PACSAFE Leg 1 OBS Deployment NFSI-005-2023-02 CCGS John P. Tully

Oct. 11 – 27, 2023

National Facility for Seismological Investigations

Dalhousie University

Funding

The NFSI-005-2023-02 cruise was the first leg of the five-year Pacific Coast Seismic Assessment for Faults and Earthquakes (PACSAFE) project, funded by NSERC Alliance grant ALLRP 571215-21. The project is a collaboration between researchers at the University of British Columbia, Dalhousie University, University of Victoria, and Natural Resources Canada. Principal Investigators and collaborators on the NSERC Alliance grant are listed below.

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Cruise Identification

Several unique identifiers are used in this and other documents to refer to this cruise. This report will use the NFSI-specific identifier wherever possible.

Organization	Cruise ID
NFSI	NFSI-005-2023-02
NSERC Alliance	PACSAFE Leg 1
NRCan	2023005PGC
Canada Coast Guard	PAC2023-059

Revision History

Date	Version No.	Author(s)	Approved By	Description
Feb 2024	1.0	G. Cairns, A. Schaeffer, K. Bosman, J. Thibodeau	G. Cairns	Base document

Contents

Cruise Participants

Science Party

Name	Affiliation	Role
Andrew Schaeffer	NRCan	Co-Chief Scientist
Cooper Stacey	NRCan	Co-Chief Scientist
Graeme Cairns	NFSI	OBS Manager
Katherine Bosman	NFSI	OBS Technician
John Thibodeau	NFSI	OBS Technician
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Sarah Oliva	UVIC	Post-doc
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Felix Parkinson	NRCan	Student

Ship's Crew (selected)

Name	Role
Frederic Hamilton	Commanding Officer
Allan Ramsay	First Officer
Melissa Knight	Second Officer
David Bolten	Third Officer
Wade Boettcher	Logistics Officer
John Gardner	Bosun
Steve Buss	Chief Engineer

Figure 0-1 - Science party celebrating deployment of the last OBS.

Summary

Between October 11 and 27, 2023, the NFSI-005-2023-02 expedition aboard CCGS John P. Tully deployed 28 broadband ocean-bottom seismometers (OBS) offshore British Columbia, in the first deployment of the five-year PACSAFE project. The original plan for this cruise was for a 30-OBS array offshore the Moresby Island region. This plan had to be abandoned due to adverse weather conditions, with other PACSAFE targets providing more tractable alternatives. In the end, 16 OBS were deployed around the Dellwood Knolls and Revere-Dellwood Fault, 10 along the Cook Bank Slope in the Scott Islands Marine Protected Area, and two in the Burke Channel along a newly identified fault in the Coast Shear Zone. Due to time constraints, only 9 of the 28 instruments were acoustically positioned on the seafloor. Positioning of the remaining instruments is planned for the recovery operation in 2024.

1.0 Introduction

NFSI-005-2023-02 was the first leg of the five-year PACSAFE (Pacific Coast Seismic Assessment for Faults and Earthquakes) NSERC-Alliance project, a collaboration between researchers at the University of British Columbia, Dalhousie University, University of Victoria, and Natural Resources Canada aimed at measuring seismicity along Canada's west coast. The PACSAFE project will deploy OBS at 5 targeted and poorly understood segments of the complex plate-tectonic fault system offshore western Canada over a 5-year period. Each fault segment possesses distinct seismic properties and can produce (or has produced) magnitude Mw 7-8+ earthquakes. The research enabled by this academic-NRCan partnership will lead to new scientific insights into the ways plate tectonic forces shape the deformation and evolution of faults offshore BC and accurate assessments of seismic, tsunami and submarine landslide hazards in Canadian Pacific territorial waters.

1.1 Background

The original objective for this cruise during Ship-time planning was to target the region offshore Moresby Island, NSERC Alliance Target `#2' (T2), to capture any remaining seismicity caused by aftershocks from the 2012 M7.8 earthquake. This was to be achieved by deploying 30 OBS in three lines sub-parallel to the trace of the Queen Charlotte Fault, as illustrated in Figure 1-1.

In the week leading up to departure, however, extreme storm forecasts led to concerns about the weather exposure of this location and loss of operational time transiting to and from shelter in Hecate Strait or coastal fjords. The plan was therefore modified prior to departure and adaptively during the cruise itself, to target alternative PACSAFE areas which could be fit within available weather windows.

In the end instruments were deployed primarily in the T4 area of the NSERC Alliance Grant: The Revere-Dellwood Fault (RDF), Dellwood Knolls (DWK), and the Cook Bank Slope (CBS) – Scott Islands Marine Protected Area (SIMPA; also referred to as SIMNWA, the Scott Islands Marine National Wildlife Area). The final deployment map is shown in Figures 1-2 (the RDF-DWK-CBS) and 1-3 (for the Burke Channel target of opportunity).

1.2 Mission Objectives

The Revere-Dellwood region separates the ocean-continent transpressive regime offshore Haida Gwaii from the Explorer Ridge (EXR) to the southeast. Deformation in this region is complex and, in contrast to the long-lived Queen Charlotte Fault (QCF) to the north, has developed recently and is evolving rapidly as a direct response to a change in relative plate motions between Pacific (PAC) and North America that occurred between ~6-12 Ma. The region can be divided into 2 components: a northern "extensional" component and a southern "compressional" one. In the north, deformation is distributed between the RDF and the southern continuation of the QCF, with concentrations at the Tuzo Wilson Seamounts (TWS) and the DWK, including 7 Mw≥6 events in the past 20 years. The TWS and DWK are enigmatic volcanic structures and have been variously interpreted as plume-driven hotspots associated with the Pratt-Welker seamount chain, spreading centers, and as a transtensional pull-apart basin.

Seismicity in this region is confined primarily to oceanic lithosphere (crust and shallow mantle lithosphere). Moment tensors of larger earthquakes are predominantly strike-slip, and compression is hypothesized to be compensated by transtension created by diffuse right-stepping structures associated with TWS and DWK between the dextral RDF and QCF. Seismicity concentrates along the RDF with 6 M>6 events recorded since 2000, with 1 of these in the last several months. A more diffuse, parallel band of weak seismicity follows the continental slope some 50 km to the northeast, along the CBS. Although the magnitudes of these events are low, they are hypothesized to represent compressional mechanisms associated with under thrusting of the Explorer Plate (Winona Block) below North America, and may portend rare but potentially hazardous (Mw≥7) thrust events.

The OBS array as deployed during this cruise includes 16 stations (T201-T216) deployed along the RDF from ~51˚N to its southern limit beyond the Explorer ridge, with an additional 10 stations (T220-T229) located along the continental slope to evaluate the extent of Winona Block under thrusting beneath NAM.

We further instrumented a target of opportunity, the crossing of Burke Channel by the Coast Shear Zone, a strain deformation feature accommodating right-lateral motion within the BC central Coast. This deformation is captured both by Geodetic instrumentation, as well as manifesting as a band of seismicity within this region. During the cruise, while running the Knudsen 3.5kHz sub-bottom profiler while transiting Burke Channel near the expected location of the strands of the Coast Shear Zone, we identified clear evidence for complete surface penetrating deformation of the Holocene sediments in the fjord bottom. As we were sheltering in this region and had a then unknown amount of time remaining in the offshore (at this point there were only 4 OBS instruments deployed offshore), we elected to drop two OBS stations in Burke Channel. The site T2BC1 is located in Burke Channel at the confluence of the North and South Bentinck Arms (~15 km west of Bella Coola) immediately adjacent to the sediment expression of the eastern extent of the Coast Shear Zone, and T2BC2, located within Burke Channel ~20km west of T2BC1, at the western extent of the Coast Shear Zone.

1.3 Maps

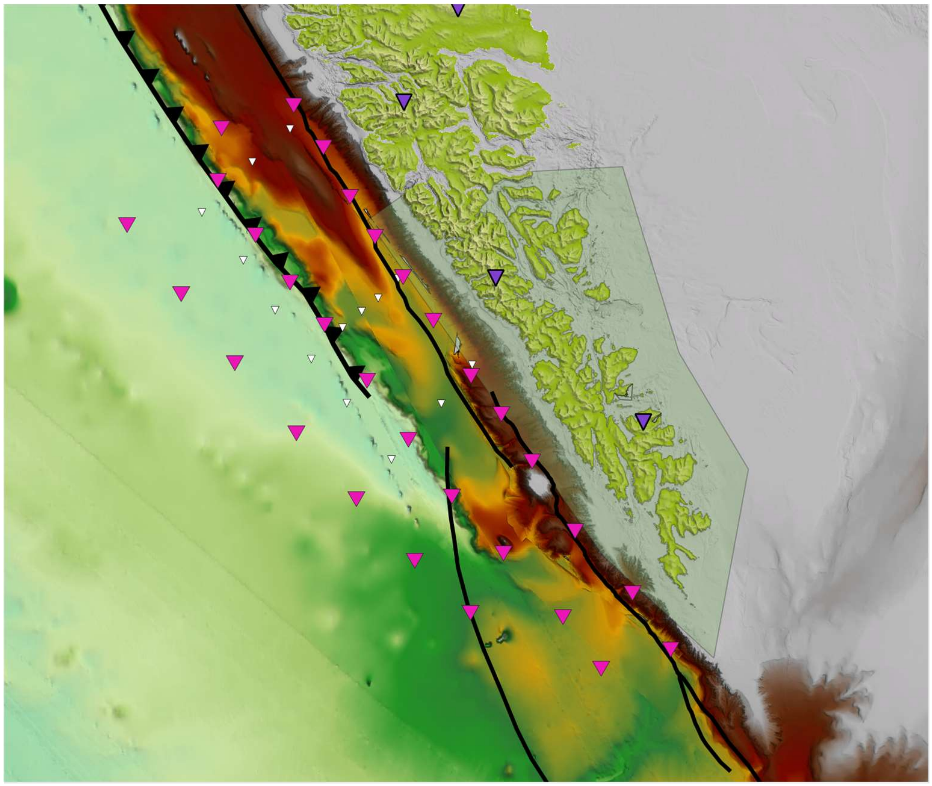


Figure 1-1: Moresby Island planned deployment. Purple triangles are existing onshore seismic stations and white triangles are past offshore short-period OBS locations. Pink triangles are the original planned OBS deployment.

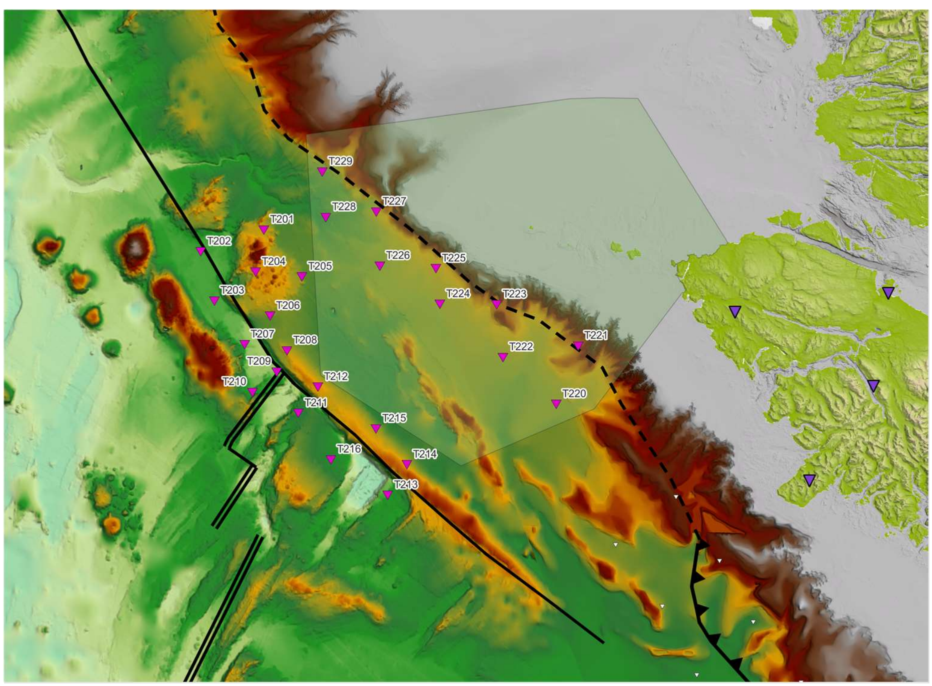


Figure 1-2: Locations of OBS drops for the NSERC Alliance T4 deployment carried out in Leg 1 (October 11-27, 2023). These 26 stations in pink denote the drop coordinates spanning the RDF, DWK, and CBS.

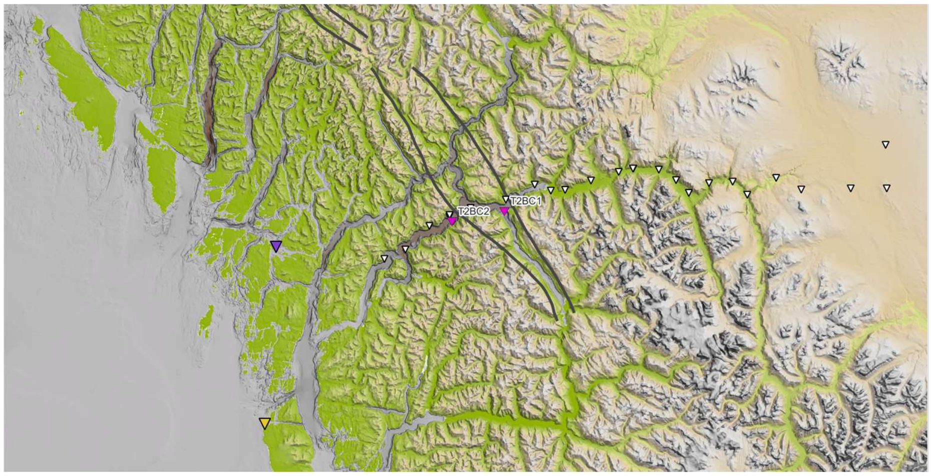


Figure 1-3: Additional two instruments (pink triangles) deployed within Burke Channel at the confluence with North and South Bentinck Arms, near Bella Coola. These sites coincide with observed seafloor deformation and earthquakes associated with the Coast Shear Zone (black lines). White triangles are decommissioned seismic stations from the 2009 BATHOLITHS project. The purple coastal triangle is CNSN Station BBB, Bella Bella. The yellow coastal triangle is station HAKB at the Hakai Institute on Calvert Island, GSC Public Safety Geoscience Program.

2.0 Instrument Preparation

Thirty Güralp Aquarius OBS belonging to NFSI had been left in storage at IOS following an attempted deployment in 2022 that was aborted due to a COVID outbreak. Ten of these instruments had been left running in their stillage boxes to test long-term performance and software stability.

On September 14, an LCL shipment of equipment was sent from Halifax to IOS in Sidney through Livingston Freight Forwarding, arriving on the 21st.

In mid-September 2023, a team of 4 engineers from Güralp arrived at IOS from the UK to carry out retrofits on the instruments in storage. This involved the following:

- Unpacking the instruments from the storage container (done by T. Carson, NRCan) and undeploying those which had been left running.
- Replacing metal inserts in the syntactic foam buoyancy, to address corrosion seen in the original inserts caused by inconsistent grades of stainless steel.
- Adding sacrificial anodes to the transponder cage and release arms to prevent corrosion.
- Modifying the release arm pivots to mount an elastic retraction mechanism.
- Replacing fragile Seacon HUML-18-BCR connectors with more robust SubConn Power Ethernet Circular DBH13M.
- Removing the HTI-04-PCA-ULF hydrophones from the instruments, to be shipped back to the manufacturer HighTech for repair. Dummy plugs were installed on the OBS in place of the hydrophone.

A circuit board on AQU-E661 was damaged during these retrofits. The electronic core of this instrument was shipped back to the UK for repair, leaving only 29 OBS available for NFSI-005-2023-02, none of which were equipped with hydrophones. All instruments underwent a 16-hour vacuum test following replacement of the ethernet connector. Unfortunately during this brief test the long-term test data from one of the instruments left running in October 2022 was lost, leaving only 9 full 11-month recordings.

On October 3rd, Katie Bosman from NFSI arrived at IOS to offload and QC test data from the instruments that had been left running, charge the batteries for the upcoming deployment, verify USBL mounting with Tom Carson, and begin other preparations for the cruise. On October 5th, an Air Canada Cargo shipment of items was forwarded from NFSI's St. Lawrence Seaway deployments of the previous week, arriving at the Victoria International Airport on the 6th. On October 8th, John Thibodeau and Graeme Cairns arrived from Halifax. Over the afternoon of the 8th and the 9th, final preparations were made with the goal of having the instruments as ready for deployment as possible before heading to sea. Preparations included:

- mounting of lifting frames and the addition of sacrificial anodes;
- cleaning and re-greasing of charger O-rings on OBSs;
- inspection of other connectors and hydrophone dummy plugs;
- assembly and testing of all recovery devices, with confirmation of Apollo messaging through the XeosOnline gateway.

Figure 2-1 - Katie Bosman cleaning O-rings on the Xeos recovery devices in the IOS hangar workshop.

Figure 2-2 - John Thibodeau working on mounting the lifting frames.

Figure 2-3 - Aquarius OBS lined up in the IOS hangar, ready for loading onboard.

3.0 Field Operations

3.1 Operational Summary

Deployment vessel	CCGS John P. Tully
Cruise start date	11 October 2023
Cruise end date	28 October 2023
Onboarding port	IOS, Patricia Bay, BC, Canada
Offboarding port	IOS, Patricia Bay, BC, Canada
OBS deployed	28
OBS positioned – Total (USBL)	9 (6)
VHF Beacon Frequency	159.480 MHz for all instruments
Long Term Backup Release Date	15 April, 2025

3.2 Mobilization

NFSI equipment mobilization to Tully started at 13:00 on October 10th. Lab/auxiliary equipment was loaded first. The 29 instruments that had been prepared in the IOS hangar were next moved 6-7 at a time using IOS' flatbed truck and stacked on the dock beside Tully, from where they were onboarded using Tully's 10T crane on the morning of the 11th. The OBS were stored in their stillage boxes on the quarterdeck as 11 stacks of 2-high on the port side, and 7 unstacked instruments within cable reach of the lab, ready for the first set of deployments. Concentration of instruments on the port side caused a significant list of the vessel until it was re-balanced before leaving port by shifting fluid between tanks.

Figure 3-1 - Instruments being lined up for loading on the IOS dock beside Tully.

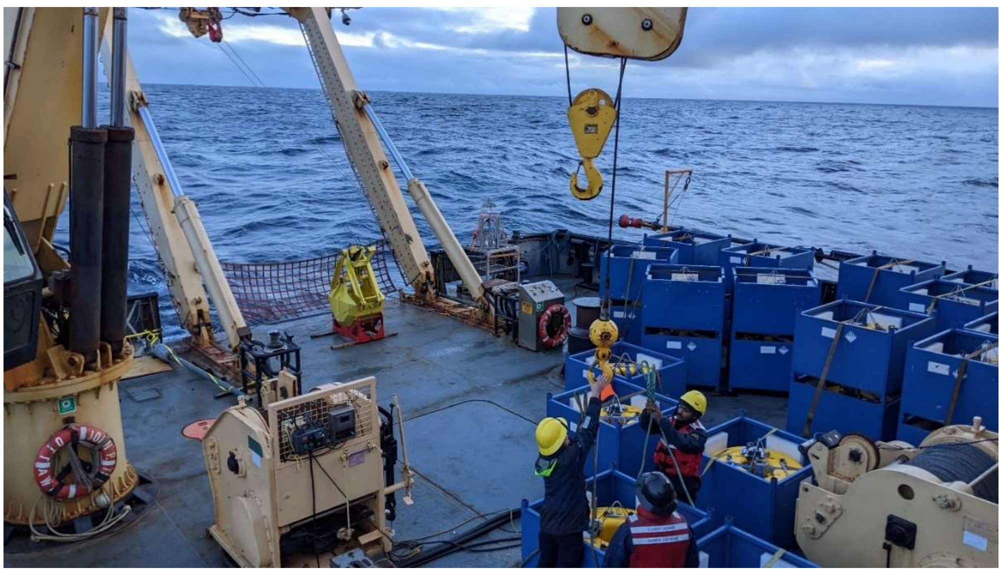


Figure 3-2 - Instrument storage on deck. 22 instruments were initially doubled-stacked on the port side of the aft deck, with 7 single-stacked within cable range of the lab in preparation for deployment.

3.2.1 USBL Installation

NFSI's Sonardyne Ranger 2 GyroUSBL was mounted on the port-side pivoting USBL pole at 15:00 on Oct. 11th, shortly before leaving port. An improvised insulating rubber flange was used to insulate the USBL head from the mounting bracket. The cable was run out of a hole in the bracket and up the pole on the outside, with tie-wraps and tape to hold it in place. The NRCan USBL Flange cable guide hole was manually enlarged by Tom Carson to accommodate the slightly larger connector of the NFSI cable from that of NRCan. The distance from the bottom of the USBL to the water line was later measured to be 5.75m. As Tully's draft is nominally 4.5m (confirmed by measurement during crew change on Oct 25th), the transducer reached only 1.25m below the bottom of the hull, significantly less than the 2m manufacturer recommended minimum for clean communication.

Figure 3-3 - Sonardyne Ranger 2 GyroUSBL mounted on port side pole of CCGS John P. Tully.

Noise levels were assessed at sea during use of the GyroUSBL. During initial testing, significant interference was observed from the 18kHz depth sounder used on board (Figure 3-4). This sounder was turned off during all following acoustic communication. Representative noise levels during USBL operations are shown in Figure 3-5. Average noise levels across the LMF range (14-19 kHz) are between 90-105 dB. Guidelines from Sonardyne consider values greater than 100dB as "noisy"; this installation can therefore be characterized as moderate-high noise. All modem addresses used in this deployment are in the top half of the LMF range (carrier frequency ≥16kHz), which experienced slightly lower noise than the low end of the range, but signal-to-noise ratios were still impacted by sub-optimal noise conditions.

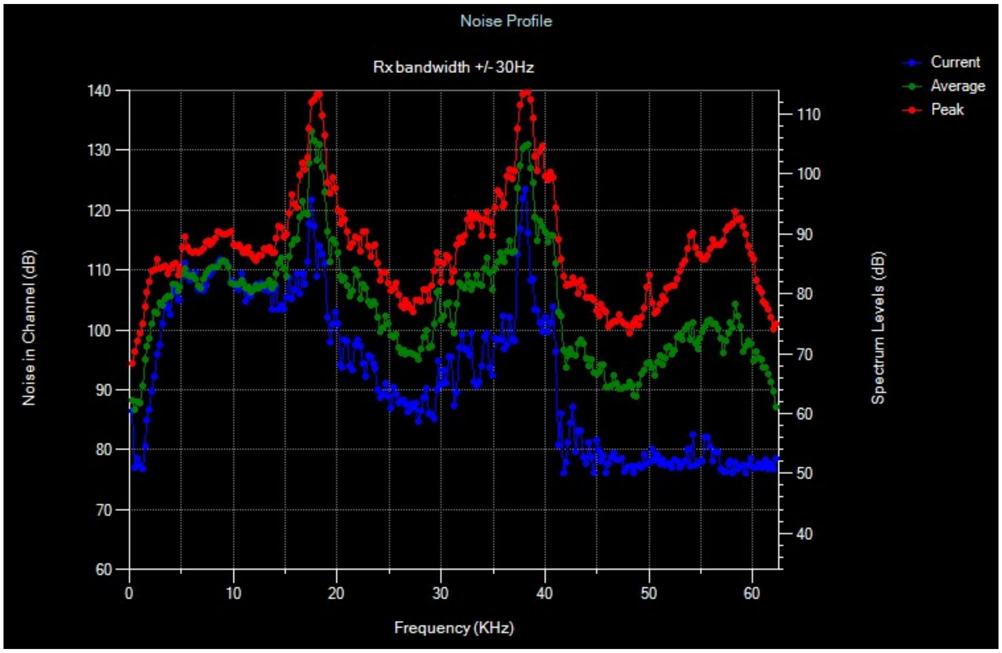


Figure 3-4: Spectral noise plot for USBL transceiver with 18 kHz sounder left on. Significant interference is observed at 18 and 37 kHz. The LMF band of interest is 14-19 kHz.

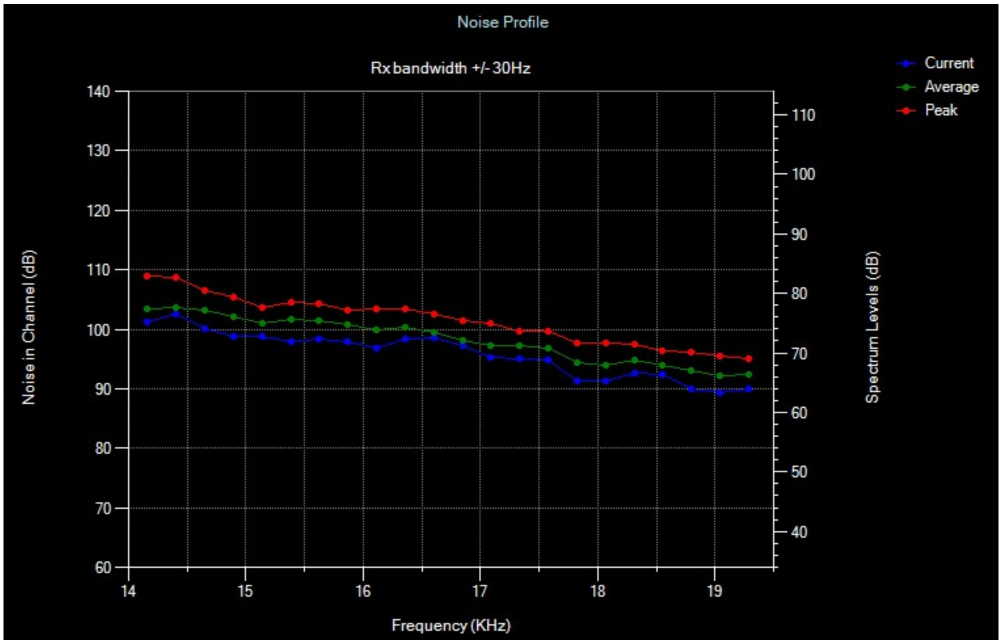


Figure 3-5: Noise levels for USBL transceiver installed aboard CCGS John P. Tully, as measured on October 14, 2023.

A COMNAV Vector G2 GPS unit was mounted directly on the top of the USBL pole. This unit, borrowed by NRCan from ROPOS, had been used in this configuration by a previous group. While having the advantage of nearly zero axial offset from the USBL in its deployed state, the positioning was found by NFSI to be poor for satellite reception, due to signal blockage by the ship's hull on one side, and from overhead structure above, resulting in low quality metrics and dropouts. We therefore switched to using the ship's GPS input after the first couple of days of operation, although only approximate measurements of offset for this were available.

Figure 3-6 - Mounting of GPS receiver on top end of USBL pole. This configuration, which had been used by previous groups, gave poor GPS reception. GPS input from the ship's navigation system was substituted later in the cruise.

3.2.2 Accessory Equipment Setup

NFSI’s accessory equipment was set up on the aft bench of the science lab, with cables run through conduits from external devices to equipment inside. The USBL computer was installed in the aft port corner, closest to the location of the USBL pole. An Aquarius Deck Unit was set up near the center of the aft bench, with cable connection to the OBS on the quarterdeck, a GPS receiver strapped to the rear port corner of the focsle deck rail, and a Sonardyne dunker used for deck-testing acoustic communications with the OBS prior to deployment.

Figure 3-7 - Laboratory setup onboard Tully. The large blue box in the back right hand corner is the USBL computer running Ranger 2. The yellow Pelican case computer left of center is an Aquarius Deck Unit, used for programming the OBS via a cable run through a conduit over the window.

When communication with deployed instruments was carried out using a dunker, rather than the USBL, a second Aquarius Deck Unit was set up in the wet lab, with the dunker cable run out of the wet lab door as the transducer was lowered over the starboard rail immediately outside the wet lab. For positioning operations using the dunker, a second GPS receiver was set up on the starboard focsle deck rail, with a cable run down to the wet lab.

Figure 3-8 - Sonardyne omni-directional dunker being deployed over the side of the ship from the wet lab.

3.3 Cruise Operations

3.3.1 Cruise Narrative

2023 Date	Event
3-7 Oct	Katie Bosman in Victoria for OBS instrument prep at IOS, with support from Tom Carson and Andrew Schaeffer. Battery charging, activating and testing Apollo GPS beacons, offloading test data from all OBS. Discussion of USBL mounting and GPS requirements. Pick up AC Cargo shipment of tools and other equipment.
Sun. 8-Oct	Graeme Cairns and John Thibodeau arrive in Victoria. Continued test data offload, instrument prep, cleaning and testing 10 VHF beacons.
Mon. 9-Oct	Full day of instrument prep – mounting cages, cleaning and testing remaining VHF beacons, cleaning O-rings and connectors. Discussion between NFSI staff and chief scientists of OBS deployment alternatives in view of poor weather forecast.
Tues. 10-Oct	Tully arrives IOS at about 07:00. Offloading of previous cruise's equipment in the morning. Repacking tools for loading onto ship. Onboarding of 2023005PGC equipment begins at 13:00. Lab equipment moved first along with other NRCan equipment, then 29 OBS shuttled from hangar to vessel in groups of 6-7 using flatbed truck. Vancouver members of science team arrive at 17:00. NFSI and Vancouver team sleep onboard. Departure scheduled for today but delayed due to need to find a replacement ship's engineer.
Wed. 11-Oct	OBS instruments onboarded with crane, arranged and strapped down on quarterdeck. 22 double-stacked on port side, 7 single stacked in deployment staging area. Lab setup completed. Discussion with bosun about hours of operation. OBS deployments will only be possible during day-shift hours (0700-1900) and positioning at night as originally planned will not be possible due to lack of experienced deck crew for raising and lowering USBL pole. 12:00 Safety briefing on bridge and ship tour. 13:00 Fire and boat emergency drill. 17:00 Complete Ranger 2 USBL mount on port side pole. 18:00 Science meeting in lab to discuss cruise and deployment plans. 18:30 Tully leaves dock, begins transit north to Queen Charlotte Strait. 19:30 GPS mount for USBL completed and tested.
Thurs. 12-Oct	Transiting to Queen Charlotte Strait. Weather foggy, seas flat calm. Latest weather forecast suggests we may need to shelter for up to 3 days early next week. Added to time restrictions for deck operations and possibly needing to head back to port 3 days early to change engineers, this cuts deployment time down to about 5 days of 12 hrs. 08:00 First OBS drop scheduled for 07:00 on Saturday Oct. 14th. Ongoing discussion between Chief Scientist and NFSI staff of deployment alternatives and tradeoff between number of instruments down vs positioning. 08:40 Toolbox meeting with bosun to outline OBS deployment procedures, safety considerations, and contingencies for possible recovery. 13:00 Katie running QC scripts remotely on Dal workstation to QC test data from 9 instruments that were left running in container at IOS over past year. 17:30 Arrive Queen Charlotte Strait, start overnight 3.5 kHz SBP survey. 19:00 Based on drift statistics from Laurentian Fan deployment (2021), agreement of project leaders to prioritize number of instruments down over accurate positioning. Plan to do full positioning on the first 2 sites in order to check drift, deploy remainder without positioning during daylight hours,

	position when possible using dunker overnight, and return with USBL if there is time at the end of deployments.
Fri. 13-Oct	QC Strait sampling: gravity cores, grab samples, camera drop operations. 14:15 Rigging up of USBL pole and testing putting it down. Interference of 18 kHz depth sounder with USBL noted. Need to turn depth sounder off during acoustic communications. 15:15 USBL pole up. Proceeding to next site for cores and grabs. 16:00 Katie and John have Discovery running on USBL computer. 16:30 Discussion of backup release timer to use for deployments. On deck, set to descent time plus 1.5 hours to allow for troubleshooting if necessary. Once deployed, reset to mid-April 2025 (18 months). 18:20 Transiting to region of Revere Dellwood Fault and Dellwood Knolls for start of OBS deployments. Weather picking up – overcast, whitecaps and building wind/waves. Deployment decision to be made at 0700 in bridge meeting, based on sea conditions. NFSI team plans to be up at 0500 to prep instruments ready to go. 19:30 Equipment being strapped down in lab in preparation for rough seas.
Sat. 14-Oct	05:00 Transiting to first drop at T204, Dellwood Knolls. ETA 0800. Prepping AQU-BA5C. Sea state moderate. 08:06 Arrive on station at T204. 08:17 USBL pole lowered to operational position in preparation for deployment. 08:33 AQU-BA5C in water at T204, water depth 1759. 09:00 Having comms problems with USBL. Status messages not being interpreted by Discovery. Tried dunker but getting no signal. 10:15 USBL comms problem partially resolved, but can only operate in manual ping mode (auto-tracking not working). Completing 270 deg. circle with manual pinging. 10:55 Begin prepping AQU-1561 for next deployment site. 11:30 USBL up. Leaving T204 to transit to T203. 12:00 Decision not to use short term backup release time, since we see no scenario in which we'd want to release and recover in current sea condition. Better to leave on seafloor for return and focus on getting more down. 12:56 AQU-1561 in water at T203, water depth 2430. USBL SNR poor and tracking not working once again. Tried tracking when instrument only ~200m down, but SNR still very poor. Initial estimate of sink rate ~45 m/min from successive status messages (every few minutes during descent). 13:55 AQU-1561 on seafloor. Beginning 270 deg. circle at ~800m for positioning, speed ~2kts, using USBL as a pinger. 14:30 Still positioning AQU-1561. Starting prep of AQU-DA61 for T206. 15:05 Stopping positioning after about 200deg circle. Pulling up USBL. 15:10 USBL up, beginning transit to T206. Wind strengthening to over 30 kts and sea state building to whitecaps with large swell. 16:44 AQU-DA61 in water at T206. Clean drop. 16:50 Talked to instrument with dunker on way down. Needed to reset backup release date that was off by 4000 hrs. Followed to a few hundred meters and then pulled dunker up to move on to T205, hoping to get one more down for the day. 17:00 Prepping AQU-0660 for T205. 18:00 On site T205. Instrument ready. Deployment called off due to sea conditions. Turn off recovery devices for AQU-0660, but leave OBS in

	deployed state on deck.
Sun. 15-Oct	07:00 Received response from Sonardyne engineer Tom Bennets about USBL settings which may be helpful, but he needs more information. Katie compiling some outputs to send him. 08:27 AQU-0660 deployed at T205. Clean deploy despite swell. Tracked to about 200m with dunker over side. Nominal. 08:40 Prepping AQU-3B61 and heading to T201, hoping to get 3 more in before we scoot to shelter shortly after lunch. The wind is down compared to yesterday. No whitecaps but significant swell. 10:00 On-site T201 with instrument ready, but deployment called off due to sea state. Heading for shelter in Burke Channel, where sediment grab sampling/coring work will be carried out and an OBS may be deployed at the limit of the multibeam bathymetry. 15:00 Email exchange with Sonardyne engineer revealed beacon interrogation channel settings got mixed up somehow in Ranger. Corrected settings to be tested at the next OBS drop.
Mon. 16-Oct	Sub-bottom profiling in Burke Channel near Bella Coola. Weather misty with light rain. 08:30 Deck crew shuffling stillage boxes on deck. Empty boxes moved up to starboard focsle deck, staging 7 single-stacked OBS for next deployments. 09:00 A Mw4.9 earthquake was detected near the Dellwood Knolls last night (T_0 2023/10/16 03:13:55 UTC). Andrew located epicenter near T206. 14:00 Discovered the GNSS feed from the GPS antenna on top of the USBL pole didn't update new positions during surveys for T203 and T204, due to invalid quality flag (very sub-optimal antenna location). John has also been recording GNSS data from the ship's GPS feed in the lab, can correlate with this. Looking into connecting this feed to the USBL PC. 17:00 A stunning rainbow across the channel as patches of sun came out.
Tues. 17-Oct	07:30 COVID outbreak amongst officers/crew announced in morning meeting. All science party to mask up with N95s. Plan for recreational outing to hot springs cancelled. Larger consequences of outbreak will need to be assessed as the situation evolves. 10:35 Measured water line estimate on USBL pole, roughly 5.75m from transceiver face. Ship's design draft is 4.5m, putting the transceiver only ~1.25m below the keel during operation. 13:30 Estimating offsets for Tully Science GPS antenna (survey unavailable). 14:00 NFSI monthly update sent to PI committee. 14:00 Approval to drop 2 OBS in channel. Locations are in Coastal Shear Zone (CSZ) near fault observed on sub-bottom profiler which may be active. Sites T2BC1 and T2BC2. Begin prep of AQU-3B61. 15:30 Bridge crew observed that planned T2BC1 drop location is directly over a fiberoptic cable. Science party revising drop location. 15:30 Told that USBL pole cannot be put down due to problem with winch. 16:01 AQU-3B61 in water at T2BC1. Substantial current. Followed with dunker to Seafloor. 16:15 Confirmed OBS on seafloor. Very poor comms, thruster running to hold station. Begin transit to T2BC2 for second drop before deck crew goes off watch at 19:00. Will return to position T2BC1 later. Begin prep for AQU-755C. 17:10 Mount GPS receiver on starboard focsle deck over wet lab to be able to position instruments with dunker. 17:25 On station at T2BC2. Clock synchronization for AQU-755C not

	stabilizing. Reboot OBS to try again. 17:45 Clock synchronization for AQU-755C still not stabilizing. Move on to next instrument (AQU-2C62) for this station, troubleshoot further later. 19:01 AQU-2C62 in water at T2BC2. Descent looks very vertical. 19:50 T2BC2 positioned with dunker 3-point. Very good intersections as ship holds position due to dynamic positioning. Transiting back to T2BC1. 21:20 On station at T2BC1. Beginning positioning survey with dunker. 22:00 T2BC1 positioned with dunker. Positioning quality not as good as at previous site as ship is drifting in stronger wind & current, and frequent activation of thrusters. End of OBS activity for the day.
Wed. 18-Oct	07:00 No meaningful change in COVID situation. AQU-755C was power-reset last night and the clock offset has dropped, but is still not able to phase lock. Emailed Güralp for suggestions. 09:30 Bosun says they can put USBL pole down using the crane. As we are close to overhead of T2BC1 in flat water with no wind, this is a good opportunity to test new settings and we will put pole down. 10:15 Pole down to test USBL offset ~175m from T2BC1 drop location. Winch modified, added an extra block in the rope to increase mechanical advantage. Manual queries initially didn't work due to too short listening window, but system worked immediately on auto-tracking with adjustments suggested by Tom Bennetts (query individual inst., not general). SNR ~5. Steam half circle around T2BC1 to lock in location, which was found to be within 3m of estimate obtained with dunker. 10:50 USBL pole up, back to coring. 17:00 Transiting back to open sea, with ETA at T201 for 0700. However, according to Windy the sea state is unlikely to allow deployment until after noon. Prepping AQU-3661 overnight anyway, to be ready to go. 18:30 Katie feeling possible symptoms of COVID, tested negative. Isolated in cabin. 20:00 Prepping AQU-3661 for possible (unlikely) early morning deployment at T201. Leaving running overnight on PoE.
Thurs. 19-Oct	07:00 Still transiting to T201 in lumpy seas. Many people slept poorly. ETA 11:00. 07:30 Switching AQU-3661 over to batteries. 12:30 On station T201. Weather clear & sunny. Not much wind, but still significant (~3.5m) swell. AQU-3661 ready to go pending deploy decision from bridge. 13:45 USBL pole down. AQU-3661 in water. Swell significant, but smooth deployment. Good comms with USBL immediately. Tracking to SF and will then do positioning L-run at offset of 600-800m. 14:00 Setting up AQU-C05E for T202. 15:30 USBL positioning survey completed. Pole up. Heading to T202. Drift from drop site ~200m NE, which is slightly over 10% of water depth. 14:00 Decision to position T202, since next site T207 is about 2 hrs transit away, and would not have time to get there and drop another tonight. Aim for early start tomorrow. 17:30 At T202, putting pole down. OBS in water 17:40. Water depth 2420. Tracking to bottom. 19:30 Finishing positioning run. Begin prepping AQU-1F61 for first deployment tomorrow morning.
Frid. 20-Oct	05:40 In lab to continue prep of AQU-1F61. Holding station near T207,

	waiting for deck crew shift to begin at 0700. 07:00 Sea state calm. AQU-1F61 ready to drop at T207. Drop location moved a few hundred meters N.E. to avoid slope seen in SBP data. Will not position – use dunker to track for few hundred meters, then move on to next site T208. 07:30 Instrument deployed, tracked for few hundred meters with dunker. Nominal. Prepping AQU-0560 as we head towards T208. 08:10 AQU-0560 ready to software deploy and RD's checked. 08:43 On site T208. Deploying. Follow with dunker for 200m then leave for T209, prepping AQU-E361. 09:30 Onsite T209. Decide to move site by 1 nm due to slope in bathy. 10:03 T209 deployed. Tracked to 200m with dunker. Nominal. Begin programming AQU-D261. 10:40 Onsite T210. OBS ready but waiting for Apollo message. Iridium signal weak. 10:50 Begin prepping AQU-2A61 for next site. 11:10 Apollo message received. AQU-D261 in water at T210. Tracking with dunker to ~250m. Nominal. Heading to T211. 11:30 Permit to deploy OBS (and other work) in Scott Islands Marine National Wildlife Area (SIMNWA) received. Chief Scientists planning drop locations and route. 12:15 Coming onsite T211. 12:30 AQU-2A61 in water at T211. Tracked with dunker to ~250m. Nominal. Unstacking/rearranging instruments on deck. T212 next. 13:00 Start prepping AQU-2B62 for next site. 13:50 Arrive T212. 14:01 AQU-2B62 deployed at T212. Tracked to ~230m. Nominal. Heading to T215. Begin programming AQU-1B61. 15:28 AQU-1B61 in water at T215. Dropped from about 1ft above water. Tracking with dunker. 15:34 Dunker out of water, proceeding to T214. 16:40 AQU-D361 deployed at T214. All good except that instrument was deployed so quickly that we didn't get the VHF turned on. Transiting to T213. 17:40 AQU-C060 in water at T213. Tracked with dunker to ~260m. Nominal. Relatively low quality metrics for acoustic comms. 19:30 AQU-BA60 in water at T216.5 (T216 in logs). Tracked with dunker to ~260m. Nominal. Will carry out grab samples overnight. Aim to restart OBS drops first thing in morning. Deck crew moving empty stillages out of way and staging new set of instruments for tomorrow. Begin programming for AQU-BB60, leave running on PoE overnight to synchronize clock. 19:40 Received news that crew change for ship's engineer will happen in Port Hardy on the 25th, then we will head back out for the remainder of our time. Return to IOS will be as planned for the 28th.
Sat. 21-Oct	05:30 Continue programming for AQU-BB60, confirm clock synchronized. 07:15 At T220. Sea state a bit lumpy. Waiting for deploy decision from bridge. Bosun needs a bit more light to see oncoming waves. 07:40 AQU-BB60 deployed at T220. Tracked to ~190m with dunker. Were not able to get confirmation on seismometer re-center command due to noise of thrusters, but fairly sure the OBS received it. Transiting to T221. ETA 0900. Begin programming AQU-CD60.

	09:25 AQU-CD60 down at T221. Tracking with dunker. Nominal. Heading to T222. ETA 11:00. Seas & wind building. Some whitecaps but swell manageable. 11:15 Onsite T222. Sea state has built significantly. Deployment called off. 12:30 Decision to transit to shelter in Quatsino sound, where some sub-bottom profiling will be carried out while we wait out the weather.
Sun. 22-Oct	AM. In Quatsino Sound. Passed Port Alice about 0800. Connect to AQU-755C to record clock synchronization channels to send to Güralp for troubleshooting. Begin preparing packing lists for post-cruise shipments. PM. Heading back offshore towards OBS deployment area. Hope to start OBS drops again 0700 tomorrow, but sea state may not be suitable until mid-day. Start programming for AQU-BC60 and leave on PoE overnight.
Mon. 23-Oct	05:30 Continue programming for AQU-BC60, confirm settings, acoustic checks. 07:30 On site T222 with OBS ready, but sea state not settled enough yet. Some issues with AQU-BC60 clock in morning, resolved by reboot. Heading South-East to take core while waiting for seas to settle. Styrofoam balls mounted on coring assembly (2100m water depth). 11:22 Core finished. Heading back to T222. ETA 12:10. 12:22 On site T222. 12:40 AQU-BC60 deployed at T222, tracked for ~250m with dunker. Nominal. Prepping AQU-BE60 while heading to T223, stranded baby crossbill bird onboard keeping us company. 13:45 AQU-BE60 had problem waking Minimus board for acoustic query in final on-deck test (post-deploy), needed to be reset. 13:50 Onsite T223. Half hour delay while waiting for clock to re-sync. 14:22 AQU-BE60 in water at T223. Tracking to ~200m with dunker. Nominal. Rearranging OBS containers on deck. Heading to T224. ETA 15:40. Prepping AQU-CB60. 15:15 Software deploy for AQU-CB60 a bit early (~25 minutes to site) to allow time if final acoustic checks fail again (all checks passed this time). 15:35 Begin prepping AQU-CB5A for next station (transit T224 to T225 is fairly short). 15:40 Onsite T224. AQU-CB60 deployed. Tracking with Dunker to ~240m. Nominal. Heading to T225. ETA 16:45. 16:50 AQU-CB5A deployed at T225 and tracked to ~230m with dunker. Nominal. 4 empty stillage boxes stowed and final 4 instruments unstacked to deployment area. 17:15 Deck secure. Transiting to T226. ETA 18:10. Begin programming for AQU-2962. 18:23 AQU-2962 deployed at T226 and tracked to ~200m with dunker. Nominal. Transiting to T227. Bridge says they agree to deck crew working overtime to about 2100, after which we will go do more coring overnight. This should allow us to get 2 more down for the day. Begin prepping AQU-C560. 19:35 AQU-C560 deployed at T227 and tracked to ~200m. Nominal. Transiting to T228. ETA 2045. Begin prepping AQU-BD60. 20:56 AQU-BD60 deployed at T228 and tracked to ~230m. Nominal. Night crew begin setting up for coring operations. Start programming for final OBS (AQU-C760) and leave running on PoE overnight.
Tues. 24-Oct	05:30 AQU-C760 had some clock weirdness going on last night. Managed to

	resync itself but had 1ms offset this morning so was reset. Weather dismal - ~30 knt wind & rain. Waves & whitecaps but not much swell. ETA 0720. 07:30 Onsite T229. Bridge has decided to proceed. 07:50 AQU-C760 in water at T229 after group photo. Last OBS down. Clean deploy. Tracking to ~230m with dunker. Nominal. 07:55 Decide not to put USBL down due to rising sea state. Transiting back to Port Hardy for shelter and crew member change. Some interesting targets for drop camera and sampling in Queen Charlotte Strait overnight.
Wed. 25-Oct	AM: Coring, sediment grabs, profiling across apparent fault. 10:40 Anchored in Port Hardy harbour. Engineer crew change. Crew set draft measurement using zodiac. - Fore draft 4.49m - Aft draft 4.6m - Starboard aft draft 4.46m 13:00-15:00 Shore break for science team 13:30 Captain would like to be tying up at IOS Friday evening (Oct 27th). This allows very little time offshore before we need to begin transit. Planning simplified USBL survey geometry for southernmost stations (T213-T215) to maximize the time available. 16:00 Heading back offshore to position OBS in remaining time. Plan to arrive at station T215 at 0700.
Thurs. 26-Oct	07:00 Onsite T215. Deck crew putting the USBL pole in the water. 07:15 Establish contact with T215. Beginning positioning transect at ~2 kts, with closest offset of 600m. Getting consistent ranges, but SNR low (1-5). Transmit power on OBS modem raised to maximum. 07:51 Finishing transect. Pulling USBL pole up and heading to T214. Data analysis shows significant benefit from dog leg in survey path, not so much for longer run out. 08:48 At T214. Pole in water. Carrying out positioning survey. SNR very low (mostly 0-1) and missed responses to several range measurements during survey. Transit speed a bit low (~1.9kts), sounds like thrusters are working more than previous site. 09:15 Finished positioning survey. Pulling pole up. 09:20 Pole secure. Transiting to T213. 09:55 On site T213. Pole in water. Carrying out position survey. Speed variable 1.7-2.5 kts, generally higher SNR at greater speed (0-2 at lowest, up to maximum of 10). 10:27 Finished position survey, pole up, start transit back to IOS in calm seas. ETA around 4PM on 27th. 20:00 Science team guitar sing along in lounge.
Frid. 27-Oct	Transiting south to IOS along west side of island. Fine weather. Very calm seas. Packing up lab equipment. Work on reports. 14:00 Photo contest. Cruise Acronym contest. 16:00 Docking at IOS. Offloading of smaller equipment. 17:00 Vancouver members of science party have left to catch ferry. Chief Scientists and NFSI team staying onboard overnight. 19:00 20 empty stillage boxes loaded onto flatbed truck with ship's crane and moved to container yard. Remaining gear offloading tomorrow morning.
Sat. 28-Oct	07:00 Offloading remaining gear. All NFSI and NRCan equipment removed from ship and personnel disembarked at 09:30

3.3.2 Station Notes

Coordinates for some stations were adjusted on-the-fly to avoid significant slopes observed in the bathymetry data collected by the sub-bottom profiler (SBP). New "planned" coordinates were not always provided for these cases, leading to high (>200m) apparent discrepancy between planned and actual drop coordinates. Actual drop coordinates were taken from the Tully Science GPS, and water depths obtained from the 18kHz depth sounder.

Table 3-1: Planned locations and actual OBS drop locations for all stations. Stations with high (>200m) distance between planned and actual were adjusted for seafloor slope observed in sub-bottom profiler data at time of deployment.

Station	Launch Time	Planned Location		Actual Drop Location			Distance from Planned (km)
		Latitude	Longitude	Latitude	Longitude	Water Depth (m)	
T201	2023-10-19 20:45	50.82111	-130.3085	50.8209	-130.309	1893	0.045
T202	2023-10-20 00:40	50.74561	-130.5896	50.74608	-130.5919	2420	0.172
T203	2023-10-14 19:55:38	50.60605	-130.5148	50.60608	-130.5153	2430	0.030
T204	2023-10-14 15:33:04	50.69707	-130.3353	50.69703	-130.3352	1759	0.007
T205	2023-10-15 15:27:16	50.69118	-130.1222	50.69128	-130.1216	2045	0.040
T206	2023-10-14 23:43:32	50.57178	-130.2575	50.57197	-130.2573	2015	0.027
T207	2023-10-20 14:25:15	50.47705	-130.3664	50.48472	-130.3653	2507	0.857
T208	2023-10-20 15:49:59	50.47978	-130.1681	50.47423	-130.1694	1877	0.624
T209	2023-10-20 16:57:40	50.41179	-130.2099	50.41153	-130.21	2529	0.031
T210	2023-10-20 18:10:56	50.34353	-130.3299	50.34758	-130.316	2366	1.084
T211	2023-10-20 19:31:18	50.29066	-130.1125	50.2948	-130.1016	2165	0.899
T212	2023-10-20 20:56:09	50.37524	-130.0198	50.37417	-130.0202	1731	0.123
T213	2023-10-21 00:40:10	50.07273	-129.6755	50.07137	-129.6764	2409	0.164
T214	2023-10-20 23:35:31	50.16364	-129.5982	50.16268	-129.5978	1916	0.110
T215	2023-10-20 22:28:26	50.26251	-129.758	50.26307	-129.7455	1966	0.896
T216	2023-10-21 02:22:17	50.1661	-129.9419	50.16568	-129.9421	2278	0.051
T220	2023-10-21 14:39:38	50.35838	-128.9323	50.35827	-128.9333	2001	0.068
T221	2023-10-21 16:21:49	50.53034	-128.8449	50.52977	-128.8444	1663	0.071
T222	2023-10-23	50.48272	-129.1768	50.48742	-129.1845	1990	0.755

	19:32:34						
T223	2023-10-23 21:22:53	50.63986	-129.2244	50.6401	-129.2248	1660	0.036
T224	2023-10-23 22:47:58	50.63377	-129.4843	50.63329	-129.4843	1966	0.054
T225	2023-10-23 23:43:26	50.73602	-129.5122	50.73606	-129.5109	1863	0.085
T226	2023-10-24 01:18:32	50.73487	-129.7672	50.7349	-129.7672	2012	0.003
T227	2023-10-24 02:29:56	50.8963	-129.7563	50.89182	-129.7966	1940	2.865
T228	2023-10-24 03:50:23	50.86692	-130.0307	50.86789	-130.0281	2132	0.214
T229	2023-10-24 14:48:09	50.99751	-130.0545	50.99904	-130.0563	2066	0.215
T2BC1	2023-10-17 23:01:00	52.31155	-126.9839	52.31165	-126.9843	482.7	0.024
T2BC2	2023-10-18 01:58:31	52.27816	-127.2439	52.27827	-127.2439	573.1	0.012

All instruments are fitted with an Apollo Mono Iridium GPS beacon and an XMB-11k VHF radio beacon. GPS position messages can be viewed through the XeosOnline portal or using the Hermes handheld receiver, and are forwarded to an email alert list of key personnel. All VHF beacons are set to a frequency of 159.480 MHz. The VHF beacon at station T214 was accidentally not activated before deployment and will not transmit upon surfacing at recovery.

Seafloor locations were surveyed for 9 of 28 stations. Due to time constraints, surveying the remaining 19 stations was postponed to the recovery operation in 2024. Full USBL surveys were performed for 6 stations. Range data were collected with the USBL for stations T203 and T204, but automatic tracking was not successful due to an incorrect setting at the time, so these data were processed later with a 3rd party triangulation tool called ob_inst_survey[1]. Stations T2BC1 and T2BC2 were surveyed using the dunker at three points spaced around the drop location and triangulation performed using ob_inst_survey. Station T2BC1 was later surveyed with the USBL for comparison with the dunker results; calculated locations agree within 3 metres. The USBL results are presented here as the most accurate seafloor location. Bearings of drift measurements are given in degrees clockwise from North.

[1] Code originally developed by Neville Palmer of GNS Science (New Zealand), modified by NFSI staff. Github repository: https://github.com/nfsi-canada/ob_inst_survey

Table 3-2: OBS drop locations and surveyed seafloor locations, for all stations surveyed during this cruise. Seafloor locations for stations T203, T204 and T2BC2 are calculated by simple triangulation, all other stations show the USBL results.

Station	Drop Location		Surveyed Seafloor Location			Horizontal Drift	
	Latitude	Longitude	Latitude	Longitude	Depth (m)	Distance (m)	Bearing (°)
T201	50.8209	-130.309	50.82224	-130.3069	1893.134	211.5	45.3
T202	50.74608	-130.5919	50.7447	-130.5935	2418.057	188.7	215.1
T203	50.60608	-130.5153	50.6089	-130.5179	2426.002	364.8	329.2
T204	50.69703	-130.3352	50.69833	-130.3369	1753.576	197.2	317.6
T213	50.07137	-129.6764	50.07205	-129.6743	2409.738	169.8	63.8
T214	50.16268	-129.5978	50.16318	-129.5963	1943.8	117.3	61.8
T215	50.26307	-129.7455	50.26191	-129.7459	1964.009	132.2	192.9
T2BC1	52.31165	-126.9843	52.31178	-126.9836	481.116	48.4	72.3
T2BC2	52.27827	-127.2439	52.2781	-127.2439	564.835	14.5	184.0

Drift measurements for stations T2BC1 and T2BC2 in Burke Channel are thought to be dominated by tidal currents. The drift data available for offshore stations does not show a meaningful pattern due to limited statistics, but suggests drift is either controlled by shore-parallel and perpendicular currents or unpredictable due to the unknown descent pattern of the instrument design. Further investigation of this pattern will be possible after all stations have been surveyed at recovery in 2024.

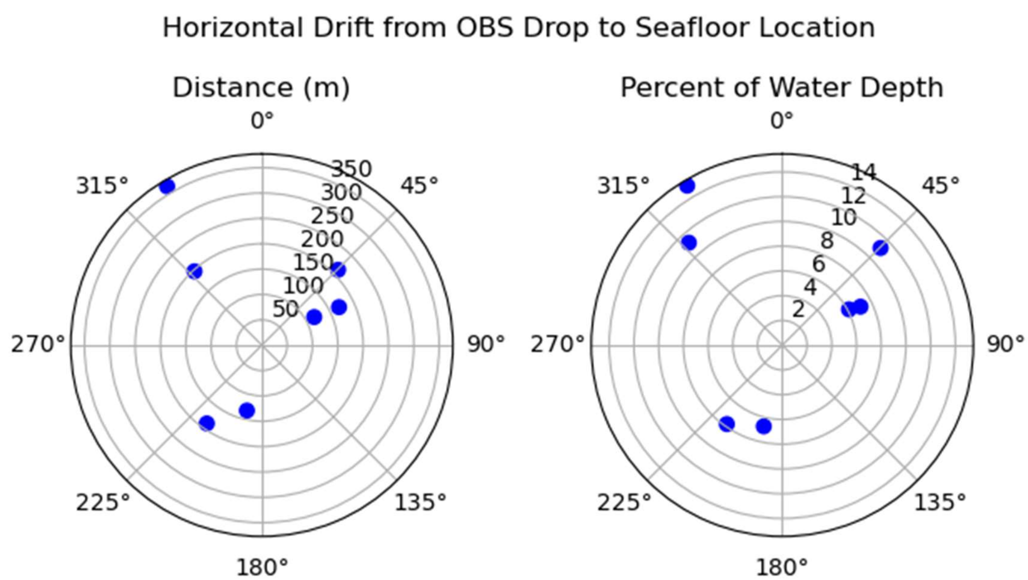


Figure 3-9: Horizontal drift measurements for offshore stations surveyed.

The table below lists the instrument serial numbers, acoustic modem information and Apollo Mono GPS beacon serial numbers for the deployed stations.

Table 3-3: List of OBS serial numbers, acoustic modem address and UID, and Apollo beacon serial number for each station.

Station	Serial Number	Modem Address	Modem UID	Apollo Mono S/N
T201	AQU-3661	5706	U007303	577
T202	AQU-C05E	5707	U007301	629
T203	AQU-1561	5805	U007308	703
T204	AQU-BA5C	5905	U00745F	514
T205	AQU-0660	5901	U007310	512
T206	AQU-DA61	5712	U007459	551
T207	AQU-1F61	5908	U007302	696
T208	AQU-0560	5802	U00745E	576
T209	AQU-E361	5813	U006AEC	560
T210	AQU-D261	5510	U007314	613
T211	AQU-2A61	5505	U00746C	698
T212	AQU-2B62	5605	U007313	559
T213	AQU-C060	5708	U006660	700
T214	AQU-D361	5610	U007312	612
T215	AQU-1B61	5703	U007304	627
T216	AQU-BA60	5906	U006AC6	689
T220	AQU-BB60	5914	U006648	575
T221	AQU-CD60	5812	U006646	564
T222	AQU-BC60	5702	U006ADD	695
T223	AQU-BE60	5507	U006662	574
T224	AQU-CB60	5810	U006AC7	554
T225	AQU-CB5A	5809	U007306	631
T226	AQU-2962	5904	U007305	630
T227	AQU-C560	5710	U00664D	632
T228	AQU-BD60	5714	U006AED	578
T229	AQU-C760	5803	U006AFE	558
T2BC1	AQU-3B61	5911	U007309	633
T2BC2	AQU-2C62	5705	U00745A	513

3.3.3 Vessel Track

The following figures show the vessel track during the cruise, down-sampled to one datapoint per half hour. Recording of the ship's NMEA GPS feed started two days into the cruise on October 13th at 5:37 UTC time. Track positions prior to this time, covering the initial transit from Patricia Bay to Queen Charlotte Sound through the inner passage, are taken from Discovery's boat tracker running on the deck unit, which is lower resolution.

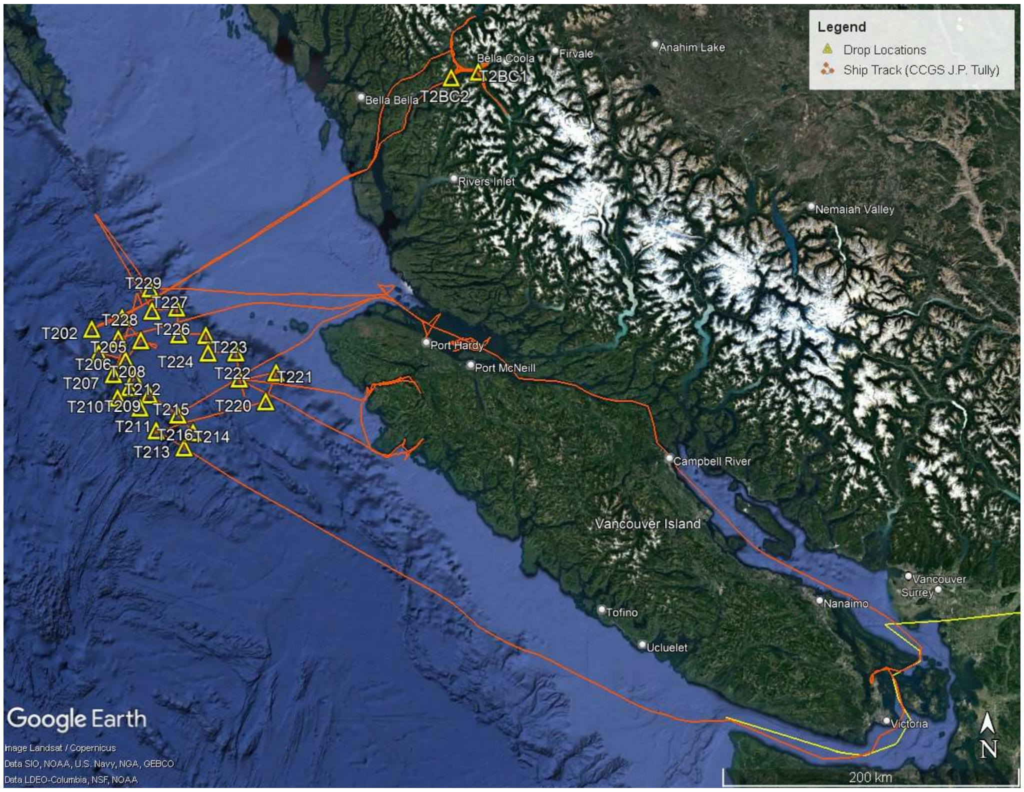


Figure 3-10: Vessel track, from departure from IOS October 11th to the end of cruise on October 27th.

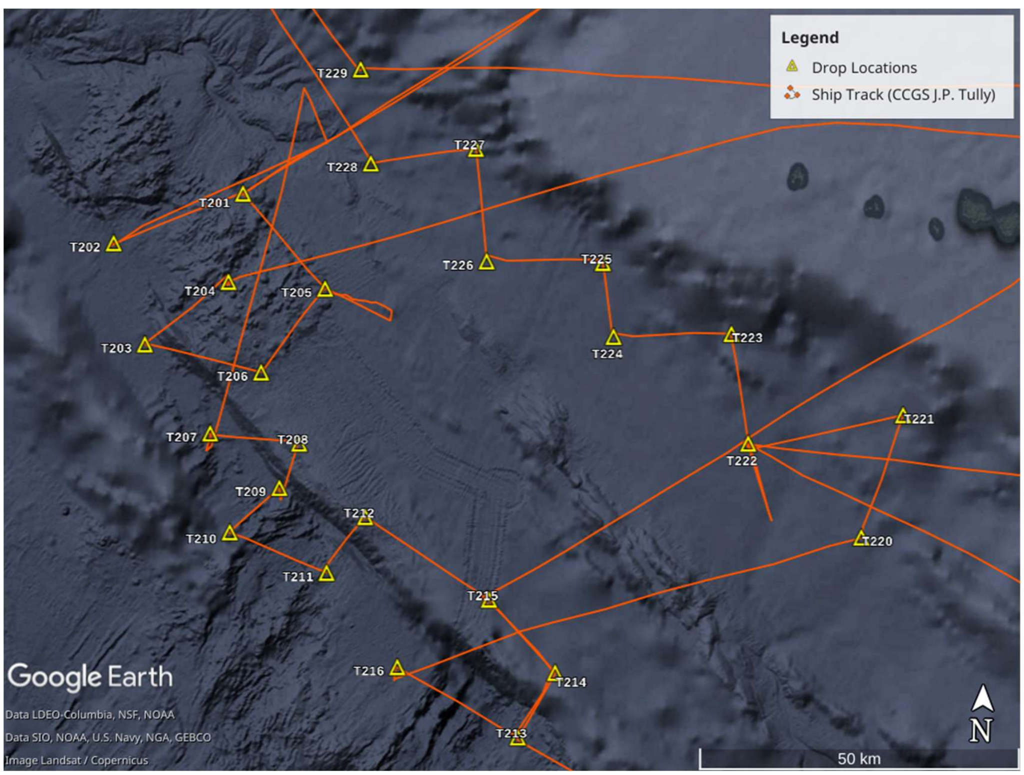


Figure 3-11: Detail of vessel track, showing OBS deployment in offshore survey areas.

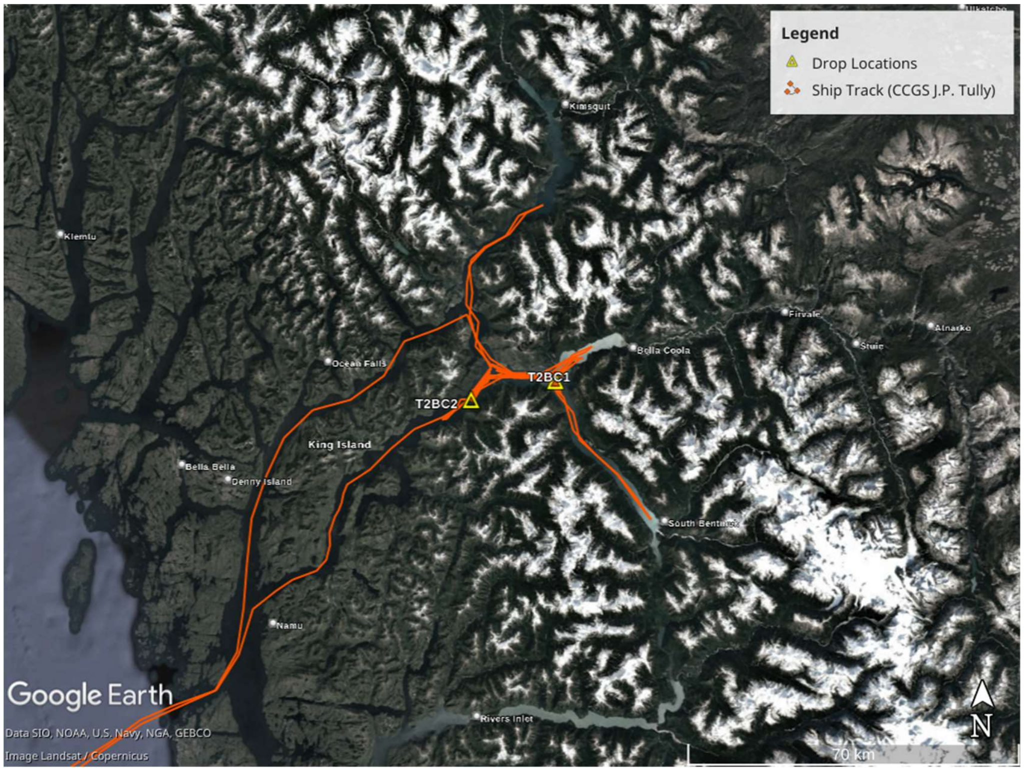


Figure 3-12: Detail of vessel track, showing locations of 2 OBS deployed in Burke Channel.

3.4 Demobilization

Demobilization of NFSI's equipment from the vessel took place on the evening of October 27th and morning of October 28th. Empty OBS stillage boxes and spare ballasts were shuttled to NFSI's storage container in the IOS yard using IOS' flatbed truck. The USBL head was dismounted from the pole using the crane, rinsed with fresh water, and offloaded. Auxiliary equipment was moved to the IOS hangar to be sorted and repacked for shipping, with some items being returned to Halifax and others air-freighted to an upcoming deployment in New Zealand. Following consultation with Güralp, AQU-755C, which had not been deployed due to clock synchronization problems, was dismantled on October 29th to remove the electronics and sensor core, which will be hand-carried back to Halifax for repair. Instrument assemblies of AQU-E661 and AQU-755C, both with missing electronics, were stored in the NFSI container at IOS. Two unused sets of recovery devices were also stored in the NFSI container for future use with these instruments, along with various packing material, other spare parts and the magnetic switch plugs for all 28 deployed OBS.

4.0 Discussion

The NFSI-005-2023-02 cruise OBS deployment plan underwent many changes as the objectives were adapted to weather conditions and resulting time constraints. The original plan for an array offshore Moresby Island was abandoned due to the weather exposure at that location. Substitute sites in the Dellwood Knolls and along the Revere-Dellwood Fault offered a serendipitous opportunity to record events and aftershocks at a site of recent and ongoing activity. Ten instruments were deployed along an under-sampled stretch in the Scott Islands Marine National Wildlife Area on the Cook Bank Slope, and 2 more while sheltering from offshore weather at opportunistic sites on a fault identified with the SBP where the Burke Channel intersects the Coast Shear Zone.

Operationally, the deployments were challenging due to sea conditions, with swells typically in the 2.5m range and going over 3m as the first winter storms of the year swept through. The deck crew under Bosun John Gardner did an outstanding job putting instruments overboard without a bump in heavy seas. Planned deployments had to be called off several times, primarily out of concern for operating the crane in heavy swell, but 28 of the available 29 OBS were successfully deployed eventually. The 29th had to be sidelined due to a technical malfunction of its clock synchronization.

The seafloor positioning of most instruments unfortunately had to be sacrificed due to time constraints. Review of statistics from previous deployments showed a typical upper bound drift of 10% of water depth, with most instruments within the 5-7% range. A positional accuracy of 200-300m, corresponding to the upper drift estimate for the water depths in question, was considered adequate for interpretation by the PI's. It was therefore decided to prioritize maximizing the number deployments, returning to position them with any remaining time, or during the recovery operation in 2024.

The first few instruments were nevertheless positioned to check whether the drift assumption remained valid in local currents. Positioning the first two OBS, deployed on October 14th at T204 and T203 on the Dellwood Knolls, was attempted using the USBL in tracking mode. This proved unsuccessful due to a setting misconfiguration. An attempt to use the over-the-side omnidirectional dunker to position T204 also proved unsuccessful due to poor signal-to-noise ratio. As the omni is rated for operations in up to 3000m water depth and the OBS was only at 1759m (based on 18kHz depth sounder), the low S/N is attributed to ship noise.

We eventually found that the USBL could be used to obtain range in manual pinging mode, so T204 and T203 were surveyed by having the ship conduct a half circle transect at an offset of approximately half the water depth from the drop location, while taking an OBS range fix every 30 seconds manually. These data were post-processed using the ob_inst_survey inversion code to get seafloor locations.

Two further instruments were deployed at T206 and T205 on October 14 and 15 in heavy swell and tracked with the dunker to about 200m. Further deployments on the 15th were cancelled due to building sea conditions. It was decided to seek shelter in Burke Channel, where sub-bottom profiling, sample grabs and sediment coring were carried out while we waited out the storm, and two opportunistic OBS deployments, T2BC1 and T2BC2 made on October 17 to monitor activity along a fault identified with the sub-bottom profiler.

T2BC1 and T2BC2 were initially positioned with the dunker, which worked for these sites due to the shallow water depth (~500m). A solution to the USBL configuration issue provided by Tom Bennetts of Sonardyne was successfully tested at T2BC1 on October 18, so that site was surveyed by both dunker and USBL.

On October 19, the next two positions deployed offshore after leaving Burke Channel, T201 and T202, were tracked to the seafloor and surveyed with the USBL in tracking mode. The sink rate calculated from these data at T201 was 42 m/min (0.7 m/s). Drifts from drop location were measured as slightly over 10% of water depth to the Northeast at T201, and slightly less than 10% to the Southwest at T202. Both drifts were around the upper limit of expected values, but within the absolute range considered acceptable for interpretation. The nearly 180° difference in the direction of drift is puzzling. Impact of local bathymetry on bottom current systems may partially explain this, but it is likely that “gliding” of the puck-shaped instrument during its descent is a contributing factor. We do not yet have enough data on these instruments to have a good understanding of their drift performance and have requested a future modification of the firmware by Güralp that will allow recording of the MEMS tiltmeter and compass during descent to provide insight into the dynamics.

Despite the significant drifts seen on T201 and T202, with another weather front closing in the remaining instruments were deployed as quickly as possible, without tracking them to the seafloor. On October 20th ten OBS were deployed in slightly over 12 hours in a good weather window, at sites T207-T212, T215-T213, and T216 in that order. Post deployment communications with the instruments were carried out using the dunker for status and parameter checks in the upper 200m, and to recenter the seismometer in a final communication, as using the dunker was faster than deploying and retracting the USBL pole.

We had hoped to get at least 4 OBS deployed on October 21st, but after T220 and T221 in the morning, deployments were called off due to worsening sea conditions. The ship transited to shelter in Quatsino Sound where some sub-bottom profiling work was carried out, and then returned offshore to resume OBS deployments.

Between noon and 9pm on October 23rd, 7 OBS were deployed in the Scott Islands Marine National Wildlife Area on the Cook Bank Slope: T222-T228, with instruments being followed to >200m for status checks and recentering using the dunker. T229 was left for the following morning so that coring could be carried out overnight.

The last site, T229, was deployed in the early hours of October 24th in marginal conditions of 30 kt wind, rain and whitecap waves although the swell was moderate. Instrument positioning with the USBL had been planned for half the day, but this was abandoned due to the worsening sea state. With a crew member change scheduled in Port Hardy on the 25th, Tully headed back to shelter, camera tows and coring in Queen Charlotte Strait.

Following the crew member change and a brief science team land-break in Port Hardy on the 25th, Tully headed back offshore. T215, T214, and T213 were positioned on the morning of the 26th using the USBL in tracking mode with good success. Rather than carrying out a full half-circle, the survey path was simplified to a shorter “hockey stick”, during which we confirmed that introducing a brief dog leg in the transit path past the seafloor instrument significantly improved positioning statistics. With time running out, the vessel began transit back to IOS when positioning of these three instruments was finished. CCGS JP Tully arrived back at IOS at 4pm on November 27th. Offloading of equipment started that afternoon and was completed on the morning of the 28th.

5.0 Suggestions for Improvement

Following each of its field operations, NFSI reviews the performance to identify problems, lessons learned and areas of improvement for future operations. Key points identified from the NFSI-005-2023-02 cruise were as follows:

1. Weather window: the biggest challenge in meeting objectives for this cruise was the weather, as the operation coincided with the arrival of the first winter storms on the BC coast. The swell these produced often made it unsafe to operate the crane for OBS deployment. Roughly a week was lost in transit as the ship went to shelter 3 times, at the cost of OBS deployment/positioning time. To mitigate this risk, particularly for the coming years of this project which will involve OBS-only recover/redeploy operations, it will be vital that the operation is scheduled at a time of year when weather conditions can be expected to be better.

2. Deck crew operating hours: with minor exceptions, deck crew operations for OBS work (both deployment and USBL positioning) were limited to 12 hrs per day (07:00 to 19:00). This stands in sharp contrast to most international research vessels on which 24/7 operations are the norm. On NFSI-005-2023-02, it also happened that some of the best sea conditions for deployment were wasted as they occurred at night. The 2024 operational objectives for this project will be much more challenging than the 2023 deployments. To meet these in the 3-week allocated time, 24-hour operations will be needed.

3. USBL Setup: while the USBL pole setup worked adequately, we see several areas for improvement.

    a. In the current setup the USBL sensor head only projects about 1.25m below the keel during operation, compared to the manufacturer's recommendation that it be at least 2m below the keel. Signals coming from the side facing the ship are therefore masked. The USBL pole should be extended by a meter or so to address this problem.
    b. In mounting NFSI's USBL head on the pole, we used a "quick and dirty" rubber spacing pad that did not provide proper electrical isolation between the USBL head and the pole, leading to potential degradation due to galvanic coupling of dissimilar metals. For repeated use, a proper spacing flange should be machined to prevent this.
    c. Lowering and raising the USBL pole required much manual effort at the beginning of the cruise, as the winch being used to lift it was not strong enough for the operation. This was improved by the addition of another block to the pulley system to improve the lever ratio. For future USBL intensive operations, putting in a more powerful winch seems a reasonable investment.

4. GPS for USBL: the initial GPS receiver position for the USBL was mounted on top of the pole in a configuration that had been used previously by ROPOS. This configuration proved to have poor reception due to signal blockage by the ship on one side and from the dome overhead. After finding that the position was not updating on the first couple of sites, we changed the setup to use the ship's GPS feed into the Ranger 2 computer. While this worked better, it took several days to establish which of the ship's GPS receivers the feed was coming

from, whether this was plain or DGPS, and the offsets relative to the USBL sensor position with the pole down (still not accurately established at the time of writing). In anticipation of future USBL work, the ship should document this information and make it readily available to science parties.

5. Deck unit cables: due to a change in ethernet connectors on the OBS during retrofits shortly before the cruise, only one Deck Unit to OBS compatible cable was available for NFSI-005-2023-02, so that only one instrument could be prepared at a time. This led to standby at one point when an instrument lost clock synchronization shortly before deployment, and we had to wait for it to resynchronize when we would normally have had a backup instrument ready. It also creates a fragile situation where if that cable is damaged, none of the instruments will be usable. NFSI should go into the field with a minimum of two Deck Unit to OBS cables, and when performing rapid serial deployments the standard procedure should be to prep two instruments together, to have one ready to go and a second in the pipeline at all times.

6. Dunker performance: although rated for operating depths of up to 3000m, our only attempt to communicate with a seafloor instrument at a depth of ~1790m using the dunker was mostly unsuccessful. Using it to position seafloor instruments as an alternative to the USBL was therefore not an option. We think the seafloor instrument was able to receive the signal transmitted by the dunker, but that the return signal was masked by the overhead ship's noise. To address this issue, NFSI has purchased a directional dunker from Sonardyne. This blocks noise from outside a directional downward looking cone and should therefore be able to communicate with instruments at greater depth against a background of ship noise. The directional dunker had been planned for use on the NFSI-005-2023-02 cruise but was delayed in delivery. We expect it to be available for operations in the coming years, giving an alternative option to the USBL for positioning seafloor instruments.

7. Apollo Iridium GPS Beacons should be started up and prepared in batches early in the day. Although it was not a big issue, at one point we were holding on station waiting to receive confirmation that the beacon to be installed on the OBS was indeed working. Having a few of these starting up at the same time and placed outside on the ship's deck would help make that first initial connection. With the positioning of the beacon affixed to the OBS inside the stillage crate, there is the potential for the sides of the stillage crate, as well as some of the ship's superstructure, to block part of the sky view.

6.0 Addendum

On November 15, three weeks after being deployed and as the NFSI team was mobilizing for another deployment in New Zealand, messages from the T227 instrument's Apollo beacon alerted us to the fact that it had surfaced prematurely. On November 21 a second instrument from station T229 also surfaced.

Weather patterns were generally pushing the instruments into Queen Charlotte Strait at the time, but there was concern that a change of wind would drive them out into the Pacific. Immediately after the first surfacing, Andrew Schaeffer contacted the Coast Guard and other local groups to try to organize a recovery operation. Fortunately, CCGS Tanu was nearby at the time and willing to help. A first attempt to recover T227 on November 16 had to be called off due to weather when Tanu was only an hour away. When conditions improved several later, T227 had temporarily lost satellite reception and was unable to transmit its position. On November 27, Tanu was able to recover the T229 instrument instead. This OBS was offloaded in Port Hardy, from where Andrew Schaeffer picked it up on November 28 and returned it by road to IOS.

Figure 6-1: Left: CCGS Tanu, which recovered T229. Right: Andrew Schaeffer picking up T229 in Port Hardy.

The T227 beacon began transmitting positions again on December 3. Its location at the time was about halfway through Hecate Strait, being pushed north quickly by an active storm system. Local communities, commercial fishing, and pleasure craft organizations in the Strait, Haida Gwaii and Prince Rupert were quickly contacted for help through emails and social media. This led to great community interest, resulting in a CBC radio interview, but despite many offers of support weather conditions continued to prevent a recovery attempt as the instrument was driven further north.

On December 6, the instrument crossed the border into Alaskan waters and the U.S. Coast Guard was notified. Shortly afterwards, the instrument turned south, re-entering Canadian waters briefly before returning to the U.S. side further west.

The last message received from the T227 instrument was on December 12 from near the rocky coastline of Long Island, Alaska, towards which it was being driven. We suspect the instrument was pounded on the rocks in stormy conditions, dislodging or damaging the GPS beacon. The syntactic foam buoyancy unit is very durable, however, so the instrument may still be drifting among the coast islands or washed up on the shore. As it has a label with NFSI's address and contact information on it, there is still some hope of recovering it.

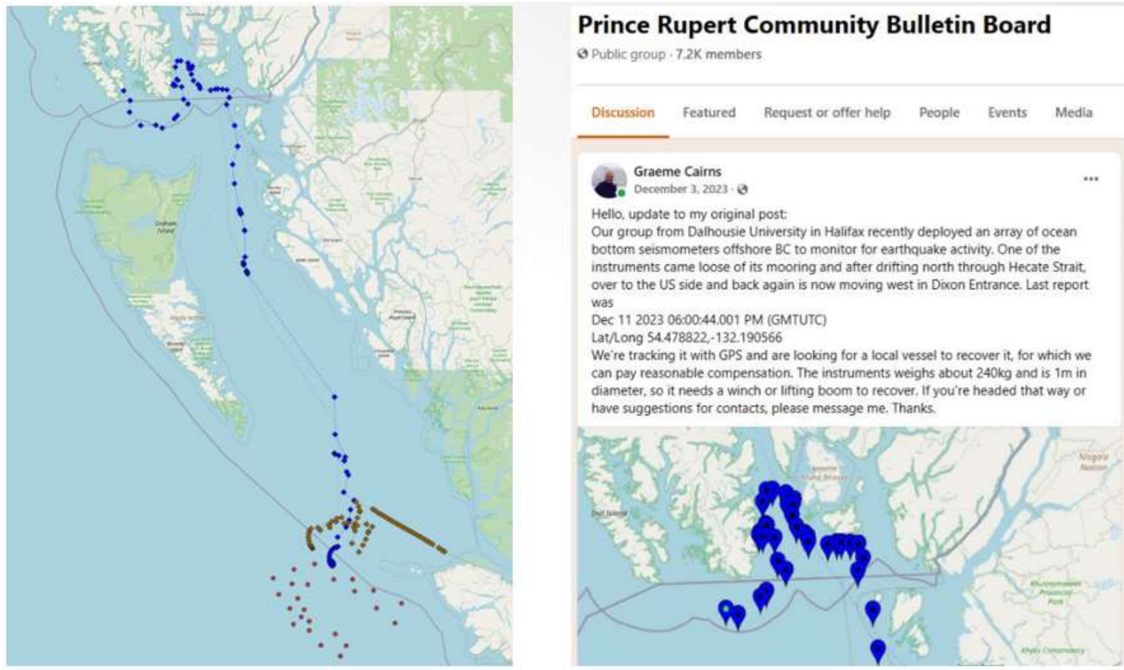


Figure 6-2. Left: Position of surfaced instruments T227 (blue) and T229 (brown) while drifting in November and December 2023. Right: Facebook post on Prince Rupert community board asking for help recovering T227.

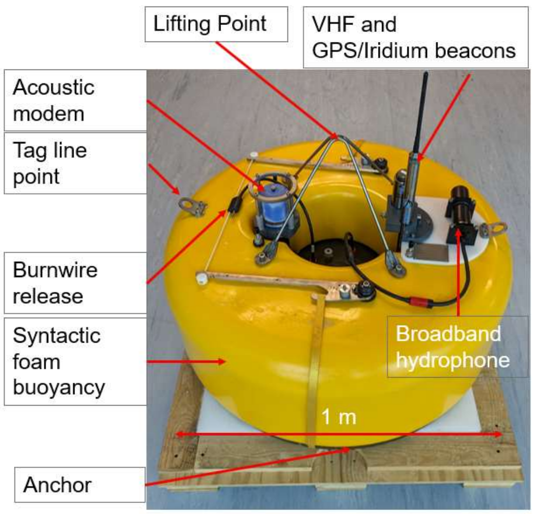
In January 2024, the T229 (AQU-C760) instrument was shipped by road from IOS to the NFSI facility in Halifax. A "forensic" session was held on February 6th to investigate the cause of early release, with Güralp personnel accessing the instrument remotely. It was found to be still running, although the battery voltage readings were nonsensical, the clock was lagging by approximately 3.66 days and the Femtomus FRAM was empty aside from reboot counters. Data offload proceeded normally and on review showed apparently normal recording up to a disc-write event at 10:39 UTM on October 21st, when there is a step change in data on all of the auxiliary channels. For a couple of write cycles (~1.5hrs) leading up to this event a gradual increase in humidity is recorded, consistent with low level leakage. Following the event, the power and voltage channels are flatlined, suggesting an unresponsive sensor. Noise signals recorded by the seismometer indicate the missing 3.66 days of data was lost prior to recovery of the instrument by CCGS Tanu, after which the clock appears to be functioning normally.

Further investigation was carried out on February 9th, with NFSI staff opening the pressure case while Güralp engineers observed through video link. Corrosion on several components and deposits inside the instrument clearly indicate saltwater ingress. The point of entry has not been definitively determined yet, but the available evidence strongly suggests the ethernet connector. Güralp and NFSI are continuing to investigate the root cause and identify how to mitigate the risk of future leak incidents.

Appendix A: Equipment Specifications

Aquarius Broadband Ocean Bottom Seismometers

The NFSI Aquarius Ocean-Bottom Seismometers (OBS) are broadband devices made by Güralp Systems Ltd. The instruments are typically deployed in free fall mode, released from a surface vessel to sink to the seafloor under the weight of their detachable ballast, and return to the surface for recovery under their own buoyancy when the ballast is released via acoustic command.



Instrument weight 240kg + 90kg anchor
Sink rate ~0.6 m/s; Rise rate ~1.5 m/s

Specification	Number	Research Impact
Number of units	120+1	High resolution and coverage
Max deployment (months)	18	Allows long-term deployments needed for earthquake monitoring
Clock drift (us/day)	<30	Precise time-keeping over long deployments
Seismometer bandwidth	120s – 100Hz	Joint use for earthquake process and structure imaging studies
Dynamic range	24-bit	Able to record broad range of signal amplitudes
Hydrophone bandwidth	100s – 8kHz	Acoustic monitoring of microseismics and seafloor compliance
Communication	Acoustic Modem	Allows real time data to surface from SF instruments
Buyancy	Syntactic foam	Unsinkable once anchor is released

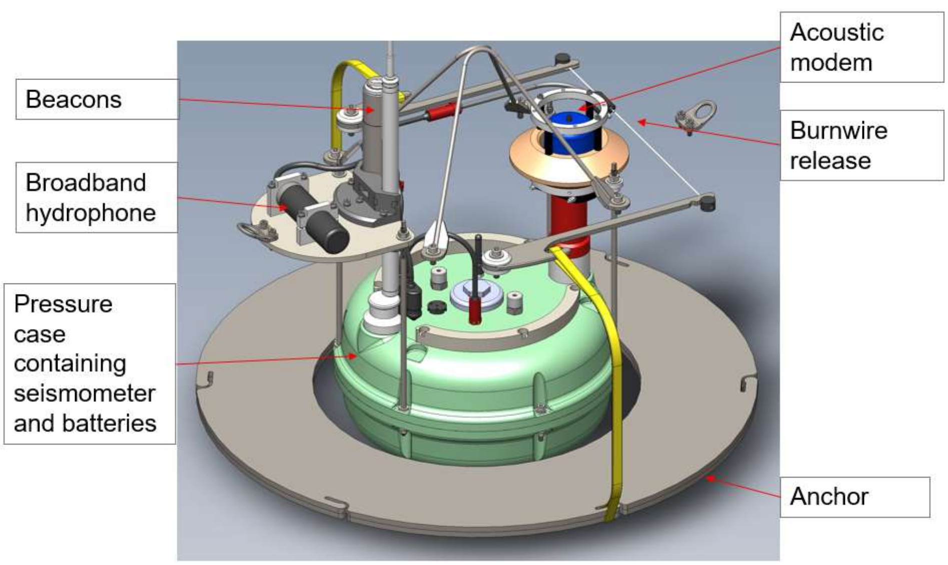


Table A-1: Güralp Aquarius OBS specifications, reflecting NFSI customizations.

Feature	Specification
Seismic sensor	• Broadband triaxial force-feedback sensor • Flat response from 120 s to 100 Hz • Nominal velocity response 2000 V/ms^{-1} • Tilt tolerance +/- 90 deg.
Absolute Pressure Gage	• Keller PA-10L. Accuracy 0.25%
Hydrophone	• High Tech HTI-04-PCA/ULF • Passband 100 s to 8 kHz; Sensitivity -194 dB re: 1V/µPa. • NOT AVAILABLE FOR 2023 BC DEPLOYMENTS
Additional Channels & State of Health	• 3-comp digital compass composed of MEMS accelerometer and magnetometer • Temperature, humidity & supply voltage sensors
Data Logger	• Güralp Ultra-Low Power Digitizer board with Certimus computer.
Data Storage & Recording formats	• 128 GB dual redundant flash cards • Data stored in miniSEED format • Metadata stored in dataless SEED, RESP and StationXML format
ADC & Sample Rates	• 24-bit low power 4-channel delta-sigma • Sample rate typically 250 Hz for seismic channels and 5 Hz for auxiliary sensors
Clock	• Double compensated microprocessor controlled TCXO • Locked to GPS time before each deployment • Uncorrected drift typically < 1 ms/day • Linear drift correction applied post-deployment
Power	• Lithium-Ion battery packs made up of 468 LG INR 18650 MJ1 cells • Total energy of 5954 Wh provides nominal autonomy of 15-18 months on seafloor, depending on application • Charge time approx. 1 hr/month of deployment
Acoustic Communication	• Sonardyne 6G LMF omnidirectional transceiver used for communication and positioning instruments on the seafloor • Used with surface transponder or USBL systems • Communication rates up to 9000 bps
Release Mechanism	• Burnwire triggered by acoustic command, timed release or critical battery level trigger
Recovery Tracking Beacons	• Xeos Apollo Mono Iridium GPS LED Flasher beacon • Xeos XMB-11K VHF beacon
Instrumentation Pressure Case	• 7000 series rolled aluminium, anodized • Pressure rated to 6000 m • Weight: 89 kg in air; 44.6 kg in seawater
Syntactic Foam Flotation	• Weight: 150 kg in air; 86 kg uplift in seawater
Ballast	• 10 mm + 15 mm steel plates • Weight: 89 kg in air, 77.4 kg in seawater
Full Instrument Weight/Buoyancy	• Air weight 239 kg instrument + 89 kg ballast = 328 kg • In-water weight: 44.6 + 77.4 – 86 = 36 kg • Buoyancy without ballast: 86 – 44.6 = 41.4 kg
Full Dimensions with Flotation and Ballast	• 1000 mm diameter cylinder • Height to top of buoyancy 459 mm • Height to top of lifting bar 725 mm

Sink/Rise Rate	• Sink rate 0.6 m/s, Ascent rate 1.5 m/s

Recovery Devices

The NFSI Aquarius OBS are equipped with recovery beacons made by Xeos Technologies Inc. These beacons are surface activated and autonomous, providing a margin of safety should the OBS batteries become depleted or the software malfunction. Two types of recovery beacons are used: an XMB-11K VHF beacon and an Apollo Mono Iridium GPS/LED Flasher beacon.

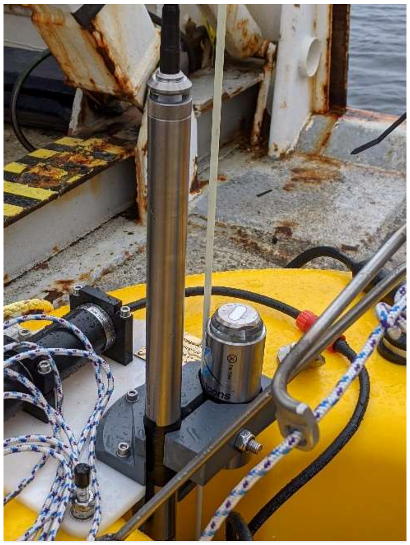


Figure A-1: Recovery devices mounted on OBS. XMB-11k VHF beacon on left, Apollo Mono GPS/LED/Iridium beacon on right.

The XMB-11K emits a VHF radio signal that can be located using a receiver equipped with a directional Yagi antenna to ranges of up to 12 km for a duration of typically 5 days (dependent on pulse length and repetition frequency) after surfacing. For the 2023 OBS deployments, all XMB-11K's were configured to 159.480 MHz.

The Apollo Mono transmits its GPS position via Iridium satellite and has an LED flasher for visually locating the instrument at night. For the first hour after surfacing, the Apollo will send positional updates every 10 minutes and activate its flasher, then switch to hourly updates. Instrument positions can be tracked via an online map or with a handheld Xeos Hermes receiver. Positional update frequency and LED activation can be reconfigured remotely through the Iridium link to extend battery life. The Apollo is powered by primary lithium batteries. Communication longevity will depend on update frequency and sea conditions, but with daily updates for a drifting instrument will be more than 1 year.

Positioning Systems

NFSI brought two independent acoustic systems on the NFSI-005-2023-02 cruise to communicate with OBS instruments and determine their position on the seafloor: a Sonardyne Modem 6 Mini-Dunker LMF LBL and Telemetry Transceiver System Type 8244-3155, and a Sonardyne LMF Ranger 2 Type 8084 Gyro Ultra-Short Baseline (GyroUSBL) 7000 Positioning System.

The Dunker is operated by lowering it over the side on the end of a cable. It is nominally able to communicate with instruments to depths of 3000m. It works as an acoustic modem to communicate with instruments on the seafloor or in the water column and can provide range measurements but not direction. Ranging can be used to position instruments with acoustic triangulation by moving the ship to measurement points that provide geometric constraint.

Table A-2: Sonardyne Modem 6 Mini-Dunker Type 8244-3155 Telemetry Transceiver System Specifications

Feature[1]	
Transceiver depth rating	3,000 m
Operating Frequencies	LMF (14-19 kHz)
Transducer Beam Shape	Omni-directional
Transmit Source Level (dB re 1 μPa @ 1 m)	187-190 dB
Tone Equivalent Energy (TEE)	193-196 dB
Range Precision	Better than 15 mm

As listed on Sonardyne datasheet

The Ranger 2 GyroUSBL system combines a 6th generation directional High-Performance Transceiver (HPT) and a Lodestar Attitude and Heading Reference System (AHRS)/Inertial Navigation System (INS) in the same housing. With the mechanical alignment of the AHRS fixed relative to the HPT's acoustic array, the requirement for a total system calibration to determine the alignment of the ship's motion sensors to the transceiver is, in many situations, eliminated. The LMF 7000 model is optimized for deep water. The system comes with a Navigation Computer which runs the Ranger 2 software application. For the NFSI-005-2023-02 cruise, the GyroUSBL was mounted on a pivoting pole over the port side of the ship, with a GPS mounted to the top of the pole. The pole was retracted during transits and put down during deployments in order to communicate with the instruments.

Figure A-2: LMF GyroUSBL transceiver mounted on side-along pole of CCGS John P Tully (stowed/transit position).

Table A-3: Sonardyne LMF Ranger 2 Type 8084 GyroUSBL 7000 Positioning System Specifications

Feature	Specification
Transceiver depth rating	
Operating Frequencies	LMF (14-19.5 kHz)
Transmit Source Level (dB re 1 μPa @ 1 m)	200 dB

Tone Equivalent Energy (TEE)	206 dB
Heading Accuracy	0.2 deg
Pitch & Roll Accuracy	0.01 deg
Heave	+/- 99m Range. 5 cm or 5% (whichever is greater) real time accuracy
Operating Range	Up to 7,000 m. Up to +/- 90 deg
Positioning Accuracy	Better than 15 mm Range Accuracy Up to 0.04% of Slant Range
Data Rates	Up to 9 kbps
Position Update Rate	1 Hz, independent of water depth
Mounting	Through hull, or over the side on pivoting pole

Appendix B: Vessel Technical Specifications

Vessel Name: CCGS John P. Tully
Official Number: 804457
Call Sign: CG2958

General Operation	Specifications
Vessel Class: Offshore Oceanographic Science Vessel	Length (m): 68.9
Port of Registry: Ont. - Ottawa	Breadth (m): 14
Home Region: Western Region	Draft (m): 4.5
Home Port: B.C. - Patricia Bay	Freeboard (m): 2.8
Crewing Regime	Gross Tonnage (t): 2195
Complement: 21	Net Tonnage (t): 645
Officers: 8	Cruising Range (nm): 12000
Crew: 13	Endurance (d): 50
Berths Available: 44	Cruising Speed (kts): 10
	Maximum Speed (kts): 13.5
	After Deck (m^2): 190
	Main Hoist:
	North Pacific Crane SWL (t): 10

Appendix C: OBS Deployment Instructions for Bridge

Overview

OBS deployments consist of instrument drops at designated waypoints followed by acoustic positioning of the seafloor instruments at pre-designated waypoints, using a USBL if possible or an overside dunker alternatively. We aim for a positional accuracy of <100 m on the surface drop location, although in rough weather there can be larger tolerances. Instrument drift from drop location will typically be less than 10% of water depth. The waypoints should be entered into the ship's Nav system, and visible to the science team on the navigation map in the lab.

Final approach to each waypoint should be with a bearing that minimizes ship roll, and for the final hundreds of meters going as slowly as practical while maintaining steerage. Time to waypoint estimates should be relayed by the bridge to the deck & lab crew at 30 and 15 min, 500-, and 50-meter points as described below. If the science crew communicates a need to delay the approach due to instrument problems, the bridge may need to adjust their approach or hold position accordingly.

A step-by-step time breakdown of typical operation with actions by bridge, deck crew, and science team is as follows:

<u>1 hour mark</u>

- Instrument positioned on deck for deployment
- Magnetic switch removed to power up instrument
- Serial numbers etc. recorded according to OBS checklist
- Connectors and ballasts checked
- Recovery devices mounted, Apollo GPS turned on and monitored to confirm transmission.
- Instrument software configured, clock sync running, burnwire and acoustic comms checks

<u>30-minute mark</u>

- Bridge notify lab at 30-minute mark
- Science team starts final instrument countdown checklist
- Software deployed, instrument disconnected, 2nd acoustic comms check with status request in deployed state

<u>15-minute mark</u>

- Bridge notifies lab and deck crew at 15-minute mark. Decrease vessel speed
- Safety strap removed, VHF beacon turned on and confirmed with receiver. All beacons on 2023003PGC will be set to 159.48 MHz. (Note that one of the beacon frequency options at 154.585 MHz interferes with emergency frequencies and must NOT be used.)

<u>500-meter mark</u>

- With ship speed down to 1-2 knots, bridge notify deck crew to put USBL pole down
- USBL pole lowered by deck crew. Yellow rubber protective cover must be removed prior to lowering if present.

<u>50-meter mark</u>

- Hold speed and heading steady for deployment

- Bridge signals lab and deck crew when waypoint is reached
- Instrument lifted overboard with crane, using taglines to control swinging
- Instrument released at waypoint. The timing of this is critical in heavy seas and needs to be judged to avoid banging into the side of the ship. The following actions need to be coordinated in rapid sequence:
  - Lower instrument
  - Release tag lines to slip free by the time instrument reaches water
  - Release hook as soon as instrument touches water

After Release

- Bridge team to log position of drop as nav waypoint
- Science team to log drop time, position, water depth
- Deck crew to move empty container out of the way and strap down
- Deck crew to position and secure next instrument for deployment
- Science team to communicate with instrument using USBL or dunker as it descends
- The instrument will descend to the seafloor at approximately 0.6 m/s (roughly ½ hr per 1000m). Time-permitting, the instrument will be tracked acoustically to the seafloor, after which the seafloor location will be determined using USBL or dunker. Transit speed during positioning with the USBL pole down should be limited to ~2knts. Positioning is carried out at an offset from the drop location of about ½ the water depth. Lab will give instructions to the bridge for this on a case-by-case basis.
- When satisfactory positioning data has been collected, bridge signals deck crew to pull up the USBL pole for transit to the next waypoint.
- Lab and bridge to confirm next waypoint
- Bridge to issue Nav Warning if waypoint is in shallow depths (<1000m) where fishing gear could interact.

Instrument Recovery

The instruments may be deployed with a backup release timer set for an hour or so after they are expected to reach the seafloor, so that they will resurface in case we are not able to establish acoustic communication. (Once communication is established, this backup release is cancelled). While this situation is unusual, every deployment should be accompanied with preparation to make an instrument recovery.

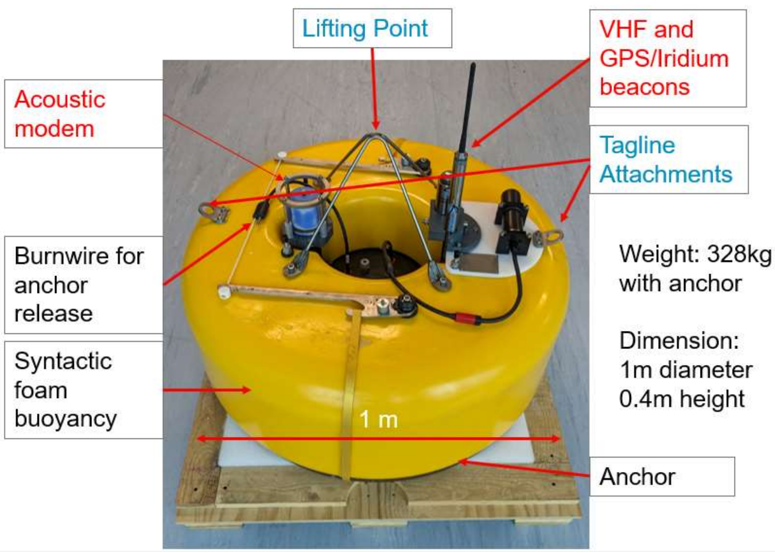
If an instrument surfaces, it will activate a VHF beacon and also communicate its GPS location via Iridium satellite, in messages which the science team receives in real time. The NFSI team has a VHF directional antenna that provides rough direction finding. The GPS positions will update every 10 minutes for the first hour after surfacing, then switch to hourly updates. During night hours, the GPS beacon will activate a bright LED strobe light. The instrument is also equipped with a flag that sticks up several feet.

The science team will guide the bridge towards the instrument using its GPS location. Once spotted, the instrument can be recovered by snagging the triangular lifting point with a snap hook, taking care not to damage the recovery beacons. The instrument should then be lifted onboard with the crane. As it will not be possible to attach tag lines for a recovery, care should be taken to minimize instrument swing. If deposited directly onto the deck, padding must be put under the instrument to protect the anodized pressure case on the bottom.

If an instrument releases early, a decision will need to be made by the technical team whether it should be redeployed.

Aquarius Ocean Bottom Seismometer Components

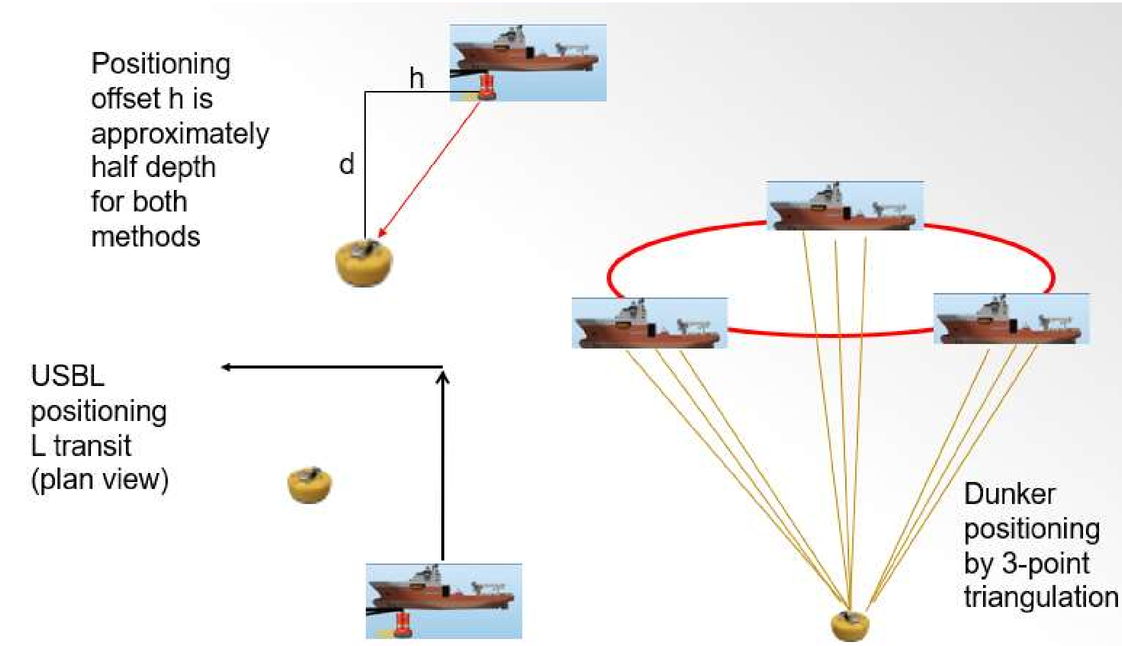
Aquarius Ocean Bottom Seismometer. Components in Red Font are fragile and should not be banged. Elements in Blue Font are deployment attachments.



Acoustic positioning of instruments on seafloor

The position of instruments on the seafloor is determined from the surface by acoustic ranging, using either a USBL (Ultra-Short Base Line) transceiver or a "dunker". The USBL is a sophisticated device, mounted on a pole which is lowered over the side of the ship, which uses the travel time and phase difference across an array of sensors of an acoustic signal from the seafloor instrument to determine both its range and direction from the ship. To lock in x-y coordinates for the instrument, a USBL survey will typically follow an L-shape over the instrument, at an offset of approximately ½ the water depth.

The dunker is a simpler transceiver, used primarily when the USBL is not available. The dunker provides range only, giving a solution of equidistant possibilities that make a circle about the ship's location. To remove this non-uniqueness, the ship is moved to multiple points around the instrument, triangulating the instrument's position through the intersection of the range circles. A minimum of 3 measurement points is needed for this, although more may be needed occasionally to get good statistics.


Positioning
offset h is
approximately
half depth
for both
methods
h
d
USBL
positioning
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Dunker
positioning
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triangulation