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EXECUTIVE SUMMARY

This report describes the experiences working with the Norwegian Coast Guard ship KV Svalbard and the expedition ship Le Commandant Charcot during the INTAROS and CAATEX projects.

The first part of the report deals with our experiences working with the Norwegian Coast Guard. The coast guard has supported Norwegian research institutes over many decades and made tremendous contribution to Norwegian polar and ocean research. The report describes complex operations carried out in 2019 and in 2020 with KV Svalbard as part of the INTAROS and CAATEX projects. Our experiences in organising two Useful Arctic Knowledge research schools in 2020 and 2021 onboard KV Svalbard are also presented. The report comes with recommendations for collaboration with the Norwegian Coast Guard.

Secondly, the report describes our experiences working with the commercial cruise operator PONANT. PONANT has 13 cruise ships operating around the world, including the Arctic and Antarctica. In 2021 they had their first expedition to the North Pole with their new icebreaker *Le Commandant Charcot*. During this cruise they carried out a dry test to test their operational capability, test and evaluate the guest facilities bringing several invited guests, as well as the research facilities onboard bringing a group of scientists. The science team consisted of two scientists from INTAROS/NERSC, two scientists from IFREMER (France), one scientist from MIT (USA), one scientist from NTNU (Norwegian University of Science and Technology), and two scientists from University of Tromsø – The Arctic University of Norway (UiT).

The science team carried out several observing programs. INTAROS deployed Snow and Ice Mass Balance buoys (SIMBA), drifting buoys for temperature and pressure observations, contributed to an oceanographic section from the North Pole and to the coast of Svalbard using XBT probes, and collected passive acoustic measurements. IFREMER deployed two Argo floats at the North Pole, contributed to the North Pole oceanographic section, deployed drifting buoys, and tested new weather balloons for atmospheric measurements. NTNU was testing accuracy of new positioning satellites. UiT participated in the Search and Rescue project. In this report we describe the INTAROS observing programs and the experiences collaborating with personnel onboard a commercial cruise ship.

Acknowledgement:
This report is a contribution to the Horizon 2020 project INTAROS and the Research Council of Norway CAATEX (Coordinated Arctic Acoustic Thermometry Experiment. The INTAROS project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 727890. The CAATEX project received funding from the Research Council of Norway project number 280531. A special thanks to the Norwegian Coast Guard for allocating ship time on the icebreaker KV Svalbard, and to the crew onboard KV Svalbard for their support to the complex operations in CAATEX and INTAROS. We also thank the PONANT for inviting us to take part in the test run with Le Commandant Charcot to the North Pole allowing us to deploy drifting buoys and collect acoustic and oceanographic observations.

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Introduction

The Coast Guard ships in the Arctic countries (Denmark, USA, Canada, Russia, and Norway) are frequently used by scientists to perform field operations in the Arctic. These collaborations have existed over several decades and stems from the coast guard and navies need to understand the Arctic ice-ocean environment to be able to carry out safe and efficient operations in this region. Both the Danish and Norwegian Coast Guards have provided ship-time to INTAROS activities, and the US Coast guard has provided ship time to the CAATEX project.

The ship time from the Norwegian Coast Guard to Norwegian institutions is provided through applications to the Research Council of Norway. The applications must be submitted by Norwegian institutions, and they are evaluated with respect to the importance for Norwegian Arctic research. Previous EU projects (e.g., DAMOCLES 2005-2010 and ACOBAR 2008-2013) have benefited from the collaboration with the Norwegian Coast Guard (NoCG). In the period from 2018 to 2021 three ongoing projects (INTAROS, CAATEX, and Useful Arctic Knowledge (UAK)) were supported with in total 20 weeks of ship time with KV Svalbard. Besides ship time, the crew onboard the Coast Guard ship contributed with experienced support during the challenging operations e.g., deployment of deep-water moorings in ice covered regions. This is an extraordinary support to research over many years.

The public are becoming more conscious about the impact of tourist traffic on the environment, in particular with respect to emissions from the engines and acoustic noise from the ship. To meet the demand for more environmental-friendly tourism, the shipping companies have increasing focus on reducing the emission from the vessels and collaborate with research institutions. The support to research ranges from providing ship time and installing autonomous scientific instruments e.g. ferry boxes, and deploying XBTs or dropping drifters. Participatory observing programs, such as HappyWhale (https://happywhale.com), eBird (https://ebird.org/home) and IceWatch (https://icewatch.met.no), are used onboard several cruise ships.

The opportunity to use cruise ships and other commercial or governmental ships as research platforms is important for several reasons. First, a limited amount of research vessels is available to scientist, especially in the polar regions where ice breaking capabilities are required. Having access to a larger number of ice-strengthened ships and icebreakers will lead to observations from a larger area of the Arctic. Second, better access to ships with icebreaking capabilities will extend the season when observations can be collected. Third, many of the ships have fixed routes, which would allow for repeated measurements along the same transects. This is important, because repeated sections are more difficult to do with traditional research vessels, as these operate more on a mission-based schedule. Such measurements are valuable to evaluate the seasonal and annual variability of a region. Finally, the coast guards and commercial cruise operators can provide important support to research institutions which does not have access to their own ships. This will increase the diversity in the polar research programs and actors.

There are several examples of collaboration between shipping companies and research institutions. Viking Cruises has partnered with research institutions like the Cornell Lab of Ornithology, Akvaplan Niva, and the University of Cambridge to join their expedition cruises to Antarctica. Hurtigruten in Norway has since 2004 had the FerryBox system from NIVA installed on one of their coastal steamers, which measures temperature, salinity, and other important parameters during the voyages. The same system is installed on the cargo ship Nordbjørn, operating between Tromsø and Svalbard, and MS Color Fantasy operating between Oslo and Kiel. It is also installed on ships from Viking Cruises. The PONANT cruise operator have recently opened for inclusion of research programs into their Arctic cruises with their new icebreaker Le Commandant Charcot (LCC). In 2021, INTAROS scientists from NERSC were onboard for the dry run to the North Pole, together with researchers from IFREMER, Massachusetts Institute of Technology (MIT), NTNU (Norwegian University of Science and Technology), the University of Tromsø – The Arctic University of Norway (UiT).

There are some similarities in how the coast guards and cruise operators collaborate with researchers. The access to the ships is based on proposals that are evaluated by independent reviews from both the science communities and from the ship owners. The ship time is free of charge, but research activities need to be adapted to the sailing plan, and tourist activities. This is a valuable solution making field experiments affordable for institutions which do not operate their own ship, and thereby creating a diverse and inclusive polar research community. High prices for renting ship time onboard research vessels drains research projects for resources if you are an external user. Ship time is used as ‘own contribution’ by institutions owning a ship while others must pay for it with research funding. This can therefore be seen as a competition driving situation in research. In this way the contribution from the coast guards and the shipping companies can be seen to reduce the non-scientific competition.

This report is divided in two parts. First the collaboration and operations with the Norwegian Coast Guard are described in the next section. Second, we describe our experiences onboard LCC is described. Concluding remarks are provided at the end of the report.

Experiences working with the Norwegian Coast Guard

NERSC has carried out a total of 14 cruises with the Norwegian Coastguard ice breaker KV Svalbard since 2008. In the period from 2018 to 2021, two research schools and four research cruises with KV Svalbard have contributed to different activities in INTAROS. All these cruises have been coordinated and led by NERSC. Through our long collaboration with the Coast Guard, we have learned together the importance of thoroughly planning the cruise, good communication, and how do systematic risk assessment to prepare for complex operations in fully ice-covered regions. In the following we present the three large field operations in support to CAATEX and INTAROS activities to demonstrate the complexity of the operations in deploying and recovering deep water moorings in thick sea ice. Two of the cruises were carried out during Arctic summer conditions north of Svalbard, and the third cruise was carried out in the Beaufort Sea in harsh November conditions.

Complex operations in challenging conditions

The Coordinated Arctic Acoustic Experiment CAATEX (2018-2022) is a joint U.S.-Norwegian acoustic thermometry experiment across the Arctic basin. The CAATEX was funded by Office of Naval Research and the Research Council Norway. The CAATEX experiment was designed to be comparable to a previous trans-Arctic propagation experiment, the 1994 Trans Arctic Propagation (TAP) experiment. The purpose was to capture the change in acoustic propagation of low-frequency sound across the Arctic basin due to changes in ocean stratification, mean ocean temperature and sea ice conditions. The goal is to explore the fundamental limits to exploit the acoustic remote sensing capabilities to characterize the large-scale properties of the Arctic Ocean.

The CAATEX acoustic network consisted of 6 acoustic moorings – three moorings in the eastern Arctic and three moorings in the western Arctic. Two of the moorings hosted a low frequency acoustic source. They were deployed 1688 km apart: one in the Nansen Basin (NERSC-1) in the Eastern Arctic, and one in the Beaufort Sea in the Western Arctic (SIO-1). Each of the moorings were equipped with 25-40 hydrophone vertical arrays each, spanning the upper 1000 m of the water column. The sources successfully transmitted every 36 hours during a yearlong deployment from fall 2019 to fall 2020. The acoustic signals were recorded on all the moorings. All six moorings were equipped with oceanographic instruments for salinity and temperature measurements at different depths, an upward-looking sonar to measure the ice thickness, and pressure gauges to measure the ocean bottom pressure.

To make the data processing uniform the moorings were built using the same design and instrumentation. Each CAATEX mooring was around 4000 m long, and they were kept vertical in the water column by means of heavy anchor and buoyancy spheres at the top. The mooring design was made by the mooring group at Woods Hole Oceanographic Institution (WHOI) based on specifications from NERSC and SIO. The INTAROS adapted this design to design and build a mooring for oceanographic measurements by IOPAN. In this way, CAATEX and INTAROS has established a benchmark or a practice for design and instrumentation of deep-water moorings in ice covered regions.

To deploy the six CAATEX moorings, cruises were planned and executed both in the Beaufort Sea and in the Nansen and Amundsen Basins. Scripps Institution of Oceanography led the CAATEX in the Beaufort Sea and NERSC led the CAATEX in the Nansen and Amundsen Basins. Because there was overlap in geographical area and project leadership, the CAATEX field work could offer significant support (sharing ship time and providing manpower) to the INTAROS field work carried out by several partners (IOPAN, CNRS, UiB, and FMI). This required significant amount of planning and coordination between the projects and the participating institutions. Weekly online meetings between the research groups were carried out. Furthermore, frequent online meetings between the Coast Guard and cruise leader were held to ensure that the ship and the researcher teams were fully informed about the plans and their capabilities.

CAATEX 2019 – Deployment cruise in the Nansen Basin

In summer 2019 the Norwegian CAATEX project were responsible for deployment of three moorings in the Eastern Arctic Ocean. The deployment cruise was conducted with the Coast Guard vessel KV

Svalbard in the period from August 14 to September 9, 2019. Eight other Norwegian and international research institutions participated in the cruise. The main goal of the cruise was to deploy three acoustic rigs, four buoys to drift with the ice, and one oceanographic mooring for the INTAROS.

See Figure 1 for the planned and the actual deployment. As can be seen from the figure, the actual deployment array of acoustic moorings deviated significantly from the planned array primarily due to a Russian short notice missile exercise at the North Pole, but also because of rough ice conditions in the North pole region. This rapid turn around of plans demonstrate the importance of having flexibility and capability during the execution of the field operation to implement a secondary plan. The planning and programming of the acoustic experiment included a large degree of flexibility so that the rearrangement did not cause any serious consequence for the scientific goals. However, the change in mooring configuration caused that we did not get oceanographic measurements from the Amundsen Basin. However, a positive consequence was that the oceanographic observations from CAATEX moorings is an extension of the INTAROS array north of Svalbard.

Besides being an important research cruise, this was a historical trip, as KV Svalbard became the first Norwegian ship to reach the North Pole. At the North pole several deployments took place: a SIMBA buoy for the INTAROS project, an Ice tethered profiler were deployed at the North Pole by WHOI (for the International Arctic Buoy Program) and an acoustic receiver buoy were deployed for Canadian research group programmed to listen to the acoustic transmissions from the acoustic source.

The crew onboard was supported by the Coastal administration of Norway providing a trained ice navigator with long experience in operations in ice. The Norwegian defence supported the field experiment with satellite communication expertise providing broad band internet access for download of continuously updated sea ice information from the Ice service at the Norwegian Meteorological Institute.

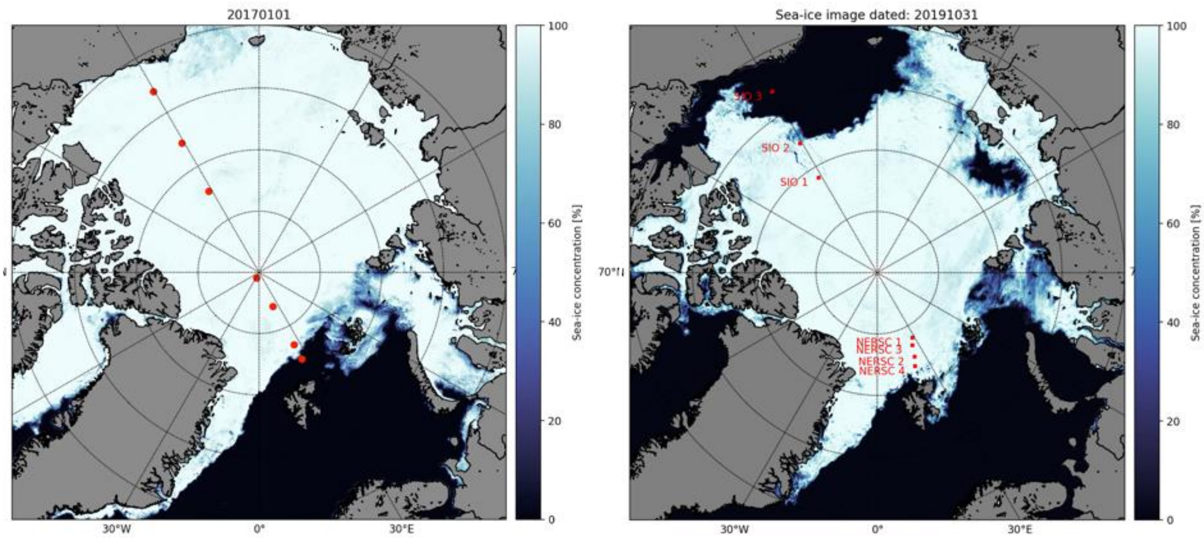


Figure 1: Planned (left panel) and actual (right panel) deployment of the CAATEX mooring array. Each 4 kilometer long mooring was secured by anchor the bottom and kept vertical by floatation elements. Each mooring carried between 45-80 instruments.

The deployment of the moorings was challenging due to varying ice drift conditions and that the bottom topography in large parts of the Arctic Ocean is not adequately mapped and known. Therefore, before deploying each mooring, the bottom topography must be measured and mapped in an area with a radius of more than 30 kilometres around the selected position. This mapping was challenging in the tight pack sea ice. Furthermore, variation in ice drift must be carefully monitored before and during the 7-9 hours it takes to put the mooring to a depth of 4000 meters. With the careful planning, previous experience, good information about the weather and ice conditions on site and a skilled crew, all four moorings (including the INTAROS mooring NERSC-4 discussed below) were successfully deployed.

A multidisciplinary mooring (NERSC-4) was deployed for the INTAROS project carrying instruments from IOPAN, UiB, and NERSC. Two SIMBA buoys were deployed for the INTAROS project (FMI). The SIMBA buoys gather information about the ice and how it will grow and vary in thickness throughout the winter and again how it will melt during the coming summer season. All buoys drifted with the ice from the North Pole towards the Fram Strait, while continuously collecting environmental information about the sea under the ice, about the nature of the sea ice and about the air near the ice. The data from these buoys provide information on where and in what part of the year the ice melts most from the underside that is in contact with a warmer seawater or where and when it melts from the surface in contact with warmer air layers.

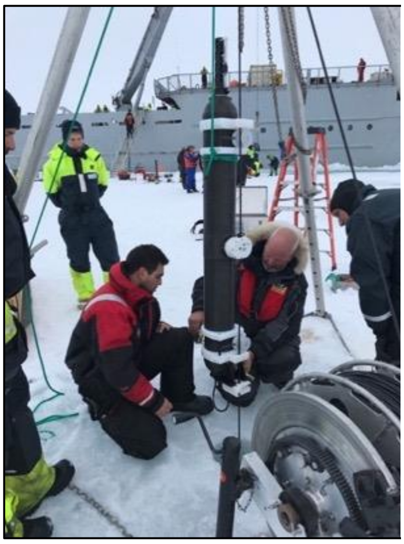



Figure 2: Deployment of the ITP at the North Pole on August 21st 2019 (left). Deployment of the acoustic source (right).

A total of nine ice stations were conducted, with *in situ* measurements and drone operations (in support to the INTAROS project). At the ice stations, ice cores were collected and taken to study the structure of ice in laboratories, and for several chemical analyses of the ice. Measurements of ocean currents and turbulence under the ice, measurements of light and algae, as well as passive measurements of sound were made. Larger areas around KV Svalbard were investigated using drones equipped with various remote sensing sensors to map sea ice and leads. Regular sea ice observations were conducted using the Arctic Shipborne Sea Ice Standardization Tool (ASSIST) developed by the International Arctic Research Center in Fairbanks, hosted by the Norwegian Meteorological Institute. See https://icewatch.met.no/cruises?year=2019.

The INTAROS data is or will be made available through registering into INTAROS data catalogue (https://catalog-intaros.nersc.no/dataset) providing information from where to download the data e.g. Norwegian Marine Data Center or PANGAEA. CAATEX data products will be made available through the Norwegian Marine Data Center.

Complex mooring operations require close coordination and good communication between the science party and the crew onboard, and full attention must be given to the operation. In total 21 researchers, students and engineers participated in the cruise. CAATEX project provided two mooring technicians and rental of a mooring winch appropriate for anchor first deployments in ice.

CAATEX project:
NERSC, Norway: Hanne Sagen (Cruise leader), Espen Storheim, Florian Geyer, acoustic instruments. Students: Henrik Hellem, Bjørnar Røsvik
Scripps Institution of Oceanography, USA: Peter Worcester. Acoustic instruments.
Woods Hole Oceanographic Institution (WHOI), USA: James Ryder, Nico Llanos. Mooring technicians.
Norwegian Polar Institute (NPI): Bonnie Raffel. Sea ice measurements.

Naval Postgraduate School (NPS), USA: John Colosi. Oceanographic instruments.
NTNU, Norway: Håvard Sagen (Camera). Making film for the project.

INTAROS project
IOPAS, Poland: Agnieszka Beszczynska-Møller, Piotr Wieczorek. Deployment and recovery of moorings.
Geophysical Institute, UiB: Alexandra Touzeau. Doing underway atmospheric measurements. (Post Doc)
Department of physics and technology, UiB: Håkon Sandven. Marine optics. (PhD student))
NORCE, Norway: Tom Rune Lauknes, Andre Kjellstrup, Rolf Ole Jenssen. (Sea ice measurements from Drones)

Personnel from other projects/institutions in support to the operations
FFI, Norway: Vidar Forsmo
Maritimt Forum, Norway: Hans Sande, Sea ice navigation
Kystverket, Norway: Andreas Kjøl, Sea ice navigation

CAATEX 2020 - Recovery cruise in the Nansen Basin

The Coordinated Arctic Acoustic Thermometry Experiment (CAATEX 2020) recovery cruise were carried out in the period from 17th of July to 10th of August 2020 with the Norwegian Coast Guard vessel KV Svalbard in the Nansen Basin. It was coordinated and led by Nansen Center. The activities during the cruise were:

1. Recovery of three moorings for the CAATEX project.
2. Recovery of four moorings for INTAROS.
3. Rescue of two moorings for third parties.
4. Deployment of drifting ice buoys for the International Arctic Buoys Program.
5. Deploy 400 small wooden boats next to the ice buoys for outreach purposes. (Float Your Boat)
6. Deployment of AIS buoys for monitoring of sea ice movement. (CAATEX)
7. Sea ice *in situ* observations, and radar and drone operations. (INTAROS)

Recovery of moorings in regions with close and drifting are a two-day intense operation. When arriving the location of the mooring a survey is carried to position the anchor. In case of an acoustic mooring each of the four transponders in the network is positioned if it was not done during deployment. This takes one day in heavy ice from KV Svalbard. After positioning of the anchor and monitoring the ice drift, the actual mooring recovery can start. This starts with positioning of the transponder on the top of the mooring visiting 3 positions. The position of the top of the mooring can be slightly different from the anchor position due to the currents. Then the ice management starts, and the large sea ice floes are crushed into small pieces of ice. The crushing is done at a calculated distance upstream relative to the anchor position. The positioning and ranging of the top are repeated and then the ship flush the ice away from the area just over the location of the top mooring. The release is done when the position is in the ice-free area, with the ship at a safe distance. This is a very tight time window as the ice will close again in few minutes and requires full attention from the scientists and the officers at the bridge. In all the cases the mooring surfaced as it should, and the mooring could be recovered. After the recovery all the instruments are flushed with fresh water and brought in-door, and wire is spooled off the winch.

Some extra challenges in the planning of the cruise due to the CoVid19 situation. The limited number of scientists resulted in more need for assistance from the KV Svalbard crew and the Coastal Administration of Norway (Kystverket). However, all tasks were successfully carried out by Norwegian scientists in collaboration with experienced KV Svalbard crew and mooring technician from CNRS.

A documentation of the recovery procedures was prepared by the crew at the bridge, deck, and the scientist. This is important for transfer of competence between crew members and teams.

INVESTIGATORS (Onboard)
NERSC, Norway: Hanne Sagen (Cruise leader), Espen Storheim (deputy cruise leader), Bjørnar Røsvik, Matias Lunde, Bonnie Raffel.
CNRS, France: Matthieu Labaste.
UiB, Norway: Nick Roden.
Kystverket, Norway: Andreas Kjøl.

Metno, Norway: Ole Jakob Hegelund.
NORCE, Norway: Tom Rune Lauknes.
FFI, Norway: Dag Tollefsen.

CAATEX 2020 - Recovery cruise in the Beaufort Sea

The recovery cruise in the Beaufort Sea were carried out in the period from 12 October to 25 November 2020 with the Norwegian Coast Guard vessel KV Svalbard in the Arctic Ocean including the Beaufort Sea. CAATEX2020 cruise was planned and coordinated by NERSC together with the Norwegian Coast Guard. The activities during the cruise were to recover three CAATEX and one INTAROS mooring, and to deploy 10 ice buoys for the International Arctic Buoy Program.
The cruise was planned and carried out as an unexpected mooring rescue operation using the KV Svalbard. This was because of a fire in the engine of the USCG Healy the 18 August 2020 just after departure for recovery of the acoustic moorings in the Beaufort Sea. The fire the caused the planned recovery cruise in Beaufort Sea (led by Scripps Institution of Oceanography) to be cancelled. This situation could damage the data quality, severely delay the project, and in worst case the objective of the CAATEX could not be reached if we could not recover the last three CAATEX moorings. This severe situation for the research project occurred because the atomic clocks in the tomographic instruments would drain the batteries, and thereby make it impossible to provide accurate timing of the travel time measurements due to clock drift.
The whole CAATEX experiment was in danger of failure, and therefore Nansen Center and the Office of Naval Research were searching for alternatives. Nansen Center contacted the Norwegian Coast Guard who confirmed that they could carry out the operation if permissions were given. The approval went all the way up to minister level in Norway, and the final approval were given just a few days before departure 12 October. Ice and weather services in Norway, Russia, Canada, and the US were involved, to support the expedition. This support effort was coordinated by the ice service at the Norwegian Meteorological Institute in Tromsø. All three moorings were recovered in darkness and under extreme temperatures. The success of this operation was an example of good collaboration between institutions at different levels and across the Arctic. More details are found https://www.marinelink.com/news/value-friends-highlatitude-places-486531.

Figure 3: To the left: The temperature was -40ºC during the recovery of SIO-1 mooring and the photo to the left shows the acoustic source safely back on deck. To the right we see the top of the last mooring (SIO-3) which was trapped under the ice. It took 2 days with intense effort to recover this last mooring. In the end Coast Guard officer Andreas Soløy dived to located and rescue the mooring. All instruments were saved. (Photos: D. Fatnes, KV Svalbard)

KV Svalbard travelled 7000 nautical miles in total distance, of which 3500 nm were in ice. She is a relatively small ice breaker which depend on smart navigation in ice to avoid areas with heavy multiyear ice to save fuel and time. The sea ice conditions in late fall in the Beaufort Sea is very different from the summer conditions North of Svalbard. During freeze up in the fall, it is difficult to distinguish between multi year ice, first year ice and newly frozen ice just by looking at SAR images, and the darkness makes it difficult for visual observations. Therefore, it was critical to get updated manually interpreted ice maps and metrological forecasts from the Ice services from Meteorological Institute in

Norway, Arctic and Antarctic Research Institute in Russia, and from services from several institutes in USA and Canada. The services in different countries have built up experiences in the different sectors of the Arctic. The amount of data available from the different services were large and the satellite communication is limited, and therefore it was important to have the Norwegian Meteorological Institute to coordinate and optimise the delivery of information to the ship.

As the ship moved to each mooring location, the first steps were to locate the mooring and to establish local information about the ice drift. The localization of the mooring and transponder network at the sea floor around it was done through acoustic positioning surveys. The local ice drift is dependent on wind conditions and the ocean current. During low winds, the latter is the primary factor for the ice drift and is heavily influenced by the tidal current and the inertial oscillation, both with a 12 hour overlapping periodicity. The local variability in current can not be observed by satellite images. Ice drift was measured using both the ship (when stationary in the ice), and by deploying AIS beacons on the ice. This made it possible to measure the rotation of the ice, as well as the drift. The ice drift is critical during release of the mooring and during the recovery.

Prior to recovery, all the necessary equipment was set up on deck. The primary component was the TSE winch mounted on the aft deck. The hydraulic system on the winch was powered by the ship, but the cold temperatures made the hydraulic oil too thick, and the winch would not operate properly. Diesel powered heaters were used to heat up the oil tank, but these also had running issues in the cold weather. The winch was operated by a person standing behind the winch, rather exposed to the elements. A wooden shed was constructed by the crew to protect the winch operator from the exposure from the freezing winds. This was a very important addition and helped to ensure the safety of the people and the operation itself.

Prior to release of the mooring from the seafloor, ice management was performed by the ship to create an opening in the thick and dense ice. The ice management procedures were planned according to the drift so that the opening was drifting across where the top of the mooring was acoustically located. Once the crew and owner of the mooring was satisfied, the command to release was given. However, he thick and dense ice in the area, combined with the drift and pressure in the ice field, made it difficult to create a big opening for the sphere to pop up. This was particularly the case at the SIO3 location, where the top of the mooring became stuck underneath the crushed and refrozen ice field. It became a very demanding recovery operation that took more than 48 hours (Fig 3b).

During the recovery operations, the freezing temperatures made the water, instruments, and hardware freeze almost instantaneously. It was therefore important to get instruments off the wire as fast as possible, and inside before they were damaged. Rotation of personnel on a regular basis was important to reduce the risk of cold exposure. This was only possible due to the amount of crew onboard KV Svalbard.

As this cruise demonstrated, it is possible to recover moorings under these harsh late fall Arctic conditions, but it should be avoided. The coast guard in Norway combines long-term civilian crew members and officers that are onboard for a given number of years, therefore these complex operations are documented onboard the ship to ensures competence transfer between the crews. This makes the Norwegian Coast Guard an excellent support to harsh scientific operations in the Arctic.

INVESTIGATORS (Onboard)
NERSC, Norway: Hanne Sagen (Cruise leader), Espen Storheim
Scripps Institution of Oceanography, USA: Matthew Dzieciuch and Matthew Norenberg.
Woods Hole Oceanographic Institution (WHOI), USA: James Ryder
IOPAS, Poland: Agnieszka Beszczynska-Møller.
Metno, Norway: Alistair Everett.

To summarize the CAATEX and INTAROS operation with KV Svalbard:

- Invaluable data from around 400 instruments were recovered for CAATEX (375) and INTAROS (50) with huge support form KV Svalbard. The value of the instruments is estimated to be 90 million Norwegian kroner. The instruments on the moorings were contributed from the CAATEX partners and INTAROS partners.

- The results from CAATEX have demonstrated that the technology for a multipurpose acoustic network for basin wide thermometry, underwater geo-positioning system, and passive acoustics are at TRL>7.
- The collaboration between scientists and the coast guards has led to procedures for deployment and recoveries under very harsh environmental conditions.

Research schools

A 10-day long research school onboard KV Svalbard was carried out in June 2020. The area of operations was Storfjorden at Svalbard, and the topics included oceanographic measurements, recording of seismic events, and both passive and active acoustical measurements. Ten students from different institutions in Norway participated, with supervisors from NERSC, Western Norway University of Applied Sciences (HVL), and UiB. Due to Covid only students already in Norway could participate. A series of CTD casts were taken along different transects that are regularly measured by the University Center in Svalbard (UNIS). These measurements thereby contribute to expand the time series, and it was easier to communicate the motivation behind the measurements to the students. Acoustic transmissions were carried out between the two small boats to investigate the acoustic propagation. Examples of these activities are shown in Figure 4. Data from this research school is submitted to Norwegian Marine Data Center and visible at the INTAROS data catalogue (see e.g. https://catalog-intaros.nersc.no/dataset/ctd-data-collected-in-storfjorden-svalbard-during-the-uak-2020-cruise).

(a) (b)

Figure 4: Students recovering water samples taken with the rosette on the CTD (a), and doing acoustic transmissions from the small boat (b).

In June of 2021, 12 students participated in a research school onboard KV Svalbard, operating in the ice north of Svalbard. The objective of this school was to give the students hands-on experience with performing *in situ* measurements and remote sensing of sea-ice, deployment of a drifting buoy, and CTD casts. Some examples of these activities are shown in Figure 4 and 5. In addition the students learned about collection of metadata and preparing the actual data for publication online. Students from the US (SIO, University of California San Diego and Carleton University, Boulder), and Norway (UiB, UiT) were supervised by instructors from NERSC, IOPAN, NORCE, MET, and ONRG. The students reported their work in in thematic videos https://uak.nersc.no/summer2021 and in the publication by Jenkins *et al.* 2022 (https://asa.scitation.org/doi/abs/10.1121/2.0001574).


(a)


(b)

Figure 5: Students getting hands-on experience with the ice-coring equipment (a), and lowering the CTD rosette into the ocean from the aft deck on KV Svalbard (b).

KV Svalbard is an excellent platform for research schools. The experienced crew and the facilities on board, in particular the lounge, hangar, and lab spaces, makes it easy to do lectures and practical demonstrations inside. In addition, these facilities allow for storage of equipment, but also preparation of equipment prior to lessons and field work. The small boats are also well suited for activities, as they can move away from the ship to do undisturbed measurements, as well as measurements in parallel with measurements from KV Svalbard.

Part of the crew onboard KV Svalbard are enlisted, who serve their 12-month mandatory military service. Most of them have just finished high school, and many are about to apply for admission into higher education at universities or university colleges. The interaction between students and enlisted crew can help recruitment in the fields of natural science, as it is often easier for them to talk with students rather than with experienced researchers.

Experiences and recommendations

The CAATEX consortium in collaboration with the crew onboard KV Svalbard have developed good practices for deep water mooring design for deployment and recovery in ice covered regions, and procedures for recovery and deployment in deep water areas with drifting and dense sea ice. The successful implementation of the basin wide prototype of deep-water moorings shows that together with the Norwegian Coast Guard we have the technical, logistical, and operational capacity to establish a full scale multipurpose acoustic network for the central Arctic. This work is reported as part of the CAATEX project. The prospect of a future full-scale acoustic network will be included in the INTAROS roadmap, highlighting the triggering effects in innovation activities within Arctic observing technologies e.g., the possibilities to expand the Euro-Argo and glider programs into the ice-covered regions of the Arctic.

The three cruises related to the field experiment, and the two research schools, were carried out under Covid 19 restrictions. Travelling to and from Norway and Longyearbyen was difficult. People were isolating at home for 14 days prior to the cruises and taking every precaution when travelling. Thus, the planning and implementation was much more demanding than normal. Despite this, the planned experiments were successfully carried out through tight collaboration, communication, and the understanding of everyone onboard the ship.

The CAATEX field experiments have demonstrated that complex operations under extreme conditions can be carried out together with the Norwegian Coast Guard. The collaboration between scientists and with the crew onboard KV Svalbard has resulted in the development of

- good practices for deep water mooring design for deployment and recovery in ice covered regions.

- procedures for recovery and deployment in deep water areas with drifting and dense sea ice including extreme weather conditions.
- procedures for coordination and implementation of high Arctic field experiments involving different institutions from several countries.

The Norwegian Coast Guard has listed some of key points that led to the success of the deployment and recovery cruises, namely:

- NERSC and the NoCG know each other well through the long-standing collaboration.
- Proper preparations and communication between the NoCG and the cruise leader /science party.
- A significant effort was put in to creating a realistic plan for the cruise. Critical voices are needed to test the plan. It is important to speak up if there is a disagreement, or another solution to a problem.
- There must be flexibility in the plan. External conditions like sea-ice and weather can significantly influence the operations, and there might be a need to shuffle activities around on short notice.
- Ensure proper and adequate equipment and infrastructure – both from the science party and the ship.
- The capabilities and limitations of the ship are well known by the crew.
- Perform a science briefing, a safe job analysis, and a toolbox talk (on deck and on the bridge) before every operation.
- Create internal procedures that describes the different activities and revise them when necessary

It is an important message that operations like in the CAATEX and INTAROS need well qualified personnel at all levels, enough ship time, and the full attention from everyone onboard.

INTAROS onboard the Le Commandant Charcot

PONANT has many years of experience in cruise expeditions in the Arctic and in Antarctica. In 2022, PONANT partnered up with the EU project ARICE (Arctic Research Icebreaker Consortium), where the EU project ARICE (https://arice-h2020.eu/about/) was given the responsibility for the calls for proposals, evaluating the proposals, and selecting the research programs which will get ship-time in 2022 with the Le Commandant Charcot (LCC). LCC has laboratory facilities onboard intended to be used by the invited scientists. The onboard facilities include two labs with computers and bench space, and a wet lab with access to a moon pool. A FerryBox system is in the process of being installed, and an electromagnetic ice thickness sensor located at the front of the ship is also available. In addition, there are zodiacs, a helicopter, a "Sherp" 4WD vehicle (https://sherpglobal.com/en/home/), snowmobiles, and hoover crafts which can be used to take the scientists away from the ship. These resources contribute to expand the radius of operation, allowing for undisturbed measurements of ice-ocean parameters, including physical and bio-geo-chemical parameters.

Observations made from commercial ships within the tourist industry can be an important contribution to an observing system providing regular and sustainable observations to the science community. Therefore, INTAROS and NERSC found the invitation from PONANT to join the dry test with Le Commandant Charcot as a unique opportunity to find out how we can mutually benefit from a collaboration. Two scientists from NERSC participated: Research leader Hanne Sagen and Scientist Espen Storheim represented the INTAROS project. Since we were invited at the last moment and since we did not know how the ship was equipped, we planned only less complicated activities to ensure that we could succeed.

The following activities were planned and carried out:

1. Deployment of 7 drifters measuring air temperature and pressure for the International Arctic Buoy Program.
2. Deployment of 2 SIMBA buoys measuring temperature from above the ice, through the ice and under the ice.
3. Launching XBT probes (T5) measuring ocean temperature profiles from 0 meters down to 1830 m.
4. Measuring 'ocean sound' for 24 hours approximately 1 kilometer away from the ship with a hydrophone hanging under the ice.
5. Outreach: Float your Boat (FyB): Deployment of small wooden boats next to a cluster of scientific buoys. Preparing presentations for the guests: 2 scientific; one FyB presentation for the naturalists, and a FyB pep talk for the participants.
6. Get an overview of the facilities available for scientific work onboard, and how this can be used in our future work.

Task 1: Deployment of 7 drifters in water and on the ice

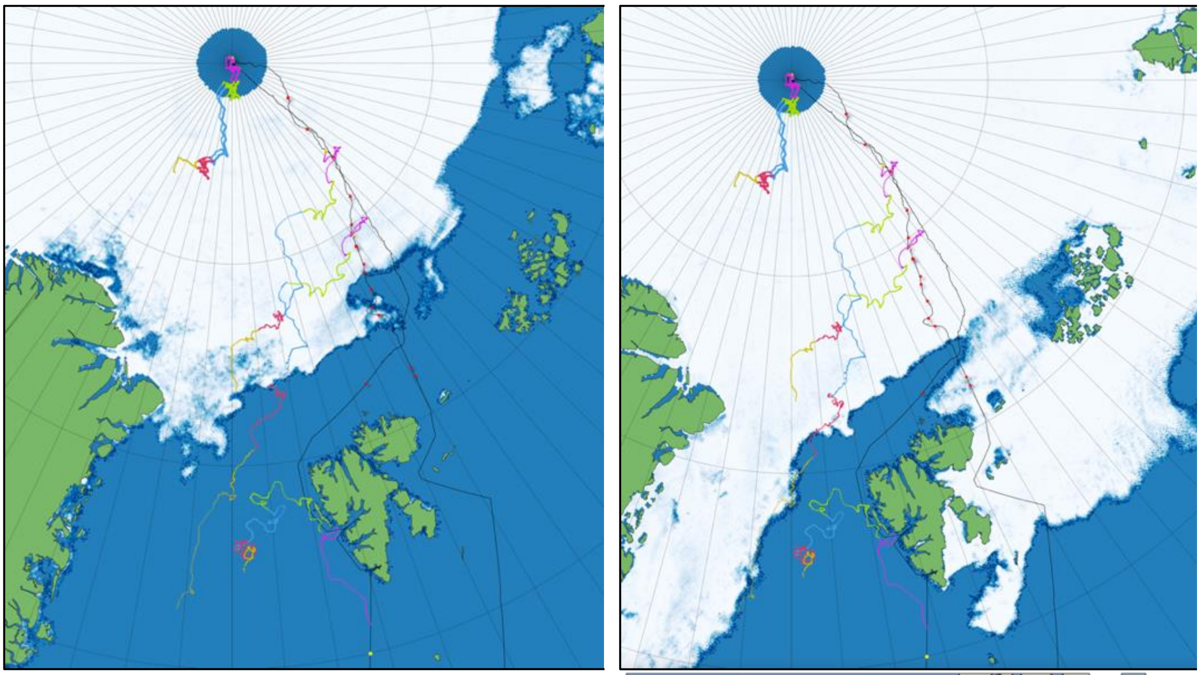
The first deployment of drifters was done in open water from the door in the wet lab. This was the first scientific deployment from the ship, and guests and staff were following the event. Most of the buoys were deployed on the ice just removing the plastic wrapped around them and the starting the buoy by removing the magnet. Table 1 below shows the serial numbers and positions of where they were deployed. Their drift can be followed at the International Arctic Buoy Program webpage https://iabp.apl.uw.edu/IABP_Maps.html. In the Buoy numbers are listed. A map containing the ship track and the buoy tracks is shown in Figure 6, and a picture of a deployed ice buoy is shown in Figure 7.

Recommendation:

Deployment of buoys and drifters like the ones NERSC deployed for the International Arctic Buoy Program, can easily be done by the naturalists onboard.

Table 1: List of buoys that were deployed during the cruise with Le Commandant Charcot.

Type of ice buoy	ID	Comment on deployment
Ice buoy – these buoys measure the temperature and pressure.	APL-UTAP-0039: 300534062029670 APL-UTAP-0040: 300534062125360	Both buoys deployed next to the SIMBA buoys near the North Pole. APL-UTAP-0039 was deployed next to the small Wooden Boats.
Drifters		
SVP-B measures the temperature and pressure, while SVP only measure the temperature.	**Drifters** 60114350 – Close to Bjørnøya 60115360 60116330 60712070 – NP 68485020 – close to NP near the SIMBA	The first buoy was deployed in open ocean near the Bear Island (Bjørnøya). All the others were deployed on the ice north of Svalbard towards the North Pole. Two of the SVP-B were deployed at the North Pole. The buoy deployed at 84° 47' 8" N, 35° 18' 46" E (60116330) was the last one to be deployed.



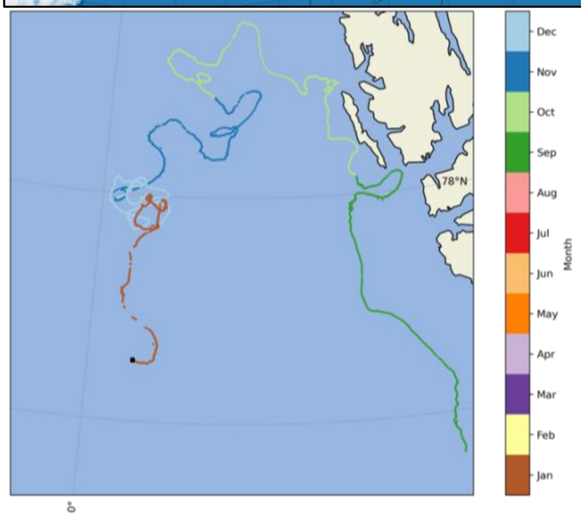


Figure 6: Map of the ship track (black line), and sea-ice concentration on 2021-09-10 (left), and 2022-01-22 (right). The red markers show the locations of the XBT casts, and yellow markers indicate location of SVP buoy deployments. The tracks of the different buoys are also shown.

The lower right panel shows a close-up of the first SVP buoy deployed from Le Commandant Charcot at 75° N. The trajectory of the buoy clearly shows the northward flowing West Spitzbergen Current, the mesoscale circulations, and how the buoy is taken by the recirculation in the middle of the Fram Strait. The colours represent the different months.

Figure 7: The white ice buoy (APL-UTAP-0039) surrounded by the wooden boats from "Float Your Boat". In front the SVP-B buoy (60712070). These buoys can be followed at the following link: https://iabp.apl.uw.edu/IABP_Maps.html

Task 2: Deployment of two SIMBA buoys

The two SIMBA buoys were deployed by NERSC for the Finnish Meteorological Institute (FMI) as part of the INTAROS project. FMI 07 04 was deployed next to ship at the North Pole near APL-UTAP-0039. The second buoy FMI 07 03 was placed 907 m away from the first SIMBA and near APL-UTAP-0040.

The SIMBA buoys are essentially a thermistor chain connected to a data logging system with IRIDIUM transfer of data via satellite. The thermistor chain measure temperature from air, through the snow and ice cover into the water masses under the ice. These measurements are made if the instrument works and as long as the buoy drift with the ice floe. In this way we can learn about the melting processes through the seasons and as the floe drifts into warmer water. Figure 8 shows the SIMBA as deployed at the North Pole, and trajectories of previously deployed buoys.

Recommendation: These buoys are more complicated than the SVP's and ice buoys and requires more time and experienced personnel to be deployed.

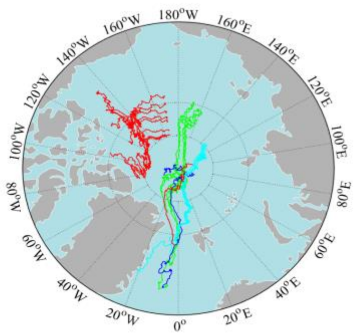


Figure 8: To the left trajectories of SIMBA buoys deployed in the Arctic in the period 2018-2020 (Courtesy: Bin Cheng, FMI). To the right from the deployment of the SIMBA at the North Pole (FMI 07 04).

Task 3: Temperature section from the North Pole to North of Svalbard

As part of the dry-run we wanted to test the possibility to make a section from the North Pole to North of Svalbard using XBT probes. This Task was a collaboration between NERSC and IFREMER. In the central Arctic we used T5 probes which provide temperature profiles from surface and down to 1830 meters. These probes were provided by the INTAROS and CAATEX projects. For deployment of T5 the ship had to move at speeds less than 6 knots. IFREMER brought T7 buoys which provide profiles down to 760 m. These probes can be launched while the ship is moving at a speed less than 15 knots. The XBT is capable of temperature accuracies of +0.1°C at a vertical resolution of 65 cm. More information about the probes are found at https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/oceanographic-instrumentation/20050054_XBT_XSV_reader_page.pdf.

An example of a profile is shown in Figure 9, and all the 15 profiles obtained by NERSC are shown in Figure 10. The team from IFREMER obtained additional shallow profiles filling in our measurements. Routine collection of such data is of great value for climate research if it is done on a regular basis.

Recommendations. This is absolutely a routine operation which can be done without having an external scientist doing it. The launching of the XBT can after some training be performed by the naturalists onboard. The training should include how to launch the probe, how to use the software, and how to judge if the launch was successful. Also, the communication with the bridge and how to position the ship during the launch should be trained. A permanent setup of launcher system, including the system would help to streamline the operation and processing system for quality control and formatting the data. In this case, access to GPS data is necessary to simplify the data collection and processing. This can be achieved either via a separate GPS antenna directly connected to the computer, or by NMEA data broadcasted over a network.

Please be aware that the number of stops influences the time schedule of the ship. Oceanographic sections should therefore be planned with the ship before the cruise starts.

CTD rosette or XBT launcher?

Our opinion here is that the XBT launcher and software should be installed first. This is because repeated sections with XBT are done much faster and less disturbing the ship operation/cruise plan.

Each station takes around 15-20 minutes in ice, while a CTD down to 5000 meters takes 2-3 hours.

Shorter CTDs can of course be taken but loosing a CTD during the operation in ice is more costly than a failed launch of an XBT or an XCTD. While a T5-XBT costs approximately 150 Euro, it only gives you temperature profile. An XCTD-2 costs approximately 750 Euro, but it will give you both temperature and salinity. More details about the probes, the launcher and software are found at https://www.lockheedmartin.com/content/dam/lockheed-martin/rms/documents/oceanographic-instrumentation/Lockheed%20Martin%20XCTD%20Profiling%20System%20Data%20Sheet.pdf

Drawback: water samples are not obtained by this system. Despite this, our recommendation is to prioritise to buy and install a permanent launcher system which can deploy both XBTs and XCTDs.

There are simple CTDs that can be operated from a Zodiac or from the ice using a small winch. We would highly recommend buying a couple of such, e.g. the Concerto from RbR, the SD204 from SAIV, or the CastAway CTD from Sontek (Xylem). Furthermore, a scientist onboard LCC would have the possibility to go away from the ship with Zodiacs or the Sherp ATV. In this way, LCC can offer scientists to obtain undisturbed salinity and temperature profiles from the surface and down to e.g. 200 m. This is very useful data to study heat transfer between ocean and atmosphere. Water samples can also be obtained form this kind of activity and analysed for all kind of chemical properties including occurrence of plastics. The latter would require some extra equipment in the wet-lab.

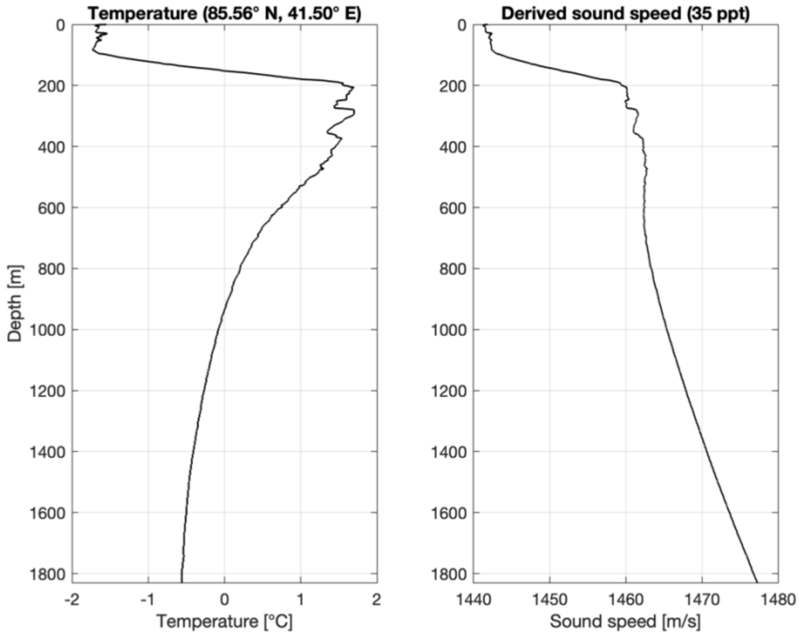


Figure 9: Example of a temperature profile taken during the dry run, and the calculated sound speed profile with constant salinity. The profile shows the typical cold-water layer at the surface below the ice, which results in a low sound speed duct which traps the sound. The sound trapped in the surface duct is interacting with the ice. This rapidly dampens sounds at frequencies above approximately 100 Hz. The fingers below indicate unstable water masses which can start mixing if the water density changed or if some dynamics introduced e.g. internal waves, tides. These fingers are seen over large areas of the Arctic.

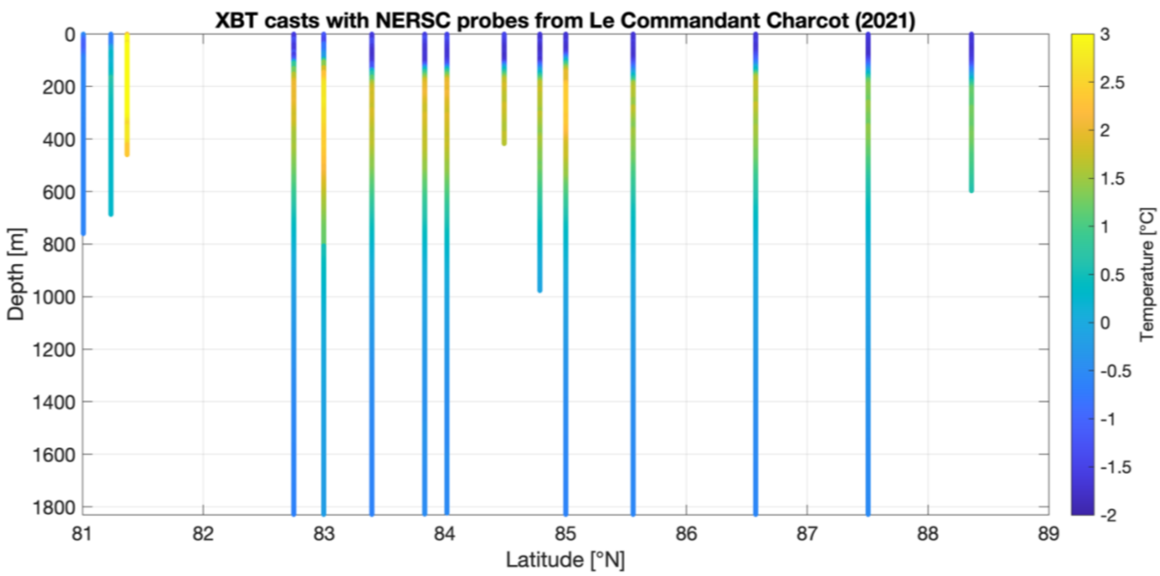


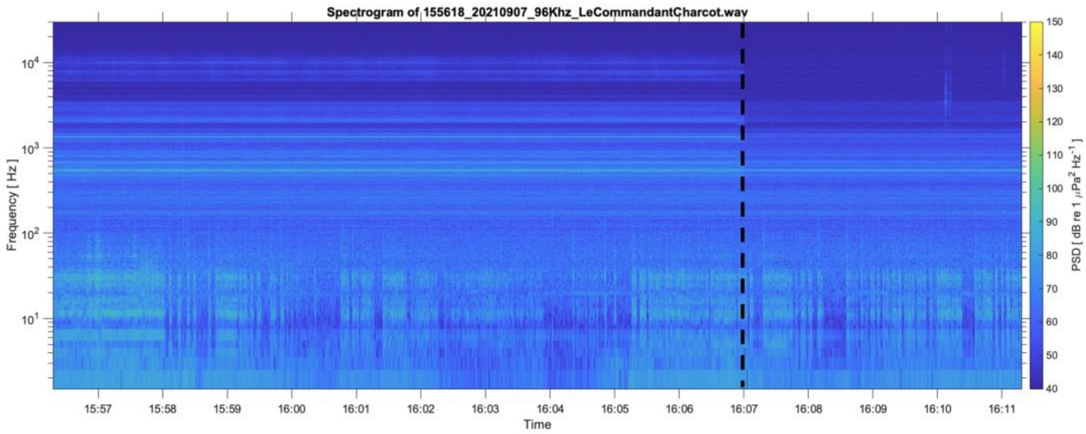
Figure 10: Temperature profiles obtained from XBT probes provided by NERSC, shown as a function of latitude and depth. The casts were made on the way back from the North Pole, with a mixture of different probes (deep and shallow).

Task 4: Measuring 'ocean sound' approximately 1 km away from the ship

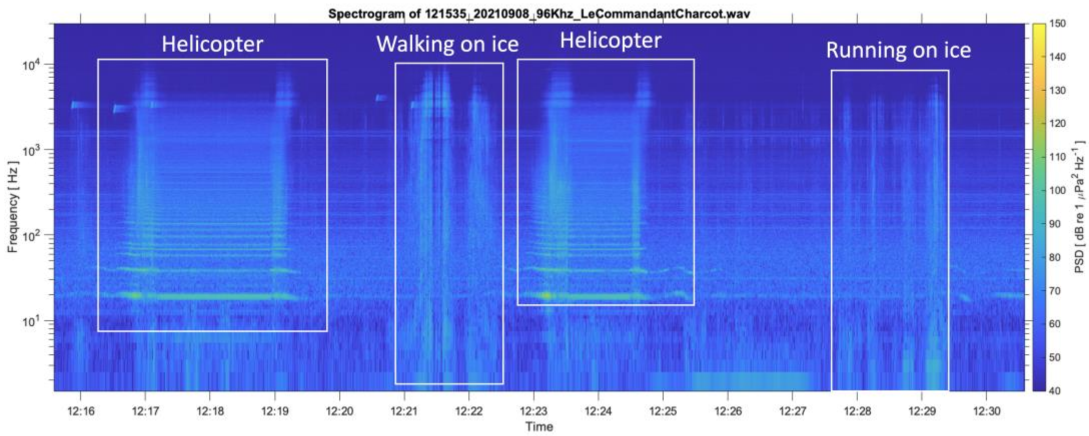
A hydrophone was deployed through a hole in the ice and kept tethered to the ice by a simple arrangement. The distance to the ship at the end of the recording were measured by laser to be 907 m. The hydrophone recorded for 24 hours. The recordings include different modes of the ship, c.f. Figure 11. The recordings show that the ship is very quiet when it is on battery. Notice these measurements are made only for a stationary ship so effect of breaking ice is not included.

Recommendations: This means that this ship is a very good platform for doing acoustic recordings and acoustic communication experiments. For communication or navigation experiments experts are needed onboard, but for simple passive acoustic experiments naturalists onboard can do this. The essential part of collecting passive acoustics is to log the time (UTC), ship geographical position, the ice conditions, wind/wave conditions. and the geographical position of the recording. It is also important to get the engine log to identify potential effects from the ship manoeuvring or changing the operation mode. We also suggest logging when there are activities on the ice, or if there are mammals in the area. Deployment and recovery of drifting listening buoys is also recommended activity from LCC, e.g., deploy in one cruise and recover at the end of another cruise. In this way one can obtain more information about the natural sounds as well as documentation how much sound the ship makes when it is manoeuvring. These recordings would have the most scientific value.

We recommend investing in some handheld hydrophones for use together with the guests either from the ice or from the Zodiacs. However, to collect scientific acoustic data from a drifting or silent platform we recommend buying well-documented hydrophone systems such as Aural hydrophones (or similar). These hydrophones are calibrated and therefore the data you obtain can be used scientifically and can be compared to data obtained by other scientists. If you want to build a buoy that can operate alone till you pick it up, you will need a surface buoy and a locator that allows you to find it back and recover it. NERSC do have this equipment and it is something that could be used for an upcoming cruise.



(a)



(b)

Figure 11: Example of spectrograms of the recordings made with the hydrophone during the deployment at the North Pole. The spectrogram in (a) is from 2021-09-07 when the port propeller was stopped (indicated by the black dashed vertical line). The recording in (b) contains sounds from the helicopter flying by the location of the hydrophone on 2021-09-08, and a person walking/running on the ice.

Task 5: Outreach

Float Your Boat is a communication project carried out at NERSC in collaboration with University of Washington, Seattle, and International Arctic Buoy Program (IABP). The concept is that children prepare and decorate small wooden boats. These boats are then taken along with cruises that is deploying floats and drifters for research programs or for the IABP. In 2020 buoys and boats were deployed as part of the CAATEX and INTAROS field experiments (see earlier in this report).

In the case of LCC cruise, children in Bergen, Seattle and London prepared and decorated altogether around 150 small boats, while the guests enthusiastically decorated 64 small boats. The boats were put together with the scientific buoys deployed at the North Pole (see Figure 7). The drift can be followed at the web page for the International Arctic Buoy Program. The Float Your Boat project is now followed up by NERSC in a project funded by the Research Council of Norway.

Scientists from Nansen Center gave two plenary scientific talks about INTAROS and CAATEX, and how the work onboard LCC gave input to INTAROS. One talk was given in the beginning of the cruise in transit to Svalbard from the shipyard in Tomrefjord, Noway. The other talk was given at the end of the cruise. We also gave one talk for the naturalists about the Float Your Boat concept and one short briefing for the guests.

Recommendation

It is important to plan for sharing scientific knowledge and how we do scientific fieldwork to the guests onboard. Questions must be addressed in in an understandable language. The naturalists can be involved to help bridge between science and tourists. Based on comments from the guests we recommend having daily update from the scientists at the recap sessions in the evening so that the guests and crew know what we are doing and what we plan to do. Activities like Float Your Boat is very engaging for the participants.

Task 6: Overview of the facilities available for scientific work onboard

Wet lab. The room provide an excellent lab space for analysing water samples and biology samples. The moon pool looks good, but we found out that we could not use it this time for our activities. We are a bit unsure how it will work when we are in ice. The ice might get into the moon pool and block for access to the water or destroy instrument cables.

Dry lab. The room was very good for preparing and instruments in a dry and clean room. This was very important for most of the activities we carried out form the ship. This time we brough all the tools we needed. One recommendation would be to have some basic tools available for the research parties. In this case, a list of these tools onboard should be available so that the researcher knows what to bring. In addition, NMEA GPS data would be nice to have available in the lab, either via a serial connection or on a network.

The Ferry box room. This room looks very good, and we strongly recommend getting a Ferry box system installed. We would recommend finding out how or when to operate Ferrybox in ice covered regions.

Sonars: The ship plan to install a sonar, and we recommend a multibeam echosounder able to do mapping of the sea floor down to 5000 m and beyond. This would be a very tremendous contribution to the research community as the bathymetry of the deep polar ocean is very much unknown or sparse. We would prioritize this investment high up on the list.

Expedition resources: The helicopter, zodiacs, kayaks, snow mobiles, the Sherp, and hovercrafts, are great resources for work away from the ship. They make it possible to get away from the ship to do measurements in undisturbed areas. This is important for oceanographic measurements, in situ observations of sea-ice, acoustical measurements, etc. The Sherp and a snow mobile was excellent to carry the personnel and equipment when the hydrophone was deployed.

Light measurements

Light conditions in the ocean under the ice are important for the ecosystem and it is changing with the changes in sea ice extent and thickness. There is a lot of attention to this topic, and we would suggest investing in a Secchi disk and camera and turbidity sensors installed in a ROV. The Secchi disk is a white disk which is lowered down into the water till you can not see it anymore. This gives an estimate about how deep down the light penetrates. If there is a lot of biological matter or other material (erosion near glaziers) this depth is reduced. To combine this with how much algae there are in the area one can use a ROV with camera and potentially some other instrumentation. More fancy instrumentation exists (e.g. LISST-VSF) but it would require a researcher experienced in operating it. Light measurements would benefit a lot from CTD and water samples in the upper 150-200 meters. Water samples can be done by a Nansen Bottle / NISKIN bottle.

Recommendation for organisation of science activities onboard

First of all, we appreciate very much the willingness from the whole crew onboard the LCC to facilitate and help to implement our science activities. Below follows some experiences from our side.

We knew that this time there was a clear priority to test the ice navigation capabilities to reach the North Pole and to do a SAR at the North Pole. Therefore, NERSC proposed in the beginning of the cruise to wait with our science activities that we knew would influence the ship schedule e.g., XBT stations in the ice and stop for the deployment of the hydrophone. Based on our experience we recommend in future to wait with the majority of scientific work till the ship is on her way back from e.g., the North Pole. In this way the science can get more focus/attention from the bridge and from the guests. Also, the North Pole will be a highlight for the guests, and it can be nice to save some activities to the return trip.

We strongly recommend a meeting with the personnel at the bridge in the beginning of the cruise to explain the cruise/sailing plan, the organisation, and responsibilities, and to adjust and clarify the science program according to the sailing plan. This time there was no cruise/sailing plan that informed the science party how they could plan their activities according to. For example, to plan deployment of buoys or how to distribute XBTs one need to know roughly the planned route.

When the science activities start it is very useful with daily morning meeting with the bridge so that the deviations from the plan that day can be informed. It is also important that the science party inform what kind of assistance they will need during the planned science operation e.g. to get away from the ship you will need a driver of the Sherpa and a polar bear watch.

We strongly recommend LCC to have an appointed person at the bridge to work with and communicate to the scientists. This was done during the dry test and very important for our implementation of science activities. However, during the dry test there was some confusion how things were organised/coordinated, partly because there was many who wanted to “coordinate” or help the science party. It is important to allow extra time for explanation when there are non-French speaking scientists to avoid misunderstanding or lack of important information.

Le Commandant Charcot has a large group of well-educated naturalists within different scientific areas, and a group of cadets. The naturalists are used to work in the Arctic environment, and they can be a resource for scientific projects (launch XBT’s, do sea-ice measurements, buoy deployments, launch atmospheric balloons, etc) with relatively little training. They are also a resource in communication of the science activities to the tourists, and safety when research activities are carried out on the ice or in Zodiacs.

Figure 12: Summarizing the Activities. Ship track (black line), buoy tracks (coloured lines, by month, see Figure 6), and XBT cast locations (red dots) with profiles shown in Figure 10. The sea-ice concentration from AMSR2 is for 2022-01-23. The Acoustic measurements and deployment of the small wooden boats were carried out at the North Pole.

Recommendations for working with cruise ships

Working with the cruise industry is rather different compared to scientific cruises with research vessels or working with the Coast Guard in Norway but this collaboration offers new and interesting opportunities. The most attractive is that the tourist ship visit places on a regular basis either once a year or several times a year. In this way long time records of measurements can be made. For example, LCC is scheduled to visit the North Pole four times in the summer, and repeated oceanographic sections can be made and buoys can be deployed at the North Pole.

Working with any tourist ship the science is at best secondary priority, and this must be considered when planning a scientific program onboard. All planning must agree with the leadership onboard and must be in agreement with the planned cruise. In this way the expectations are clarified from both sides.

Below is a list of recommendations:

- Provide a detailed description of the planned activities to the cruise operator and crew well in advance. During the planning of the science activities, it must be found out if they can be carried out in parallel with normal ship activities.
- Appoint a chief scientist to coordinate with the ship. Get a dedicated science liaison amongst the officers at the bridge with responsibility to follow up the science party throughout the cruise.
- Prepare for daily coordination meetings between crew (bridge and staff involved in science) and science party. Update the Science Plan the science activities using available ship route, weather forecast and ice information.
- Joining these cruises will give scientists contact with people who are genuinely interested in the Arctic. The tourists pay a lot of money to join the cruise, and the interaction with researchers to learn more about the Arctic is part of their cruise package. Therefore, it is important that the science party are willing to do outreach towards passengers and involve passengers in what they do. In this way the tourists will understand that instruments deployed on the ice that must be left undisturbed. However, usually, the sensitive instruments are deployed away from the area dedicated for the tourists.
- Research parties should present data management plans fulfilling the FAIR principles e.g., where will data and documentation be published and stored.

The possibilities onboard the LCC and other cruise ships are:

- Cruise ships repeats routes once or several times a year and it is recommended to focus on measurements that can be repeated along a certain track, to obtain a longer time series of measurements or to deploy expendable drifters.
- It is also possible to deploy equipment on the ice and pick it up on the way back, given that the equipment is properly tracked so that it can be found easily and prepared for easy recovery. This activity requires the ship to stop and must be planned and agreed upon in advance. It could be coordinated so that it fits with activities on the ice for tourists.
- If possible, engage passengers through citizen science activities (e.g., Float Your Boat, and apps like HappyWhale, eBird, and IceWatch) and/or let the tourists be involved in the research activity onboard the ship to increase their knowledge about the Arctic and Arctic research.
- Involve tourists and naturalists in your measurement program if you need spatial coverage of e.g. ice thickness measurements and coring; or making CTD casts and taking water samples from Zodiacs.

When planning for attending one of the cruise expeditions one should keep in mind that there are no possibilities to do time demanding operations or operations deviating from the planned route such as mooring deployments.

Concluding remark

The coast guards operating in the Arctic regions are an important resource for polar research, development of services for operators in the Arctic, and for development and testing of new technologies. The successful recoveries and deployment of the basin wide prototype for acoustic moorings in CAATEX and the INTAROS moorings North of Svalbard shows that we together with the Norwegian Coast Guard have the technical, logistical, and operational capacity to establish a full-scale multipurpose mooring network for the central Arctic.

We have shown that complex and time demanding operations can be carried out onboard the coast guard ship KV Svalbard. However, procedures should be gradually built up if the crew onboard the coast guard ship is not experienced in the operation. In other words, do not start with the most complex operations! Good communication between the commanding officers onboard the ship and the cruise coordinator, both during planning and implementation of the field experiment, is essential for the success doing research from a coast guard ship. Furthermore, the interest, knowledge, and experience that the coast guards have are important for research-based innovations for services and technologies to be used in the Arctic. Two-way exchange of knowledge is highly recommended!

Working with the cruise ship industry is like working with the coast guard, but different in many ways. Most cruise ships are not equipped for heavy operations like deployment or recovery of larger installations. Furthermore, time consuming operations are difficult to put into a tourist cruise, and some operations can become difficult to do due to safety issues. However, as demonstrated in the INTAROS participation in Le Commandant Charcot cruise, many ice/ocean/atmosphere observation programs can be supported by cruise ship e.g., XBT sections and deployment of drifting buoys. What we did not try out was the citizen science programs based on apps for example eBird, HappyWhale, and IceWatch. This is recommended to do in future cruises.

In conclusion, the coast guards and the cruise ship industry are a huge resource for research programs to increase the number of observations in the Arctic region. This is particularly important in the sparsely sampled Eurasian Basins. The coast guards and the shipping industry can contribute to a more diverse and inclusive polar research.

This report will be the foundation for developing reports to be implemented into the Arctic Practices System (APS), currently being developed within the CAPARDUS project (https://capardus.nersc.no). The APS system is linked to the https://ioc.unesco.org/media-and-publications/ocean-best-practices-system.

INTAROS

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