1. How many instruments are needed?
2. What deployment duration capabilities are required?
3. What deployment depth capabilities are needed?
4. What is the areal extent of typical OBS experiments?

We use metadata from over 16 years of OBSIP experiments (12/1/2001 to 3/31/2018) contained in a virtual network (http://www.ds.iris.edu/mda/_OBSIP/) in the IRIS DMC archive to parse key information about usage. Assembled data sets, typically archived in SEG-Y and not miniSEED, do not show up consistently in _OBSIP and thus may be underrepresented in this analysis.

B2.1. Deployment Size and Frequency

At present funding levels, an instrument pool of 90 short-period instruments and 70–80 long-period instruments may be adequate to support baseline demand (i.e., excluding periods during major community experiments). Although it may never be possible to operate as many OBSs as land instruments, the comparison to PASSCAL indicates potential unrealized demand.

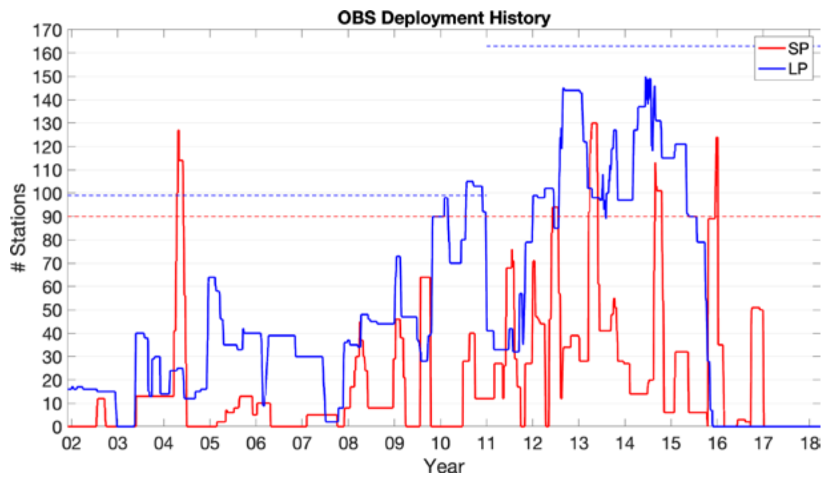

Figure B1. Instrument utilization over time with one month padding before and after deployment to account for staging and shipping equipment. Dashed lines mark the size of the instrument pool (~99 long period [LP]) pre-2011, ~163 LP after, 90 short period [SP] throughout). Spikes in SP instrument usage exceeding inventory are driven by redeployments during individual experiments.

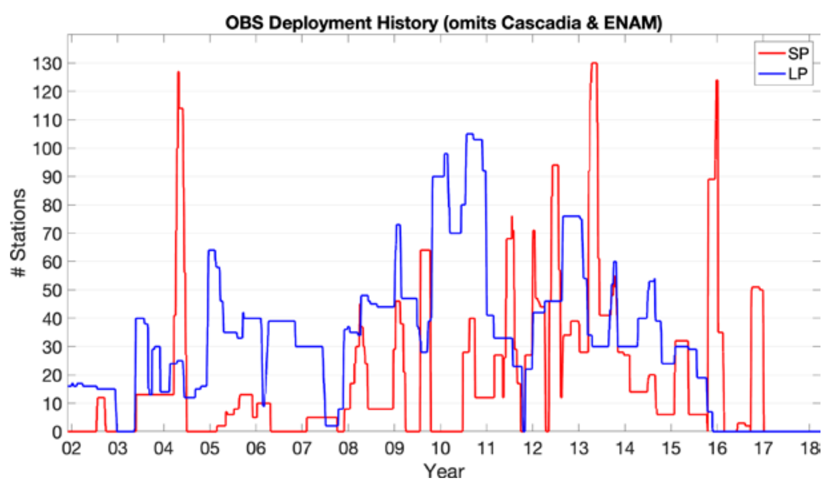

Figure B2. Same as previous figure but excludes the Cascadia and ENAM community experiments.

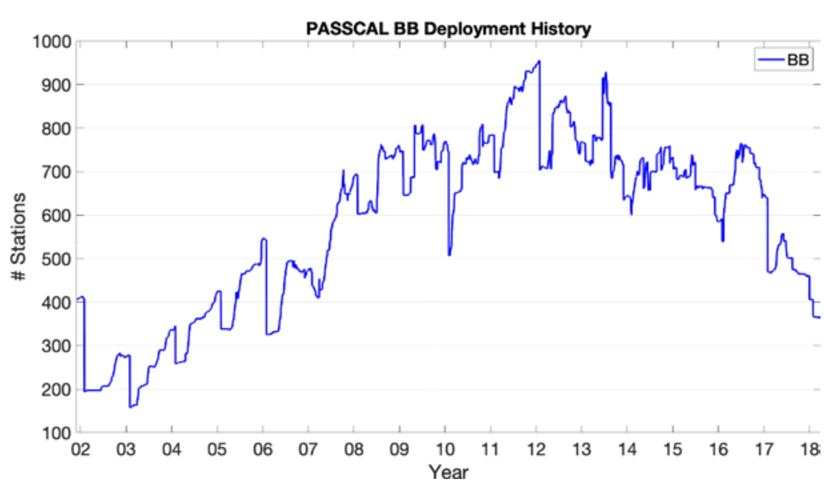

Figure B3. Instrument utilization over time for PASSCAL broadband (BB) with one-month buffer before and after deployment.

B2.2. Deployment Duration

Most PASSCAL broadband deployments have been for considerably longer durations (6–12 months) than OBSIP LP instrument deployments. Thus, LP instrument deployments for OBSIP appear to be artificially limited by the capabilities of the instruments.

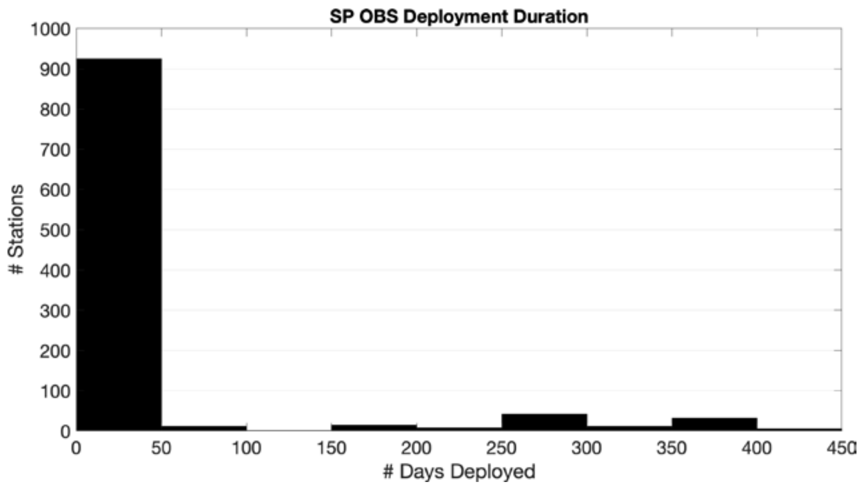

Figure B4. Deployment duration for all SP instruments.

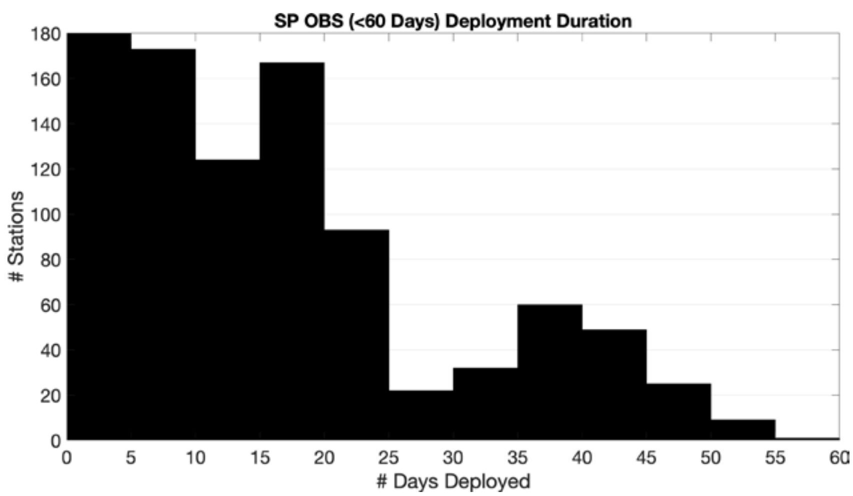

Figure B5. Deployment duration for SP instruments operating less than two months per station.

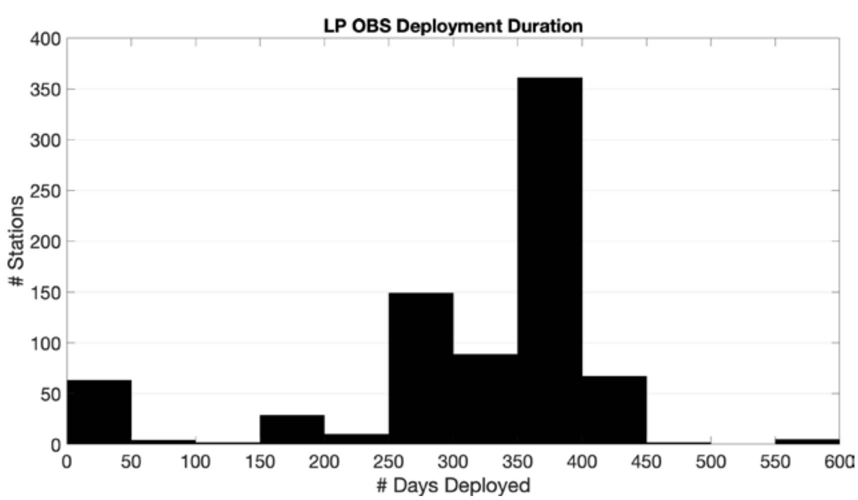

Figure B6. Deployment duration for all LP instruments.

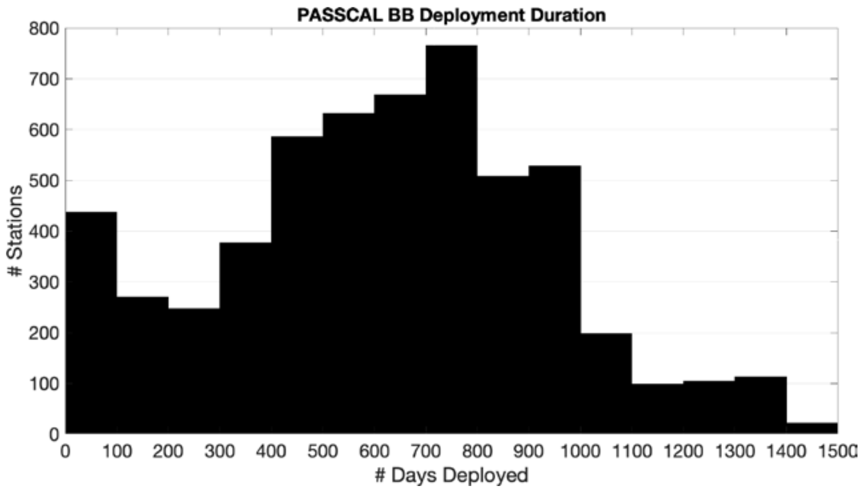

Figure B7. Deployment duration for all PASSCAL BB instruments.

B2.3. Deployment Depth

Many experiments span a large depth range, and it may be difficult to have shallow-water-only instruments in the fleet despite the potential cost advantages of such instruments.

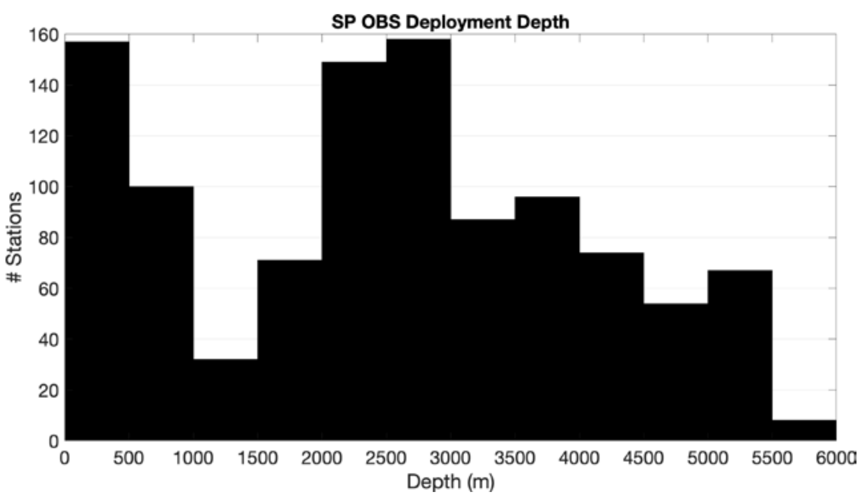

Figure B8. Depths deployed for SP instruments.

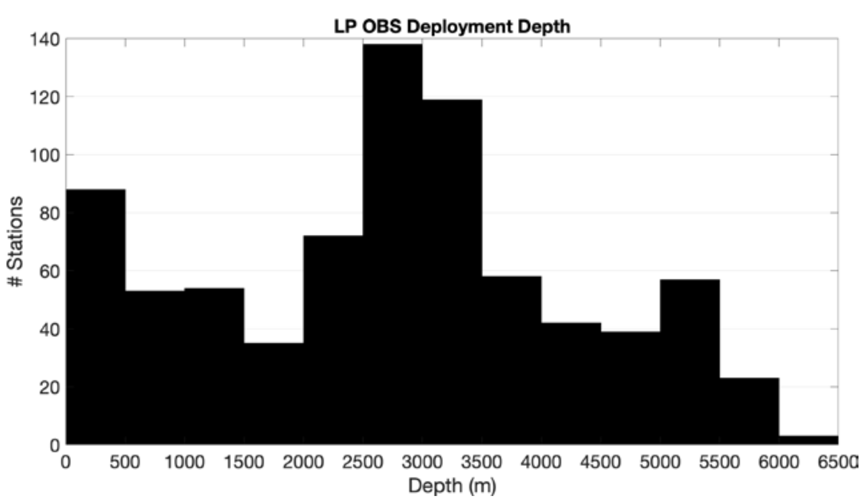

Figure B9. Depths deployed for LP instruments.

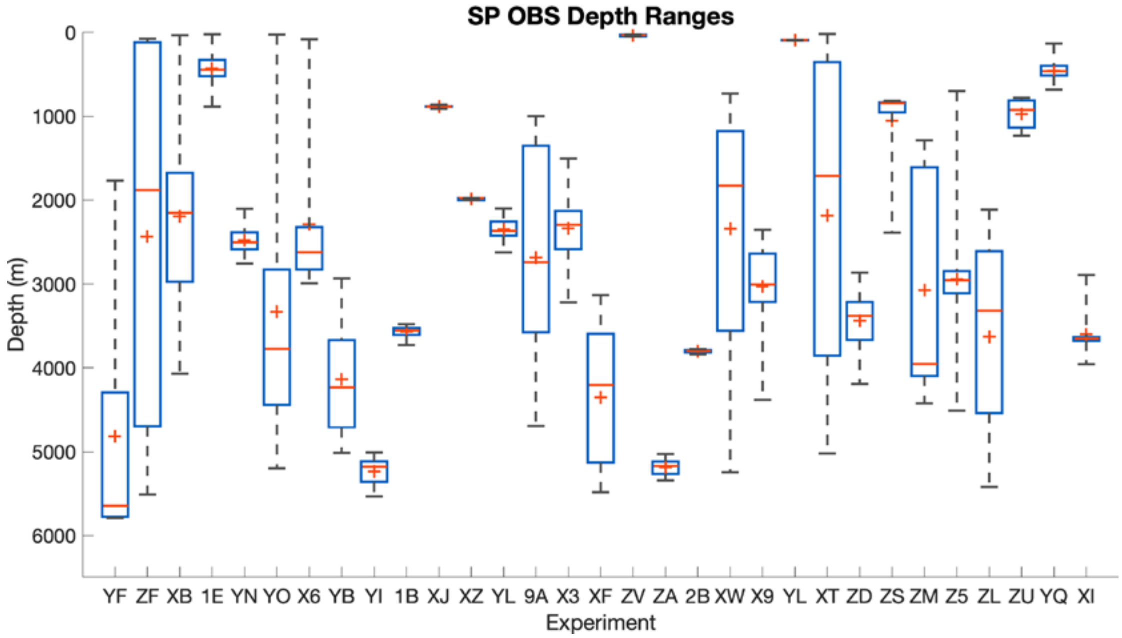

Figure B10. Range of depths for each SP experiment. Symbols used: mean (+), median (–), 25-75% percentile (□), dashed (--) upper and lower limits show minimum and maximum depth.

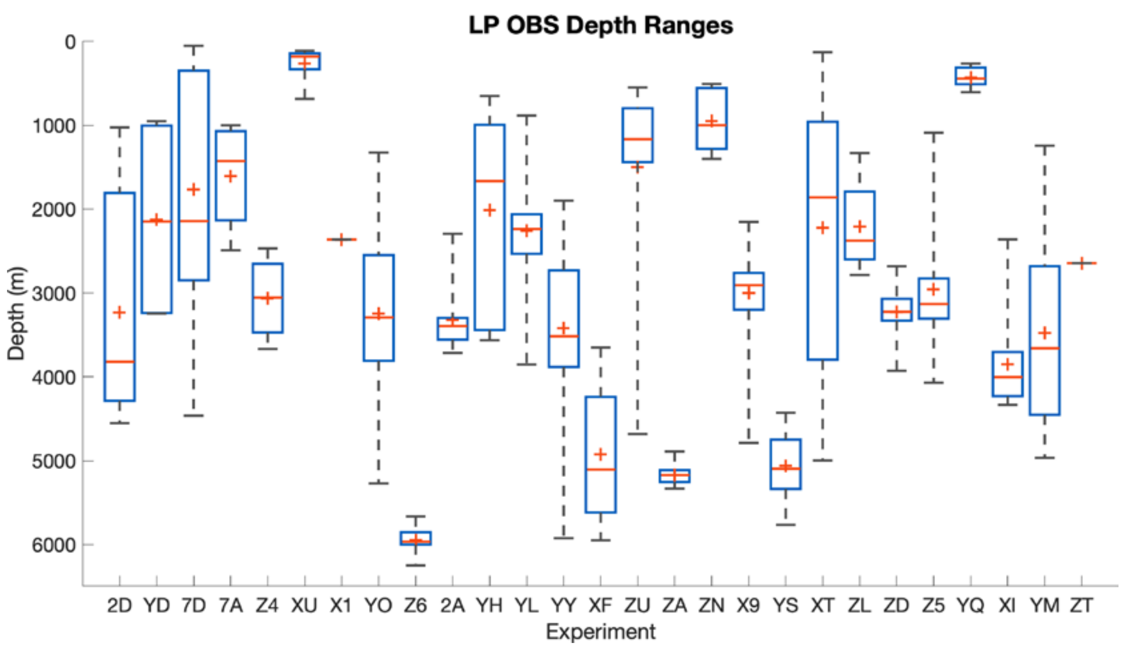

Figure B11. Range of depths for each LP experiment. Symbols same as previous figure.

B2.4. Deployment Area

Most experiments are deployed over areas that are less than ~300 x 300 km. The relatively modest inter-station spacing that is implied thus puts a premium on the ability to prepare and deploy instruments rapidly, with minimal deck-based check-out processes.

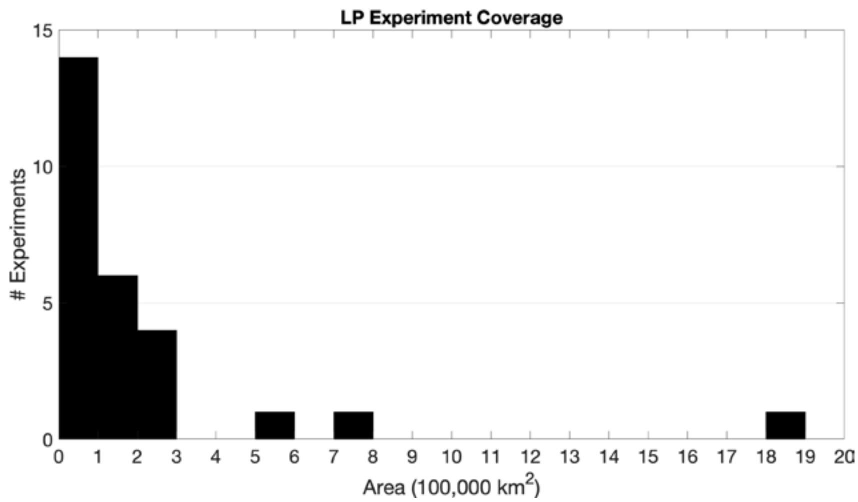

Figure B12. Areal distribution of LP experiments. Outliers are the Cascadia Initiative, MOANA, and PLUME.

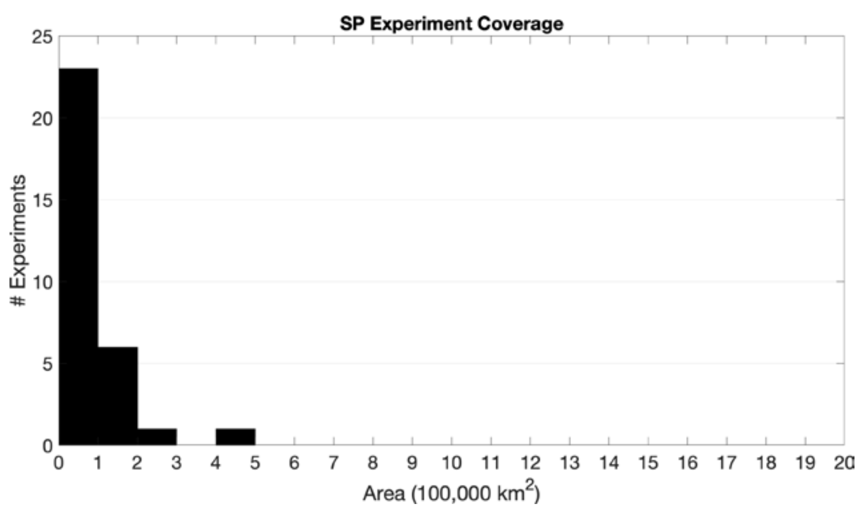

Figure B13. Areal distribution of SP experiments. The outlier is the SE Caribbean Passive Experiment.

B3. INSTRUMENT PERFORMANCE

By examining the quality characteristics of OBSIP data we can understand if the instruments are performing as well as they should, in terms of both data return for recovered stations and the ambient spectra recorded throughout an experiment. We use quality metrics generated by MUSTANG (http://services.iris.edu/mustang/measurements/1/) to develop a high-level look at these aspects of OBSIP data archived in miniSEED.

B3.1. Uptime

Network deployments on land typically achieve a mean uptime above 85%. There appear to be two trends at work. LP stations appear to have a lower data return than SP stations, possibly relating to the length of deployment (i.e., the longer an instrument is deployed the more time there is for something to fail). However, when factoring in component failures that can be seen visually in SP spectra, these instruments appear to be more sensitive to failures and thus potentially diminish the data returns even for short deployments.

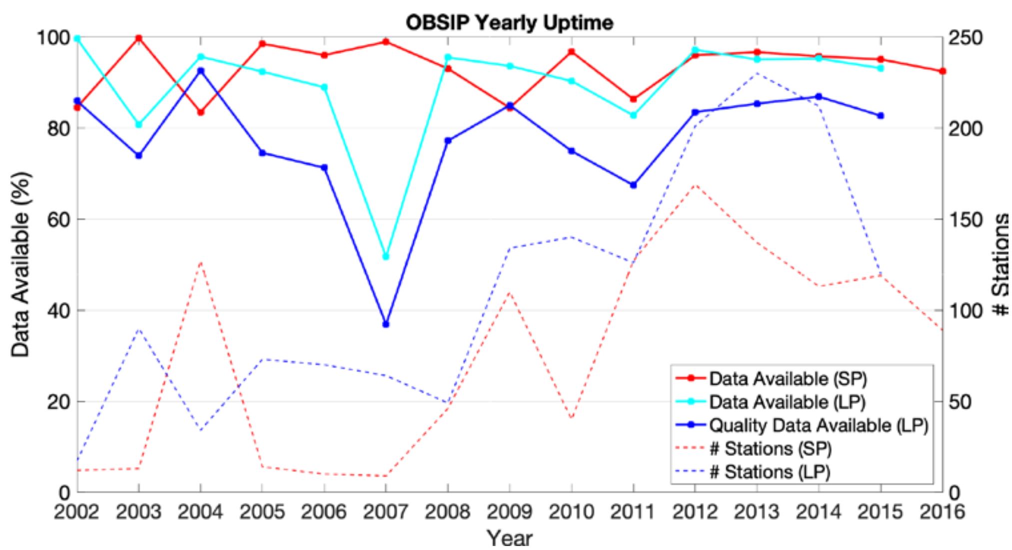

Figure B14. We show the yearly uptime and number of stations deployed for LP (BH/HH channels) and SP (EL channels) from 2002 to 2016. Mean percent availability for SP experiments is 93%. Mean percent availability for LP experiments is 89.4%. Mean quality data availability, which has screened out potentially dead channels for BH and HH data, drops to 77% for LP experiments. Note: Many SP experiments are very short duration, and thus data availability for those may be lower than expected due to partial days at the beginning and end. In addition, when instruments are lost during experiments sometimes their metadata are not entered into the IRIS DMC, resulting in an artificially higher return.

Net	H Passed	Z Passed	H Failed	Z Failed	Z Passed	3C Passed
2A	11	11	23	23	32.4%	32.4%
2D	17	17	5	5	77.3%	77.3%
7A	10	10	0	0	100.0%	100.0%
7D	194	199	58	53	79.0%	77.0%
X1	1	1	0	0	100.0%	100.0%
X9	29	29	1	1	96.7%	96.7%
XF	9	9	11	11	45.0%	45.0%
XI	11	11	5	5	68.8%	68.8%
XT	10	10	1	1	90.9%	90.9%
XU	9	10	7	6	62.5%	56.3%
YD	2	2	5	5	28.6%	28.6%
YH	7	7	3	3	70.0%	70.0%
YL	41	45	10	6	88.2%	80.4%
YM	12	12	9	9	57.1%	57.1%
YO	26	26	4	4	86.7%	86.7%
YQ	6	6	0	0	100.0%	100.0%
YS	52	52	10	6	89.7%	83.9%
YY	31	36	41	36	50.0%	43.1%
Z4	2	2	2	2	50.0%	50.0%
Z5	31	32	13	12	72.7%	70.5%
Z6	6	6	4	4	60.0%	60.0%
ZA	15	15	7	7	68.2%	68.2%
ZD	21	22	7	6	78.6%	75.0%
ZL	8	8	0	0	100.0%	100.0%
ZN	7	7	1	1	87.5%	87.5%
ZU	27	27	2	2	93.1%	93.1%
All	**595**	**612**	**229**	**208**	**74.6%**	**72.2%**

Table B1. For archived LP stations with calculated power spectral densities (PSDs), we examined the performance of individual components. If a component showed obvious signs of failure for the majority of the deployment, then it was removed from consideration. Because station orientation is non-geographic, we removed both horizontal components even if only one had failed. Overall 74.6% of stations had a useful vertical component recording and 72.2% of stations produced usable data for all three components.

Net	H Passed	Z Passed	H Failed	Z Failed	Z Passed	3C Passed
1B	6	6	8	8	42.9%	42.9%
1E	64	75	23	12	86.2%	73.6%
2B	5	15	12	2	88.2%	29.4%
9A	5	8	7	4	66.7%	41.7%
XF	35	41	9	3	93.2%	79.5%
XI	7	12	6	1	92.3%	53.8%
XJ	9	14	6	1	93.3%	60.0%
XT	44	83	70	31	72.8%	38.6%
XW	42	46	9	5	90.2%	82.4%
XZ	30	39	16	7	84.8%	65.2%
YB	18	24	17	11	68.6%	51.4%
YF	2	4	7	5	44.4%	22.2%
YI	2	4	3	1	80.0%	40.0%
YL	22	35	19	4	89.7%	53.7%
YN	40	58	24	6	90.6%	62.5%
YO	73	84	22	11	88.4%	76.8%
YQ	21	21	5	5	80.8%	80.8%
Z5	17	19	3	1	95.0%	85.0%
ZA	14	20	10	4	83.3%	58.3%
ZD	2	10	22	14	41.7%	8.3%
ZL	11	22	17	6	78.6%	39.3%
ZL	1	1	2	2	33.3%	33.3%
ZM	1	4	4	1	80.0%	20.0%
ZS	7	12	9	4	75.0%	43.8%
ZU	10	11	2	1	91.7%	83.3%
ZV	3	4	2	1	80.0%	60.0%
All	**491**	**672**	**334**	**151**	**81.7%**	**59.5%**

Table B2. We conducted a similar analysis for SP stations. Overall 81.7% of stations had a useful vertical component recording and 59.5% of stations produced usable data for all three components. This appears to demonstrate a much higher failure rate for individual channels on SP instruments, despite typically shorter run times.

B3.2. Ambient Spectra

Different experiments and classes of instruments under OBSIP show significant variations in performance that likely relate to multiple factors. Further analysis of these trends may help to inform future instrument development and deployment practices to maximize data quality.

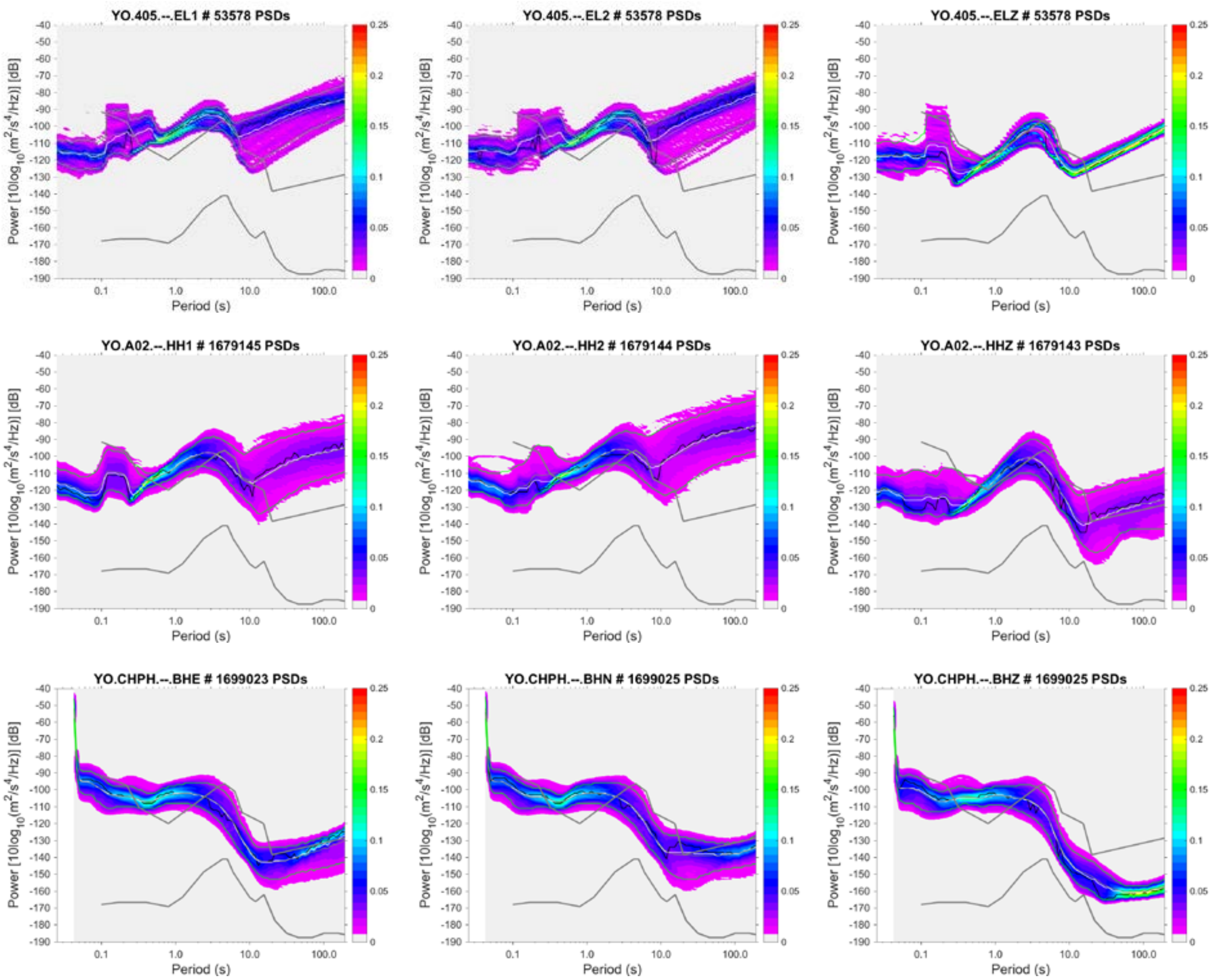

Figure B15. Probability density functions (PDFs) of all PSDs for example SP (405), LP (A02), and on-shore BB (CHPH) stations from the ENAM (http://ds.iris.edu/gmap/#network=YO&starttime=2014-01-01T00:00:00&endtime=2015-12-31T23:59:59&planet=earth) community experiment. These examples show different characteristic spectra relating to both the type of instrument and deployment environment. Low ambient signal power at short and long periods generally indicates that arrivals from natural and artificial seismic sources may be effectively recorded.

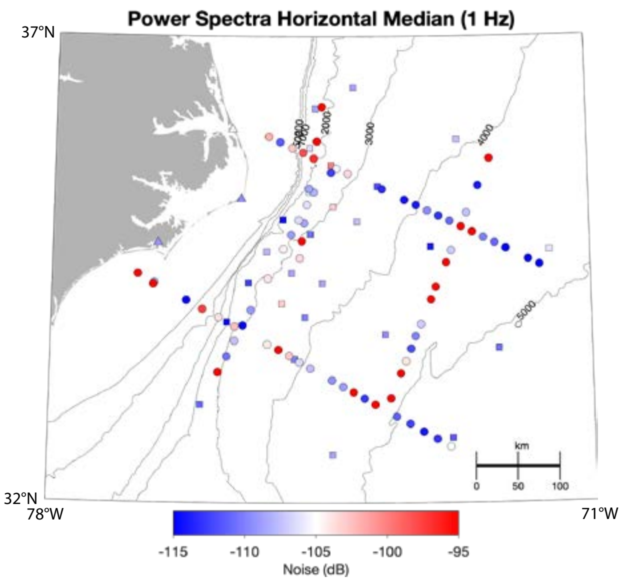

Figure B16. For ENAM, we map the median horizontal and vertical spectra at LP (□), SP (○), and on-shore BB (△) stations at 1 Hz. Power level at this period largely depends on the proximity to the break in the continental shelf, but variations within the array can also be observed.

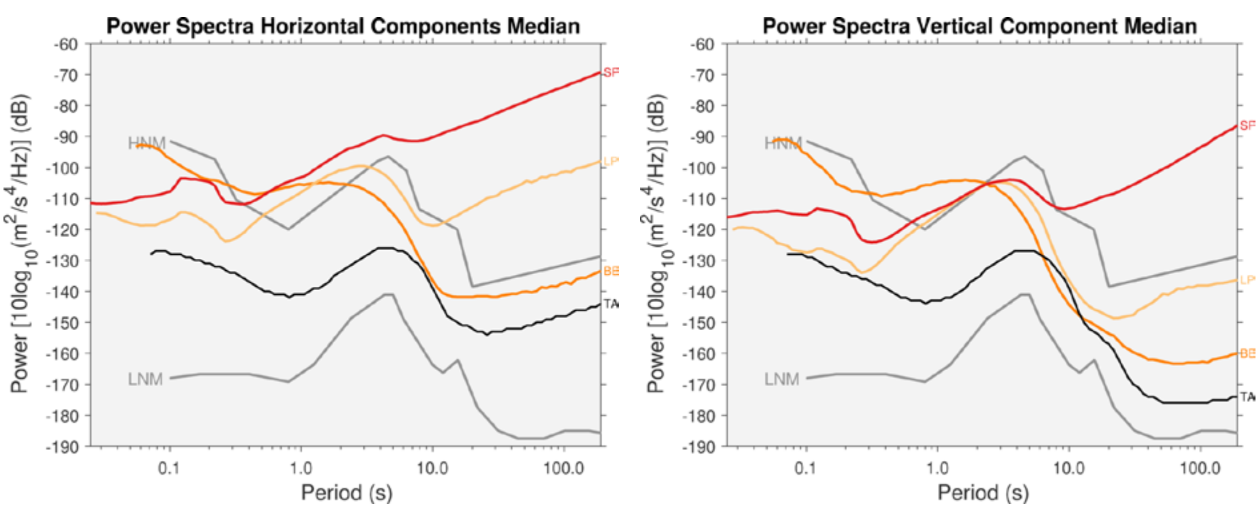

Figure B17. For ENAM, we compare the median power spectra from the PDFs for all SP, LP, and BB stations. SP instruments are generally insensitive to longer periods. The EarthScope Transportable Array in the Lower-48 US is included.

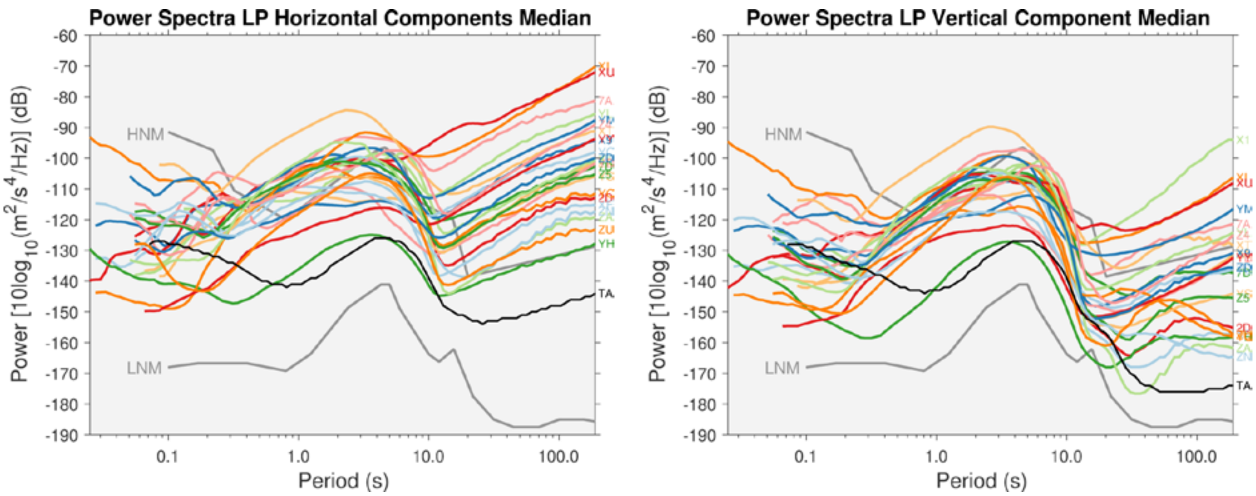

Figure B18. The median power spectra for all LP experiments.

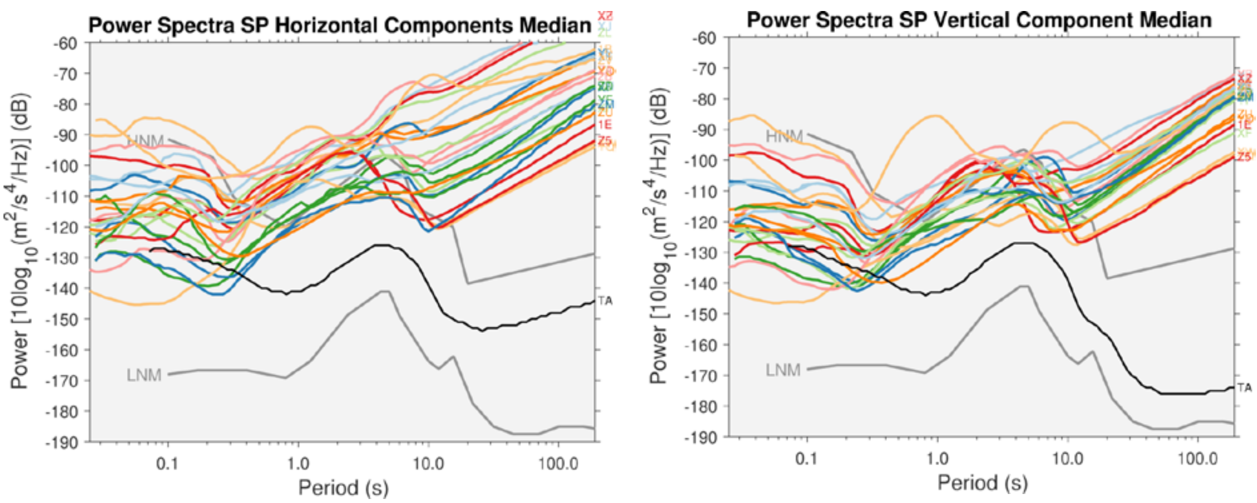

Figure B19. The same analysis is conducted for SP experiments.

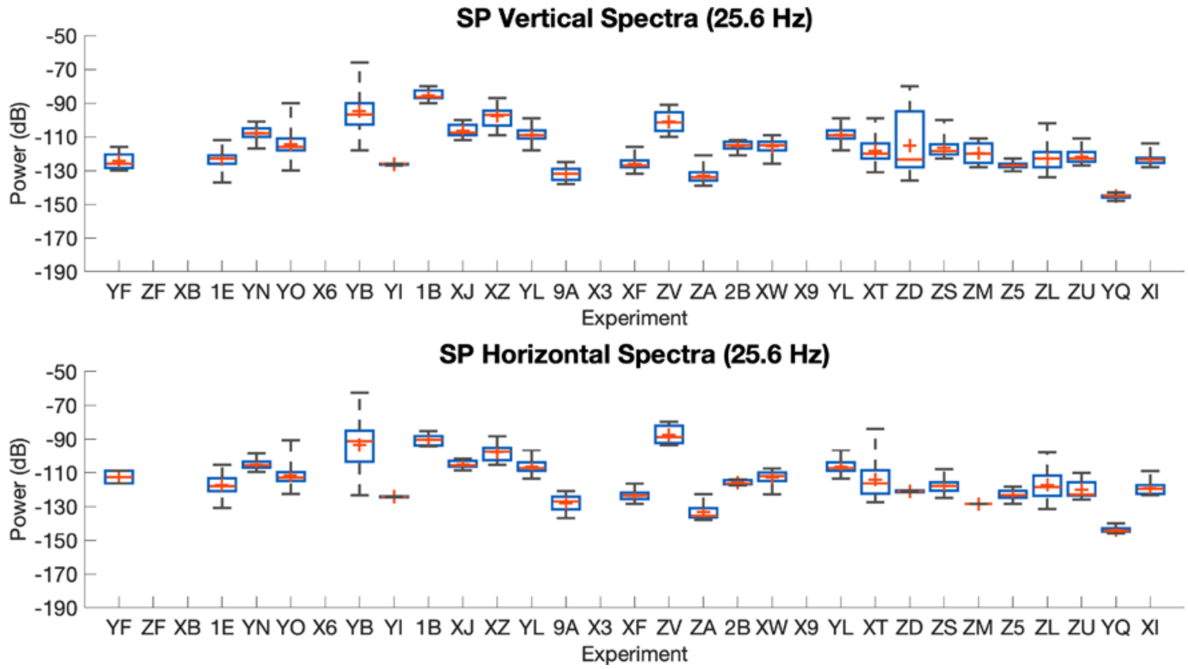

Figure B20. Power spectra for OBSIP SP experiments at 25.6 Hz. Symbols used: mean (+), median (–), 25-75% percentile (□), dashed (--) upper and lower limits show minimum and maximum noise for all LP stations in each deployment.

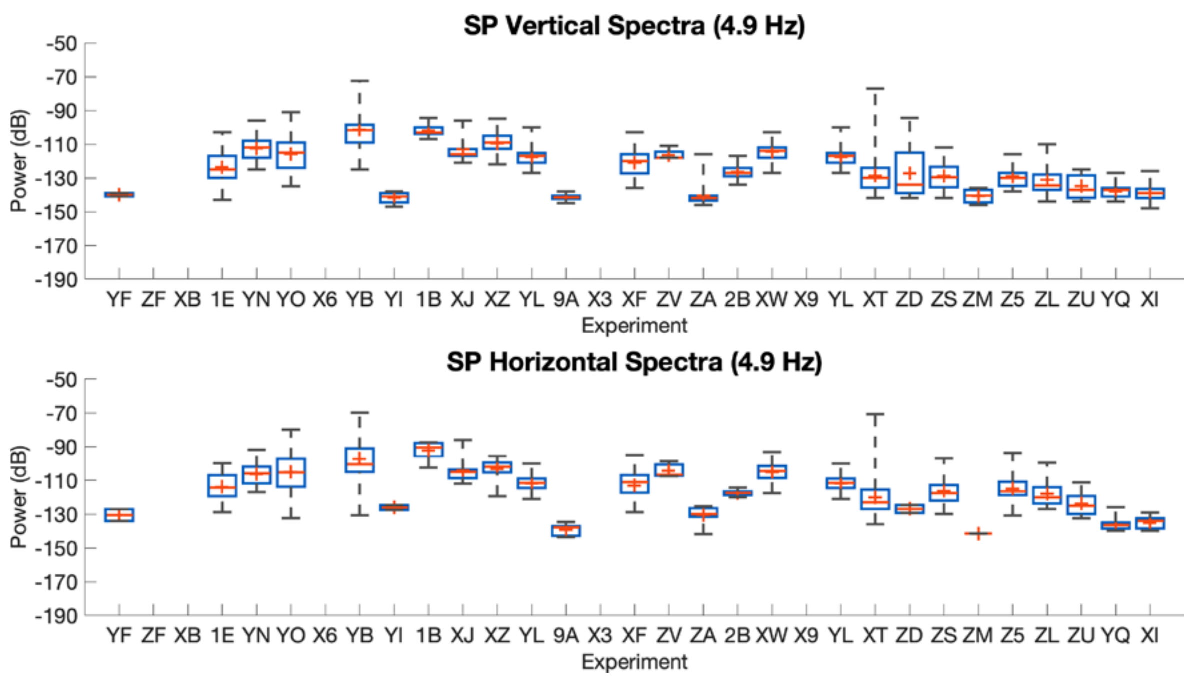

Figure B21. Power spectra for OBSIP SP experiments at 4.9 Hz. Symbols same as previous figure.

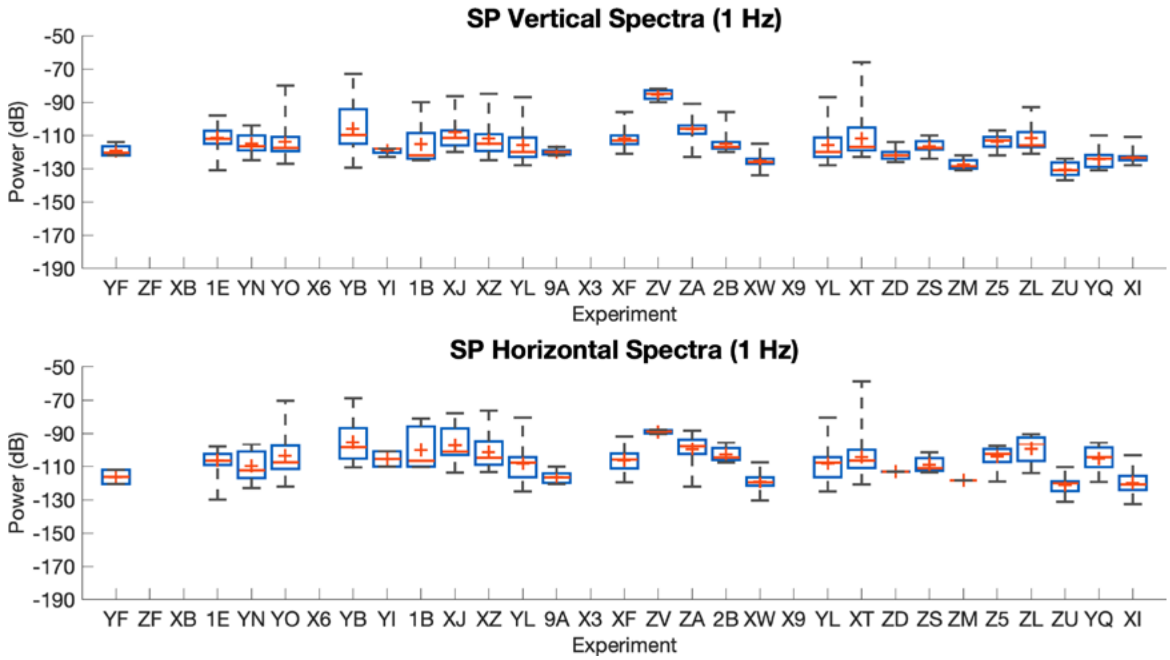

Figure B22. Power spectra for OBSIP SP experiments at 1 Hz. Symbols same as previous figure.

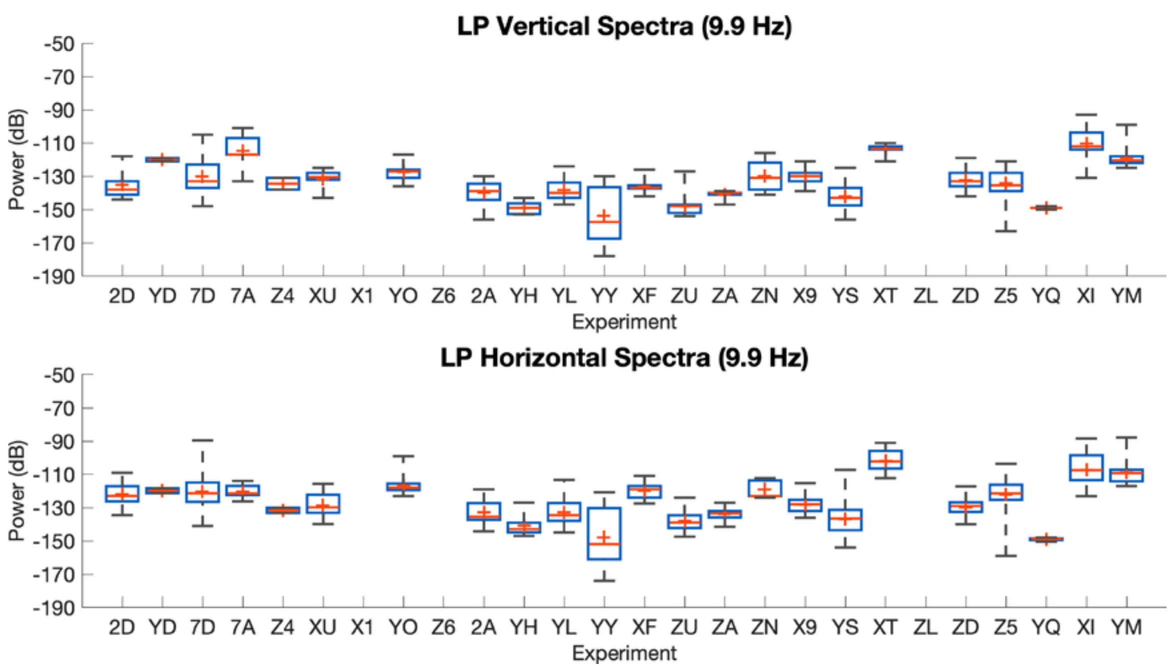

Figure B23. Power spectra for OBSIP LP experiments at 9.9 Hz. Symbols same as previous figure.

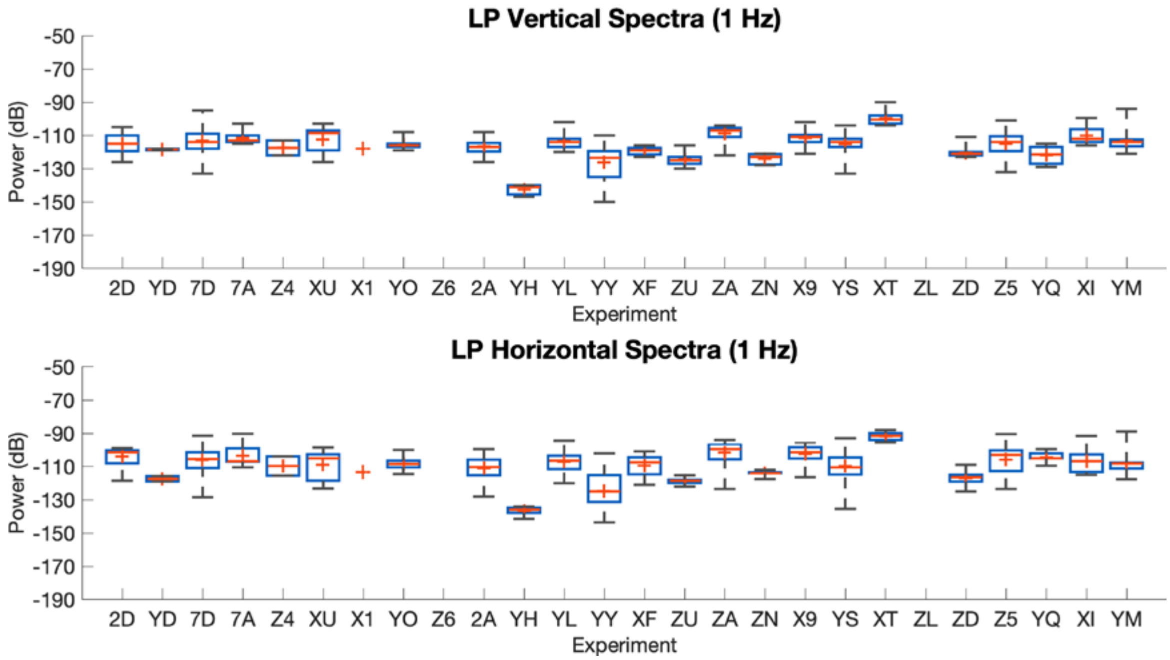

Figure B24. Power spectra for OBSIP LP experiments at 1 Hz. Symbols same as previous figure.

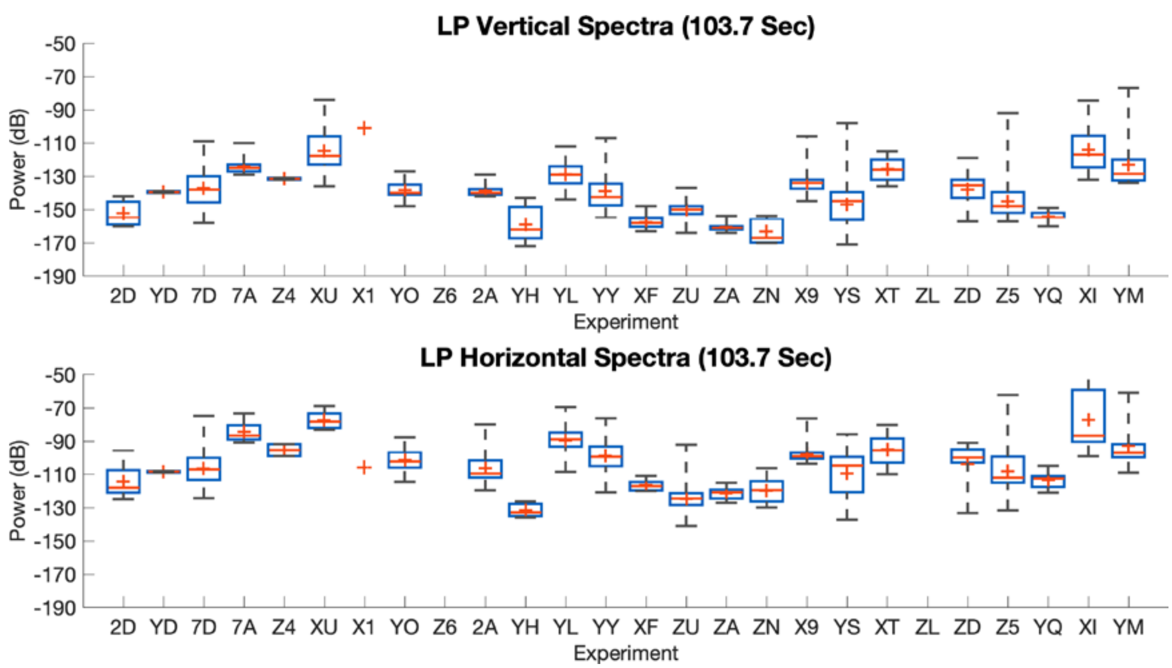

Figure B25. Power spectra for OBSIP LP experiments at 103.7 seconds. Symbols same as previous figure.

B4. COST CONSIDERATIONS

Proposals planning to use OBSIP facilities included informational budgets produced by OBSIP management, and only a subset of these experiments were funded. Prior analysis indicates that these budgets track reasonably well with funds actually expended to support an experiment.

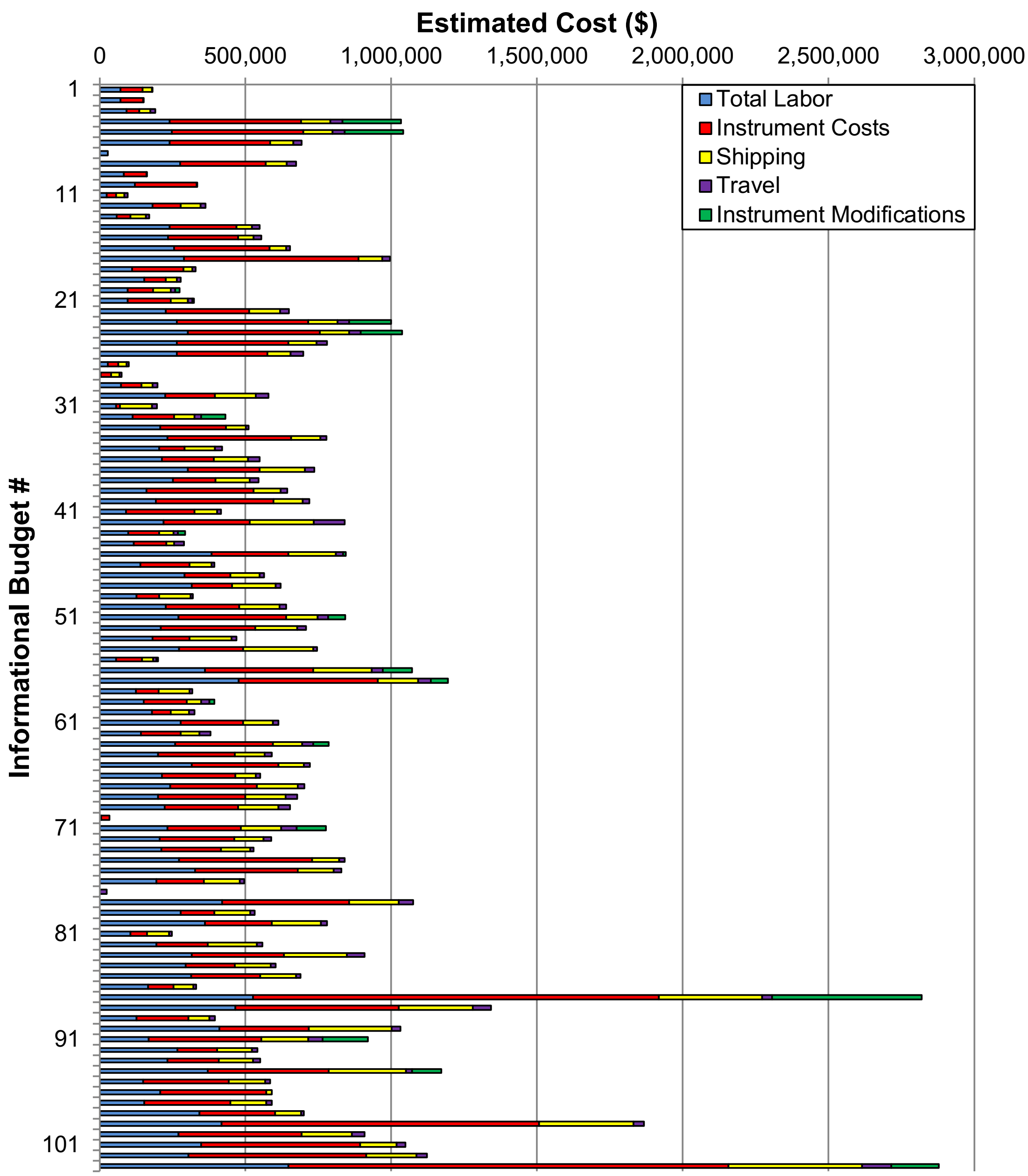

Figure B26. A compilation of 103 informational budgets furnished for proposals between 2012 and 2018 that shows that the labor required to support the instruments and the actual instrument costs (largely batteries and drop fees) are the dominant cost drivers. Apart from ship-time considerations, the high current cost of performing OBS experiments makes it obvious why only a small number of experiments per year are funded.

Appendix C
Bibliography of OBSIP Citations (2011–2019)

Publications, reports, dissertations, and theses that were aided or enabled through the use of the OBSIP facility are listed below, arranged first by year of publication and then alphabetically by first author. Frequent updates and citations searches were made, however this list may not be comprehensive.

2019

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Seafloor absolute pressure gauges from LDEO are lashed to the deck of R/V *Roger Revelle* to keep them secured during rough seas offshore Gisborne, New Zealand during the HOBITSS experiment. *Photo credit: Justin Ball*

The final three SIO ABALONE OBS stand ready for deployment on R/V *Oceanus* during the 2013 deployment cruise for the Cascadia Initiative as the sun dips down below the horizon. *Photo credit: Kasey Aderhold*

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