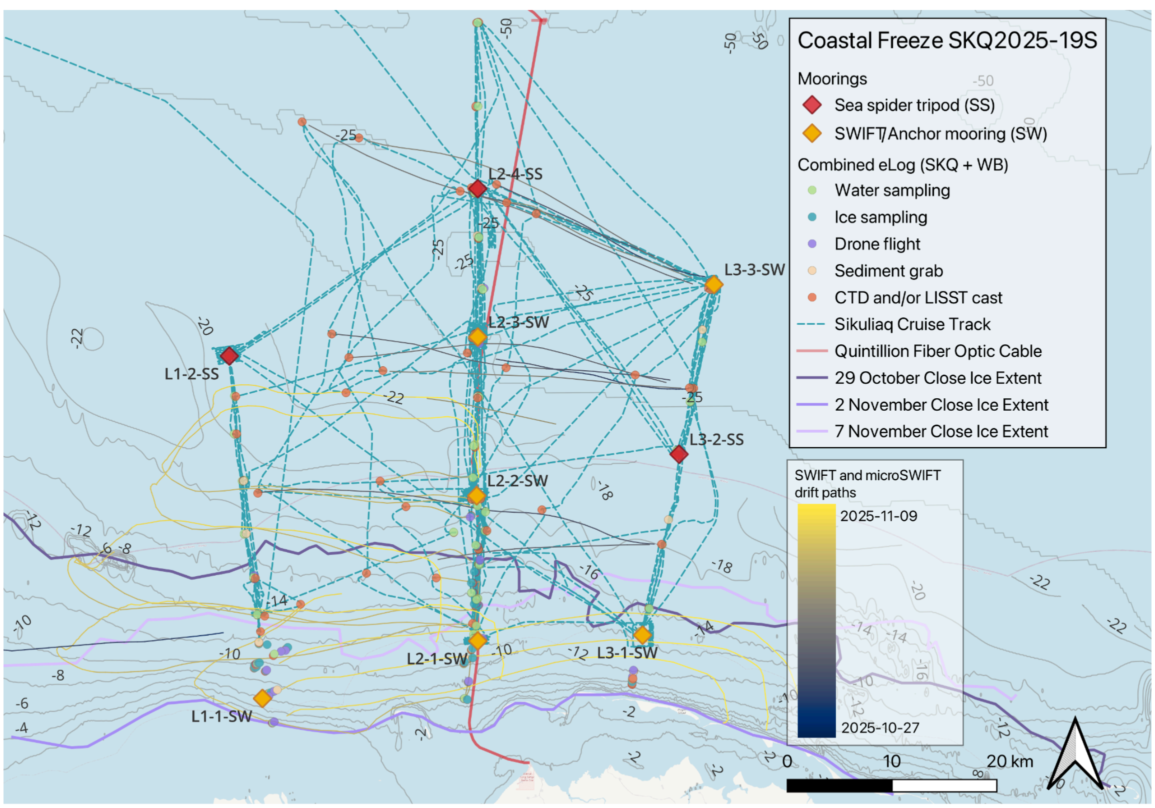
Cruise Report for Coastal Freeze R/V Sikuliaq 2025

Cruise dates: October 16 - November 10, 2025
Cruise ID: SKQ2025-19S
Chief Scientist: Maddie Smith
Co-chief Scientists: Emily Eidam, Jim Thomson

Overview and science motivation:

The goal of the Coastal Freeze project is to observe the interactions of waves, sea ice, and sediment during the initial formation of landfast sea ice in coastal Alaska. Key questions include: (1) do waves and currents help or hinder ice formation?, (2) how much sea ice does it take to effectively shut off seabed sediment resuspension and transport? A process study cruise aboard the R/V Sikuliaq targeted observations of these processes, including recovery and redeployment of moorings, transects using CTD and other profilers, and drifter deployments and recoveries. This report provides a description of the platforms used, a narrative summary of activities, and preliminary findings for further investigation. Measurements suggested that strong easterly winds can drive upwelling of warm water, further mixed by waves and currents, which melt newly forming ice. Wave resuspension of sediment was associated with a notable increase in turbidity, and expansive formation of heavily sediment-laden ice.

Cruise map



By the numbers:

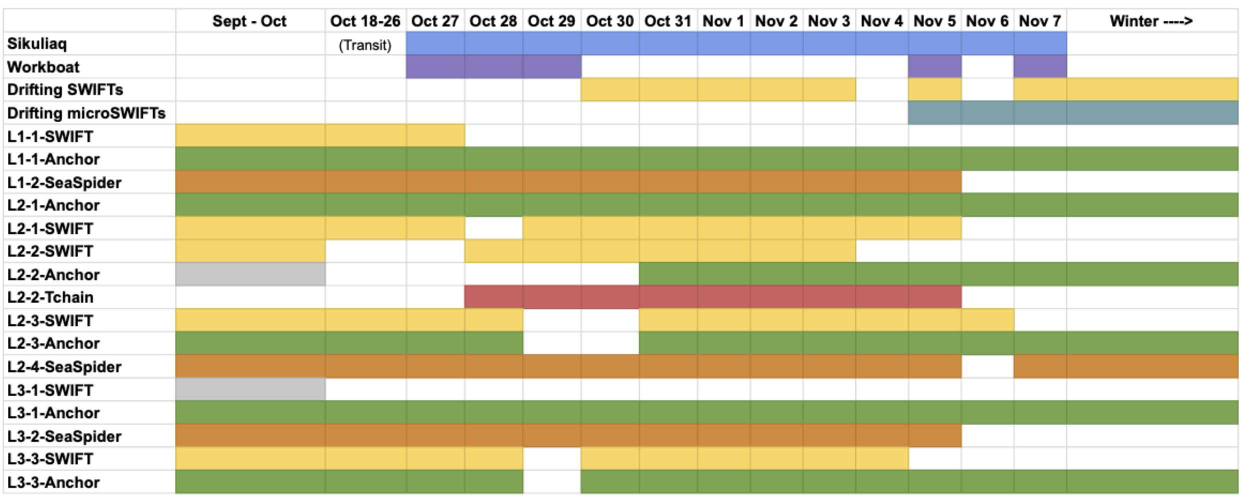
- 13 mooring recoveries
- 11 mooring deployments
- 172 CTD casts
- 97 LISST profile casts
- 189 sea ice and water samples
- 148 visual ice observations
- 11 small boat trips
- 28 drifter deployments
- 28 drone flights
- 42 sediment grabs
- 9 eDNA samples

Summary of daily activities:

The below summarizes the daily activities, which are described in more detail in narrative text that follows. A detailed event log ("eLog"), archived as .csv, provides a thorough record of all activities during the cruise, including the time (UTC) and positions concatenated from both Sikuliaq and workboat.

October 16	Science party arrives in Seward. Mobilize onto Sikluiaq.
October 17	Sikuliaq completes sea trials in Resolute Cove.
October 18	Begin transit to operation area. Safety training and orientation
October 19-26	Transit. Science trainings and talks.
October 26	Transit. SWIFT 21 recovery.
October 27	Arrive operation area. Landing craft recovery of SWIFT 09 and L3-1. Workboat trips (2) to recover moorings L1-1 and L2-1 and sample. Mooring recoveries at L2-3-SW and L3-3-SW from Sikuliaq, and temporary T-chain mooring deployed at L2-2-SW-r.
October 28	Workboat trips (2) to inshore sampling along L3 and L2 (conditions: muddy pancake ice). Mooring deployments at L3-1 and L2-1 from Sikuliaq. Sampling (coarse) along L3 and L2.
October 29	Workboat trip (1) near L1-E in consolidating ice. Deployment of drifting SWIFT, and redeployment of two seafloor anchors (L2-3-SW and L3-3-SW), with moored SWIFTs.
October 30	Deploy two drifting v4 SWIFTs along L3 line. Full sampling (casts) along L2. Redeployment of L2-2-ANC. Recovery of two drifting v4 SWIFTs.
October 31	Deploy three drifting v4 SWIFTs along L3 line (south to north). CTD/LISST profiles (and some water samples) following SWIFT drift tracks (zig-zag). Recover SWIFTs in the evening.
November 1	Deploy three drifting SWIFTs along L3 line (south to north). Full survey with casts of L2. Recover SWIFTs in the evening.

November 2	Deploy three drifting v4 SWIFTs along L3 line (with 1 recovered shortly after; 2x drifting for day). Transect with casts of L1 (from L1-F to L1-2-SS). Recover the drifting SWIFTs in the evening.
November 3	Deploy three v4 SWIFTs along L3. Full survey with casts of L2. Recovery of drifting SWIFTs, plus a v4 SWIFT that broke free from the top of the T-chain mooring.
November 4	Attempted recovery of 3 tripod moorings (1 recovered).
November 5	Deploy three drifting v4 SWIFTs across ice edge (attenuation experiment). Workboat trips (2) to new ice bands along L2; microSWIFT deployments. Recovery of T-chain at L2-2.
November 6	Recovery of 2 remaining tripods. Redeployment of tripod at L2-4-SS.
November 7	Workboat trips (2) to the expanding ice edge over L1. Deployment of drifting buoys including microSWIFTs (4), and SWIFT (1).
November 8-9	Transit.
November 10	Arrival in Nome and demob.



Summary timeline of activity and instrumentation by date

Instrumentation and methods

LISST200X

The LISST200X is a laser scattering in situ transmissometer made by Sequoia Scientific. We deployed it in concert with an RBR Maestro from Sikuliaq or by itself from the workboat. Our goal was to collect in situ measurements of suspended particle (and/or aggregate) sizes to characterize fall-season sediment transport and inform models of sediment-ice entrainment. We also used the LISST in a benchtop flow-through mode (using our own flow-through setup design) to measure the disaggregated sizes of sediments entrained in slush and pancake ice.

RBR CTD with peripherals

We used three different profiling RBR CTDs. The two workhorse instruments were Maestros:

- s/n 200201 (OSU), outfitted with CTD/Tu/PAR/Chl (Tu obtained from OBS)
- s/n 234554 (WHOI), outfitted with CTD/PAR/Eco-triplet

We also used an older model from UW for the one landing craft trip which was a CTD/Tu assembly (Tu obtained from OBS). The goal of the CTD casts (with peripheral measurements) was to characterize the water column structure primarily in terms of temperature, salinity, and turbidity. We also used the data to supply temperature and salinity data to the shipboard sound speed manager software (for use in tuning the multibeam echosounder data). We performed shipboard natural sediment calibrations to convert Tu to TSS (Total Suspended Solids) for each sensor (filters were saved to be dried and weighed in Corvallis). Data were trimmed into downcasts by hand and binned into quarter-meter intervals.

Shipek grab & mini van veen samplers

We used a stainless steel Shipek sampler and mini Van Veen sampler to collect bottom grab samples. The Shipek was used on the underwire winch (SKQ starboard side) and the mini Van Veen was run by hand from the workboat. Samples were bagged in whirlpak bags for later grain-size (and possibly LOI) analyses at OSU. Some sediments were saved from a few grabs for eDNA analyses by colleagues at Exeter (these samples were saved in centrifuge tubes that were wiped down with sanitary wipes; samples were then stored in the -80deg freezer onboard the ship).

Ice and water sampling

Ice samples were collected, primarily from the workboat, for analysis of sediment load as a function of ice state. Collection included both pancake ice and pieces of brash ice, and separated frazil (using a french press method). When possible, the thickness of the ice was measured.

Surface water samples were collected from Sikuliaq using a clean 5-gallon bucket and samples were collected at ~5-20 m depth using a small (<2L) Niskin Bottle. The Niskin was troublesome at first because the messenger would miss the plunger (due to wire angle), but we solved this by adding weight to the base and taping the line to the top of the plunger to reduce the offset distance. When possible a Hobo pressure logger was fixed to the Niskin and evaluated in post to refine estimates of sample depths, which were typically within 1-2 meters of targeted depths. We were comfortable using a 5-gallon bucket for many samples because the turbidity values were quite low and we expected everything to remain in suspension for some time. Fresh bucket samples did have to be stored in the Baltic Room before subsampling (else they turned into slush on some cold days).

On the workboat, we generally collected 1-L bottle samples by dipping a bottle in by hand. We tried to clear the slush and only sample water in these cases. We used the Niskin to sample at depth in an effort to constrain TSS values (and in some cases suspended, disaggregated grain sizes) at depth. When slush was present, we sampled it with a 1-L french press which we used to extrude the water out of the slush (in this case we measured the height of the plunger and then converted this into a volume of water). This sampling was somewhat difficult and we were not always able to capture the entire sample in a bottle (some slush stayed in the french press). The bigger issue was that the “slush” layer was often thinner than the diameter of the french press, and so we did not feel that we were getting a representative slush concentration measurement. We also used 4-L bottles to sample the slush layer from the workboat; these samples were designed to be run through our benchtop LISST flow-through setup for grain-size distributions (rather than frazil/slush concentration).

SWIFTs (micro, v3, and v4)

SWIFT and microSWIFT platforms provided measurements of surface conditions. The SWIFTs measure surface waves, meteorological variables, sea surface temperatures, surface salinity. They were deployed both as drifters and as surface moorings. Version 3 (v3) SWIFTs were mostly moored and did not include current measurements. Version 4 (v4) SWIFTs were mostly drifting and included current profiles using downlooking Nortek Signature 1000 profilers.

The microSWIFTs are a miniaturized, expendable version of the SWIFT. They have been used regularly to measure waves and temperatures in the western Arctic for the past few years. As part of the Coastal Freeze project, openOBS turbidity sensors were integrated on the microSWIFTs, including Iridium telemetry of the data.

The choice of moored or drifting approaches had many scientific and practical considerations. During the early autumn, the moored v3 SWIFTs provided stationary time series to observe cooling of the coastal ocean. Once the ice begins to form, the moorings become a practical liability, because the SWIFTs can be dragged off station and/or pulled under the surface as the ice advects through the region. For these cases, the moored SWIFTs pulled under must use post-processed IMU data to determine wave spectra (as opposed to using both GPS and IMU data). Drifting SWIFTs are a preferred approach within the ice, as they move with the ice and measure in this natural (Lagrangian) reference frame. However, the drifting SWIFTs require ship time for regular (daily) recoveries and repositioning within the domain.

Moorings

Six moorings were deployed in September from the R/V Ukpik. Most were deployed initially as a coupled instrumented seafloor anchor and surface SWIFT, except for L3-1 which was deployed as a separate anchor package (with release) and SWIFT. All had a combination of sensors to provide measurements of waves, turbidity, and ocean temperature (various depths), with some additionally providing measurements of salinity, and met. A detailed summary of instrumentation, deployment and recovery locations, and timings can be found in a separate mooring table.

Tripods

Three “Sea Spider” tripods were deployed in September from the R/V Ukpik. Each has a Nortek Signature 500 profiler mounted in the center for measurements of currents, waves, and ice, and additional sensors for temperature, turbidity, light. Some additionally had salinity sensors or hydrophone. A detailed summary of instrumentation, deployment and recovery locations, and timings can also be found in the separate mooring table.

Sea spider tripod mooring after recovery

Drone

A variety of UAVs (drones) were used for collecting aerial imagery of sea ice and ocean surface. In particular, we imaged the ice distribution (e.g., concentration, floe sizes) and sediment load. Platforms aboard included DJI Mini 2, DJI Phantom 4 Pro, and Skydio X2. DJI were equipped with an optical camera, while Skydio additionally had an IR camera.

Sontek ADCP

A Sontek-M9 RiverSurveyor on a towed "surfboard" setup was used on occasion towed at the hip of the work boat to provide measurements of currents. Use was limited at times due to heavy levels of ice, that made submersion challenging. Compass calibrations were attempted by driving the work boat in slow circles, but were not successfully completed on most deployments, so directions should be treated with caution until further correction.

Shipboard instrumentation

Seawater flow through system

Near-surface seawater conditions were sampled by the Sikuliaq flowthrough system with an intake at 6 m below the water line in the bow thruster room. Ocean temperature was measured immediately upon intake, and salinity, dissolved oxygen, nitrate, chlorophyll, and other parameters were measured by instrumentation on the "wet wall" in the main lab. Specifically, for the measurements discussed in this report, temperature was measured with a Sea-Bird SBE 38 thermometer (SBE 38_1362), salinity was measured with a Sea-Bird SBE 45 MicroTSG thermosalinograph (TSG SBE 45_0385), and nitrate was measured by a Satlantic Sea-Bird Submersible Ultraviolet Nitrate Analyser V2 (SUNA_V2-1999). Underway data in one-minute bin averages at the "best" quality level (suspect or failed data removed from the averaging bin) were downloaded from Coriolix.

Shipboard ADCP

Currents were measured using a Teledyne RDI Workhorse 300 kHz ADCP mounted on the centerboard of the vessel, adjusted flush with hull (approximately 7 m depth).

Shipboard atmospheric (met) measurements

Underway data in one-minute bin averages at the "best" quality level (suspect or failed data removed from the averaging bin) were downloaded from Coriolix for this report. Datastreams come from a variety of sensors mounted on the ship:

Met Stations:

Air temperature, barometric pressure and relative humidity observations are from Paroscientific MET4A (fan-aspirated) meteorological measurement system (Meteorologic MET4A_146582) located on the forward mast 14.9m above sea level.

Anemometer:

True wind speed was used and measured using Gill Instruments WindObserver 75 (heated) Anemometer(Anemometer Gill 1006 True Winds). It is located on the forward mast 15.5m above the surface. An additional Metek uSonic-3 recorded three-axis turbulent winds at 10 Hz and is available for post-processing direct covaraince wind stress.

Radiometers:

Downward shortwave and longwave radiation was measured using Kipp and Zonen SMP21 pyranometer (Pyranometer SMP21_0196) and Kipp and Zonen SGR4 pyrgeometer (Pyrgeometer SGR4_0132) respectively; both instruments are located above SCR on the 03 deck. Both instruments were routinely cleaned about every 2-3 days with a kimwipe.

Workboat logger

The Sikuliaq's work boat (22' inboard) was used for operations typically in shallower water than was reachable with the Sikuliaq, including transect observations. A logger was setup by the ship's MT to record the position and depth over the surveyed areas. On some trips **the logger output the wrong times to workboat logs**, including in the ZDA time strings, so caution should be used when matching observation times to times in the workboat logger. Workboat sample times and positions were taken via GPS waypoints at each station; these times and positions should be used when there is disagreement with the time/position information provided by the workboat logger. Depth at a given position is believed to be correct in the workboat logger.

Hydrophones

Underwater acoustic dataloggers (SNAP from *Loggerhead Instruments*) recorded underwater ambient sound on two different platforms at the study site; each datalogger was equipped with a single hydrophone. During the cruise period, an acoustic datalogger was deployed with a SWIFT (v4) drifter at station L3-3 five times. The hydrophone was located 10 m below the surface, and the sound pressure was sampled at 96 kHz. Additionally, two additional acoustic dataloggers (recording 60 s every 600 s) were co-deployed on two seafloor-moored tripods (L3-2-SS and L2-4-SS) from mid-September until mid-November. One of the acoustic dataloggers was re-deployed on a tripod (L2-4-SS) to record over the winter. The expected battery life is 2 months with a 10% duty cycle.

Seafloor distributed acoustic sensing

Synchronous with the measurements being made aboard the ship, distributed acoustic sensing (DAS) data is being collected in collaboration with Sandia National Laboratories on the Quintillion seafloor fiber optic telecommunication cable in the center of the domain (~150 W, L2). The high density of wave and ice observations are expected to be able to be used to produce a high-quality calibrated dataset of wave parameters throughout the late summer and fall. This effectively provides a continuous, high-resolution wave dataset along L2 for the duration of the cruise (and beyond). All moorings were offset from the cable by a minimum of 250 m, as requested by Quintillion.

Narrative summary

Below is a condensed narrative summary of the entire cruise. The full narrative is included as Appendix 1.

Transit (October 18-26)

The science party departed Seward aboard the Sikuliaq on October 18, beginning transit north. The mobilization location and schedule was a departure from as originally planned due to mechanical issues causing delays the week prior. The week of transit focused on safety drills, shipboard systems briefings, and a series of science and instrument trainings. Topics included mooring operations, sediment and turbidity sampling, IceWatch protocols, meteorological and drone systems, and shipboard sensors. Daily science talks covered sea ice processes, sediment transport, and remote sensing methods. Transit slowed at times due to heavy weather. Hands-on orientations included bottom grabs, CTD casts, and drone flights. By October 24, the team crossed the Arctic Circle, and on October 26, the ship reached the operations area in the Beaufort. Preparations and instrument calibrations were completed, and a previously adrift SWIFT buoy (21; formerly at L2-2-SW) was recovered using the fast rescue boat.

Mooring recoveries, workboat sampling, and transects (October 27-29)

The Coastal Freeze team began intensive field operations, recovering and redeploying moorings along Lines L1–L3 and conducting multibeam mapping, CTD and LISST casts, sediment grabs, and drone surveys. The workboat performed full sampling sequences at ice-covered stations, collecting frazil, pancake ice, and sedimented ice. All remaining moorings (excluding tripods) were recovered, except for the anchor at L2-2-SW, and several were redeployed (with separated anchor moorings with releases, and anchored SWIFTs). Simultaneous shipboard mapping and sampling continued. Transects along L2 and L3 captured gradients from open water through new ice. By October 29, the team completed additional mapping and sampling along L1 and deployed SWIFT 17 drifting for wave and turbidity data. Increasing winds and seas concluded this phase.

Drifter experiments in high winds (October 30-November 3)

From October 30, operations shifted to experiments with drifting SWIFT buoys to study ice-ocean interactions and surface processes. Arrays of 2-3 SWIFTs (versions 4) were deployed along L3, drifting westward under persistent strong easterly winds. Repeated transects and

CTD/LISST casts documented evolving thermal and turbidity structure, revealing a warm-water intrusion spreading across the domain (likely due to upwelling). Some days showed icing on instruments, while others did not, highlighting variable freezing spray conditions. SWIFTs were recovered and redeployed daily, and sediment and water sampling continued along L1–L3. On November 2–3, strong winds, waves (2–3 m), and ship icing challenged operations (and multibeam data was typically of poor quality). In general, the new ice observed earlier in the cruise was absent during this phase as it was melted by warmer water and compressed against the coast.

Mooring redeployment, workboat sampling, and transects (November 4-7)

The final phase emphasized recovery and redeployment of seafloor tripods and additional cross-shore ice sampling, which returned to the area following relaxation of winds. Between November 4–6, the team successfully recovered sea spider tripods along L1–L3, overcoming release communication issues and rough sea states. A tripod was redeployed for the winter at L2-4-SS. Seafloor mapping and CTD casts followed each recovery. Educational outreach was conducted via a live broadcast to classrooms worldwide.

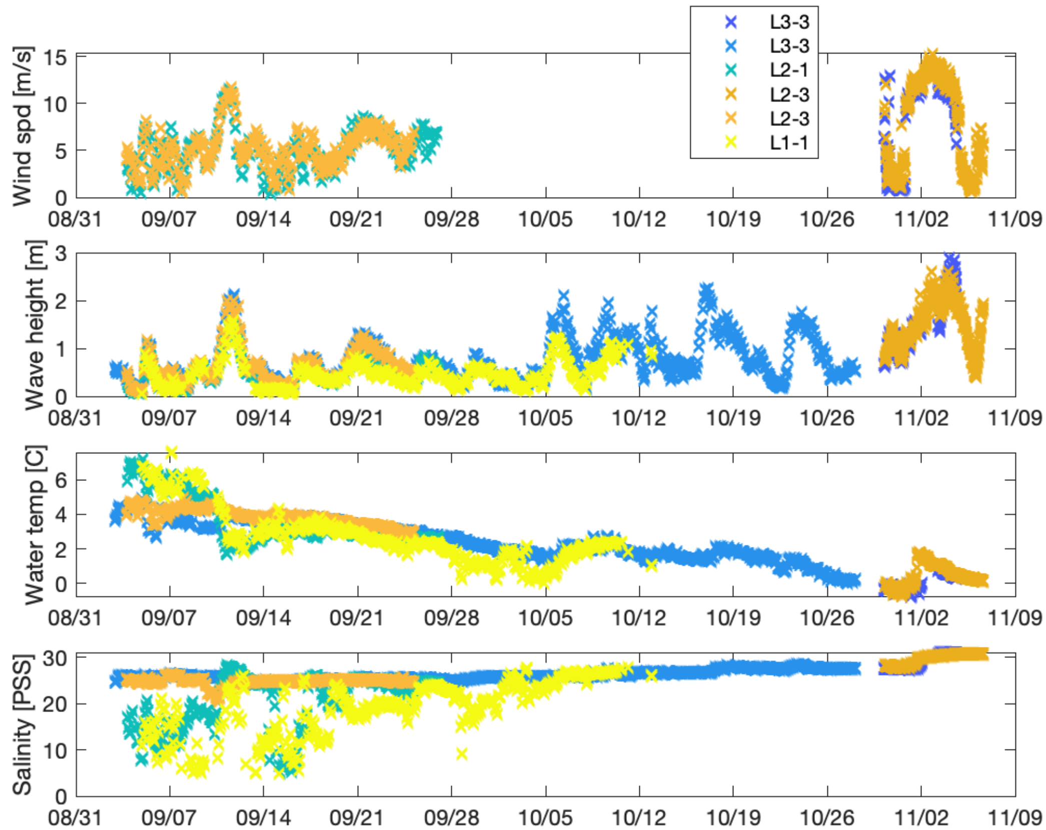
Workboat operations resumed November 5–7, targeting new ice formation and sediment-laden pancakes nearshore along L2 and L1. Multiple microSWIFTs (with newly integrated turbidity sensors) and SWIFT drifters were deployed across gradients from open water to compact ice. Drone flights documented evolving ice morphology. By November 7, final transects, sampling, and multibeam mapping were completed near L1. After recovering all small instruments and buoys, science operations concluded and the Sikuliaq began transit back to Nome.

Preliminary results

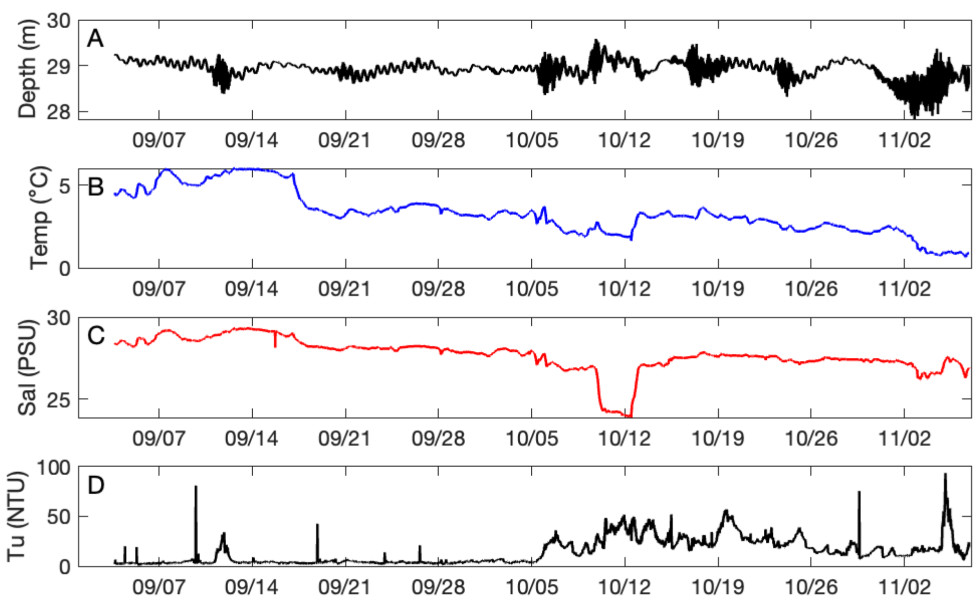
Moorings (seafloor anchors and moored SWIFTs)

Time series from the seafloor anchors are shown in the figure below. October had notably larger wave events than September, though the largest waves of the season did not occur until Sikuliaq arrived (see SWIFT time series in next section). Wave heights varied across the array, presumably as a result of refraction (for remotely forced waves) and fetch (for locally generated waves). Bottom temperatures actually *increased* in September, then cooled through October. This is an important distinction from the surface temperatures measured by the SWIFTs in the next section. The warmest bottom temperatures are measured at L3-3, which is the farthest offshore of these seafloor moorings.

Time series from the six SWIFTs (version 3) moored starting in September are shown in the figure below. The records are incomplete, because some of the SWIFTs broke free and/or expended their battery before Sikuliaq arrived. Sites L3-3 and L2-3 were reset with SWIFTs at the beginning of this cruise. The time series show winds and waves typical of autumn conditions in the region, including winds speeds up to 15 m/s and significant wave heights up to 3 m. The surface water temperatures (0.5 m depth) cool throughout the fall, with the exception of some variability in early September and the arrival of warm water during the storm in early November. The surface salinity is highly variable in the first half of September, when the Colville River discharge into the area was anonymously strong. After this period, the salinity steadily increases through the fall.

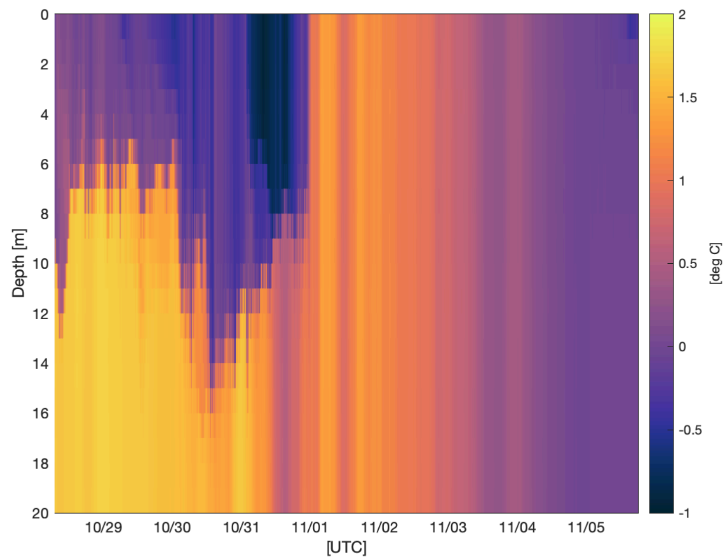


Time series records of turbidity were recovered from most seafloor anchor/release packages or tripods. A salinity and temperature record from L3-1-SW was also recovered. Temperature and salinity signals generally decreased between September and October. Turbidity values (shown below from L3-1) peaked once in early September in response to a wave event and then increased and remained high starting around October 5 in response to increased wave energy.



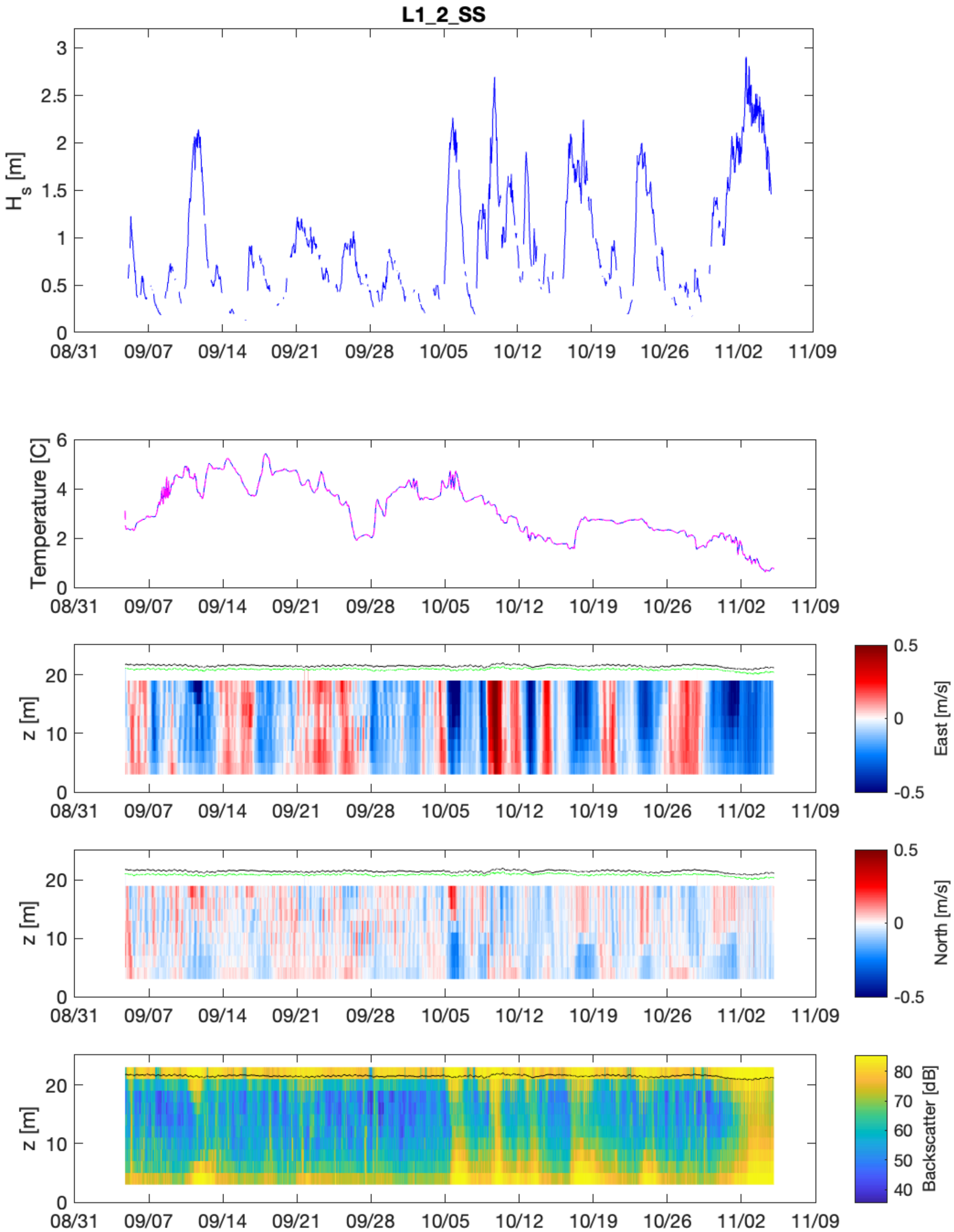
T-chain mooring

A short-term mooring with a T-chain (2 m spacing over 20 water depth) was deployed at site L2-2 (“L2-2-SW-r”) during the observational period. The figure below shows the warm upwelled water in the first few days, then a well-mixed water column after the storm on Nov 1-3 (effectively increasing the temperature at the surface). The water column then cooled, remaining well mixed.

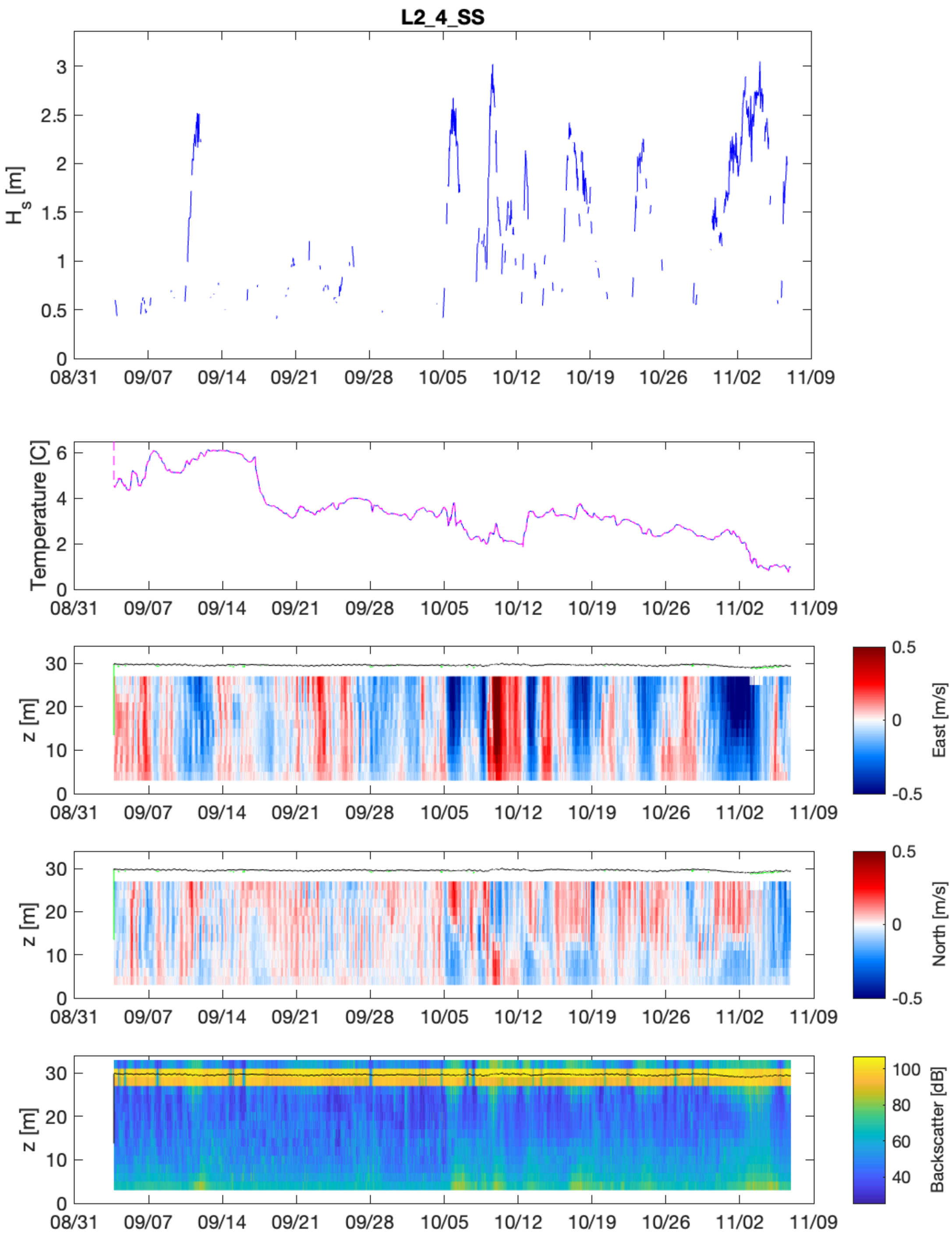


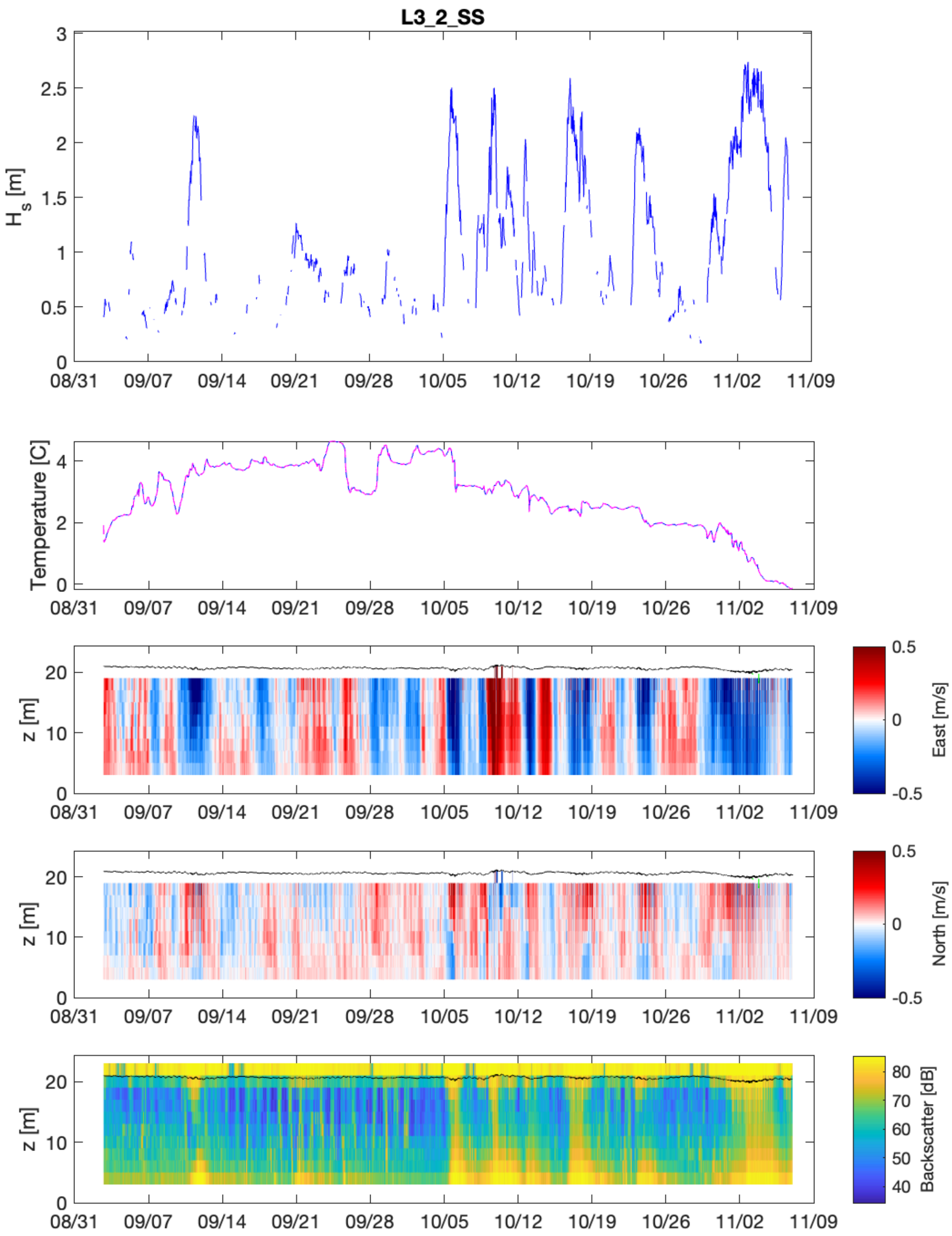
Seafloor tripods

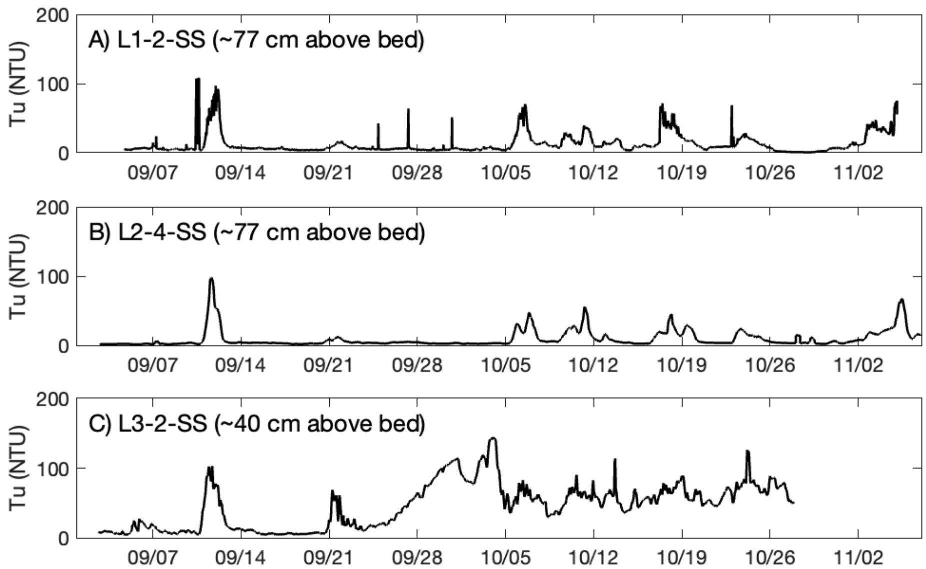
Three “sea spider” (SS) tripods deployed in the first week of September were recovered toward the end of the cruise, each with complete data records from the uplooking Nortek Signature 500 ADCPs. The following three figures are for each of the three tripod sites (L1-2, L2-4, L3-2). These data show repeated fall storms, with significant wave heights from 1-3 m, and a cooling trend in bottom water temperatures. The current profiles are dominated by east-west flows, which are depth uniform and show strong reversals that are likely related to wind-driven upwelling and downwelling modes. The north-south components are weaker, with notable shear in the mid-water column. The shallower sites (L1-2 and L3-2 are both around 20 m) have strong backscatter signals that suggest suspension of sediment during the storms, with the deeper site (L2-4, 30 m) having much less backscatter. These records were validated by RBR turbidity data.



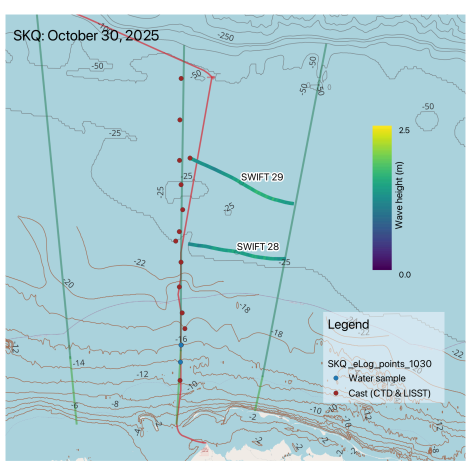
L1_2_SS
H_s [m]
Temperature [C]
z [m]
East [m/s]
North [m/s]
Backscatter [dB]
08/31
09/07
09/14
09/21
09/28
10/05
10/12
10/19
10/26
11/02
11/09

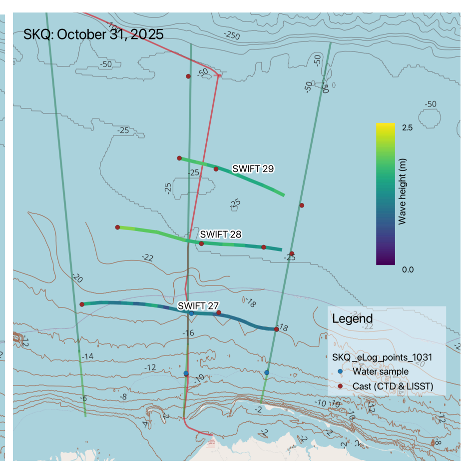

L2_4_SS
H_s [m]
Temperature [C]
z [m]
East [m/s]
North [m/s]
Backscatter [dB]
08/31
09/07
09/14
09/21
09/28
10/05
10/12
10/19
10/26
11/02
11/09

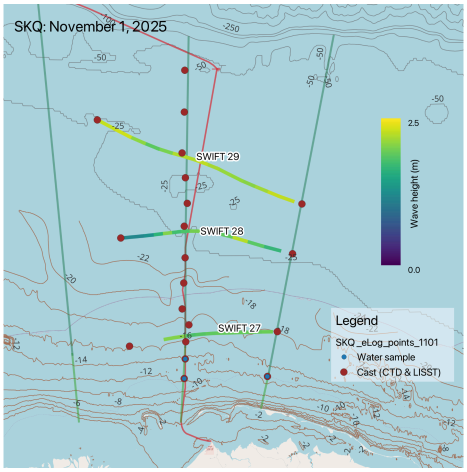

L3_2_SS
H_s [m]
Temperature [C]
z [m]
East [m/s]
North [m/s]
Backscatter [dB]
08/31
09/07
09/14
09/21
09/28
10/05
10/12
10/19
10/26
11/02
11/09

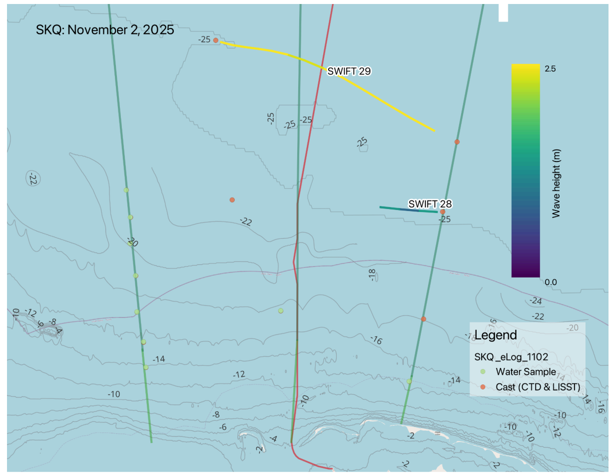


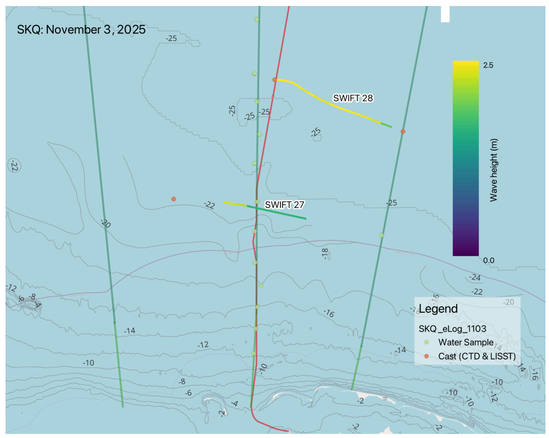
Drifting buoys (SWIFTs, microSWIFTs)
Combined drift tracks of all drifting buoys deployed over the cruise, colored by day, can be found in the cruise overview map. Daily deployments of drifting SWIFTs (version 4) occurred in open water throughout the storm and then in the ice once it shifted farther offshore. During the storm, the SWIFTs in open water measured strong waves (Hs up to 3 m) and winds (U~15 m/s). The 5 maps below show the drift tracks of SWIFTs on these dates (October 30 - November 3), colored by observed wave height. Points indicate additional measurements (water and ice; casts) made on the same dates. They also observed spatial gradients in surface temperatures and salinities, with a general pattern of warmer and saltier offshore.



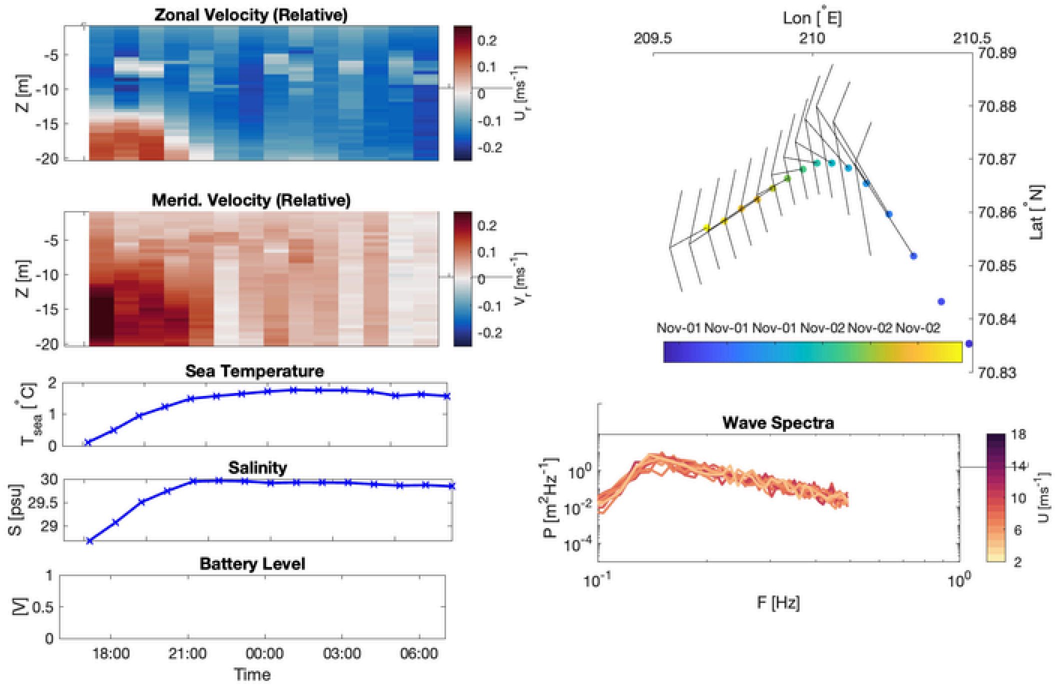






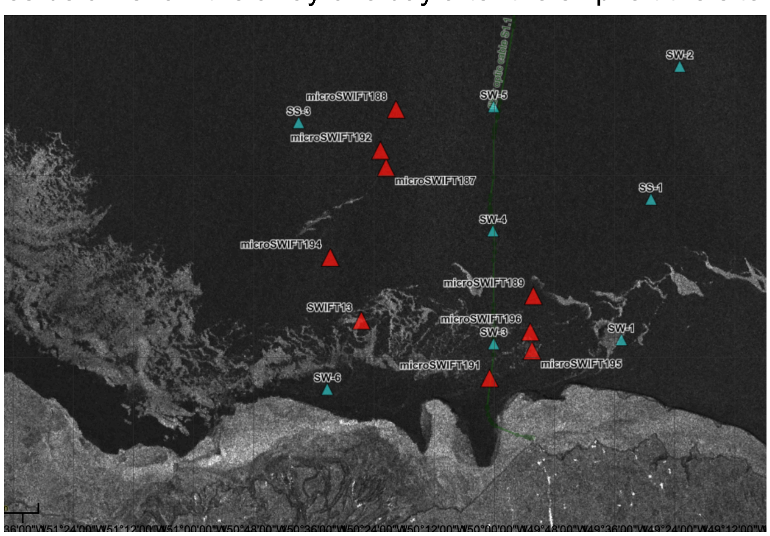


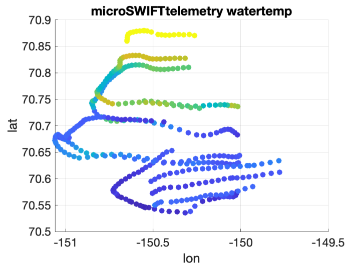
The integrated Nortek Signature 1000s showed bubble plumes reaching greater than 5 m depth, as well as shear associated with coastal upwelling. The figure below shows an example of the along track measurements from one of the buoys. The initial drift is towards the northwest and strong shear is observed. As the SWIFT turns west and drifts into warmer and saltier surface water, the subsurface shear reduces.

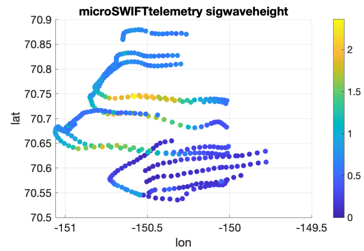


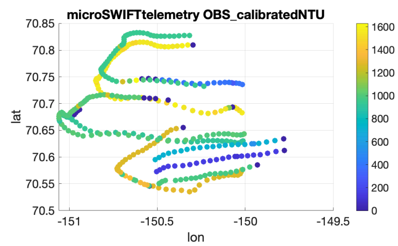
The last two days of v4 SWIFT deployments, November 5 and 7, targeted the re-advancing new ice edge. Drifting buoys were deployed across this edge, providing an attenuation experiment and indication of wave and current conditions within the ice.

In addition to the sub-daily v4 SWIFT deployments, an array of ten microSWIFTs and one v3 SWIFT was deployed and left in place during the last few days of the cruise. These will continue to observe surface conditions through the rest of the freeze-up (another 6-8 weeks) while reporting hourly telemetry with waves, water temperatures, and optical backscatter (for turbidity). The figures below show the array one day after the ship left the site.



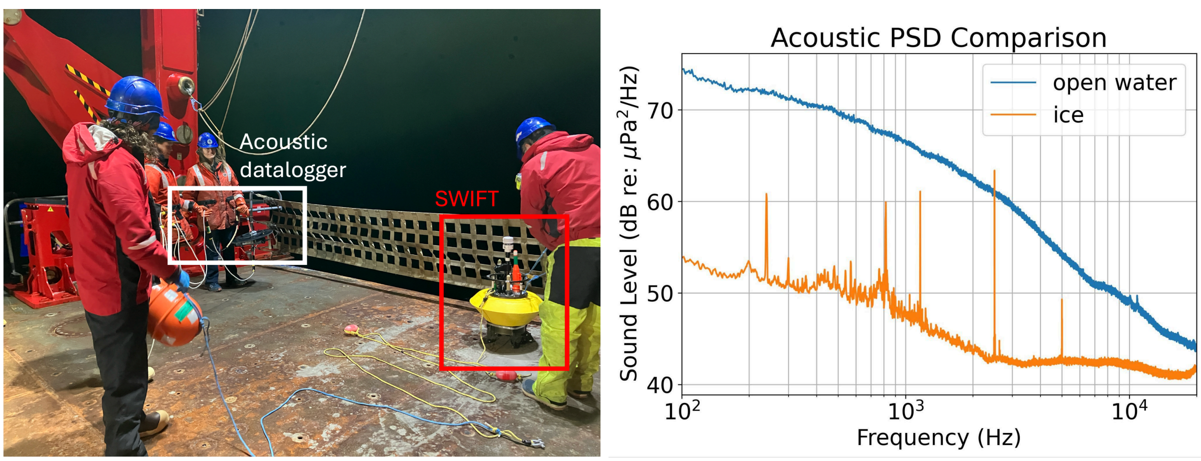






Passive acoustic study (co-deployed on tripods; SWIFTs)

The drifter along with the hydrophone was deployed and recovered on the same day of the deployment, and data underwater were collected at least 9 hours a day. The data measured by the co-located SWIFT are processed to extract the significant wave height, wind speed, and bubble plume depths. We intend to compare these measurements with the acoustic recording to study their correlation. Similarly, the acoustic recordings from the tripods will be compared with wave height and bubble plume measurements obtained from other instruments mounted on the same tripod. The re-deployed acoustic datalogger will record the ambient sound over the freeze-up period.



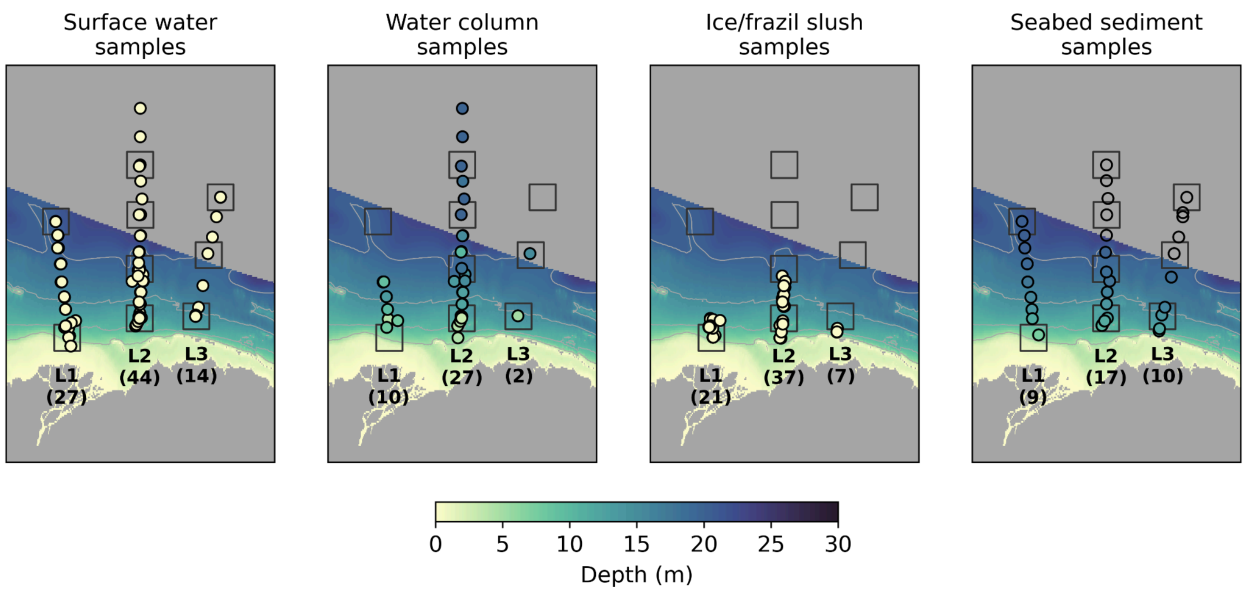
[left] The SWIFT drifter setup with the acoustic datalogger. [right] The power spectral density (PSD) comparison of the ambient sound when the drifter was in the open water with a wind speed of 5 m/s (blue) and when it was under the sea ice (orange). The acoustic data were recorded on two separate days. The sharp peaks in the 'ice' case correspond to the tonal sound of the ship noise when the ship was in a dynamic positioning status 6 km away from the recording system. Nonetheless, the PSD of the ambient sound is clearly higher in the open water than in the sea ice.

While most drifter deployments occurred in open water, one was carried out within a band of sea ice on November 5. It eventually drifted out of the sea ice into the open water before recovery. An increase in the sound level is expected as the drifter comes out of the ice. The figure above compares the power spectral density (PSD) of the ambient sound in the open water and that in the presence of sea ice (two separate deployments).

For the drifting system, two main signal-processing challenges were identified: ship noise and instrument self-noise. Ship sounds were detectable even when the vessel was more than ten kilometers away, owing to efficient acoustic propagation in the shallow-water environment. Sounds generated by the buoy, rigging, or other loose components often dominated the recordings. The self-noise was progressively reduced through iterative improvements made between deployments.

Ice and water sampling

A total of 189 sea ice and water samples were collected, 103 from the Sikuliaq and 86 from the small boat. A map of collected ice, water, and sediment samples (overlain on Harrison Bay bathymetry) is provided below. The number collected along each transect is listed.



Ice cover was generally greater inshore, and thus sea ice samples were primarily collected at shallow southerly sites accessible only by the work boat. Because small boat operations were limited to periods with relatively calm waters, collection of ice samples was also limited to periods of lesser wave activity. Observed ice ranged in composition and development stage, including thin layers of frazil slush, young thin pancakes, and floes exceeding 6 inches thickness. Visible sediment content was highly heterogeneous across sites and between ice floes, though at most sites a pronounced gradient in sediment load between the ice (high) and waters (low) was reported. Particularly turbid waters were however observed at L1-1 during the morning workboat trip on October 27. Once melted, retrieved ice samples revealed high sediment loads composed primarily of fine silts and occasionally sands. A turbidity sensor was submerged in the combination of seawater and mechanically suspended sediments from an especially muddy pancake, measuring turbidities O(500 NTU). In situ, sediment loads generally increased toward the bottom of the ice. Floes sighted from the small boat which appeared especially muddy were assumed to have been overturned.

Most of the water samples collected from depth from the Sikuliaq and workboat during station sampling were retrieved along transect L2 on November 3 (local) coinciding with a period of sustained open water and heightened wave activity. Gradients in turbidity, both cross-shore (increasing inshore) and vertical (increasing toward bottom), were visually observed along the L2 sampling line, with turbid waters reaching the surface particularly at the inshore sites. These early observations suggest greater potential for sediment resuspension with increased wind and wave energy, shallower depths, proximity to the high sediment input from the Colville River, and reduced sea ice cover. Post-cruise processing of sediment concentrations within collected samples will strengthen insights into these relationships. The typically greater sediment loads in ice relative to the underlying water column could be explained by several mechanisms, including differential retainment of sediments following a previous high-energy sediment suspension event or concentration of sediments within ice during melting. Comparison with coincident measurements of near-surface ocean conditions will help to identify likely scenarios, as it was challenging to visually distinguish whether observed ice features were actively growing or melting.

Measurements of sediment concentrations (total suspended solids (TSS)) within ice and water samples require post processing and further lab work and thus will be available following the cruise. Water samples and melted sea ice/frazil samples collected both from surface and shallow depths (up to 20m) were melted if necessary and stored in a fridge on the vessel before vacuum filtering through millipore 0.45 um MCE membrane nitrocellulose 47 mm filters *or* glass fiber filters (GFFs) to allow for organic combustion. If enough volume (more than 2L) was taken from the field, samples were run through a LISST 200X flow-thru system for sediment grain size distributions before being run through vacuum filtration. 47 samples, including seawater and melted sea ice, were run through the LISST 200X flow-thru system. See instrumentation for LISST description. In some cases, a turbidity and salinity sensor (RBR) was submerged in the samples as they were mechanically mixed on a stir plate.

	Total	**Ice**	**Frazil/slush**	**Surface water**	**Water at depth**
Number of samples	189	41	24	85	39

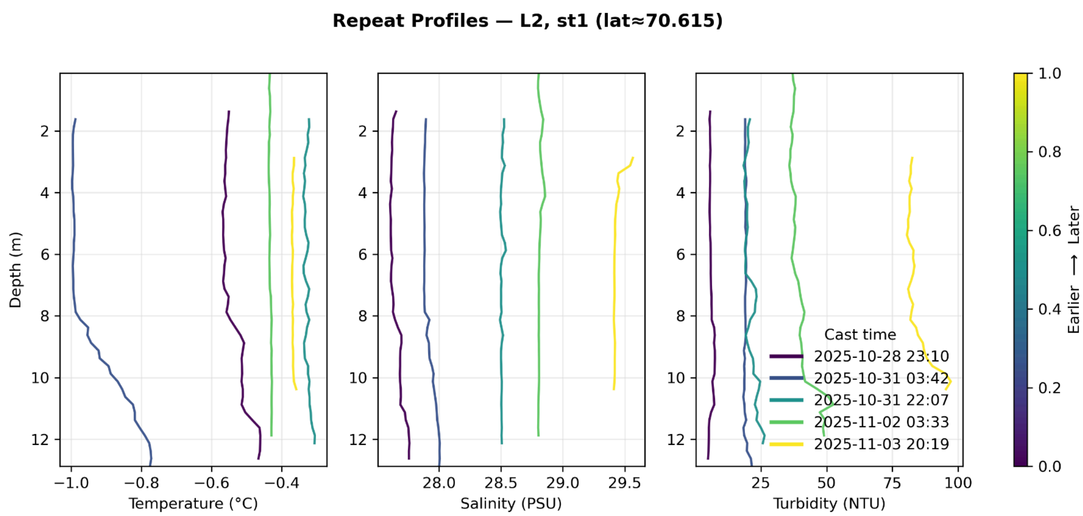
Seafloor sediment sampling

Sediments were clumped mud in most places. Some sorted sands were recovered along line L1, though a small amount of mud was present on the surface of these as well. Very soft mud was recovered in the mini Van Veen seaward of L1-1 and likely represented fresh deposition from the Colville during the spring, summer, and/or fall. In some locations on the middle shelf the sediments were very compact clay which likely represented the basal deposits in keel scours. Seafloor sediments will be analyzed for grain sizes at OSU. Some will likely be analyzed for bulk organic content as well using a loss-on-ignition approach. Qualitative descriptions of sediments are available in the eLog. Subsamples which were saved in falcon tubes will be analyzed for eDNA for colleagues at University of Exeter for a separately funded study.

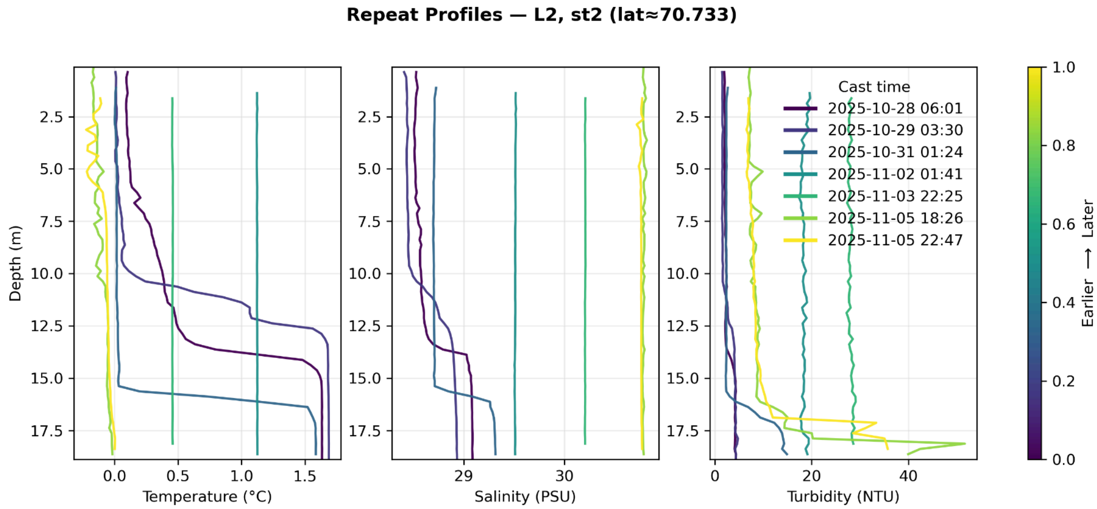
CTD profiles

A total of 141 RBR casts were collected from the Sikuliaq and 31 RBR casts were collected from the workboat. Heat loss to the atmosphere, upwelling, and ice melt appear to be primary processes driving the temperature-salinity evolution of the water column. Repeat casts from three sites on the well-sampled L2 line illustrate the ocean's spatiotemporal evolution (see also the results from near-surface temperature and salinity for a map view of this evolution).

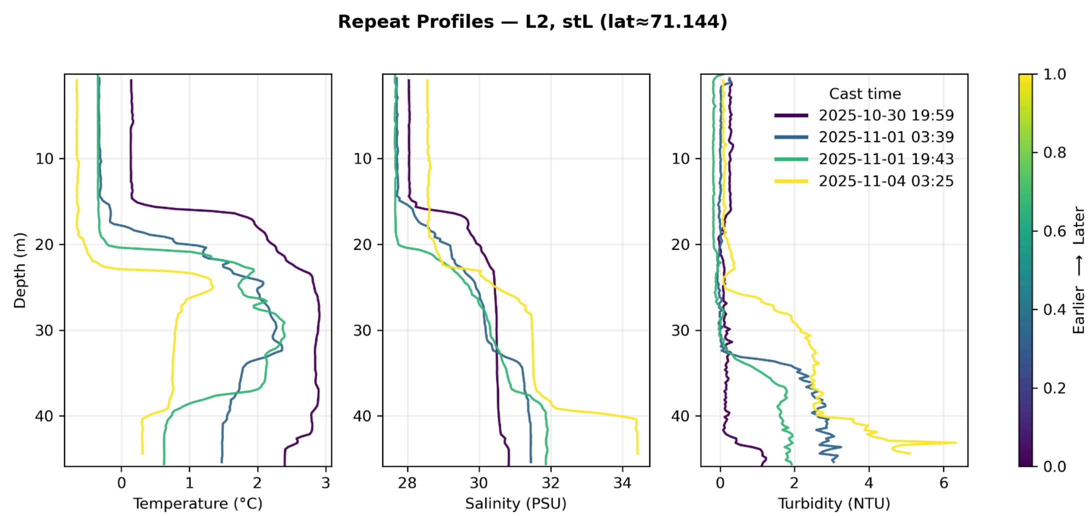
The water column was generally well mixed in all casts at the inshore example site, L2-1 (~13 m depth). From the first to second occupations of the site, temperature decreased but salinity and turbidity increased from 28 to 31 October, perhaps reflecting competing influences of surface heat fluxes cooling the water column and the upwelling's onset increasing the temperature and salinity of the water column. Salinity and turbidity continued to increase in subsequent casts, presumably reflecting the increasing influence of upwelled waters. Temperature fluctuated, again reflecting the opposing influences of warm water upwelling and surface cooling (possibly coupled with ice melt, as this site was intermittently ice covered; see the ASIP ice support map for 4 November).



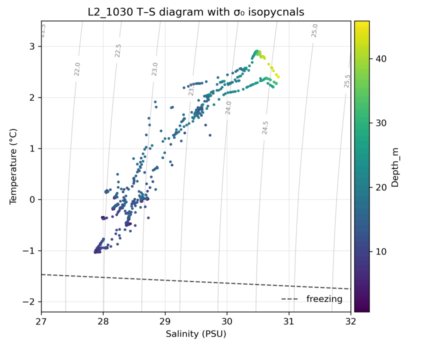
The water column was initially stratified but transitioned to well mixed at the mid-depth example site, L2-2 (~18 m depth). The first three casts from this site, collected between 28 to 31 October, showed the mixed layer deepening, cooling, and increasing in salinity, consistent with the combined effects of heat loss to the atmosphere and upward mixing of warmer, saltier water from the pycnocline. Upwelling's influence was apparent in casts taken on and after 2 November, in which the water column was well mixed and salinity increased with time. Turbidity was highest midway through the upwelling event on 3 November, and decreased to intermediate values in the final casts taken on 5 November. Temperature was highest on 2 November in the first upwellling-influenced cast, then cooled uniformly throughout the water column over the following days. The T-chain data show a higher temporal resolution picture of the water column's rapid transition from stratified to well mixed at this site.

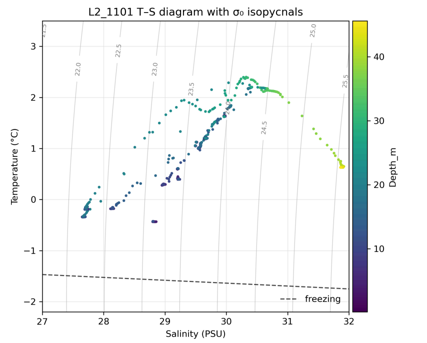


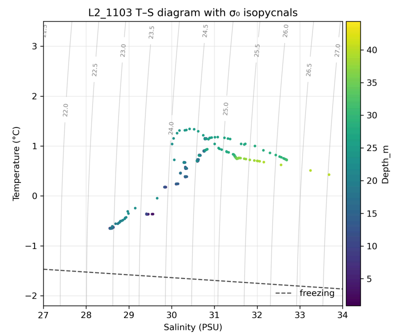
The offshore example site, L2-L (~45 m depth) showed smaller upwelling signals at the surface than the inshore sites but evidence of upwelling at depth. The mixed layer cooled and deepened throughout the study period, and mixed layer turbidity remained low. Temperature and salinity signals below the mixed layer are somewhat difficult to interpret. In contrast to more inshore sites at which upwelling was associated with increasing water temperature, at least initially, at L2-L the pycnocline cooled throughout the study period. Salinity showed varying trends with depth, and turbidity increased below 25 m. Notably, the final cast on 4 November showed waters with salinity above 34 psu at the bottom of the water, suggesting upwelling brought Atlantic Water as far inshore as this site.



T-S diagrams below are colored by depth (m) for L2 transects completed on October 30, November 1, and November 3. Early on, primarily two distinct water masses are observed with mixing between (~linear). While the warm near-surface peak was eroded in later dates, profiles become more well-mixed overall (clusters of points).

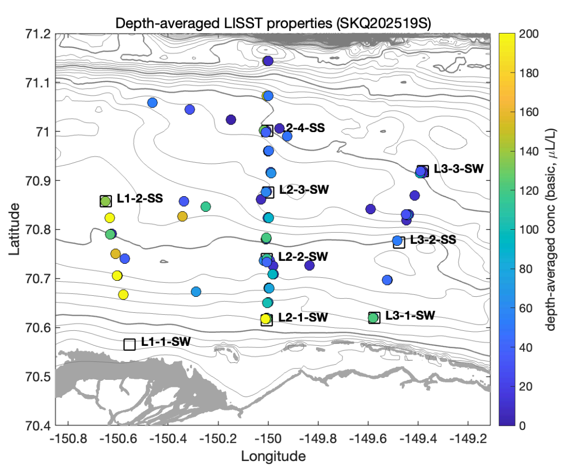


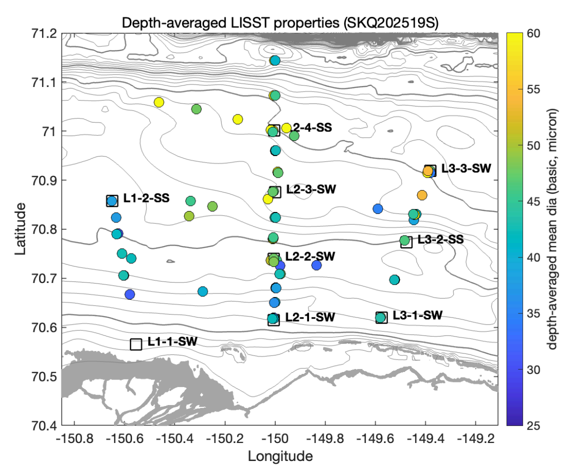




LISST profiles

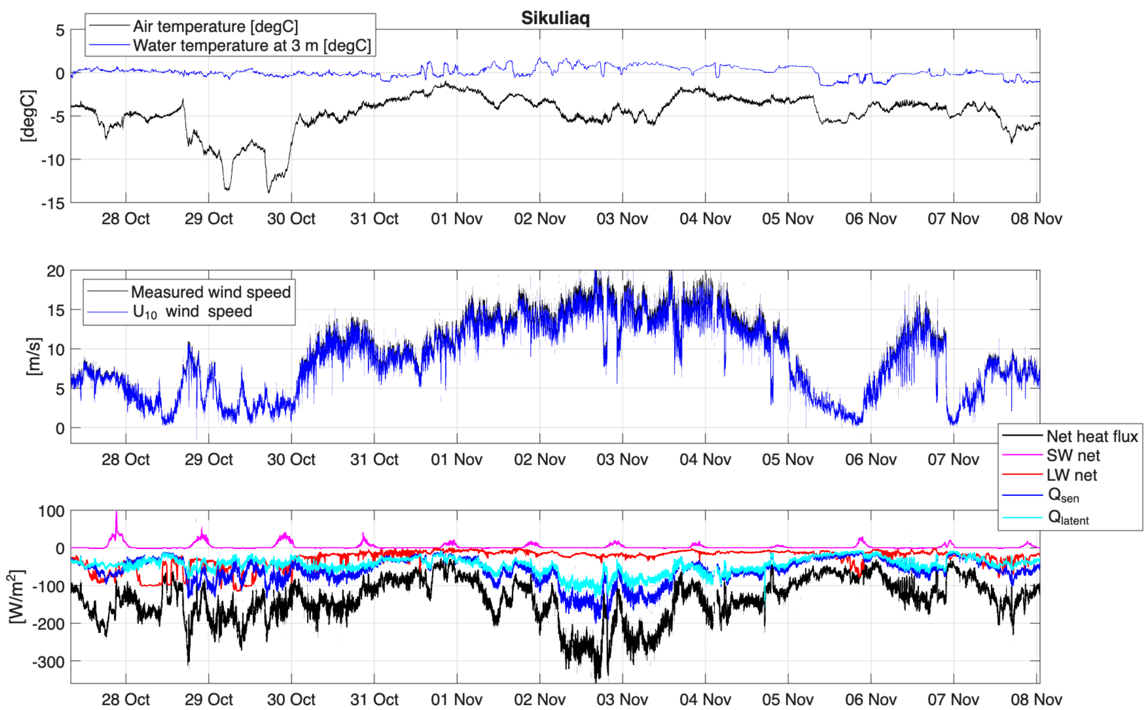
A total of 97 LISST profiles were collected from the Sikuliaq and an additional 33 were collected from the workboat. Particle-size distributions were impacted by Schleiren effects (imposed by strong density gradients) but data corresponding to these density gradients were removed during the trip and the resulting data are still quite dense (roughly one datapoint was collected for every 0.5 m of water column). Particle-size distributions commonly exhibited modes at 6 phi and 2 phi, corresponding to fine/medium silt and fine/medium sand, respectively. The sand sizes likely represent flocs and not actual sand in suspension. Depth-averaged particle concentrations decreased in a seaward direction while mean particle sizes increased (based on data processed through 11/01; see plot below). These trends likely represent a transition from smaller flocs closer to shore dominated by lithogenic sediments to larger, low-density flocs offshore which were more biological.





Underway ship sensors

Met

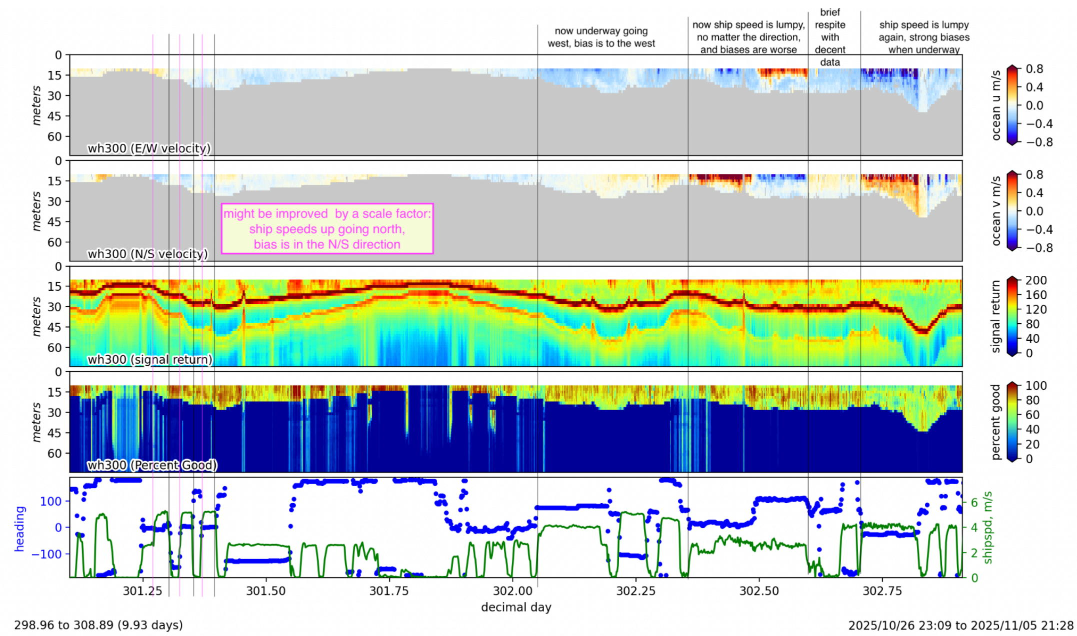


Given the time of year, shortwave radiation was low throughout the time on station, peaking around 30 W/m^2. Note that the netwave shortwave fluxes shown in the figure are calculated using an assumed open water albedo of 0.08; adopting a spatially varying albedo to account for the ship's intermittent incursions into the sea ice would reduce the already-small net shortwave fluxes into the ocean. With the exception of October 28-30 and briefly on 5 November, there was consistent cloud cover that caused the net longwave radiation's cooling effect to be steadily low throughout most of the time on station.

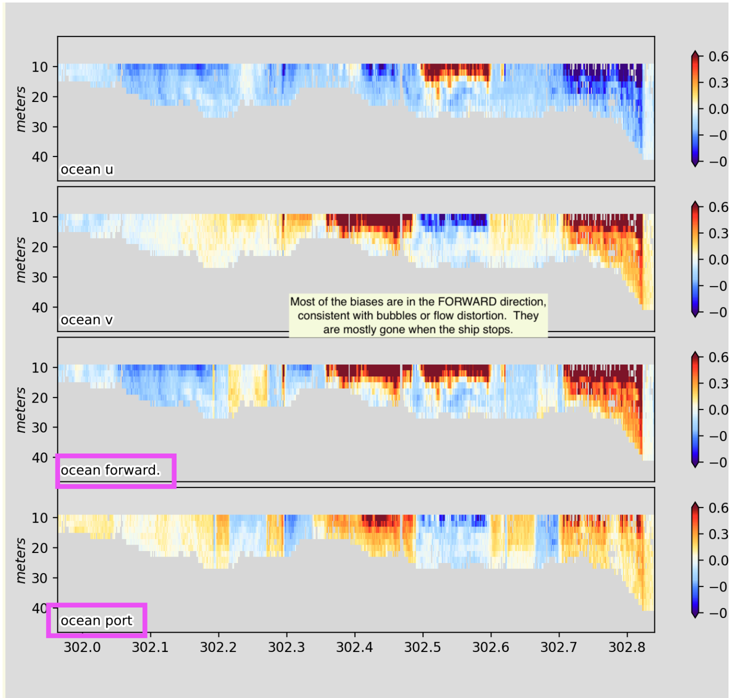
Air temperatures varied significantly ranging between -2 and -12°C. Compared to air temperatures, water temperatures remained stable above freezing around 0°C, even approaching 1.5 °C in the first few days of November. Wind speeds picked up around October 30th and continued before tapering off around November 5th. Latent and sensible fluxes were calculated by inputting ship meteorological observations into the COARE algorithm (version warm 3.6). From November 1-4, the combination of a decrease in air temperature and persistent winds created both notable temperature differences between the air and water and turbulence required to create the greatest significant sensible and latent heat loss throughout the study. Net heat fluxes during this time exceeded 300 W/m^2 (as a loss rate from the ocean to the atmosphere).

ADCP

Raw data from the workhorse 300 ADCP are processed using University of Hawaii Data Acquisition System (UHDAS) software. Midway through data collection, we noticed the current magnitudes and velocities were biased in the direction of ship travel. After reaching out to Jules Hummon at UHDAS, it was determined that most biases are in the forward direction during ship travel due to bubbles or flow distortion, leading to unreliable data. The only way to limit this noise is to lower the centerboard, which was not possible due to shallow water operations. Parts of the record when the ship was stopped may contain useful data but the remainder is highly biased and should not be used for current measurements.



Annotated plot of wh300 ADCP measurements, processed by UHDAS, during October 29th and 30th, 2025 (Jules Hummon, UH). Biases in E/W and N/S ocean velocities are high when the ship is moving.



Annotated plot above shows current velocities corrected for ship motion (panels 1 and 2) and uncorrected current velocities (panels 3 and 4) from wh300 ADCP, processed by UHDAS, on October 30th. There are significant biases in the forward direction of ship motion which are not resolved during ship heading and velocity correction processing (Jules Hummon, UH).

TSG observations of near-surface ocean conditions

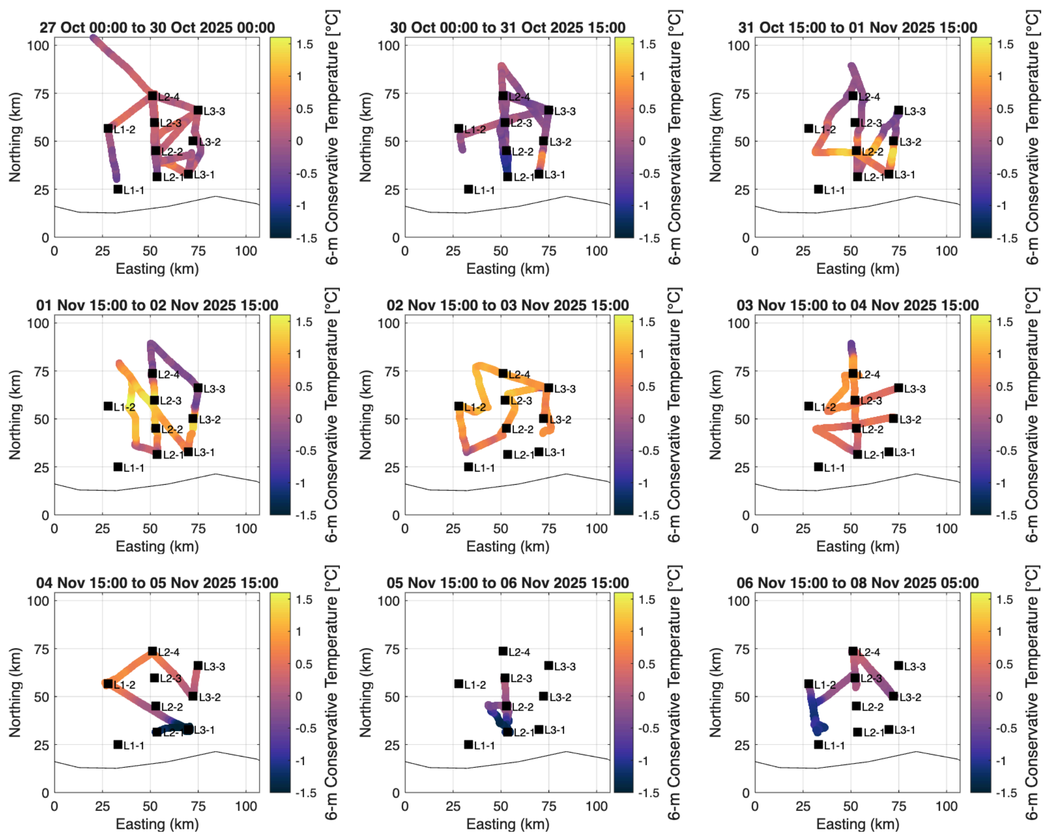
Changing near-surface temperature and salinity reflected dynamic ocean conditions throughout Sikuliaq's time in the study region. From the ship's arrival on 27 October to the onset of the wind event on 30 October, absolute salinity was relatively uniform throughout the array, averaging around 28 g/kg. Conservative temperature showed some spatial variability, but generally cooled from around 0.25°C to around -0.25°C.

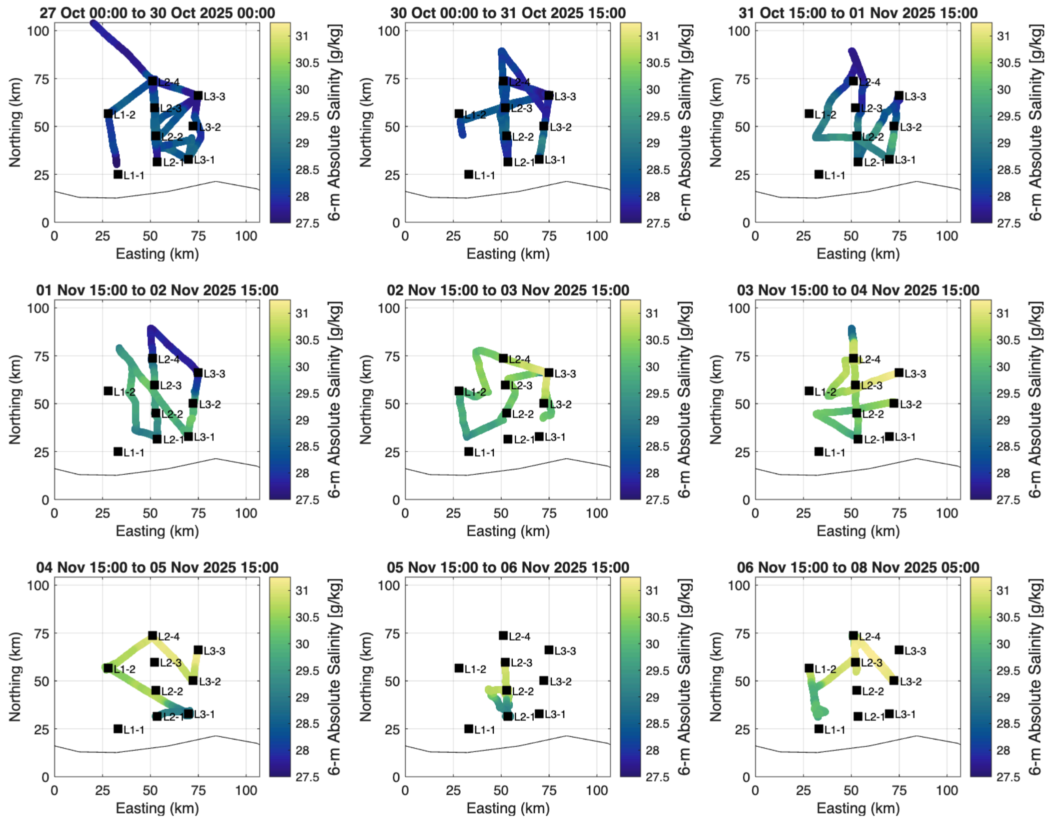
The first indication of upwelling appeared on 31 October, when anomalously warm and saline water was observed between L3-1 and L3-2. Upwelling then spread across the study region, and the warmest near-surface water temperatures, observed on 2 November, exceeded 1.5°C. A sharp front in temperature and salinity developed, apparently separating inshore regions in which warm and salty upwelled water had reached the sea surface and offshore regions where it had not. The density change across this front was nearly 2 kg/m^3. SWIFT 28 appears to have drifted across this front on its 1-2 November (UTC) deployment; its ADCP showed coincident vertical and horizontal velocity shear.

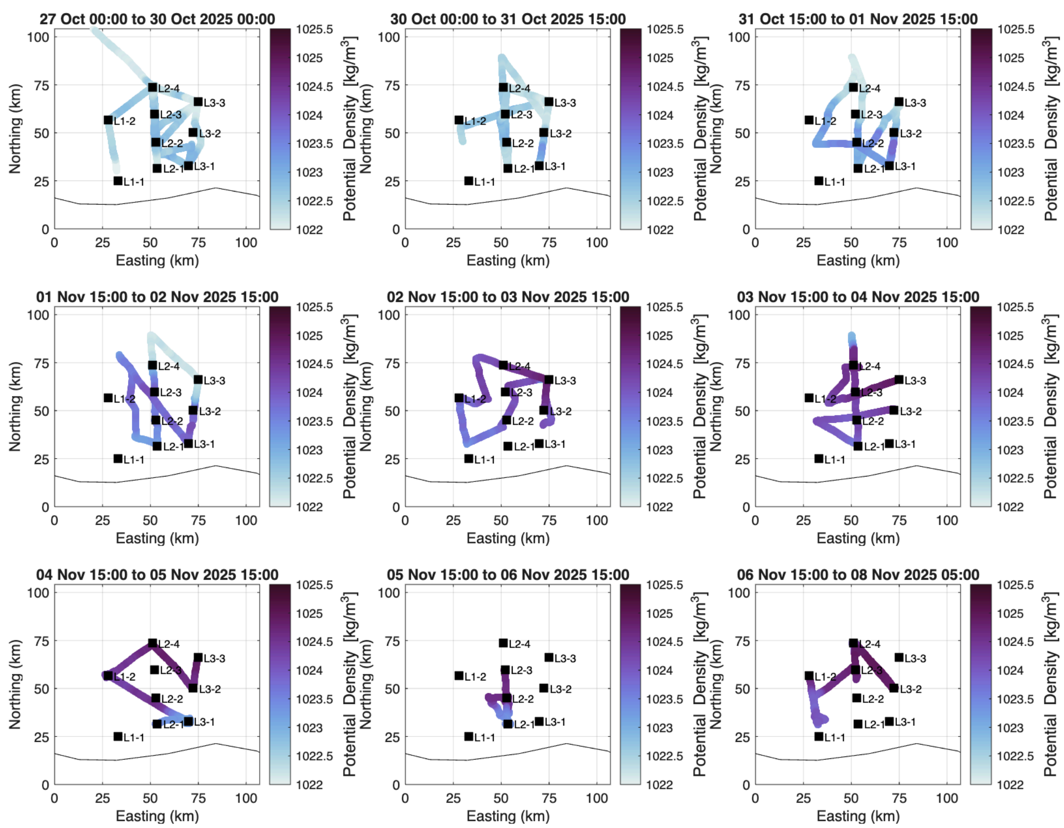
By late in the day on 3 November, this front was replaced by the saltiest water (absolute salinity >31 g/kg) seen near-surface anywhere in the study area throughout the study period. This salty water was first observed near L3-3. The appearance of this salty water was accompanied by an increase in nitrate, suggesting that the upwelling event had progressed to surfacing a new, deeper watermass.

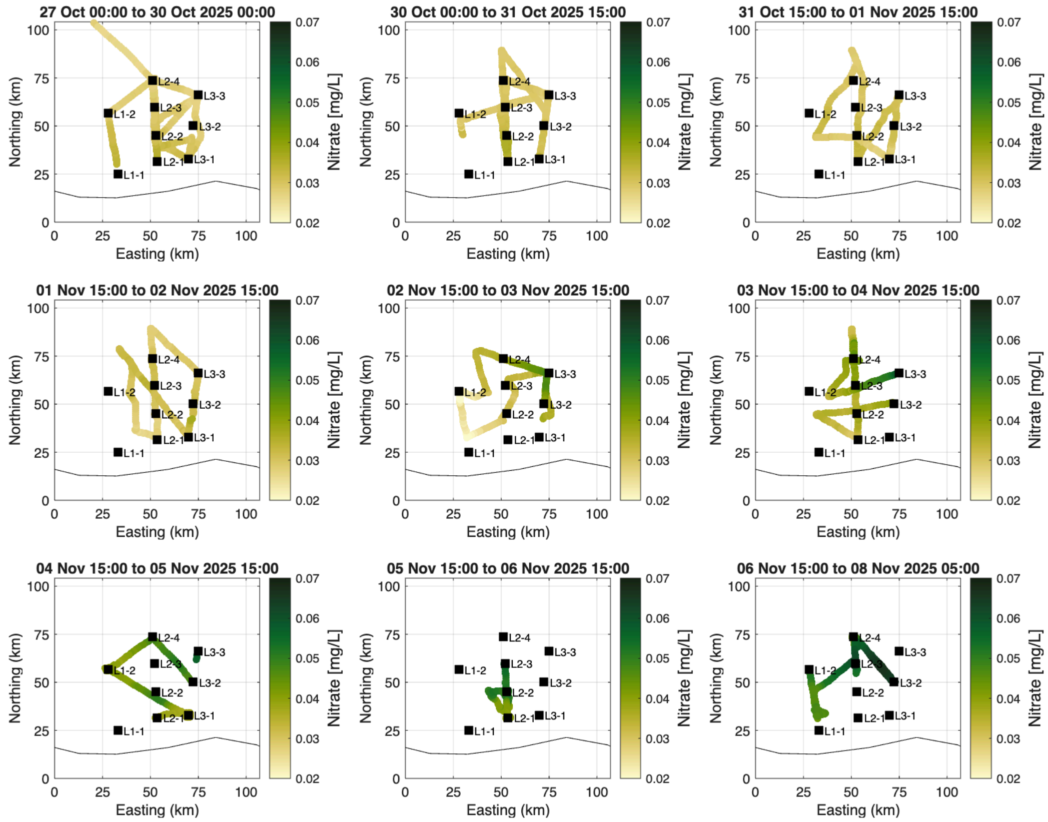
From 4 November until the ship's departure on 8 November, this salty, nitrate-enriched water spread across most of the study area. It was not present at the surface at the most inshore mooring sites (L1-1, L2-1, and L3-1), but this may reflect ice melt reducing near-surface temperature and salinity rather than an inshore limit to the upwelling's propagation. For example, the L2-1 cast taken on 5 November at 14:07UTC showed a two-layer structure, with salinity at depth exceeding 30 g/kg while surface salinity was less than 29.4 g/kg.

Figures below: Conservative temperature, absolute salinity, potential density, and nitrate by Sikuliaq's seawater flowthrough system.




27 Oct 00:00 to 30 Oct 2025 00:00
30 Oct 00:00 to 31 Oct 2025 15:00
31 Oct 15:00 to 01 Nov 2025 15:00
01 Nov 15:00 to 02 Nov 2025 15:00
02 Nov 15:00 to 03 Nov 2025 15:00
03 Nov 15:00 to 04 Nov 2025 15:00
04 Nov 15:00 to 05 Nov 2025 15:00
05 Nov 15:00 to 06 Nov 2025 15:00
06 Nov 15:00 to 08 Nov 2025 05:00
Northing (km)
Easting (km)
6-m Absolute Salinity [g/kg]
L1-1
L1-2
L2-1
L2-2
L2-3
L2-4
L3-1
L3-2
L3-3

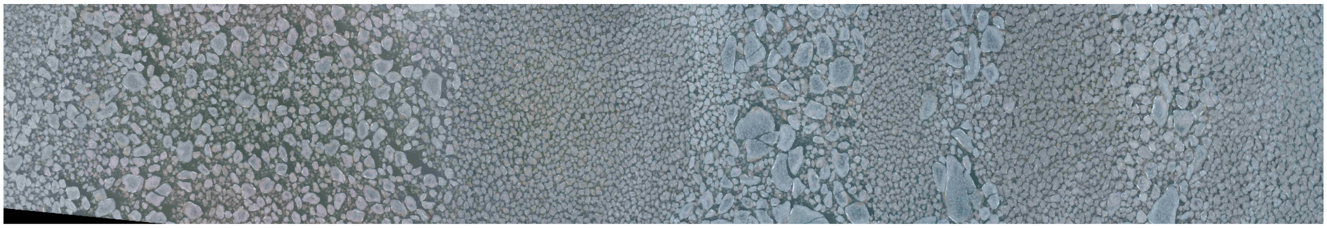

27 Oct 00:00 to 30 Oct 2025 00:00
30 Oct 00:00 to 31 Oct 2025 15:00
31 Oct 15:00 to 01 Nov 2025 15:00
01 Nov 15:00 to 02 Nov 2025 15:00
02 Nov 15:00 to 03 Nov 2025 15:00
03 Nov 15:00 to 04 Nov 2025 15:00
04 Nov 15:00 to 05 Nov 2025 15:00
05 Nov 15:00 to 06 Nov 2025 15:00
06 Nov 15:00 to 08 Nov 2025 05:00
Northing (km)
Easting (km)
Potential Density [kg/m³]
L1-1
L1-2
L2-1
L2-2
L2-3
L2-4
L3-1
L3-2
L3-3



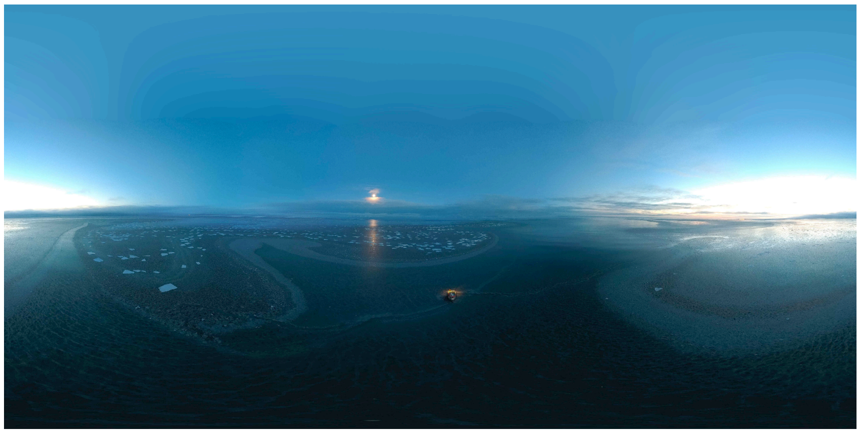
Drones

Drone flights with DJI Mini 2, and John Guillote's DJI Mavic 3 provided contextual information for samples collected on the small boat, and Sikuliaq, highlighting the variability in ice concentration, floe size, and color.

A total of twenty-two flights were conducted from the workboat and six from Sikuliaq. Flights were concentrated near, and beyond, the ice edge. Two primary modes of imagery were prioritized: 1) Nadir-looking (straight down) single images along ice gradients to capture variability in floe size along the ice edge and 2) higher angle 360 degree panorama (video or photo sphere setting) to capture the ice conditions around the sampling site. The imagery captured in these flights show substantial variability in all parameters in the immediate area of the sampling locations, which in many cases extended to larger spatial scales than were feasible to sample with the drone. Lighting conditions, time constraints and lack of automated mapping tools precluded larger area survey of floe size and ice concentration with the UAS. Imagery is processed and rectified using OpenDroneMap, PanoramaStitcher, and custom python rectification rectification code .



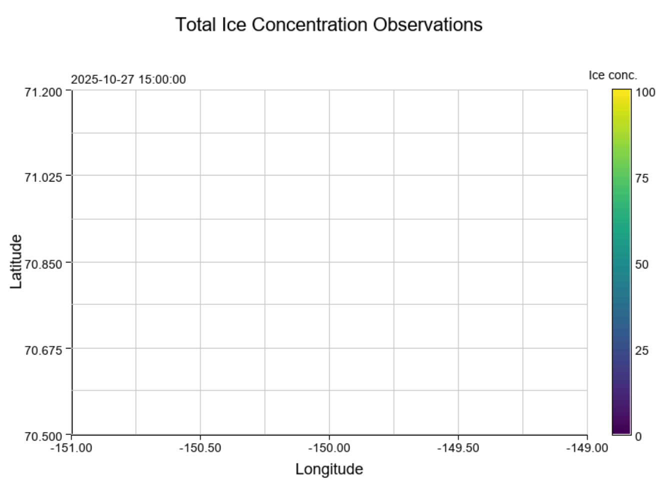
Othorectified Imagery showing variability in floe size



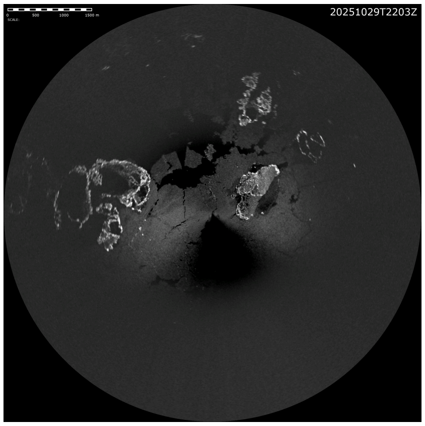
Panoramic Photo Sphere showing spatial heterogeneity in ice type and concentration

Ice observations (visual and imagery)

Visual ice observations using the ASPeCt protocol were taken at approximately the top of each hour during science operations, starting at 15:00 UTC on 10/27/2025 and ending at 01:00 UTC on 11/08/2025. A total of 148 observations were recorded, 25 had total ice concentrations above 0% and the rest (123) were of open water. Ice observations were taken from the bridge and were prioritized when the ship was actively in ice or moving through areas with ice nearby. During long periods of open water or when the ship was stationary for an extended time, hourly observations were reduced and less frequent. The primary ice type observed was pancake.



Additional perspectives of the sea ice conditions around the ship come from recordings of the Rutter radar (both sea ice products produced by CSTARS, and geotiffs; example on left), and bridge cam imagery (every 10 minutes; example on right).



Multibeam bathymetric mapping

Multibeam mapping data were collected along tracklines throughout the survey and in patches at 9 of the mooring sites. When possible, we transited at a survey speed of 5-6 kts to generate good quality data. Sometimes good quality data were also gathered at 8-10 kt transit speeds. However, we had numerous tracklines of very low-quality data collected during periods of strong winds and heavy seas. Further post-processing will yield more information about the number of good-quality data files. E. Eidam batch-processed the raw .all files from the EM710 using mbsystem and generated .grd and .tif (geotiff) files. There were 387 of each file type spanning a date range of 10/24 to 11/07. Note that this includes part of the transit to the site (surveying started on 10/27). Hopefully at least half of these files are of good quality. A new file was started every hour by default in the software but occasionally extra files were generated during troubleshooting or in relation to when the ship resumed surveying after being on station.

The trackline datasets yielded useful information about zones of keel scour versus smoother substrates. The patches collected at some mooring sites were very useful and examples are provided below. Note that the two inshore sites where we did patch surveying yielded noisier data than the offshore sites (likely because the MBES struggles at such shallow depths). Further post-processing (i.e., manual point killing) will be needed if higher-quality data products are desired.

Mooring locations where patches were mapped:

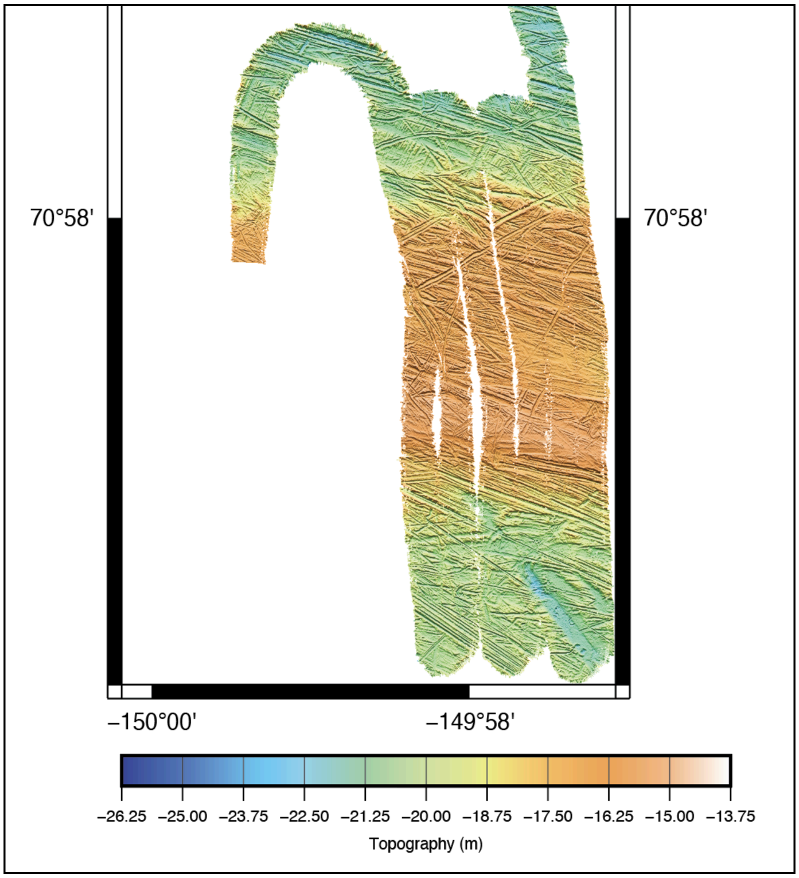
Location	Notes	Brief description
L1-f	Small area of bonus mapping that was done while waiting for the small boat on the last science day	
L1-j	Very small patch due to limited time; a couple of passes while waiting to arrive on station	

L1-2	First patch completed and one of the nicest; ~1 nm square	Heavy keel scours
L2-1	Partial patch; largely missed the mooring site (mapped to south)	Relatively smooth seafloor though it's difficult to assess based on noise
L2-2	Nice patch; likely covers mooring site	Muted keel scours; somewhat noisy
L2-3	Nice patch	Heavy keel scours
L2-j	Bonus small patch completed to highlight shoal where fiber cable was cut; very nice map	Heavy keel scours; shoal
L2-4	Nice map of keel scours	Heavy keel scours
L3-1	Only did a partial patch here due to time and it was on the eastern edge of the 1-nm box (we missed the mooring site).	Interesting dataset; noisier, but seafloor is smoother here than the keel-scoured sites except for a few locations where large bedforms are visible.

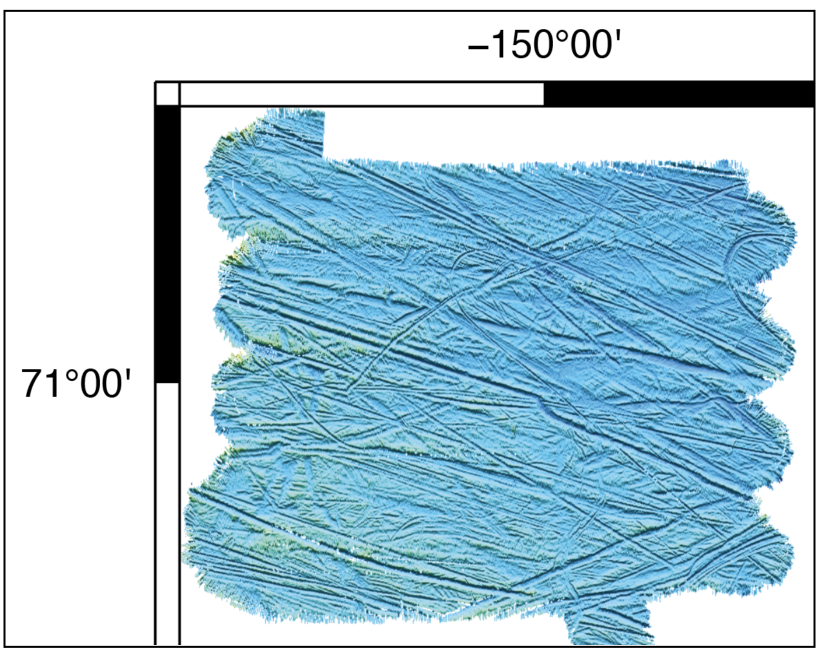
Note that we did not survey L3-2 and L3-3 in detail due to lack of time, and L1-1 was unable to be reached by the Sikuliaq.

−150°01'00"
−150°00'30"
−150°00'00"
−149°59'30"
70°53'00"
70°52'30"
70°52'00"
−26.25 −25.00 −23.75 −22.50 −21.25 −20.00 −18.75 −17.50 −16.25 −15.00 −13.75
Topography (m)

L2-3 map



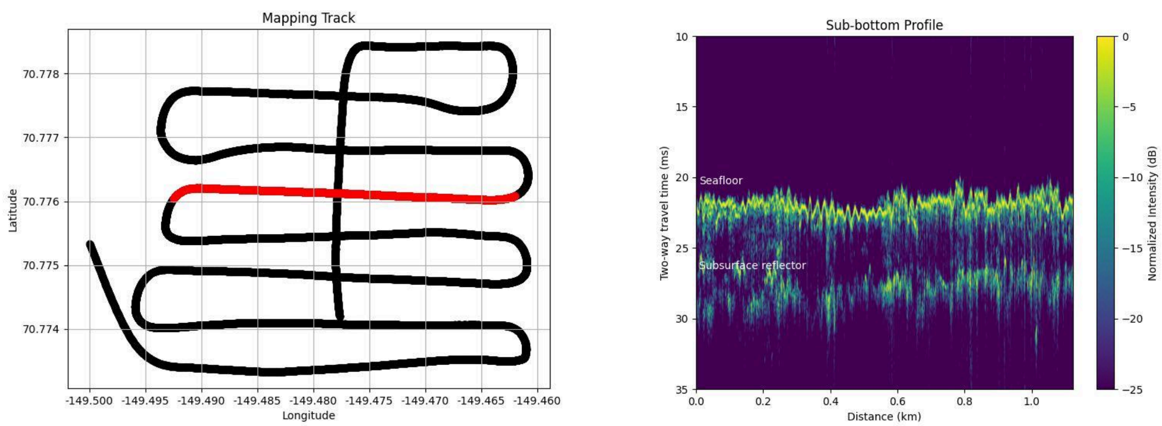
L2-j shoal mapping



L2-4 map

Topas seafloor mapping

Sub-bottom profiles (SBP) were collected using the TOPAS PS-18 on the ship. The primary goal was to collect data for modelling the acoustical environment (e.g., to support interpretation of hydrophone and DAS data). Since the study site is shallow (water depth < 30 m), the sound is expected to interact with not only the seafloor but also the sediment layers below it. There was a focused SBP mapping at the two tripod deployment sites (L2-4-SS and L3-2-SS). A Ricker pulse of either 4 or 6 kHz was used due to its high spatial resolution. Sediment grab samples indicate substantial spatial variability in composition across stations in the study site, with sediments comprising a mixture of sand and mud whose relative proportions varied considerably. The figure below shows an example SBP collected over one of the legs of the lawn mower mapping at site L2-4-SS. Some profiles also clearly revealed filled in keel scours, which may complement bathymetric mapping and sediment transport analysis.

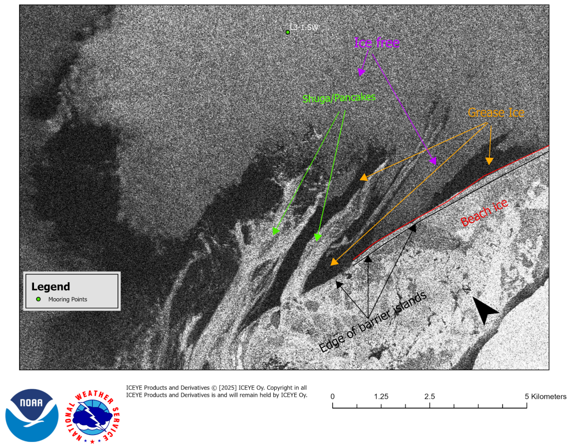


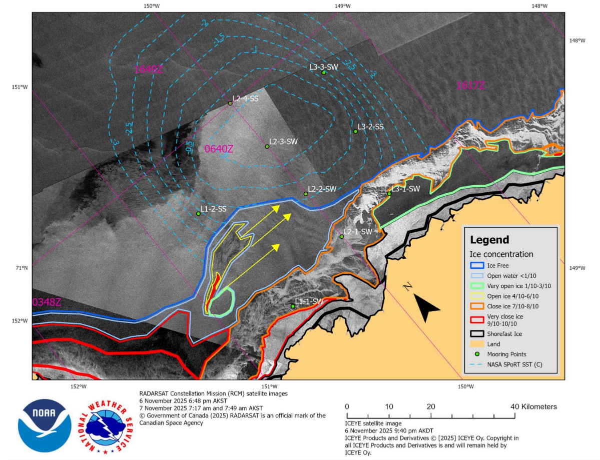
[left] The mapping tracks of the TOPAS at site L2-4-SS. [SBP] Sub-bottom profiles (SBP) obtained from using the TOPAS PS-18 along the track highlighted in red in the figure on the left. The TOPAS system emits an acoustic pulse that propagates downward through the water column. At each boundary between materials with differing acoustic properties (e.g., water and sediment layers), part of the signal is reflected. These echoes are received by the TOPAS transducer, and their intensities are displayed at the corresponding two-way travel times. In this figure, a distinct sub-seafloor reflection is visible approximately at 30 ms, indicating a sharp contrast in acoustic properties below the seafloor.

Ice imagery support

Targeted sea ice product support and analysis was provided by NWS Alaska Sea Ice Program (ASIP). Throughout the project, targeted support is being provided in the form of daily analysis of real-time sea ice conditions and sea surface temperatures (see example below). Additionally, an expert ice analyst (M. Lawson) sailed on the cruise to provide real-time analysis and forecasts to guide operations. He provided a daily briefing to both the science party and crew on weather and ice conditions, and custom products (such as animations) highlighting rapid changes in ice coverage and type.

This activity was supported by the request for targeted high-resolution satellite imagery (primarily SAR), including ICEYE, over the operations area during our cruise.





Examples of support products from October 27 (left), zoomed into the area of small boat operations, and more typical support for November 7 (right), using ICEYE imagery.

Educational and outreach activities

Two educational livestreams were completed from the ship during the cruise, hosted by Exploring by the Seat of Your Pants (led onboard by Onpoint Outreach). The first introduced the scientific goals of the project and the tools used at sea, while the second explored life on a scientific research vessel and paths to science careers. Both were attended live by dozens of classrooms around the world, with an estimated 3k students reached (with more views asynchronously via YouTube).

The cruise intentionally engaged a high fraction of early-career participants (see science party table below), who were active participants in the science activities. The more formal training prior to the cruise and during transit were complemented by informal mentoring throughout the cruise.

Communication with local communities

Communication and coordination with local communities was a key consideration, especially given the transit and operation in areas adjacent to subsistence hunting zones. Prior to the cruise, plans were presented to the Alaska Eskimo Whalers' Commission (AEWC) for feedback and approval. The ship observed subsistence buffer zones during transit and operations, particularly around Utqiagvik and Cross Island.

Throughout the cruise, a community observer (C. Zeller) provided daily updates via email to a list of community members, in coordination with the chief scientist. Updates included a brief summary of daily activities, a photo, projected locations for the next two days, and air and water temperatures. Questions and responses were handled jointly by the community observer and chief scientist.

Wave buoys deployed as part of the cruise (SWIFTs and microSWIFTs) have data streams integrated as part of the "Backyard Buoys" to make data accessible in real-time to local communities and stakeholders.

Science party

Table of science party, institutional affiliations, and role.

Name	Institution	Role
Maddie Smith	WHOI	Chief Scientist
Jim Thomson	UW	PI
Emily Eidam	OSU	PI
Laura Crews	UW/UAF	Post-doc
Junsu Jang	WHOI	Post-doc
MacKenzie Jewell	OSU	Post-doc
Ian Robertson	WHOI	PhD student
Malcolm LeClair	UW	PhD student
Emily An	OSU	MS student
Cal Hobson	WHOI / Middlebury	Undergrad student
Maddie Kimmel	UW	Undergrad student
Maya Moran	OSU	Undergrad student
Joe Talbert	UW	Engineer
John Guillote	Onpoint Outreach	Outreach specialist
Clarissa Zeller	UIC/Battelle	Community observer
Michael Lawson	AWS	Ice observer

Summary and outlook

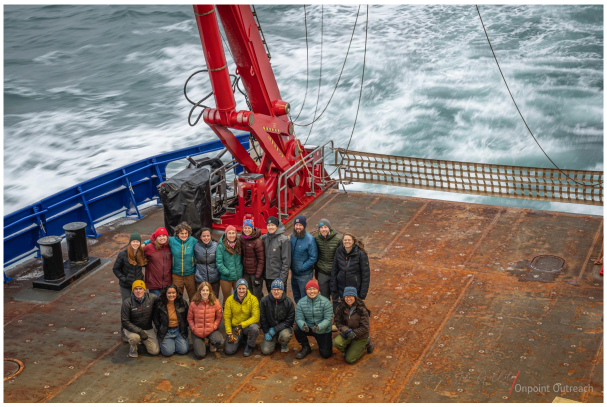
The Coastal Freeze process cruise in fall 2025 provided an in-depth look at the coupling between the ocean, ice, and seafloor during the early part of freeze-up on an Arctic shelf. Data will continue to be collected over the domain of interest to capture the ongoing transition to freeze-up and a stable landfast ice pack. This includes 7 seafloor packages (1 tripod; 6 anchor moorings), which will be recovered from the R/V Ukpik in September 2026. In addition, a suite of drifting assets including 10 microSWIFTs and 2 drifting v3 SWIFTs will provide data in real-time via telemetry through the freeze-up of 2025.

Analysis will be ongoing for the data collected during this cruise. Several themes in the observations that have emerged for further investigation include:

- A notable upwelling event was observed over a 5-day period, which caused ice retreat and delayed advance. Analysis may explore details of this event (e.g., observed along-shore variability in the upwelling), how representative the conditions leading to this event are in the climatology and prior observations, and relationship with other observed processes including water level setup (pressure sensors) and upper ocean shear (SWIFT v4 ADCPs).
- Strong turbidity signals and highly sedimented ice can be used to understand the sediment uptake rate in sea ice as a function of conditions. Observations during the cruise can also be related to what happened prior – fall season sediment transport, as observed by moorings – and what will happen following – looking at where muddy ice ends up in the spring, using satellite imagery. Using additional sensors on CTDs and the ship's flow-through system (e.g., nitrate), the fate of sediment transported by ice may be used to suggest transport of nutrients within the system.
- Heat and salinity budget of the early ice formation, and relationship with thermodynamic vs. dynamic (rafting) contributions to early-season ice thicknesses. Onshore winds and water level setup likely drove a decrease in ice area and increase in ice thicknesses (observed from October 27 to November 3). At the same time, upwelled warm water and mixing drove melting of thin ice. Both should consider the potential influence of strong riverine signal, and if this is representative of typical conditions.
- Use of drone (aerial) imagery to estimate the relationship of floe size distribution/ice stage and sediment load. Observations suggested that color doesn't necessarily correlate with sediment load, but could be related to satellite imagery for the freeze-up period to understand the history of conditions for observed ice.
- Wave data and ice observations can be used to create a high-quality calibration of synchronous distributed acoustic sensing measurements on the seafloor cable. Analysis of this dataset can be used to investigate high-resolution changes in wave attenuation (e.g., exponential attenuation) and the attenuation of bed stress throughout the domain.
- Collocation of hydrophone data with the wide variety of environmental measurements, as well as the seafloor cable, could be used to explore environmental noise characteristics as a function of waves, breaking (bubbles), and new ice formation. Relatedly, the ice conditions may impact the ambient and/or ship noise characteristics.

Acknowledgements

Funding support provided by National Science Foundation Arctic National Science's program, awards OPP-2336693 (WHOI), 2336695 (OSU), 2336694 (UW).



A huge thanks to the captain (John Hamill), crew, and marine technicians (Jenny Grischuk, Carmen Greto) of the R/V Sikuliaq who went above and beyond to support our science. This research cruise was a success because of their expertise and hard work.

Appendix 1: Full Cruise Narrative

October 16

Science party arrives in Seward and mobilize on Sikuliaq.

October 17

Sikuliaq completes sea trials in Resolute Cove. Safety briefing and orientation.

October 18

Ship departs Seward and begins transit. Ship's drills. Training on ship's eLogger and data systems. Rocky and rolly.

October 19

Training on SWIFT buoy sensors, deployment and recovery, and data access. Afternoon science presentations postponed due to weather.

October 20

Training on IceWatch (visual ice observation) protocols. Training on sediment bottom grabs and turbidity sensors, including best practices. Science talks by two of science party on interannual variability in fall freeze-up (Ian Robertson) and winter ice processes on the shelf (MacKenzie Jewell)

October 21

Training on ship's instrumentation, especially including meteorological measurements, locations on ship, processing. Live educational livestream to classrooms around North America on science questions and work on the ship, hosted by Exploring By the Seat of Your Pants. Science talks by two of science party on determining emergence of landfast ice stability with InSAR (Cal Hobson) and landfast ice wave and thickness measurements using on-ice DAS (Junsu Jang). Engine room tour for science party .

October 22

Transit slows due to strong headwinds and waves. Morning overview of drone systems, including launch and recovery protocols and general flight strategies. Presentations on Arctic coastal fall heat budgets (Maddie Kimmel) and waves in winter polynyas (Laura Crews). Second engine room tour for science party.

October 23

Overview of mooring equipment in the water, including recovery and redeployment approaches with deck crew. Science presentation on Arctic sediment supply (Emily Eidam). Slow transit continues due to strong headwind.

October 24

Overview of small boat science operations and sequence of events, including operation of towed Sontek ADCP, ice and water sampling, review of LISST and RBR profiling, grab samples with mini van Veen, and drone ops. Presentations in the afternoon from the AWS Ice Analyst aboard (Michael Lawson) on the process of analyzing satellite imagery for sea ice conditions, and available products, and then on application of turbidity and sediment methods (as used on this project) to observing a glacial plume in Greenland (Emily An).
Transit continues, with the highlight being crossing the Arctic Circle.

October 25

Completed training on use of multi-beam for mapping bathymetry, data collection, and watchstanding tasks. Also covered a brief overview of Topas datastream. Knots practice in the afternoon, followed by polar bear awareness and hands-on firearms safety refresher prior to coastal small boat work. Prior to dinner, a short test station was completed primary to collect sediment for turbidity calibrations. Two Shipek bottom grabs were completed with under-wire winch, followed by a CTD cast (RBR maestro). Simultaneously, three short test drone flights were completed from the 04 deck (aft of bridge) with DJI mini and Phantom.

October 26

The ship passed through new ice forming offshore in the early hours to the west of Barrow. There was no formal agenda for trainings or talks, while the science party focused on preparations for arriving in the ops area the following day, including calibration of turbidity sensors (microSWIFTs, RBR sensors, openOBSs) using mud collected the day prior. microSWIFT calibration attempt revealed issues that require further troubleshooting.
In the evening, SWIFT 21 (adrift from L2-2-SW mooring) was recovered off the shelf, with ~12 m of line including an openOBS with pressure sensor. Buoy was located in the last mile by Rutter radar signal, and was recovered using fast rescue boat (FRB). After recovery, post-processing provides SWIFT wave data from approx 2-12 Sep and 11-22 Oct. The gap might have been time under an ice floe.

Proceed to op area for multibeam survey in early morning.

October 27

Multibeam between L2 and L3-1 in morning hours to repeat tracks from CODA. The workboat was deployed around first light, and transited to L1-1-SW for mooring recovery and sampling shakedown. The site was covered in pancakes with muddy frazil between. The full sampling progression was tested, with some issues using the Sontek ADCP. Pancake and frazil ice were collected.

The landing craft was launched at sunrise, and recovered SWIFT 09 (L3-1-SW) from the beach and then L3-1-SW anchor mooring.

In the afternoon, the workboat recovered mooring from L3-1-SW followed by sampling at the site. Simultaneously, the Sikuliaq recovered the mooring at L2-3-SW, aided by the FRB to get a line on the buoy.

The mooring at L3-3-SW was recovered in the same manner following dinner, followed by some nice northern lights. The new, temporary mooring for L2-2-SW-r (moored SWIFT v4, with T and OBS chain) was deployed from the Sikuliaq.

Overnight mapping L2 line with Multibeam and TOPAS mapping.

October 28

Mapping with multibeam and Topas finished at L3-3 in the early morning. 3 sites along L3 the outer part of L3 were sampled in the morning, and then the Sikuliaq transited to L3-1. The workboat was launched near L3-1, and then completed sampling on the transect inshore from there. A total of 2 full and one partial sampling stations were completed in the ice and near ice edge, including sampling of new pancakes and frazil:

1. First station near L3-a (as far onshore as ice conditions would permit): In order: RBR cast, LISST casts (x2 to try to improve lowering smoothness using the davit for the second cast), frazil sampling, pancake sampling, water/slush sampling, sediment grab, drone flight. Strong offshore breeze meant we drifted during our sampling effort and the end of the sampling was about halfway between L3-a and L3-b. All waypoints logged for each sample type. At the beginning of this station's drift we were in quiescent ice with near-total wave attenuation, but at the end of this station's drift there were waves propagating into the ice.
2. Second station near L3-b, just inshore of the ice edge. Same sampling order. RBR cast x2 because unsure if we reached the bottom (either time), but faster lowering on the second cast made the line more vertical. Asked boat operator to reposition on station for each sample so all should be at approximately same location
3. Third, abbreviated station was completed approximately midway between L3-a and L3-b. RBR and LISST only. Intention was to have casts representing the waves-in-ice conditions present at the end of our ice and sediment sampling efforts of Station 1.

Meanwhile, the Sikuliaq redeployed the seafloor package at L3-1-SW, and then completed sampling on the transect along 3 points outwards. After the work boat returned, we transited to L2 and the workboat was deployed for the afternoon. The workboat pushed through the ice to the inshore part of L2, through relatively large (5-10 m) broken floes of new ice. 3 workboat sampling stations were completed with the reduced sampling work plan, including a successful test of the new Sontek surfboard rigging.

On both inshore transects with the workboat, bands of new ice of a variety of sizes (from proto-pancakes to larger pieces of consolidated pancakes), many with visible sediment.

During the L2 WB sampling, Sikuliaq crept in to L2-1 (to determine if accessible based on bathymetry for future mooring redeployment) and encounter , then completed a series of stations from L2-1 mooring site outwards (continuing after the WB resumed). A drone flight was completed from SKQ at L2-1 to image the visibly sedimented floes.

In the evening, the Sikuliaq returned to L2-1 site to deploy the seafloor anchor mooring, and a moored SWIFT (noting that the deployed SWIFT has intermittent telemetry).

The Sikuliaq transited out past the most recent L2 sampling site and continued sampling stations until 0200. It was not possible to sample all of the newly added “alphabet” stations, but at least the major numbered stations along L2 were completed.

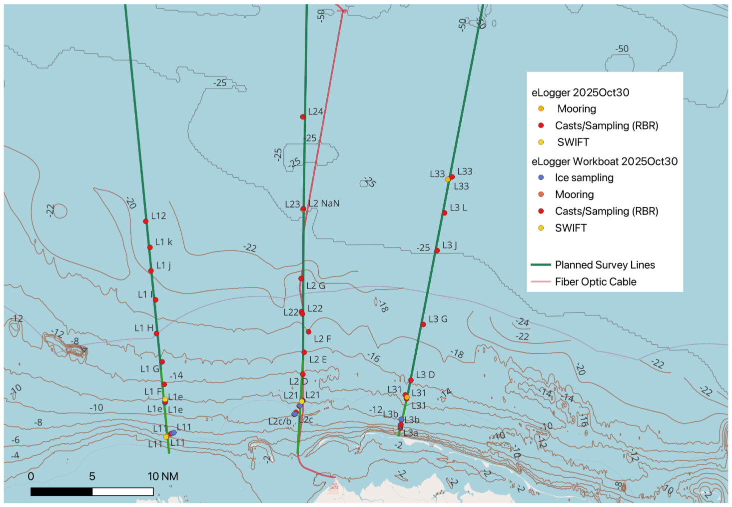
October 29

Multibeam and Topas mapping was completed from L2-4-SS to L1-2-SS and then down the L1 line. A few sampling stations were done along the L1 line.
Morning workboat trip targeting L1-1 SWIFT deployment and inshore sampling was delayed due to cold issues with workboat engine. The workboat was deployed around 1000, and was able to push with much effort into ice no more than a couple nm ahead of the Sikuliaq. Workboat was not able to progress (likely due to ice in the strainer) and so sampling was conducted at that point. Included sampling of ice (broken off chunks of 4 cm surface ice), frazil, near surface water, 4 m depth water. French press sampling of frazil was attempted but there was very little notable frazil under the consolidated surface ice. LISST profile and CTD profiles to bottom, followed by bottom grab. Drone flight to low altitude (limited by visibility/fog) for nadir imagery, and short GoPro under-ice. NMEA position/depth logging was not turned on for this workboat deployment (so there’s no file).

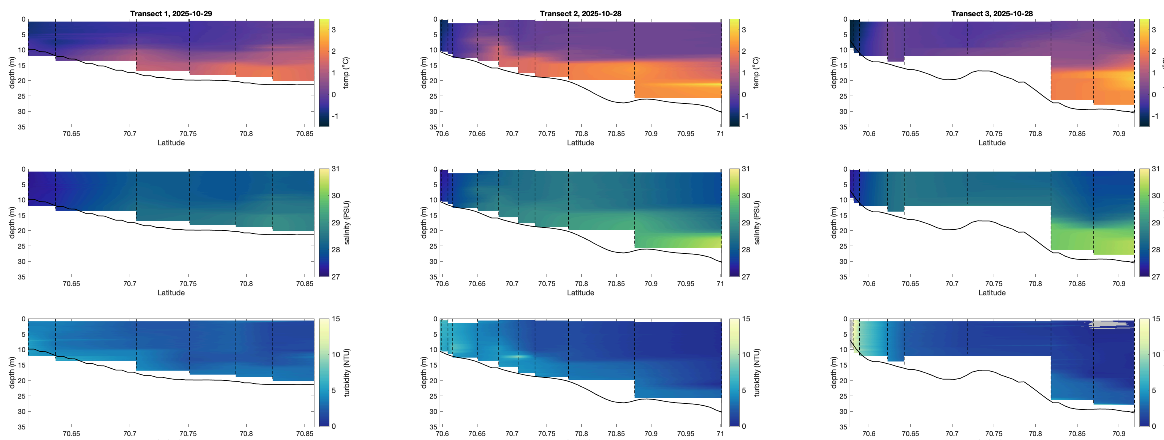
SWIFT 17 was deployed from the SKQ instead upon small boat return without mooring due to significant level of ice, and with addition of OBS. It has since drifted west across Harrison Bay. We then continued stations offshore/outwards along L1 filling in gaps between stations sampled in the morning.

Turned on geotiff recording (every 1 min) for ice radar (~1300 local), in addition to data recording that was already occurring.

In the evening, we deployed seafloor anchor moorings with separate moored SWIFT at two sites: L3-3-SW, and L2-3-SW. We also CTD cast at both sites. We then checked on the SWIFT (26) moored at L2-2, which has only been calling intermittently. The SWIFT looked fine and was riding well on the catenary to mooring buoy. There was no sea ice within the 4 nm range of the Rutter radar, and no visible icing on the buoy. We decided to leave it as is, rather than recover and swap. As we finished evening watch, the seas were building and the winds became a steady 20 knots.



Summary of actions October 27-29



Section plots of temperature, salinity, turbidity from all CTD stations from October 27-29.

October 30

In the morning, two drifting v4 SWIFTs (29, 28) were deployed along L3 with the intent that they will drift towards L2 as the winds and seas continue to build. One was deployed with catenary to float with 10 m cable to hydrophone, instrumented with T sensors (8) and OBS (2). The second was deployed with 5 m drogue to duet and OBS.

We transited to offshore of the L2 and began casting with CTD and LISST only at all L2 stations, finishing by the evening (total of 13). In addition, the new L2-2-ANC mooring was deployed while at that station. Some water samples were taken at the last 3 (inshore) sites with bucket and Niskin.

After completing L2, both drifting SWIFTs were recovered, with a CTD cast taken at each. The SWIFTs had drifted west from L1 to L2 with the steady easterly winds all day. Both SWIFTs had significant icing accumulation above the water line (grab ring, met senor, antenna, etc).

The steady winds appeared to compact the ice along the coast, and most of the study area was ice free by the end of the day. We saw no ice at any of the stations.

October 31

Overnight multibeaming took us from the SWIFT recovery site, near L2-4, down L2 including over a shallow shoal near L3-h (minimum depth 10 m). Starting in the morning we began casting (L3-1) and deploying 3 drifting v4 SWIFTs along L3 (L3-f, L3-j, L3-3). The first two SWIFTs were additionally instrumented with a 5 m line with RBR duet, equipped with peanut float and drogue. The third SWIFT was instrumented with the same T-chain and hydrophone as the day before.

SWIFTs began advecting to the west across the domain due to the easterly winds and currents. The ship did a zig zag pattern to continue sampling between them, with additional points onshore and 1 offshore near L2-l. In addition to casts at all sites, water samples (surface and 10m Niskin) were taken at the most inshore points. Including the deployment and recovery, 4 transects aligned with the buoy spread were completed, with typically around 4 profiles each. Surface water measurements from the ship as well as casts reveal a consistent spreading of warm water across the eastern, inshore part of the domain, hypothesized to be due to upwelling.

In the evening, the 3 drifting SWIFTs were recovered after drifting almost to L1. We were surprised to see no icing on the buoys, in strong contrast to yesterday. The conditions were very similar between the two days, with freezing spray likely in both cases. So how/why was there ice accumulation one day and not the next? Maybe the capsizing (which we witnessed) is clearly the ice.

November 1

Overnight multibeaming took us from the SWIFT recovery site (almost L1) to L3-1. Note that the multibeam data were problematic overnight and through the morning; we were taking the waves at an angle and the ship had a persistent list due to the wind. Bubbles degraded the multibeam signal and the data may not be salvageable along the L3 line. We also traversed to the east of the shoal between L3-3 and L3-2, but found more discrepancies in the charted values and ended up in a shallow zone. Some overnight LISST casts were problematic (the sensor was giving transmission values >1).

Starting in the morning we began casting (L3-1) and deploying 3 drifting v4 SWIFTs along L3 (L3-f, L3-j, L3-3). The first two SWIFTs were additionally instrumented with a 5 m line with RBR duet, equipped with peanut float and drogue. The third SWIFT was instrumented with the same T-chain and hydrophone as the day before. We perfected our sliplining procedure.

Throughout the day, we completed the full set of stations on L2 with CTD and LISST casts at all. In addition, we did Shipek grabs at 3 new locations (not previously sampled) and water sampling (surface and Niskin) at 2 most inshore locations. Over this time, the SWIFTs drifted across the L2 transect. All sources of surface temperature, including the ship underway, drifting SWIFTs, and casts, suggested a notable blob of warm water had spread westward over the center of the domain, reaching nearly 2˚C.

In the evening, we recovered SWIFTs between L1 and L2. All buoys had some icing. Initial look at SWIFT 28 data shows some notable sub-surface shear associated with the warm surface water arriving at L2-3.

We also continued microSWIFT debugging.

November 2

Overnight multibeam data was very poor quality due to sea state. Repeating operations from previous days, after a station at L3-1, 3 drifting SWIFTs were deployed along L3 at L3-f, L3-j, L3-3, with casts at each. After beginning transit to L2-2 following the last SWIFT deployment, it was discovered that SWIFT 27 was not sending good data or positions, so we changed course to recover.

In the afternoon to early evening, we completed a survey of L1, with casts at all sites (from L1-F to L1-2-SS) with additional surface water samples at all and Niskin samples at some of the inshore sites. The water was visibly muddy, especially at the shallower sites, likely due to strong mixing and resuspension from the wave activity.

The remaining two SWIFTs were recovered in the evening, each with significant icing. The temperatures again show colder to the east and warmer surface water to the west. Waves continue to be 2.5 - 3 m under steady 12-15 m/s winds.

The ship is beginning to ice (except for the heated aft deck). The foredeck has significant ice.

November 3

First CTD cast at SWIFT drifter deployment at L3-3. SWIFT28 was swapped in for deployment at this site with the hydrophone as SWIFT29 was sending empty telemetry with poor (Iridium) positions. After noticing that SWIFT 26 was adrift (from T-chain site at L2-2-r), we elected to only additionally deploy SWIFT 27, with the 5 m drogue and temperature sensor, at L3-2. Casts, sediment, and water sampling were also completed at the site. We then continued towards L2-2, following the drift trajectory from SWIFT 26 telemetry calls. It was picked up on AIS at over 8 nm out, and recovered.

We completed a full survey of L2 over the afternoon into early evening, with casts (RBR and LISST) and surface and Niskin water samples at all sites. Water was visibly turbid along the first half of the line, with apparently larger grain sizes in water samples from near bottom.

In the evening, SWIFTs 28 and 27 were recovered just west of L2. SWIFT 27 recorded data for only a few hours of the deployment. The ship then surveyed overnight on the way back to L3-3.

November 4

At L3-2-SS, the Benthos release did not communicate when positioned 300 m north of the site. Sonardyne made communication and confirmed [approximately] original deployed location by ranging at 300 m and 150 m (see elog for exact positions and ranges). The sonardyne confirmed a successful release command, but no float was seen at the surface. Attempted to communicate with Benthos again from new position 200 m south of site, but no coms. Sonardyne also did not communicate from the south position.

Continued to L2-4-SS, and attempted coms from 300 m north of site. Again no coms with Benthos, but a successful series of ranges (220 m, then 96 m) from Sonardyne as we moved closer– these are consistent with the original deployed location. Confirmed release by Sonardyne. Still no float at surface– suspect too much tape at the exit of the line canister will delay the surfacing of the float. Did not try another bearing to the site for the Benthos, but did try the ship's deckbox + hull transducer (still no coms).

Proceeded to third (final) tripod site at L1-2-SS to try to use remaining daylight. Again, the Benthos deckbox was unable to get comms from around 200 m away. Sonardyne release ranged at 210 m (but no release), and then sent successful release after repositioning to 117 m. Float was spotted within 30 s of release code finish send. The tripod was successfully recovered from the A-frame. A CTD cast was completed on site after recovering (as was done at other sites).

Overnight, careful multibeam mapping was completed at L1-2-SS and L3-1-ANC. A few hours were spent at each "mowing the lawn" over the mooring site areas to observe differences in keel scour density.

November 5

In the early morning, SWIFT 21 was recovered from L2-1-SW. Change in locations via Geoforce indicated it had dragged, but at recovery it was on anchor with only notable damage the loss of peanut float on the recovery line. Some icing on the recovery ring and AIS. We then completed multibeam mapping over the L2-1 site while waiting for daylight for small boat deployment.

Inshore of L2-2 had evolved into intermittent bands of new ice (varying thicknesses) overnight. Sampling focused on observing gradients in the new ice relative to evolving water conditions, with work boat stations collecting hand casts (LISST and CTD), drone flights for ice characteristics, and surface ice and water samples.

A first workboat trip (Emily E, MacKenzie, Malcolm) was deployed around first light. The workboat transited as close to shore as possible given ice conditions. There was little ice where the workboat was launched near the L2-1 site, and then increasing concentrations and sizes of pancake ice. We also saw some larger tabular floes - we ended up chipping a corner off of one and it measured around 15 cm thick. On the way back north, after re-crossing the relatively open water, we ended up in a thick ice melange which was an interesting mixture of frazil/slush, pancakes (ranging from clean to extremely muddy), and larger blocks of ice which we theorize had formed during the onshore winds and were then pulled back seaward when the wind direction changed. In total we did three major stations: one in thick pancakes near shore where we deployed Microswift 188 (~7 m water depth) , one farther north in thinner ice where we deployed 193, and one in open water where we deployed 194. We also did some extra sampling very close to our first station, a bonus CTD/LISST profile on the way north, and some bonus sampling while we were mired in thick ice waiting for SKQ to come pick us up - so we collected 6 CTD/LISST profiles total but did three major stations. At each of our major stations we deployed the V4 swift for 10-20 minutes and did a drone flight. We also did a drone flight at the last bonus station. Overall the ice varied from very thin, loose slush to relatively large (order 10 m) broken new ice floes intermixed with smaller floes. Total of 3 microSWIFTs deployed.

At the same time, the SKQ completed recovery of the T-chain (now without SWIFT 26; previously recovered), at L2-2-SW-r. Following recovery, we deployed two drifting SWIFT buoys straddling the edge of the new ice, with SWIFT 26 in open water around 0.5 nm from loose ice edge (based on radar), and SWIFT 29 (with hydrophone) deployed about 0.5 nm inside the compacted pancake/new ice edge. Over the afternoon, two additional SWIFTs were deployed further south along L2/into the ice (SWIFT 26, then SWIFT 13), with casts at each and additional sites. Another three microSWIFT were deployed, spanning Line 2 in an array from open water to high ice concentration. Drone flights from the ship included a test of Skydio (with IR camera) over the small swell in pancake ice.

The afternoon workboat trip (Maddie S, Emily A, Maddie K) focused on sampling variability in the new ice band between L2-1 and L2-2. A total of 6 stations were sampled (with 5 complete; 1 without drone flight and ice sampling). These included areas of somewhat thicker (still “new”) ice with heavy sediment loads as well as mixed types and newer pancakes (including “ghost pancakes” that appeared to have begun forming since the morning and appeared clean). Some heavily sediment ice pieces were sampled, although these were not representative of the typical ice conditions in a given area. One station was directly near drifting SWIFT 28 (deployed by SKQ). The last two stations were close together, straddling the “compact ice edge” (with very new/fragile pancakes on one side).

Multibeam mapping over the L2-1 site was continued into the evening. Then, all 3 drifting v4 SWIFTs (28, 29, 26, from S to N) were recovered. 28 was still in high ice concentration.   29 had moved from high ice concentration to almost completely open water.   26 was in open water (just as when deployed).   Easterly winds and a moderate sea built into the evening, which seemed to compact the ice back towards shore (and send all drifters westward).

At the conclusion of the evening, a total of 6 microSWIFTs and one v3 SWIFT were drifting westward (i.e., alongshore) in a cross-shore array spanning open water to high ice concentration.   A second v3 SWIFT (17) is adrift in Harrison Bay, and a third v3 SWIFT (16) is still moored offshore at L2-3.

November 6

Multibeam at L2-2 overnight. Casts and water sampling at two sites (L2-G, L2-H), and then recovery of the moored SWIFT (16) at L2-3. Proceeded for L2-4-SS to re-attempt tripod recovery. The float was not at the surface, indicating the Sonardyne release had not shaken to the surface. We began attempting communication with Benthos release (alternating between mobile deck unit and hull-mounted), from a 100 m circle around the known tripod anchor location. Ranges from the Sonardyne confirmed the location. After nearly three hours since arriving on site, communications had not been established. As our last effort, we attempted driving straight over top of the site continuously pinging with the ship's transducer, and got comms right as we were passing over and triggered a release, which quickly popped the float close off the starboard side of the ship. Sea states were moderately high (winds around 25 kts, waves around 2 m). The tripod was recovered from the starboard crane and all instruments were in good condition. The Sonardyne release appears to have been too tightly mounted, preventing the float from popping (despite successful release code).

Before leaving the site, some seafloor mapping (Topas) was completed, and a CTD cast, as well as mud collection from the tripod legs.

We hosted an educational livestream on the ship through the platform Exploring By the Seat of Your Pants. The livestream covered some of the science happening on board, as well as life and careers on the ship, and reached dozens of classrooms from around the world.

We arrived at the site for the final tripod recovery in the early afternoon. As before, a quick search revealed no float at the surface from the prior sonardyne release command. (This search was made easier by calmer sea state). Given the earlier outcome, we positioned the ship within 50 m off the known tripod location, off the starboard. No comms were obtained using the Benthos transducer (deck unit only, b/c of newer R500 model), and the Sonardyne was used again to confirm the range consistent with the waypoint. The ship crept in (on the same relative heading) to 20 m of the known position. The Benthos deck box still suggested no communication with the instrument (i.e., no response to "wake up" or "status" requests"). Yet, selection of the "release" command (which usually comes after wake up) popped the float. The tripod was recovered from the starboard crane again, with all instruments in good condition. Following recovery, seafloor mapping (Topas) directly over the mooring location was completed for about 10 minutes, coincident with a CTD cast. We mapped about a ½ by ½ nm area over the mooring location before transiting back to L2-4-SS for tripod redeployment (where another ½ by ½ nm grid was also mapped).

The L2-4-SS tripod was turned over and redeployed at the same site (intended for recovery in Sept 2026 from the R/V Ukpik). The Sonardyne release was re-rigged with straighter lead and no lashing between shackles; this was intended to reduce the side-loading and allow the release to function as designed.

The ship then did multibeam mapping of a patch over a shoal between L2-3 and L2-4 (location of Quintillion cable break) and a patch over L2-3.

November 7

The final day of observations focused on observations and sampling of expanding ice formation near L1. In the early morning, some stations were completed along L1. A workboat trip (Maddie S, Laura, Ian, John) deployed an array of 3 microSWIFT buoys with wave and turbidity measurements in an array from as far inshore back towards L1-1. Each were spaced 1.3 nm, with the nearest to shore in only 1.6 m water depth near the delta shelf. At each, casts, sampling of ice and water, and short drone flights were completed.
A v4 SWIFT (26) was deployed in the morning from the workboat near L1-E and recovered in the afternoon by the Sikuliaq to provide currents over the area.

A second workboat trip in the afternoon (Emily E, Cal, Maya, John) completed 4 more ice sampling stations, prioritizing collecting more new ice with sediment entrainment. Casts and drone flights were completed at each. The Sikuliaq completed sampling along the L1 transect, and did a small multibeam survey near L1-F.

After workboat recovery, the science activities for the cruise were complete, and the ship began its transit back towards Nome.