SCIENCE AND TECHNOLOGY ORGANIZATION
CENTRE FOR MARITIME RESEARCH AND EXPERIMENTATION

Technical Report CMRE-MR-2023-006

NREP23 Cruise Report and Data Catalogue

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About CMRE

The Centre for Maritime Research and Experimentation (CMRE) is a world-class NATO scientific research and experimentation facility located in La Spezia, Italy.

The CMRE was established by the North Atlantic Council on 1 July 2012 as part of the NATO Science & Technology Organization. The CMRE and its predecessors have served NATO for over 50 years as the SACLANT Anti-Submarine Warfare Centre, SACLANT Undersea Research Centre, NATO Undersea Research Centre (NURC) and now as part of the Science & Technology Organization.

CMRE conducts state-of-the-art scientific research and experimentation ranging from concept development to prototype demonstration in an operational environment and has produced leaders in ocean science, modelling and simulation, acoustics and other disciplines, as well as producing critical results and understanding that have been built into the operational concepts of NATO and the nations.

CMRE conducts hands-on scientific and engineering research for the direct benefit of its NATO Customers. It operates two research vessels that enable science and technology solutions to be explored and exploited at sea. The largest of these vessels, the NRV Alliance, is a global class vessel that is acoustically extremely quiet.

CMRE is a leading example of enabling nations to work more effectively and efficiently together by prioritizing national needs, focusing on research and technology challenges, both in and out of the maritime environment, through the collective Power of its world-class scientists, engineers, and specialized laboratories in collaboration with the many partners in and out of the scientific domain.

NREP23 cruise report and data catalogue

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This document, which describes work performed under the Project/the Programme ACT-EKOE SAC000E06 (ASW Environmental Acoustic Support in a Rapidly Thawing Arctic Ocean) of the STO-CMRE Programme of Work, has been approved by the Director.

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NREP23 cruise report and data catalogue

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Executive Summary: The CMRE research project ASW Environmental Acoustic Support in a Rapidly Thawing Arctic Ocean (SAC000E06) proposes to advance the understanding of the environmental transformation, including the underwater ambient noise, in a thawing Arctic Ocean and how these variations will transform the future of Arctic ASW. The objective of the project is to provide environmental understanding and databases to enable the selection of sensor designs, system configuration and signal processing to support future NATO's ASW operation in the Arctic Ocean.

The Nordic Recognized Environmental Picture 2023 (NREP23) sea trial was conducted from June 20 to July 11 in the Fram Strait, to investigate the potential impact of spatially distributed ice floes in the underwater acoustic propagation in an upward refracting environment. The objective is to assess SONAR performance in this increasingly common Arctic landscape. This report describes the oceanographic and acoustic activities conducted during the NREP23 sea trial and details the inventory of the collected data. The final aim of this document is to facilitate the exchange and portability of the NREP23 dataset to NATO nations.

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NREP23 cruise report and data catalogue

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Abstract: The Nordic Recognized Environmental Picture 2023 (NREP23) sea trial was performed in the Fram Strait, where ice floes are still present during the summer season. The sea trial was designed to measure the scattering of such structures as well as their integrated effect on acoustic propagation. Environmental observations, including sea ice distribution, were gathered along an acoustic transmission line defined by a source and receivers. These measurements are expected to conclude the research initiated in NREP21 (and followed in NREP22) to study and to quantify the impact of different physical phenomena on Arctic Sonar and underwater communications (UComms) operations.

This Memorandum Report (MR) provides a detailed overview of the oceanographic and acoustic measurements collected by both the NRV Alliance and autonomous platforms during the NREP23 sea trial. It also summarizes the raw and processed data available in the CMRE data repository.

Keywords: Arctic Ocean, acoustic data, oceanographic data, NREP, ice.

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1 Introduction

As part of the great power competition, Russia has projected its naval influence on the Arctic Ocean. This naval projection is primarily aimed at gaining underwater dominance in the High North. Russia began conducting regular patrols to the Arctic Ocean with nuclear powered submarines after deploying, in 2007, the Russian flag on the seafloor at the North Pole (Caitlyn L. A., 2011).

Russia's re-emergence of its submarine force representes a significant threat for the Euro-Atlantic security space. Rebuilding anti-submarine warfare (ASW) skills is now a NATO priority. Recovering and enhancing Arctic ASW must rely on re-generating knowledge of the Arctic domain. This update is required by the drastic environmental transformations suffered by the Arctic Ocean that makes our previous environmental knowledge of the region obsolete.

The realization of the sea trial Nordic Recognized Environmental Picture 2023 (NREP23) campaign led by the Centre for Maritime Research and Experimentation (CMRE) supported the Environmental Knowledge and Operational Effectiveness (EKOE) program outlined in the Management Plan for the Project *ASW Environmental Support in a Rapidly Thawing Arctic Ocean-SAC000E06* funded by the Allied Command Transformation (ACT).

This report describes the oceanographic and acoustic activities conducted during the NREP23 sea trial and provides a detailed inventory of the collected data. These measurements are expected to conclude the research initiated in NREP21 (and followed in NREP22) to understand/quantify the impact of different physical phenomena on Arctic Sonar and underwater communications operations. The final aim of this document is to facilitate the exchange and portability of the NREP23 dataset to NATO nations. Specifically, an overview of the cruise area and external participants is detailed in this section. The report follows with Section 2 describing the moored autonomous platforms CIO1 and S1 raw/processed data available in the CMRE data repository. Section 3 details the data collected by the autonomous platforms while ship-deployed platforms are described in Section 4. Finally, Section 5 is dedicated to remote sensing data used to support NREP23 activities, *i.e.* satellite, drone and ROV. To conclude, an overall summary of the oceanographic data is presented in Section 6. Additional details on the acoustic experiments are provided in Annex A, while details on drone acquisition are reported in Annex B.

1.1 Geographic area and sea trial objectives

The NREP23 sea trial was conducted between June 20th and July 11th 2023 in the Fram Strait. Figure 1 shows the area of operations during NREP23 (red polygon, geographical coordinates are listed in Table 1). The white polygon marks the area where several acoustic experiments[1] were performed (geographical coordinates are listed in Table 2).

The positions of the CIO1 and S1 oceanographic-acoustic moorings are also shown (geographical coordinates are listed in Table 3). Green lines represent CTD transects.

Table 1: Coordinates of the NREP23 operating area.

Area	**Corner Points**	**Coordinates**	
		Longitude	**Latitude**
NREP23 operational Area (red)	1	011° 14’ E	80° 32’ N
	2	009° 22’ E	79° 57’ N
	3	009° 15’ E	78° 46’ N
	4	010° 12’ E	78° 14’ N
	5	015° 09’ E	76° 15’ N
	6	015° 13’ E	75° 57’ N
	7	000° 40’ E	76° 09’ N
	8	002° 54’ W	78° 28’ N
	9	001° 38’ W	79° 50’ N
	10	003° 05’ E	80° 40’ N

[1] Several hours of acoustic transmission were performed during NREP23 over a period of five days (25-26-27-29 June and 1 July). Such acoustic transmissions were carried on under variable ice-coverage conditions and at different transmitter-receiver ranges. Details on the acoustic experimentations can be found in Annex A.

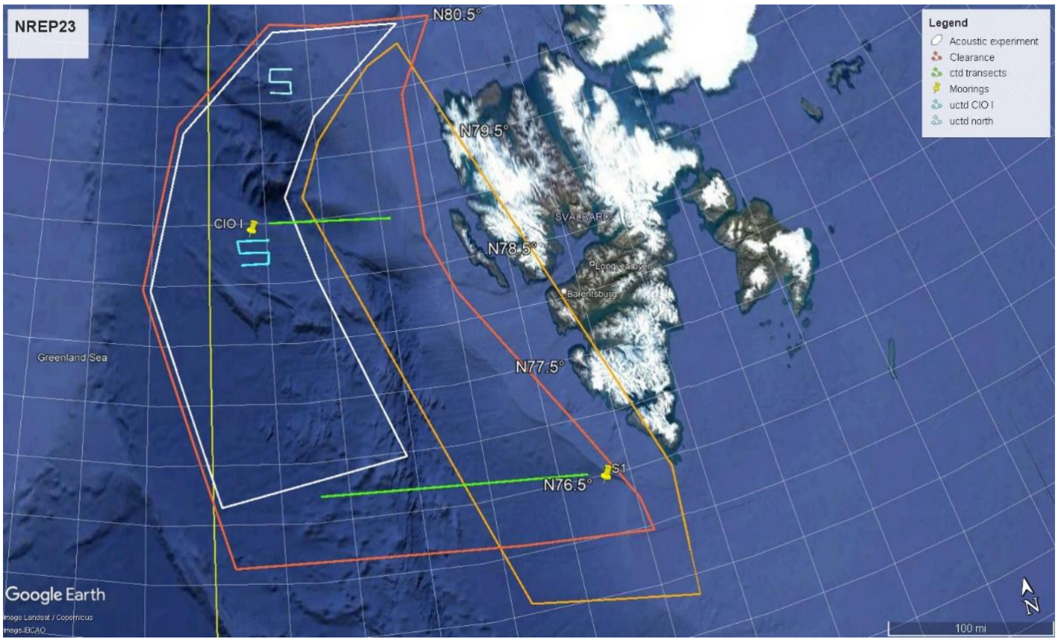


Figure 1: The red polygon defines the NREP23 operation area, the orange polygon represents the whale-area[2] while the white polygon defines the area of the acoustic experiments (geographical coordinates are detailed in Table 1). Positions of CIO 1 and S1 oceanographic-acoustic moorings are also shown. The green lines represent CTD transects.

Table 2: Coordinates of the area for the acoustic transmission line.

Area	Corner Points	Coordinates	
		Longitude	Latitude
Acoustic Area (white)	1	009° 44' E	80° 32' N
	2	005° 08' E	79° 50' N
	3	003° 19' E	79° 11' N
	4	004° 33' E	78° 32' N
	5	007° 14' E	76° 58' N
	6	000° 17' E	76° 38' N
	7	002° 35' W	78° 27' N
	8	001° 10' W	79° 46' N
	9	003° 22' E	80° 36' N

[2] The orange area represents the portion of the region for whale grazing from July 1st to September 30th (adapted from figure A 1.4 of the report from the Institute of Marine Research: Havforskningsinstituttets rådgivning for menneskeskapt støy i havet-Kunnskapsgrunnlag, vurderinger og råd for 2022 (https://www.hi.no/hi/nettrapporter/rapport-fra-havforskningen-2022-1, last access 11th October 2023).

Table 3: Coordinates of the acoustic-oceanographic moorings CIO1 and S1.

Moorings	Coordinates	
	Longitude	Latitude
CIO1	01° 44’ E	78° 53’ N
S1	13° 57’ E	76° 26’ N

1.2 Acoustic experimental designs

This section describes the three acoustic experimental designs which were implemented during the NREP23 sea trial. These measurements are expected to conclude the research initiated in NREP21 (and followed in NREP22) to understand/quantify the impact of different physical phenomena on Arctic Sonar and underwater communications operations.

Experiment I: 3D sound scattering by ice floes

The main goal of this experiment was the characterization of the scattering by ice floes. To achieve this, the ice floe three dimensional geometry was inferred with a drone and a ROV. The scattering field was also monitored with a portable linear array at different ranges and angles (Figure 2).

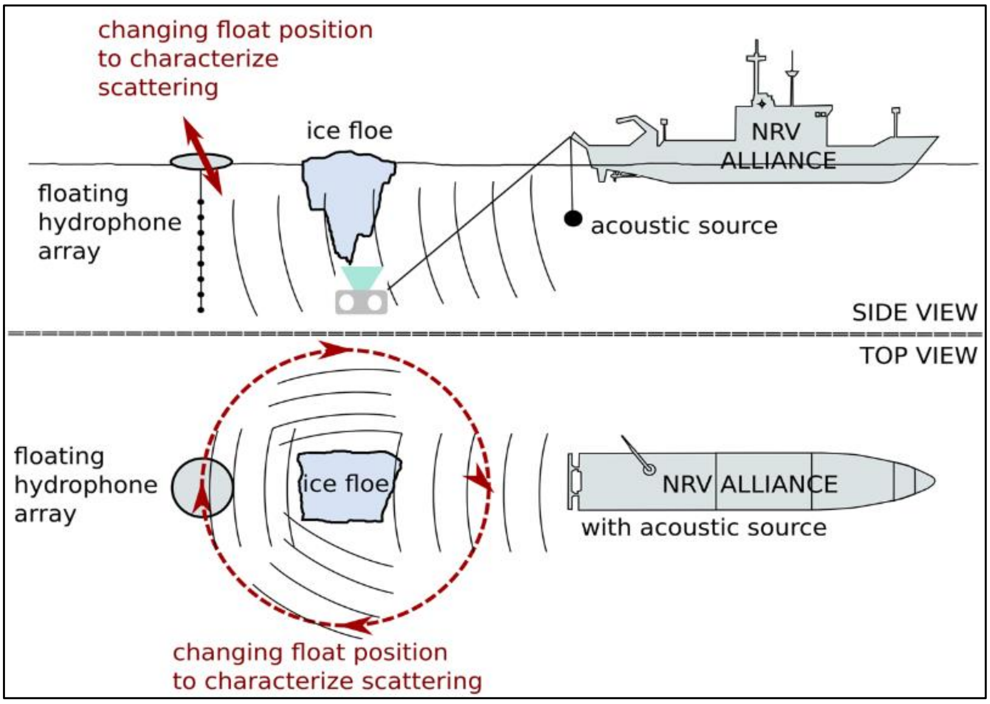


Figure 2: Acoustic experimental design I.

Experiment II: Leaking of scattered sound by ice floe in a shadow area
The main goal of this experiment was to study the leaking of scattered sound with acoustic transmissions at different frequencies and ranges (Figure 3).

Experiment III: Transmission Loss (TL) dependence on ice floe density
The main goal of this experiment was to study the TL dependence on the ice floes density using orthophoto of the ice flow filed. The acoustic transmissions were performed at different distances to characterize the TL (Figure 4).

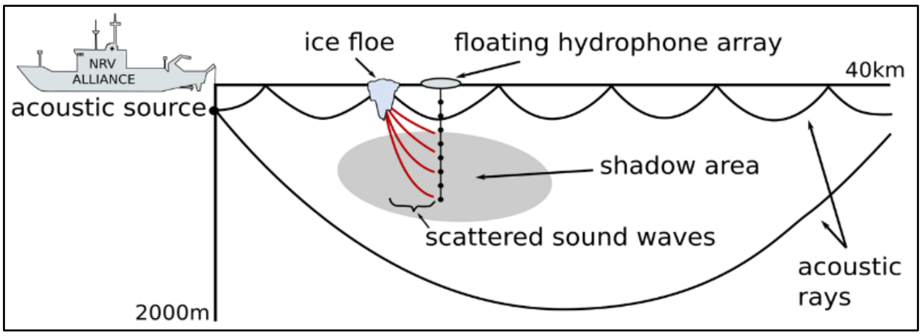


Figure 3: Acoustic experimental design II.

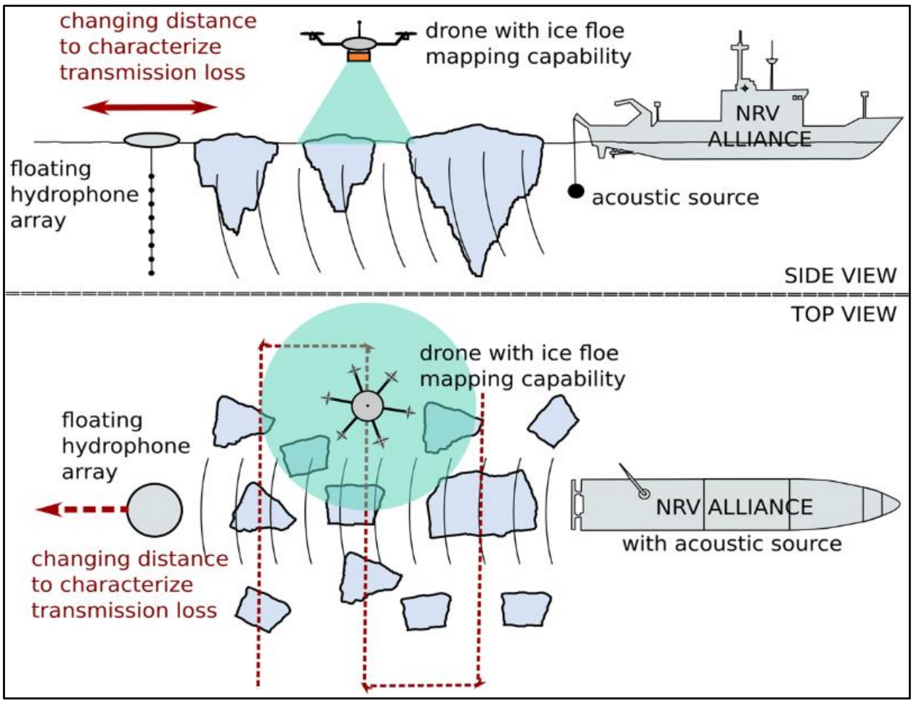


Figure 4: Acoustic experimental design III.

1.3 External Partners

NREP23 involved five external partners on board and for scope of collaborations. Official Partners are entitled to have access to the data sets collected during the sea trial after acceptance of the corresponding Memorandum Among Participants-MAP. Access to the NREP23 dataset can also be granted, under request, to other NATO institutions to support defence requirements.

- **CNR/ISMAR:** Consiglio Nazionale delle Ricerche, Istituto delle Scienze Marine (ITA)
- **CNR/ISP:** Consiglio Nazionale delle Ricerche, Istituto delle Scienze Polari (ITA)
- **OGS**: Istituto Nazionale di Oceanografia e Geofisica Sperimentale (ITA)
- **DSTL:** Defence Science and Technology Laboratory (UK)
- **DGA:** French Directorate General of Armaments (FRA)

2
Moored autonomous platforms

During the NREP23 sea trial, oceanographic and acoustic moorings were deployed in the operational area (as showed in Figure 1 and detailed in Table 3). Technical details about the different mooring designs and installed sensors are provided in the following sub-sections.

2.1 Mooring CIO1 (CMRE)

The mooring CIO1 was deployed on June 23rd 2022 during the sea trial NREP22 and it was intended to be recovered in 2023 during the NREP23 sea trial. Unfortunately, in late June and July exceptional difficulties prevented recovery of the mooring as the sea ice prevented the access to CIO1. For this reason the recovery was postponed to 2024[3] during the planned NREP24 sea trial. The mooring is equipped with eleven Seabird SBE37 CTD sensors, ten RBR-duet temperature-pressure sensors, two AANDERAA[4] current-meters and six Loggerhead acoustic recorders. Table 3 provides a summary of the available oceanographic and acoustic data being collected by CIO1 while Figure 5 shows the mooring's design.

Table 3: Summary of the sensors available on the mooring CIO1.

Sensor	Variables and sampling details	Time start	Time end	Files	Size
AANDERAA (RCM9)	temp [ºC]; water current [m/s] 150 pings, 30min, 600ds	23/06/2022	postponed in 2024	-	-
SBE-37	Cond [mS/cm];temp [ºC];Press [dbar];sea press [dbar];depth [m];sal [PSU];sv [m/s];specific cond [µS/cm]; dens anomaly [kg/m³] 30 sec	23/06/2022	postponed in 2024	-	-
RBR duet	Temp [ºC]; Press [dbar]; 15min	23/06/2022	postponed in 2024	-	-
Acoustic recorders (Loggerhead)	120 sec, sleep 750, 96 KHz, 2.05 dB 436 ds	23/06/2022	postponed in 2024	-	-

[3] The area became ice-free in the second week of August 2023, when NREP23 operations were ended.

[4] Recording Current Meter Model 9 (RCM-9).

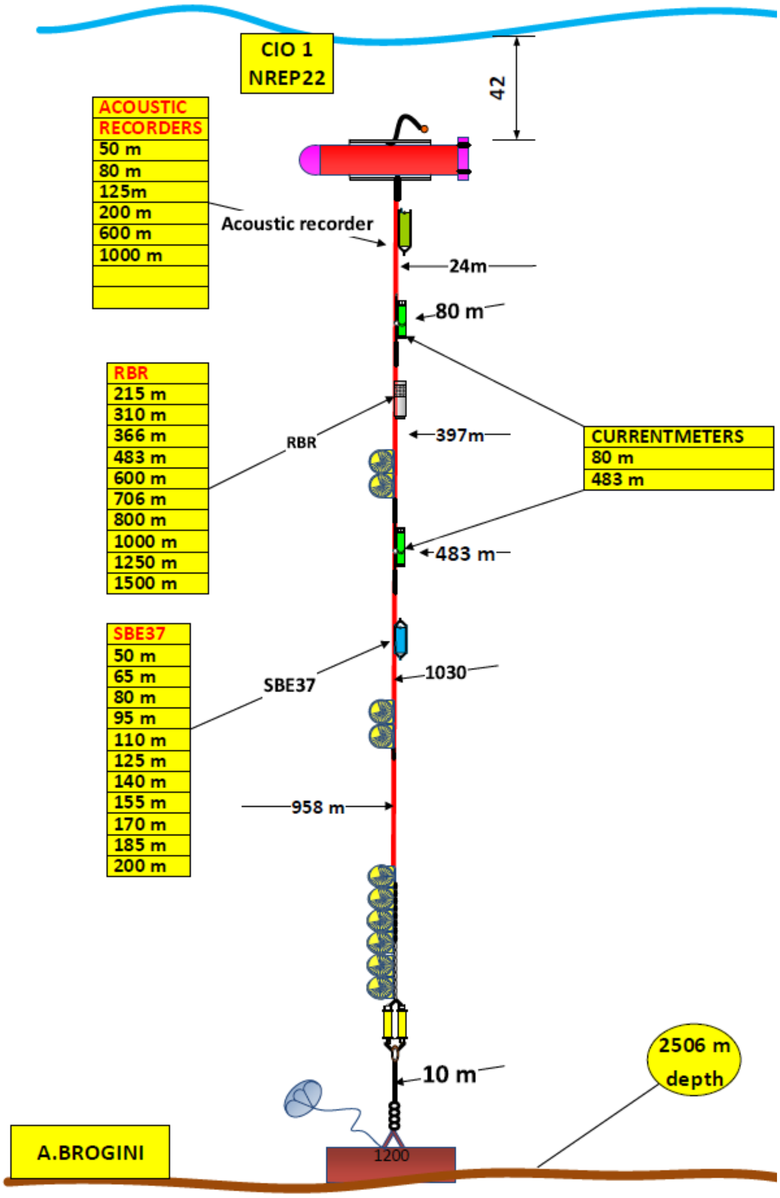


Figure 5: Sensors distribution on the mooring CIO1.

2.2 Mooring S1 (managed by CNR/ISP and OGS)

Mooring S1 was deployed on June 25th 2022 (9.30-13:00 UTC) and was recovered on June 22rd 2023. The mooring incorporates two Loggerhead LSIX acoustic recorders, two SBE-37 CTD and three RBR temperature-pressure recorders provided by CMRE and located in the upper part of the mooring. Figure 6 displays the mooring design. The oceanographic and acoustic data collected available from the mooring are detailed in Table 4.

Table 4: Summary of the sensors and variables available[5] from the S1 mooring.

Sensors	Variables and sampling details	Time start	Time end	Files	Size
Oceanographic SBE-37	Cond [mS/cm];temp [ºC];Press [dbar];sea press [dbar];depth [m];sal [PSU];sv [m/s];specific cond [µS/cm]; dens anomaly [kg/m³] 30 sec	23/06/2022	22/06/2023	raw	5.52MB
Oceanographic RBR duet	Temp [ºC]; Press [dbar]; 15min	23/06/2022	22/06/2023	raw	527MB
Acoustic recorders (Loggerhead)	120 sec, sleep 750, 96 KHz, 2.05 dB 436 ds LH 550m & LH 650m	23/06/2022	22/06/2023	raw	1.25TB

[5] \\isilon\NREP23\Trial_Data\CMRE\acoustic\moorings\S1 (acoustic data); \\isilon\NREP23\Trial_Data\CMRE\environmental\moorings\S1 (oceanographic data)

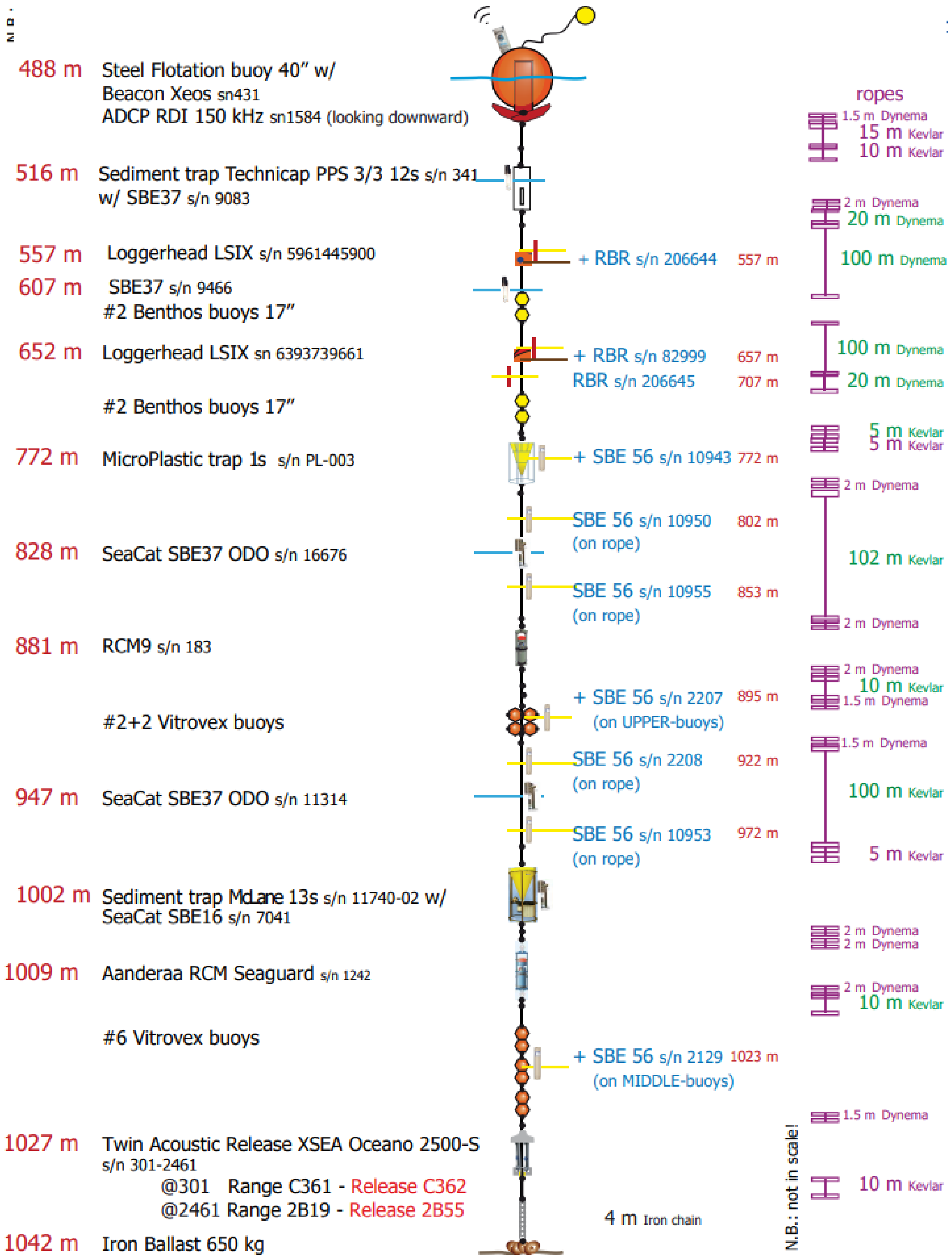


Figure 6: Design of the oceanographic and acoustic instrumentations available on the mooring S1 developed by CNR/ISP and OGS.

2.3 Real-time Wirewalker (WW)

During the sea trial NREP23, a real-time Wirewalker (WW) was deployed in drifting mode on June 26th 2023 at 78.1866 N 1.9552 E. The WW profiler was equipped with a RBR Concerto CTD and a Nortek Signature 1000 acoustic Doppler current profiler (ADCP). Table 5 provides a summary of the oceanographic data available from the Wirewalker.

The WW profiler sampled the water column from near surface to around 300 m depth. It was recovered on June 27th 2023. Figure 7 shows the sound speed field measured from the wirewalker in drifting mode.

Table 5: Installed sensors and available[6] WW oceanographic data.

Sensor	Variables and sampling details	Time start	Time end	Files	Size
RBR concerto	cond [mS/cm]; temp [ºC]; press [dbar]; seapress [dbar]; depth[m]; sal[PSU]; sound vel [m/s]; specific cond [µS/cm]; density anomaly [kg/m³]	26/06/23 07:40	27/06/23 13:50	Level 0 Levels 1-2 -3 (netcdf)	326 MB
ADCP 1000kHz (Nortek)	water current [m/s]	26/06/23	27/06/23	Level 0 (raw)	9 GB

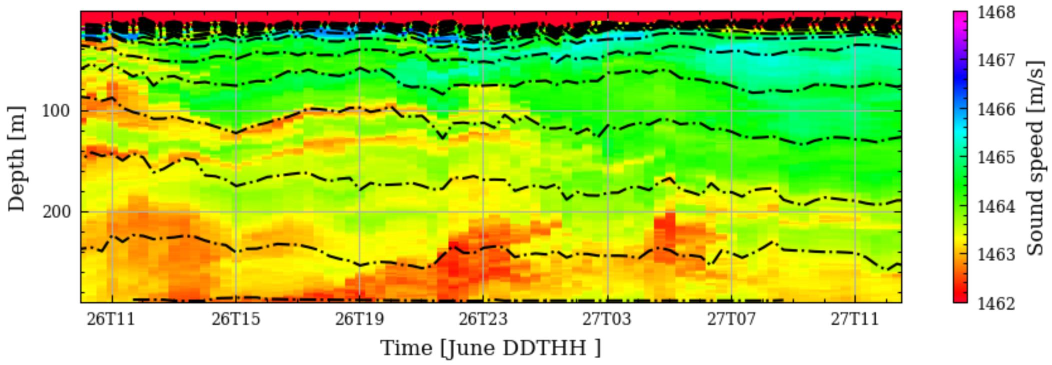


Figure 7: Sound speed field as measured from the wirewalker in drifting mode.

[6] \\isilon\NREP23\Trial_Data\CMRE\environmental\wirewalkers\raw\06_26\SIGNATURE\101670 (acoustic) and \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\wirewalker (oceanographic)

3
Autonomous platforms

3.1 Surface Velocity Program (SVP) Drifters

Four Surface Velocity Program (SVP) drifters were deployed during the NREP23 cruise with the following configurations:

- Two drifters (id *3800* and *2960*) were equipped with three hydrophones at 20 m, 30 m and 40 m of depth;
- Two custom-developed logarithmic and linears arrays (id *ps_lim* and *ps_log*) (Figure 8).

Table 6 provides a summary of the oceanographic acoustic data available from the four drifters.

Figure 8: A picture of the custom developed drifter equipped with a logarithmic acoustic array.

Table 6: Summary of the data available from the four SVP drifters.

Drifter id	Date and time (UTC)	Files	Size
2960[7]	26/06/2023 from 09:00 to 10:30	Level 0 (raw data, wav)	26 GB
3800[8]	27/06/2022 from 08:32 to 15:00	Level 0 (raw data, wav)	58 GB
	30/06/2022 from 12:20 to13:30	Level 0 (raw data, wav)	
	01/07/2022 from 08:50 to 11:50	Level 0 (raw data, wav)	
ps_lin[9]	26/06/2023 from 08:30 to 18:30	Level 0 (raw data, wav)	88 GB
ps_log[10]	25/06/2023 from 14:00 to 17:00	Level 0 (raw data, wav)	143 GB
	26/06/2023 from 10:40 to 17:20	Level 0 (raw data, wav)	
	30/06/2023 from 06:00 to 15:20	Level 0 (raw data, wav)	
	01/07/2023 from 06:00 to 15:20	Level 0 (raw data, wav)	

[7] \\isilon\NREP23\Trial_Data\CMRE\acoustic\drifters\drifter_1_2960

[8] \\isilon\NREP23\Trial_Data\CMRE\acoustic\drifters\drifter_3_3800

[9] \\isilon\NREP23\Trial_Data\CMRE\acoustic\pslim_lin (linear array)

[10] \\isilon\NREP23\Trial_Data\CMRE\acoustic\pslim_log (acoustic)

3.2 SLOCUM Gliders

Two SLOCUM gliders were deployed during the NREP23 sea trial:

- Glider *Dora*: a G2 SLOCUM hybrid (thruster capability) glider with standard oceanographic configuration with SBE pumped CTD, Wetlab EcoPuck with backscatter, chlorophyll (CHL) and CDOM. The oceanographic glider Dora was deployed on 22nd June 2023 (17:28 UTC) and recovered on June 7th 2023. Details are reported in Table 7.
- Glider *Anna*: a G3 SLOCUM acoustic glider with single hydrophone and compact Volumetric Array Sensor (cVAS) also equipped with a non-pumped RBR CTD sensor. Details from the Anna deployments are reported in Table 8. The acoustic glider was deployed on June 27th 2023 and recover on the same day.

Table 7: Summary of the data available[11] from the glider Anna.

DORA	Deployment	Recovery	Files	Size
Oceanographic data (density, ctd, currents, salinity, sound speed, temperature)	22/06/2023	07/07/2023	Level 0 (raw data); Level 1-2-3 (netcdf)	2.5 GB

Table 8: Summary of the data available[12] from the glider Anna.

ANNA	Date	Time (UTC)	Files	Size
Acoustic data from Single Hydrophone and Vol. Array	27/06/2023 From 07:00 to 14:00		Level 0 (Wav files and TS video)	40 GB
Oceanographic data (density, ctd, currents, salinity, sound speed, temperature)	27/06/2023 From 07:00 to 14:00		Level 0 (raw data); Level 1-2-3 (netcdf)	56 MB

Figure 9 shows the gliders deployment areas and tracks while Figure 10 and Figure 11 show a scatterplot of the available measurements of temperature and salinity.

[11] \\isilon\NREP23\Trial_Data\CMRE\environmental\gliders\delayedmode\dorajr\

[12] \\isilon\NREP23\Trial_Data\CMRE\environmental\gliders\delayedmode\anna\depl001\ (oceanographic) \\isilon\NREP23\Trial_Data\CMRE\acoustic\gliders\anna (acoustic)

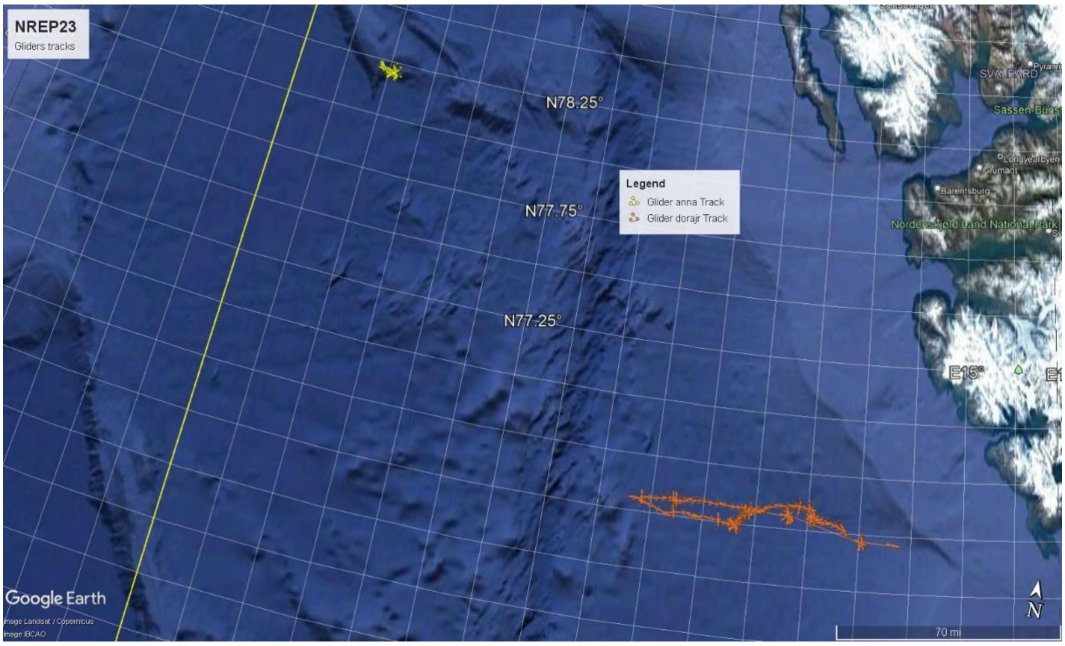


Figure 9: Gliders transects performed by the glider Dora (Orange) and Anna (yellow) during the cruise NREP23.

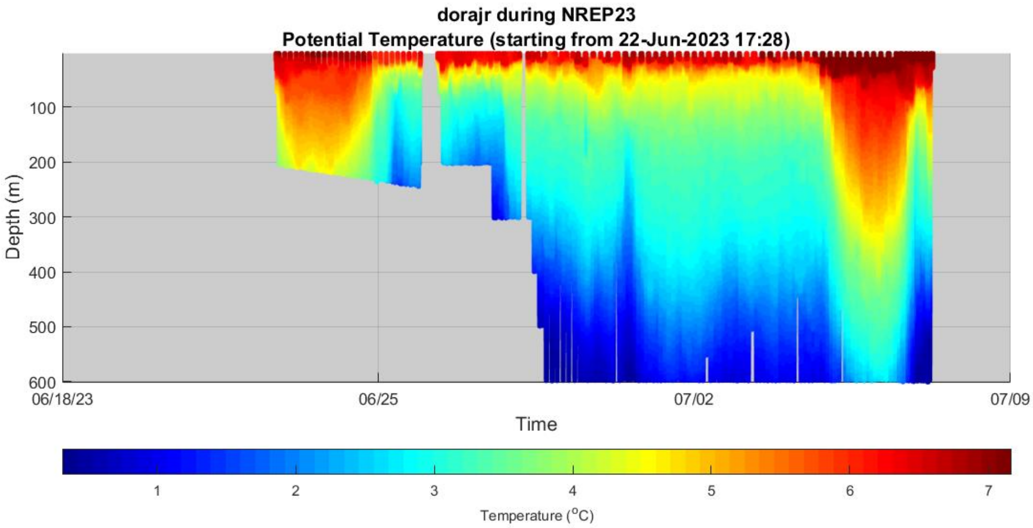


Figure 10: Dora underwater sampling performed during NREP23: *in situ* measurements of temperature [ºC]. During the first part of the sampling (22-29 June) the glider pressure sensor didn't work properly and the glider dove only between the surface and 300 m. After the 29th June, the pressure sensor problem was fixed allowing a dive from the surface to 600 m.

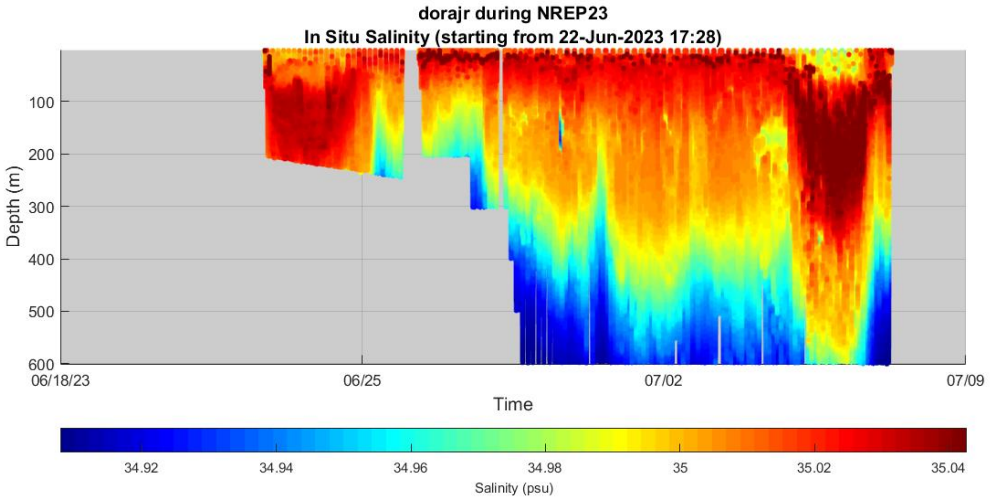


Figure 11: As Fig. 10 but for Salinity.

4
Sensors deployed from the NRV Alliance

4.1 METEO, Along-track thermosalinograph (T_S) and Acoustic Doppler Current Profiler (ADCP) data

GPS data were logged aboard the NRV Alliance, ship meteorology data were available from GILL systems on foremast, T_S data were available from underway CT SBE45 and SBE38 (thermosalinograph) with hull water intake at about 2.5 m below the sea surface while ADCP data were available from Ocean Surveyor 75 kHz.
Table 9 provides a summary of the GPS, METEO and T_S data available from the ship while Figure 12 displays the Alliance positions with GPS, meteo and T_S data available.

Table 9: Summary of the GPS, meteo and T_S data available[13] from the ship.

Platform name	Sensor (variables)	Time start (UTC)	Time end (UTC)	Files	Size
NRV Alliance	GPS (depth, speed, heading, lat, lon, time)	19/06/2023 19:07	01/07/2022 10:11	Level 0 (raw data) Level 1 (netcdf)	310 MB
	METEO	19/06/2023 19:07	10/07/2023 11:25	Level 0 (raw data) Level 1 (netcdf)	32 MB
	T_S (along track sea water temp, cond, sal, sound vel, lat, lon, time)	20/06/2023	03/07/2023 07:00:37	Level 0 (raw data) Level 1 (netcdf)	255 MB
	ADCP 75 kHz	20/06/2023 14:00	03/07/2023 05:53	Level 0 (raw data)	3.5 GB

[13] \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\ship\gps (gps); \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\ship\meteo (meteo); \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\ship\T_S (T_S).

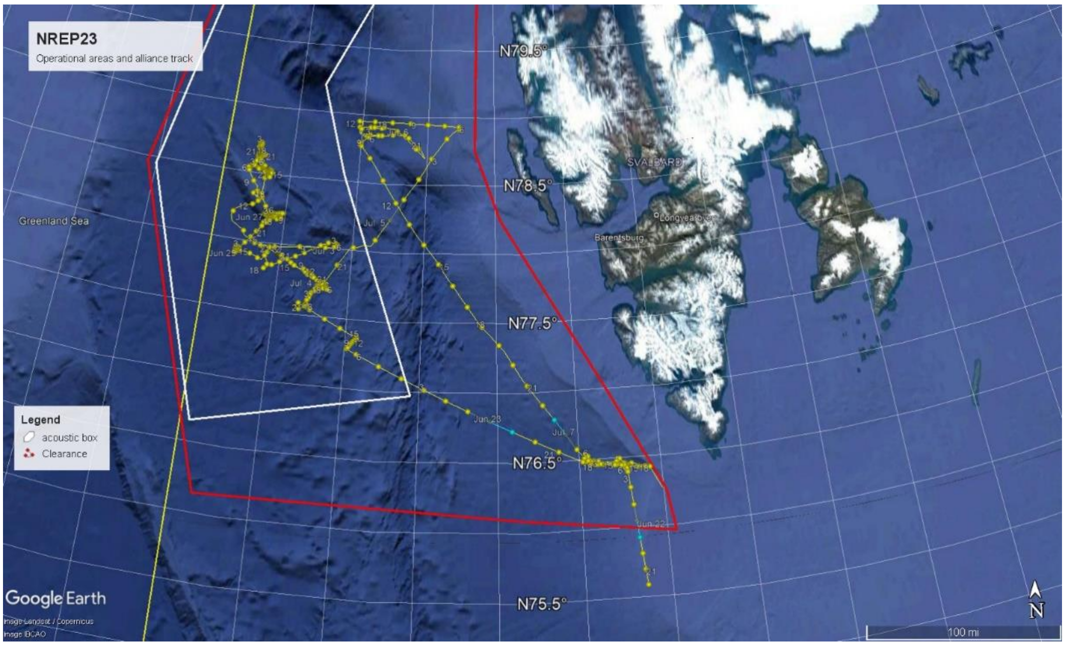


Figure 12: NREP23 NRV Alliance track (yellow) with GPS, meteo and T_S data.

4.2 Lowered CTD (Conductivity, Temperature and Depth), dropped eXpandable CTD (XCTD) and BathyThermograph (XBT)

Twenty-three CTD casts were performed from the NRV Alliance from June 22th 2023 to June 7th 2023. Figure 13 shows the lowered CTD Seabird 911 system with rosette sampler and ancillary sensors (*i.e.* dissolved oxygen, transmissometer, fluorometer, turbidimeter, altimeter, and optical sensor). Table 10 provides a summary of the available data while Table 11 details the time and position of each CTD profile.

Table 10: Data available[14] from the lowered Alliance system.

Platform name	**Sensor (variables)**	**Files**	**Size**
NRV Alliance (rosette)	CTD (pressure, conductivity, Oxygen, temp, time, turbidity, depth, density, sound velocity)  Figure 13: Picture of the lowered CTD Seabird911 system with rosette sampler and ancillary sensors (*e.g.* dissolved oxygen, transmissometer, fluorimeter, turbidimeter, altimeter and optics).	Level 0 (raw data) Level 1 (netcdf)	132 MB

[14] \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\ship\ctds

Table 11: Details on the available CTDs profiles preformed during the sea trial NREP23.

Platform name	Latitude North	Longitude East	Deployment Time	Recovery Time
CTD002	76.4333	14.5405	22-Jun-2023 13:13:03	22-Jun-2023 13:26:22
CTD003	76.4457	13.9807	22-Jun-2023 14:58:47	22-Jun-2023 15:19:05
CTD004	76.4765	12.8552	22-Jun-2023 18:43:21	22-Jun-2023 19:05:58
CTD005	77.7112	3.8617	24-Jun-2023 09:41:10	24-Jun-2023 09:57:31
CTD006	77.9288	0.9775	25-Jun-2023 11:37:49	25-Jun-2023 11:57:26
CTD007	78.1737	1.9352	26-Jun-2023 05:32:58	26-Jun-2023 05:46:53
CTD008	78.1748	1.9453	26-Jun-2023 06:05:49	26-Jun-2023 06:08:25
CTD009	78.1802	2.2382	26-Jun-2023 18:21:38	26-Jun-2023 18:35:54
CTD010	78.2142	2.086	27-Jun-2023 06:13:10	27-Jun-2023 06:27:34
CTD011	78.5677	1.4438	28-Jun-2023 06:09:42	28-Jun-2023 06:28:23
CTD012	78.7155	1.3	29-Jun-2023 05:44:01	29-Jun-2023 06:03:41
CTD013	78.6098	1.2847	29-Jun-2023 08:49:11	29-Jun-2023 09:07:02
CTD014	78.6405	1.3877	29-Jun-2023 19:16:18	29-Jun-2023 19:34:08
CTD015	78.6483	1.3548	30-Jun-2023 06:34:00	30-Jun-2023 06:54:00
CTD016	78.5355	1.7203	01-Jul-2023 05:59:27	01-Jul-2023 06:21:38
CTD017	78.5403	0.935	02-Jul-2023 06:48:50	02-Jul-2023 07:05:48
CTD018	78.0193	4.3843	03-Jul-2023 06:31:58	03-Jul-2023 06:50:21
CTD019	77.7357	4.2037	03-Jul-2023 17:34:48	03-Jul-2023 17:54:30
CTD020	78.9378	8.6828	05-Jul-2023 05:37:51	05-Jul-2023 05:43:20
CTD021	78.7997	4.9998	06-Jul-2023 06:36:09	06-Jul-2023 07:23:56
CTD022	76.4648	13.2148	07-Jul-2023 14:20:50	07-Jul-2023 14:47:10
CTD023	76.4455	13.9892	07-Jul-2023 16:34:57	07-Jul-2023 16:52:55
CTD024	76.4353	14.291	07-Jul-2023 18:03:40	07-Jul-2023 18:18:24
CTD025	76.4315	14.6292	07-Jul-2023 19:27:37	07-Jul-2023 19:37:52

Figure 14 shows the CTDs stations sampled during the cruise overlaid on the General Bathymetric Chart of the Ocean (GEBCO[15]).

Nine XCTD casts and one XBT were also performed during the NRE23 cruise. Table 12 provides details on the available casts while Figure 15 displays the CTD and XCTD positions (XBT not shown because it was taken out of the NREP23 working area). XCTDs have demonstrated to be very useful to rapidly collect data and get maximum profit from transits.

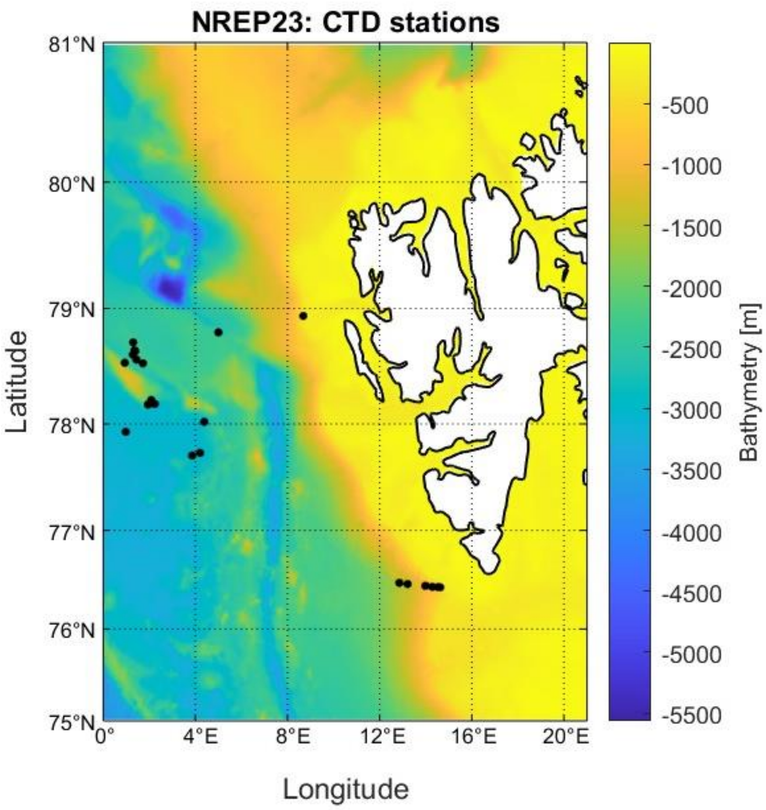


Figure 14: NREP23 operational area with position of the performed CTDs (black dots) overlaid on the Gebco[15] bathymetry [m].

Table 12: Details on the available[16] XBT and XCTD casts preformed during the sea trial NREP23.

Platform name	Sensor (and variables)	Lat (North)	Lon (East)	Release time (UTC)	File (and Size)
NRV Allance	XBT (pressure, temp, time)	69.7243	17.6253	20-06-2023 09:41	Level 0-1 (85 KB)
	XCTD (conductivity, salinity, temp, sound velocity, density)	78.9439	8.2458	07-05-2023 06:43	Level 0-1 (7.5 MB)
		78.9478	7.8147	07-05-2023 07:26	
		78.9511	7.4109	07-05-2023 08:07	
		78.9554	6.9829	07-05-2023 08:42	
		78.957	6.55	07-05-2023 09:21	
		78.9567	6.1254	07-05-2023 09:59	
		78.9568	5.7367	07-05-2023 10:31	
		78.9575	5.3007	07-05-2023 11:15	

[15] https://www.gebco.net/data_and_products/gridded_bathymetry_data/

[16] \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\ship\xbts and \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\ship\xctds

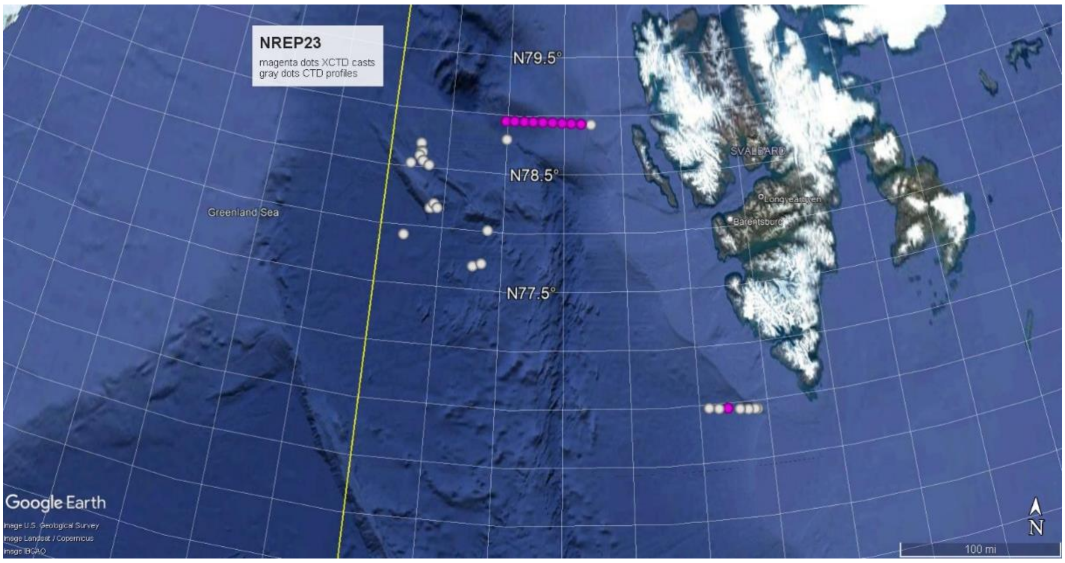


Figure 15: CTD profiles (gray dots) and XCTD casts (magenta dots) performed during the cruise NREP23 (XBT not showed because it was taken outside the NREP23 working area).

4.3 Rapidcast underway profiling CTD (UCTD)

Six UCTDs surveys were performed from the NRV Alliance from June 23th 2023 to July 9th 2023 for a total track of 78 kilometers. Figure 16 shows the rapidcast underway profiling CTD used during the NREP23 sea trial. Table 13 and Table 14 provide details on the available data while Figure 17 shows the UCTD tracks (green dots).

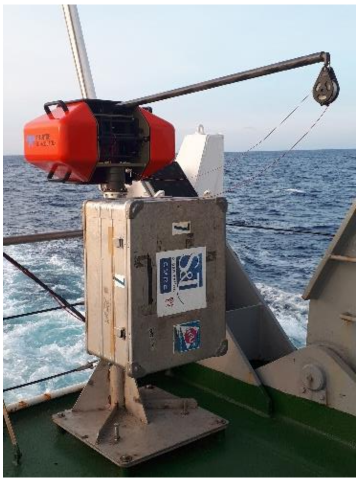


Table 13: Summary of the available[17] UCTD data.

Platform name	Sensor (variables)	Files	Size
NRV Alliance	UCTD (lat, lon chl, density, sound velocity, salinity, conductivity, temperature, pressure, depth, time)	Level 0 (raw data) Level 1 (netcdf) Level 2 (netcdf) Level 3 (netcdf)	86 MB

Figure 16: Picture of the Rapidcast Underway Profiling CTD (UCTD).

[17] \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\uctd

Table 14: NREP 23 UCTDs details.

#	Track Length [km]	Start (lat N, lon R)	End (lat N, lon R)	Deployment (UTC)	Recovery (UTC)
1	2.4392	77.5784 3.4923	77.5882 3.401	23-Jun-2023 18:28:13	23-Jun-2023 18:45:51
2	7.013	78.1828 1.9871	78.1882 2.2941	26-Jun-2023 08:17:42	26-Jun-2023 09:03:29
3	26.8881	78.532 0.92903	78.3143 1.4527	02-Jul-2023 07:47:49	02-Jul-2023 10:42:33
4	4.7338	77.9693 2.0833	77.9635 2.2856	03-Jul-2023 12:43:53	03-Jul-2023 13:27:53
5	18.1261	78.9141 4.9261	78.9114 5.7736	05-Jul-2023 14:03:21	05-Jul-2023 16:04:51
6	7.932	70.5019 16.006	70.4829 15.8001	09-Jul-2023 10:45:34	09-Jul-2023 11:59:13

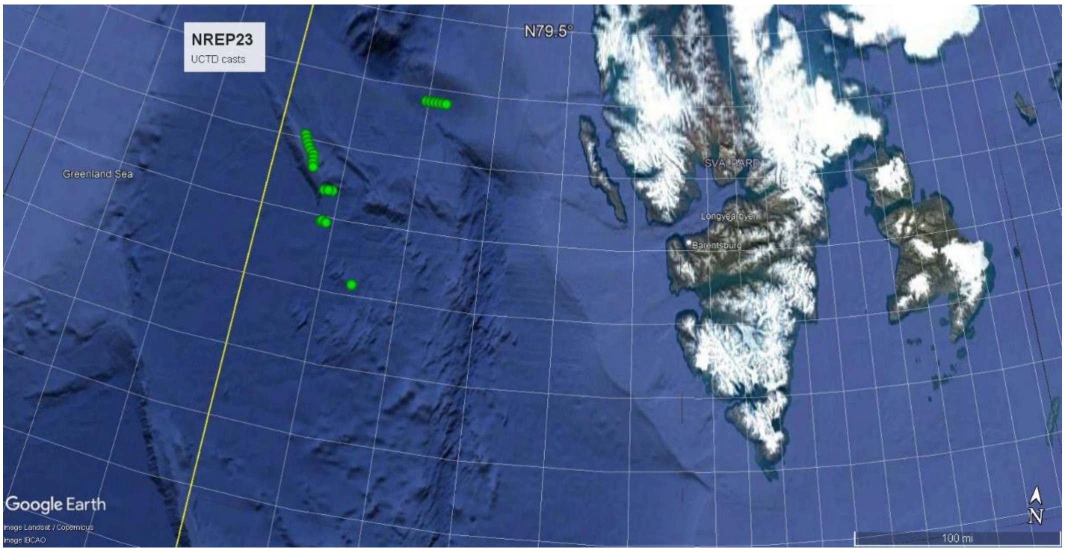


Figure 17: UCTD tracks (green dots) performed during NREP23 (UCTD number six is not showed because it was out of NREP23 operational area).

4.4 Sonobuoy

Sonobuoys were deployed on 29th and 30th June 2023, data are available here: \\isilon\NREP23\Trial_Data\CMRE\acoustic (6.7 GB). The use of this type of fast and easily deployable technologies have demonstrated to be very useful to carry out acoustic experiments in the Marginal Ice Zone (MIZ).

4.5 Acoustic sources: REP11 and DEMUS

Two different acoustic sources were deployed during the NREP23 cruise: DEMUS and REP11 (showed in Figure 18). Acoustic source details of REP11 and DEMUS are listed in Table 15and Table 16, respectively.

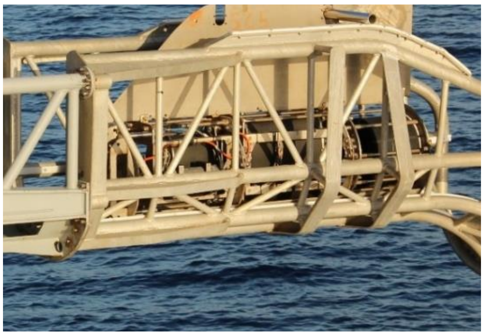


Figure 18: Acoustic sound source REP11.

Table 15: REP11 Acoustic sources details[18].

Source Name REP11	Frequency [Hz]	Max. Source Level achievable dB re 1 µPa @ 1 m	Max Pulse Length @ max SL seconds	Duty Cycle (%)
Mod 30	800-1600	205	10	10
Mod 40	300-700	195	10	10
ITC2010	1000-4000	192	10	10

Table 16: DEMUS acoustic sources details[19].

Source Name DEMUS	Frequency [Hz]	Max. Source Level achievable dB re 1 µPa @ 1 m	Max Pulse Length @ max SL seconds	Duty Cycle (%)
	2100-4200]	217	8	13

[18] \\isilon\NREP23\Trial_Data\CMRE\acousticsources\rep11source

[19] \\isilon\NREP23\Trial_Data\CMRE\acousticsources\demus

5
Remote sensing data

5.1 Satellite data

To establish the most suitable areas for the acoustic experiments in consideration of the sea ice extent, a large number of satellite images of the NREP23 operational area were considered and provided in real-time to the ship. Specifically:

- Images from AMSR2 and Sentinel-1, available from the Copernicus Marine Environment Monitoring Service (CMEMS), were used to observe the ice extent and drift in the NREP23 operational area. The available CMEMS products are generated from a combination of the sea ice concentration[20] retrieved from the Advanced Microwave Scanning Radiometer 2 (AMSR2[21]) and the Synthetic Aperture Radar (SAR) data (from Sentinel-1). The resulting image is first classified into ice/water at a 40x40 m pixel resolution and successively the concentration is estimated from ice area within 1x1 km. The two concentrations products are then subsampled to the same 1x1 km spatial resolution and merged in an optimal interpolation.
- Sea ice concentration SAR images with a spatial resolution of 50 m available from the satellite Sentinel-1 were also used to support operations during the NREP23 sea trial. These images were available from the commercial IcySea[22] map-based application which is designed to display and deliver ice relevant information for operational purposes in the polar regions.
- Sentinel-2 Optical data (which carries a single Multi-Spectral Instrument-MSI) available from Sentinel Hub which is a multi-spectral and multitemporal big data satellite imagery service capable of real-time processing. The image resolution is 10 m, 20 m and 60 m (depending on the wavelength).
- COSMO SkyMed radar commercial images provided by e-GEOS[23] company on behalf of the Agenzia Spaziale Italiana (ASI). The COSMO-SkyMed satellite main payload is an X-band, multi-resolution and multi-polarization imaging radar, with various resolutions. The spatial resolution of the images[24] used to support the NREP23, Strip map Level-1B, is 5 meters.

Details on the available satellite data archive used during NREP23 are summarized in Table 17. Figure 19 shows an example of the Sentinel-1 SAR images used to

[20] The percentage of an area covered by sea ice

[21] Data produced from the 89 GHz channel with a spatial resolution of 5x5km

[22] https://driftnoise.com/icysea.html (last accessed on October 10th 2023)

[23] https://www.e-geos.it/

[24] Stripmap Level-1B

monitor ice cover status of the area during the cruise while Figure 20 shows a high resolution commercial acquisition from the COSMO-SkyMed provided by e-GEOS.

Table 17: Details on the available satellite data archive used during NREP23.

Provider	**Platform**	**Resolution**	**Files**	**Size**
CMEMS[25]	AMSR2 and SAR	1 km	Level 4 (jpg and kmz)	1.1 GB
IcySea[26]	Sentinel-1 SAR	50 m	Level 4 (jpg and kmz)	1.5 GB
Sentinel Hub[27]	Sentinel-2 (Optical)	60 m	Level 4 (jpg and kmz)	120 MB
e-GEOS[28]	COSMO-SkyMed	5 m	Level 2 Level 3 (HDF5) Level 4 vel 4 (jpg and kmz)	83 GB

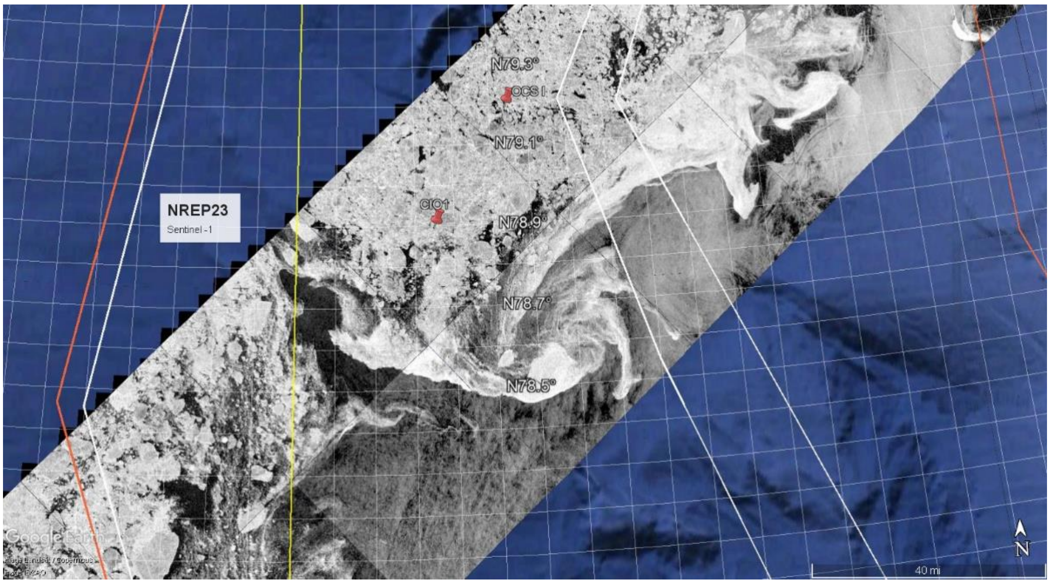


Figure 19: An example of total sea-ice extent of the working area imaged by 16 Sentinel-1 satellite swath from the 25th June 2023 overpasses. The positions of the moorings (CIO1 and S1) are also displayed (red pointers).

[25] \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\satellite\Cmems_1km

[26] \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\satellite\Sentinel-1

[27] \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\satellite\Sentinel-2

[28] \\isilon\EKOE_Sea_Trials_Data_Processed\NREP23\satellite\Cosmo

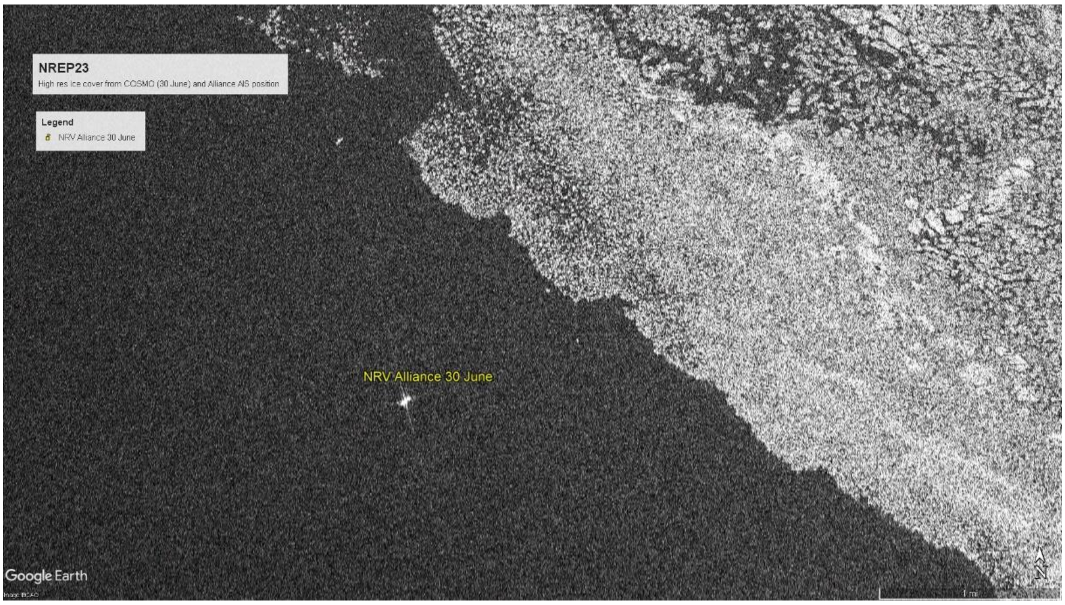


Figure 20: An example of total sea-ice extent of the working area acquired by COSMO-SkyMed the 30th June 2023. The high level resolution allows the identification of the NRV Alliance.

5.2 Drone Data

To support the NREP23 acoustical experimentations, an aerial drone (ANAFI) was used to characterize the sea ice conditions along acoustic path, Figure 21 shows a picture taken during deployment operations of the drone. As is detailed in Annex A, the drone imagery have been critical in the characterization and quantification of the surface conditions.

Figure 21: Picture taken during NREP23 before a drone flight.

ANAFI is stabilised on five axes (two mechanical axes and three electronic axes), the Sony optical sensor built into the drone allows clear images to be taken, despite the vibrations associated with drone flights. The x3 zoom and the 180° tilt of the camera provide a detailed view of the observed target. Additional details on its technical specifications[29] can be found in Table 18.

Table 18: Details on the drone ANAFI used during the NREP23 cruise.

Main characteristics	
Unfolded (LxWxH)	175x240x65mm
Folded (LxWxH)	244x67x65mm
Weight	320 g
Ready to fly	28 seconds
Temperature range	-14 ºC/40 ºC
Humidity	93%
Speed	15 m/s
Max Wind Speed resistance	50 km/h
Flight time	25 minutes
Max distance	14 km at 11.5 m/s
Video resolution	4K UHD 3840x2160 24/25/30 fp HFOV 69°
Photo resolution	Wide: 21MP (5344x4016) / 4:3 / 84° HFOV Rectilinear: 16MP (4608x3456) / 4:3 / HFOV 75.5°

[29] https://www.parrot.com/assets/s3fs-public/2020-07/white-paper_anafi-v1.4-en.pdf

During the drone acquisitions performed to support the NREP23 acoustic experimentations, the operation flight mode was set to a fixed altitude (~50 m) and fixed focal length (no zoom) which corresponded to a ground pixel size of ~1.5 cm. Figure 22 shows an example of a single raw image acquired by the drone under the specified characteristics during a flight done 28 June. Figure 23 shows the orthomosaic product retrieved from the 51 raw images available from the total drone-track. Figure 24 shows the drone flying areas which are summarized in Table 20. More details on flight tracks and data can be found in Annex B.

Figure 22: Raw image (single swath) acquired by the drone during a flight done the 28th June 2023, 1pm. The spatial resolution is ~1.5 cm.

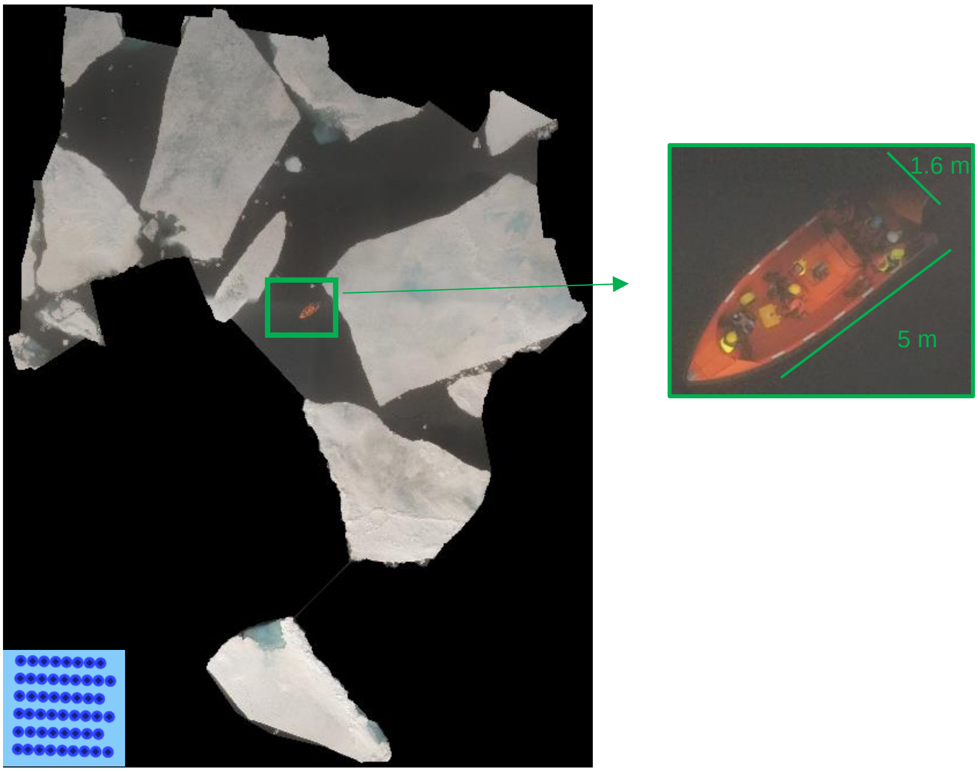


Figure 23: Orthomosaic product retrieved from the drone total track (lower left blue dots, 51 raw images) performed on 28th June 2023, 1pm. The final size of the swath is 168 m x 124m (lon, lat). The spatial resolution is 1.5 cm.

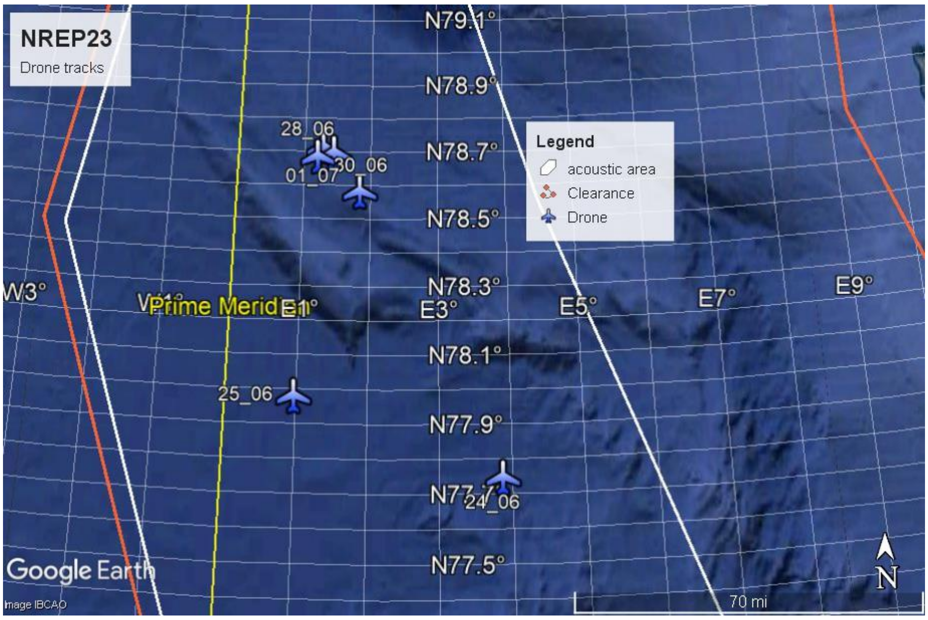


Figure 24: NREP23's Drone flight areas. More details on flight tracks and data can be found in Annex B.

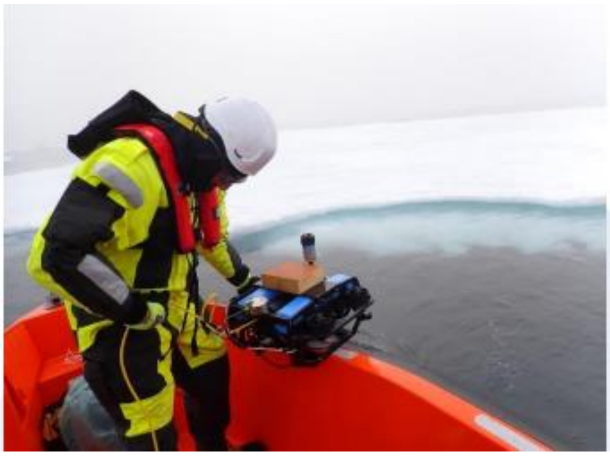
Table 19: Summary of the available[30] HiPAP data.

Platform	Start Time	End Time	Files	Size
Drone	24 June 2023 14:10	24 June 2023 14:26	Raw	1GB
	25 June 2023 10:06	25 June 2023 10:10	Raw	1 GB
	25 June 2023 10:18	25 June 2023 10:23	Raw	
	25 June 2023 10:33	25 June 2023 10:37	Raw	
	25 June 2023 16:41	25 June 2023 16:47	Raw	
	25 June 2023 16:54	25 June 2023 16:57	Raw	
	28 June 2023 13:40	28 June 2023 13:45	Raw	1.5 GB
	28 June 2023 14:07	28 June 2023 14:11	Raw	
	29 June 2023 14:53	28 June 2023 14:58	Raw	650 MB
	30 June 2023 14:35	30 June 2023 14:42	Raw	230 MB
	1 July 2023 10:49	1 July 2023 10:59	Raw	290 MB

5.3 ROV data

A remoted operated vehicle – ROV was deployed to characterize the draft and the bottom roughness of sea ice structures along the acoustic path.

Figure 25 shows a picture of a ROV deployment during the NREP23 cruise. Figure 26 shows a ROV sample of sea ice bottom roughness made on 28 June 2023. Details on the data deployment can be found in Table 20. As the drone data, ROV has been critical in the characterization and quantification of the sea ice conditions (the former above and the latter below the sea surface).



[30] \\isilon\NREP23\Trial_Data\CMRE\environmental\drone\

Figure 25: A picture of a ROV deployment during the NREP23 cruise.

Figure 26: Underwater imagery of sea ice roughness captured by the ROV.

Table 20: Summary of the available[31] ROV data.

Platform	Start Time	End Time	Files	Size
ROV	24 June 2023 8:10	24 June 2023 08:46	Raw	5.2GB
	28 June 2023 12:30	28 June 2023 12:56	Raw	6.6 GB
	29 June 2023 13:09	29 June 2023 13:15	Raw	2.5 GB
	30 June 2023 12:54	30 June 2023 13:05	Raw	1.95 GB
	1 July 2023 9:21	1 July 2023 9:9.34	Raw	2.5 GB

[31] \\isilon\NREP23\Trial_Data\CMRE\rov\

6
Summary and Final considerations

6.1 Summary

The NREP23 dataset described in this report represents a complete and multidisciplinary dataset to investigate the acoustic impact of Arctic sea ice aggregates.

Figure 27 summarizes the NREP23 data collection available in the CMRE data repository (isilon).

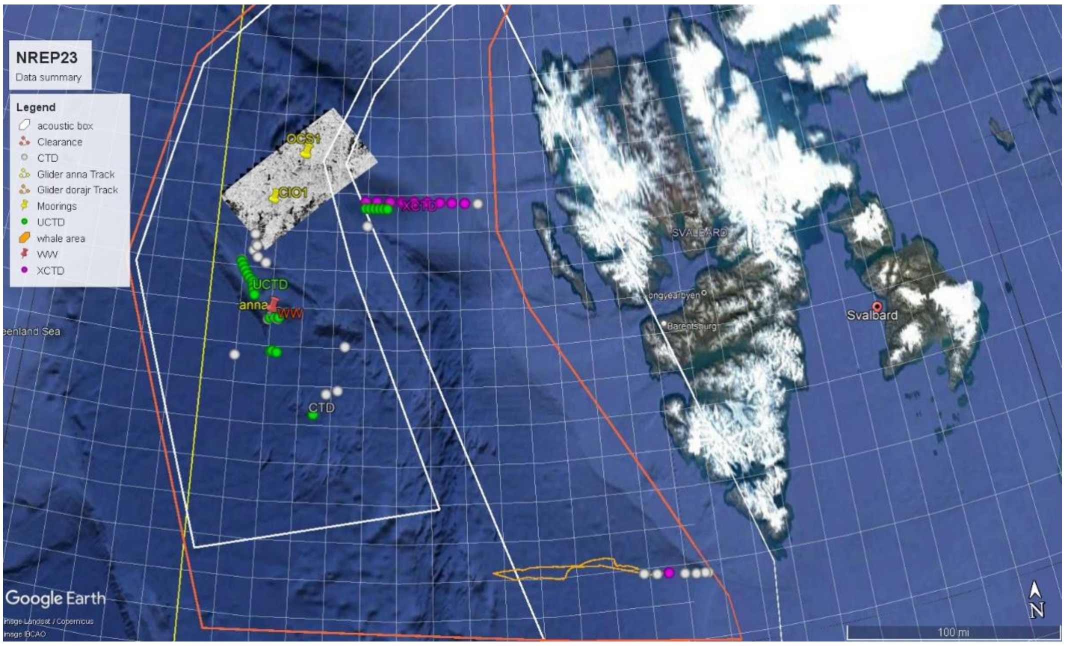


Figure 27: NREP23 oceanographic data summary: gliders (Anna and Dora), uCTD, CTD, XCTD moorings (OC1 and OCS1), wirewalker, SAR images.

6.2 Lesson learned and further research developments

The distribution of ice floes in open waters will be very common in vast areas of the future Arctic. The optical satellite imagery displayed in Figure 28 shows a very dynamic state with important operational implications. The “fluid ice” composite state is a new research subject with important operational applications in the future Arctic. Further researches are proposed to focus on the acoustic impact on SONAR performance of the composite, on the prediction of ice flow patterns (relevance of satellite imagery), and on the development of autonomous ocean observing technologies to operate in “fluid ice” conditions.

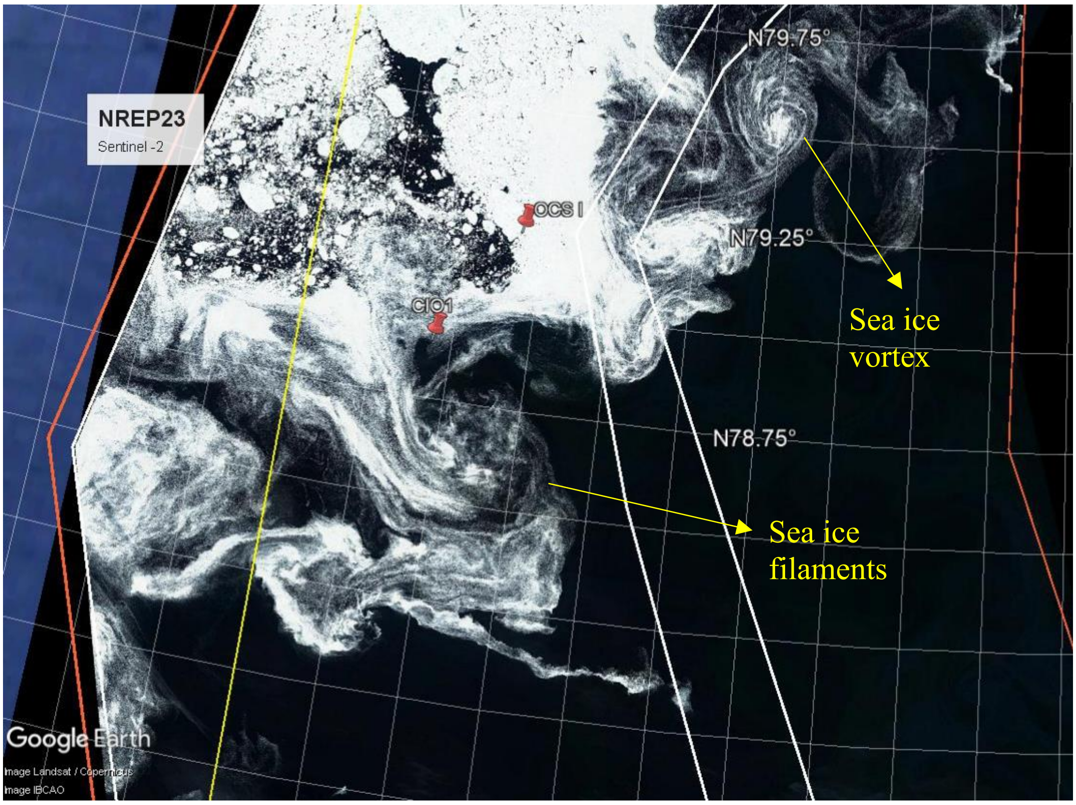


Figure 28: dynamic state of the Arctic area as imaged from the satellite Sentinel-2 (optical image 5 July 2023).

References

- The Russian Arctic in the Twenty-First Century, Caitlyn L. A. in Arctic Security in an Age of Climate Change, pp. 107 – 128, Cambridge University Press, 2011, DOI: https://doi.org/10.1017/CBO9780511994784.008.

- Nordic Recognized Environmental Picture 23 – NREP23, Trial Plan, CMRE-TP-2023-06-NREP23.

Annex A: Acoustic experiments details – sequence of events

This Annex details the acoustic experimentations performed during the NREP23 sea trial which covered three main experiment design (see Section 1.2: Figure 2, Figure 3 and Figure 4).
The three experiments were executed over five days, testing different acoustic channel configurations. The acoustic sources were the REP11 (omnidirational) and the DEMUS (directional) and receivers were the portable drifting arrays, the acoustic glider Anna and suonobuoys.
In order to be complaint with the marine mammals risk mitigation requirements, each session of acoustic transmission was proceeded by a ramp-up procedure in which the source level of the involved acoustic sources is increased until reaching the maximum allowed level.

25 June 2023

The following figures are displayed to provide a preview of ice cover distribution for this experiment which was estimated in 56%.
Specifically, Figure 29 shows the ice coverage distribution as measured by the ship radar, the ship and the array positions, Figure 30 shows the ice cover acquired with the drone while Figure 31 shows the results from the ROV ice inspection.

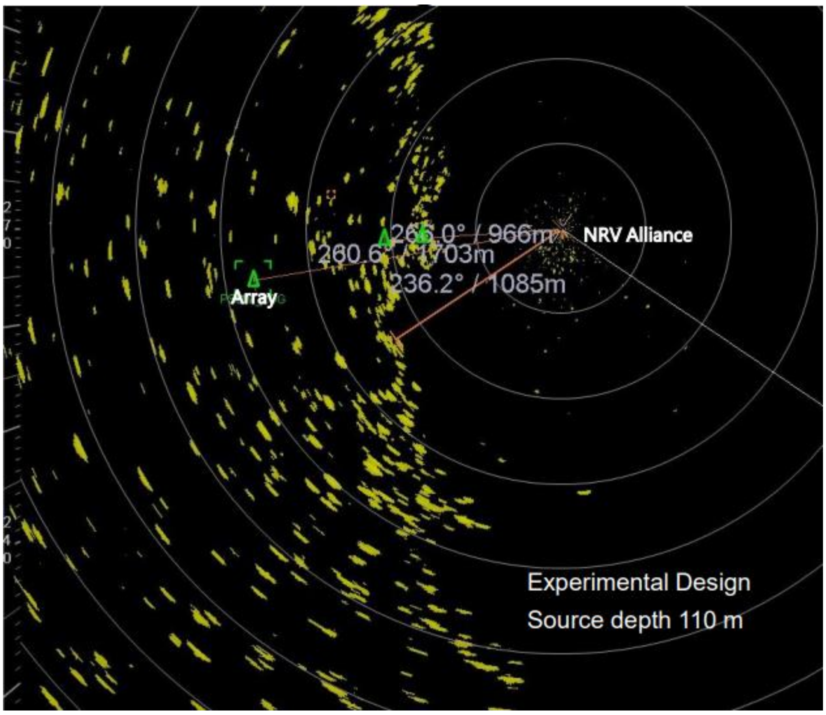


Figure 29: Ice coverage distribution (yellow) measured with the WAMOS RADAR, NRV Alliance and array positions during the experiment (source depth = 110 m).

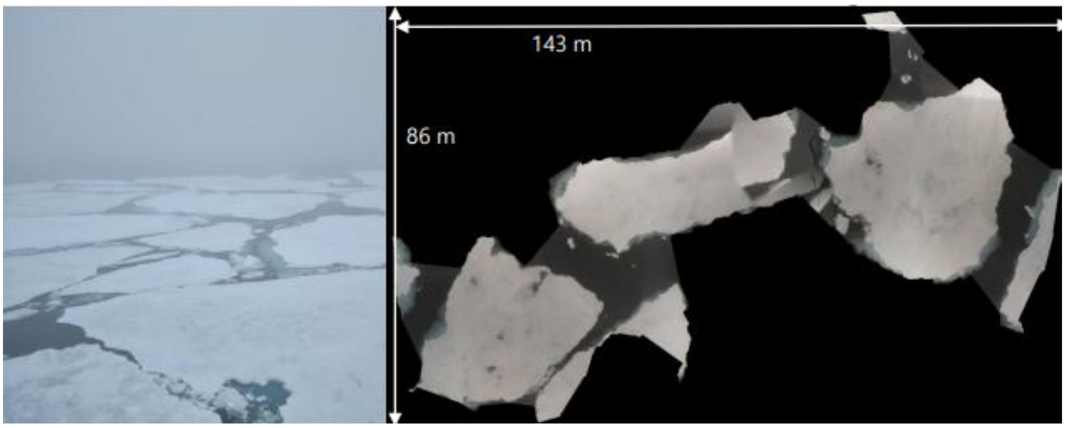


Figure 30: Drone orthomosaic.

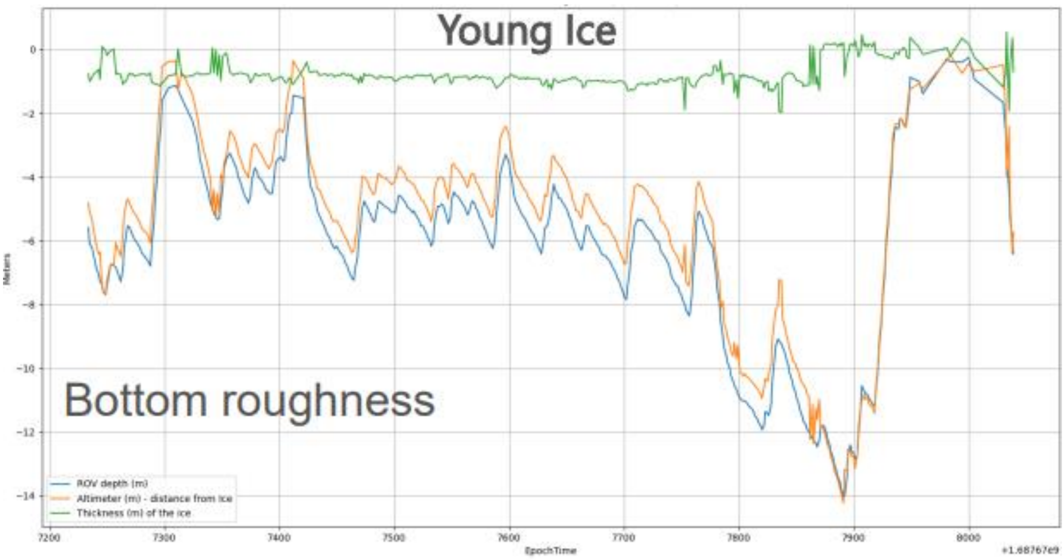


Figure 31: ROV ice Inspection (mission 01) from 2023-06-25: Thickness of the ice (green line), Altimeter (orange line) and ROV depth (blue line).

During this first experiment was employed the REP11 omnidirectional source at 110 m depth (Figure 32).

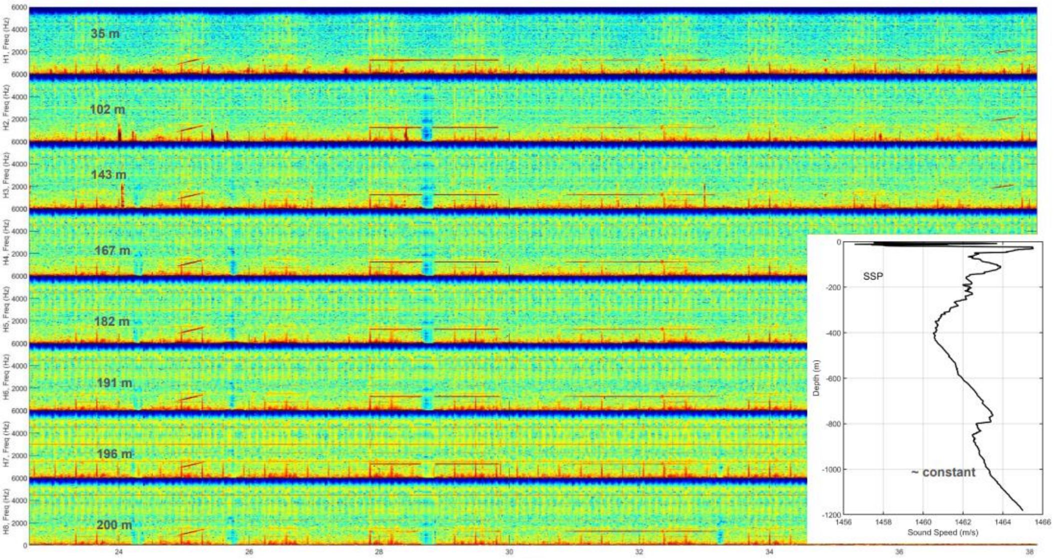


Figure 32: sample of the acoustic records gathered by the logarithmic array (omnidirectional source at 110 m depth).

26 June 2023

The spatial configuration of the acoustic assets involved in the experiment is summarized in Figure 33. The main focus of the acoustic experiment done during this day was the analysis of thermohaline sound-speed structures induced by internal waves and spice and of their impact on acoustic transmissions – near stationary ac. channel geometries. Specifically the main objectives were to:

- characterize the impact of oceanographic fluctuations on acoustic transmissions in stationary acoustic channel geometries;
- Exploit of drifting heterogeneous platform as acoustic receivers (Log. Array, Linear Array and Drifter) in short range acoustic channel configuration (Figure 34);
- Test the usage of multiple acoustic sources, directional and omni-directional, simultaneously.

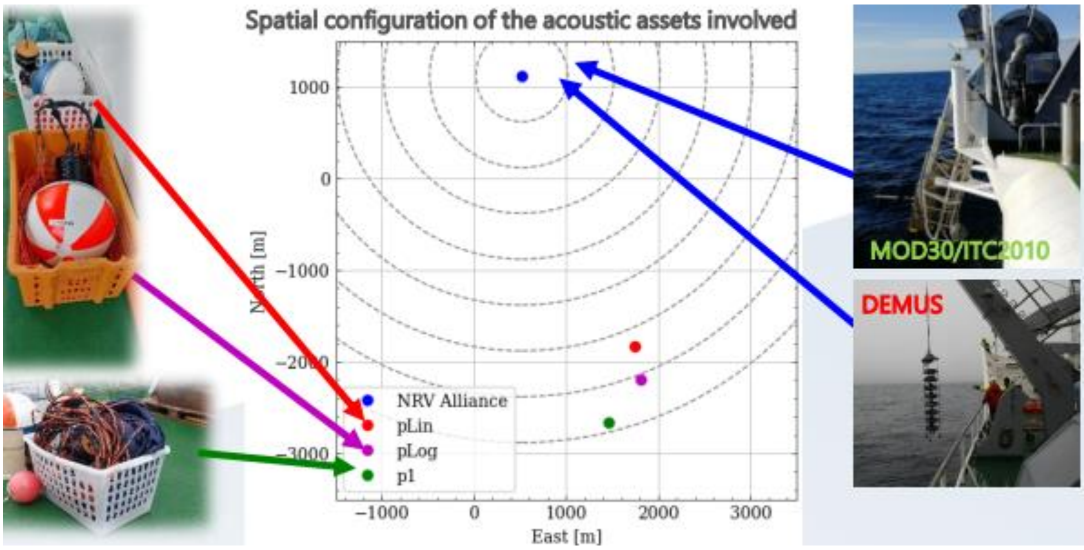


Figure 33: Spatial configuration of the acoustic assets involved in the experiment.

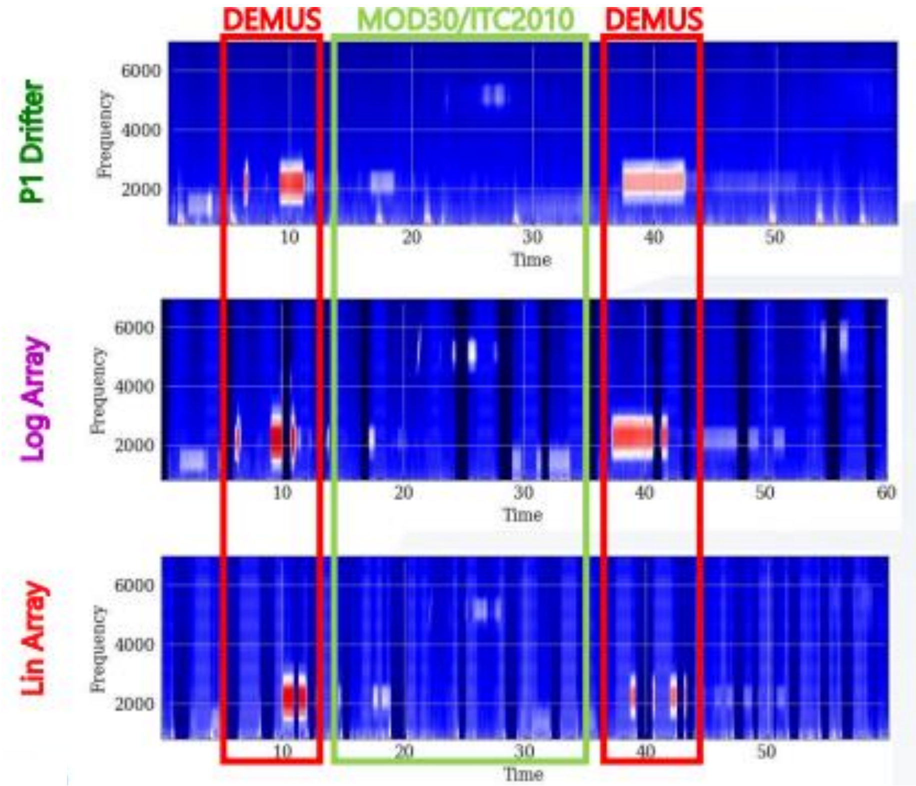


Figure 34: Spatial configuration of the acoustic assets involved in the experiment.

27 June 2023

As continuation of the experiment performed the previous day, the main objective of this experiment was to characterize the impact of oceanographic fluctuations on acoustic transmissions in dynamic acoustic channel geometries with a varierity of receiving nodes. The following figure shows the spatial configuration of the acoustic assets involved in the experimentation.

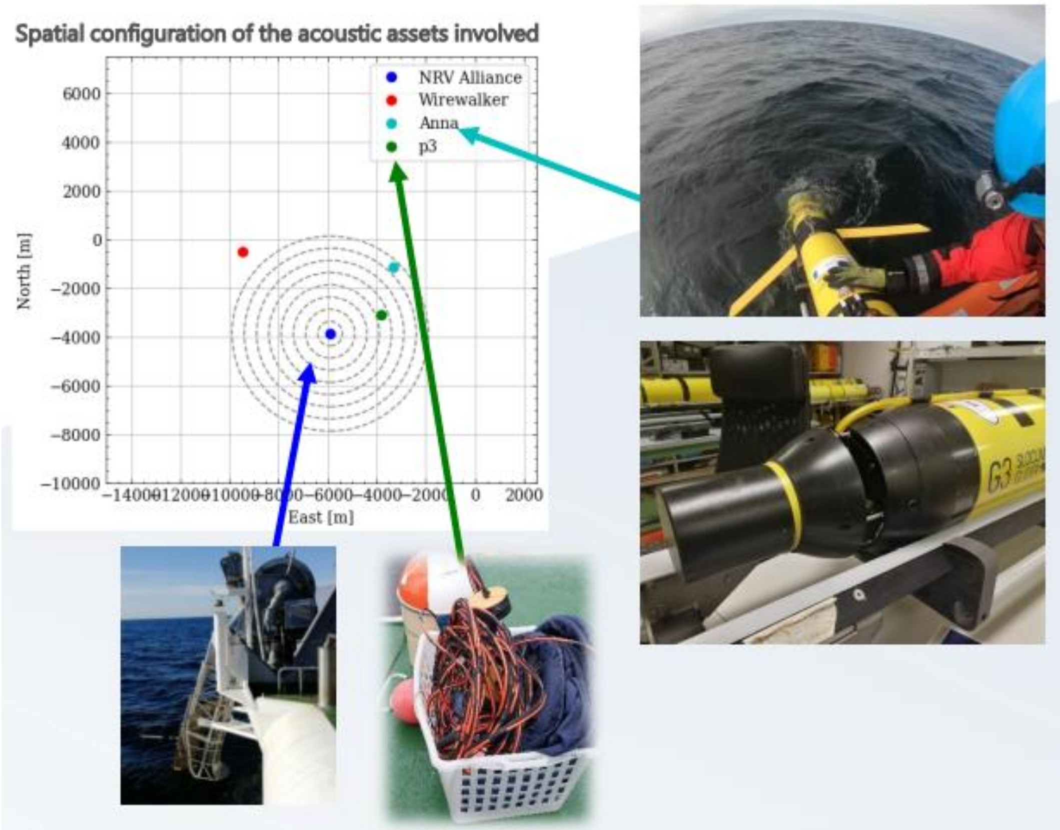


Figure 35: Spatial configuration of the acoustic assets involved in the experiment.

Figure 36 shows the exploitation of a drifting platform and acoustic glider Anna as acoustic receivers in short range acoustic channel configuration.

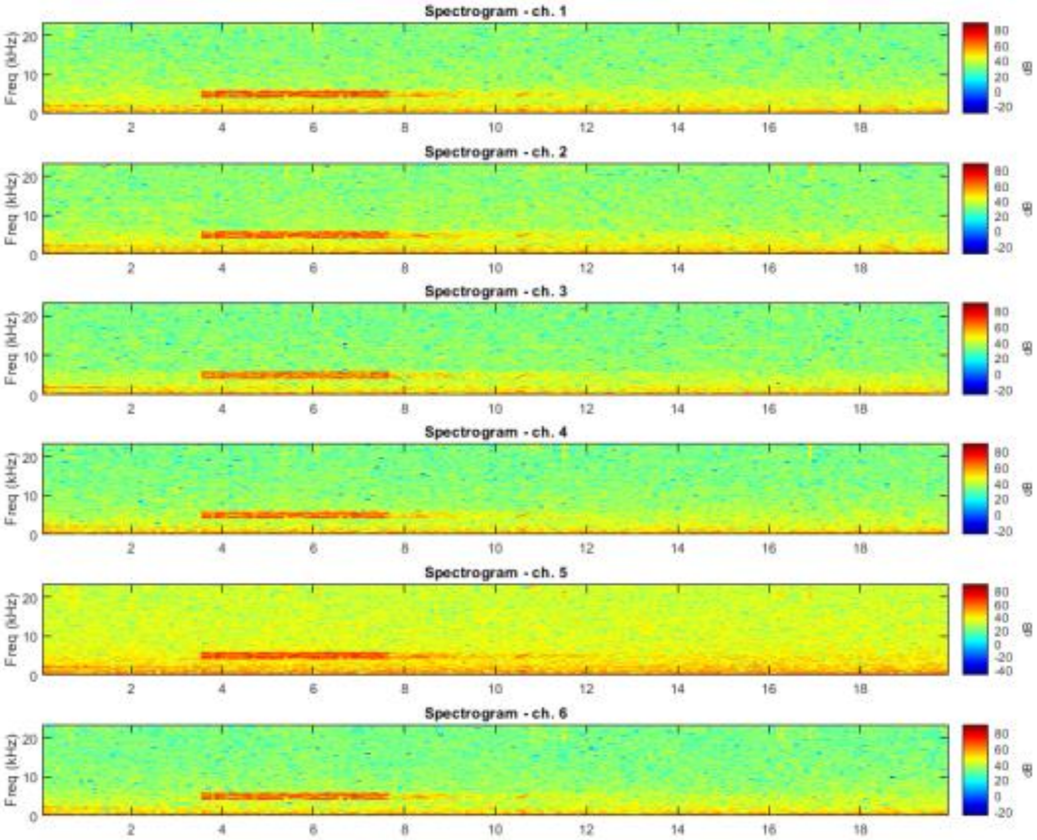


Figure 36: Exploitation of a drifting platform and acoustic glider Anna as acoustic receivers in short range acoustic channel configuration.

29 June 2023

The experimental design of the experiment done the 29th June 2023 is displayed in Figure 37 while the multi-year Ice bottom roughness plot and the sonobuoy spectrogram are displayed in Figure 38 and Figure 39.

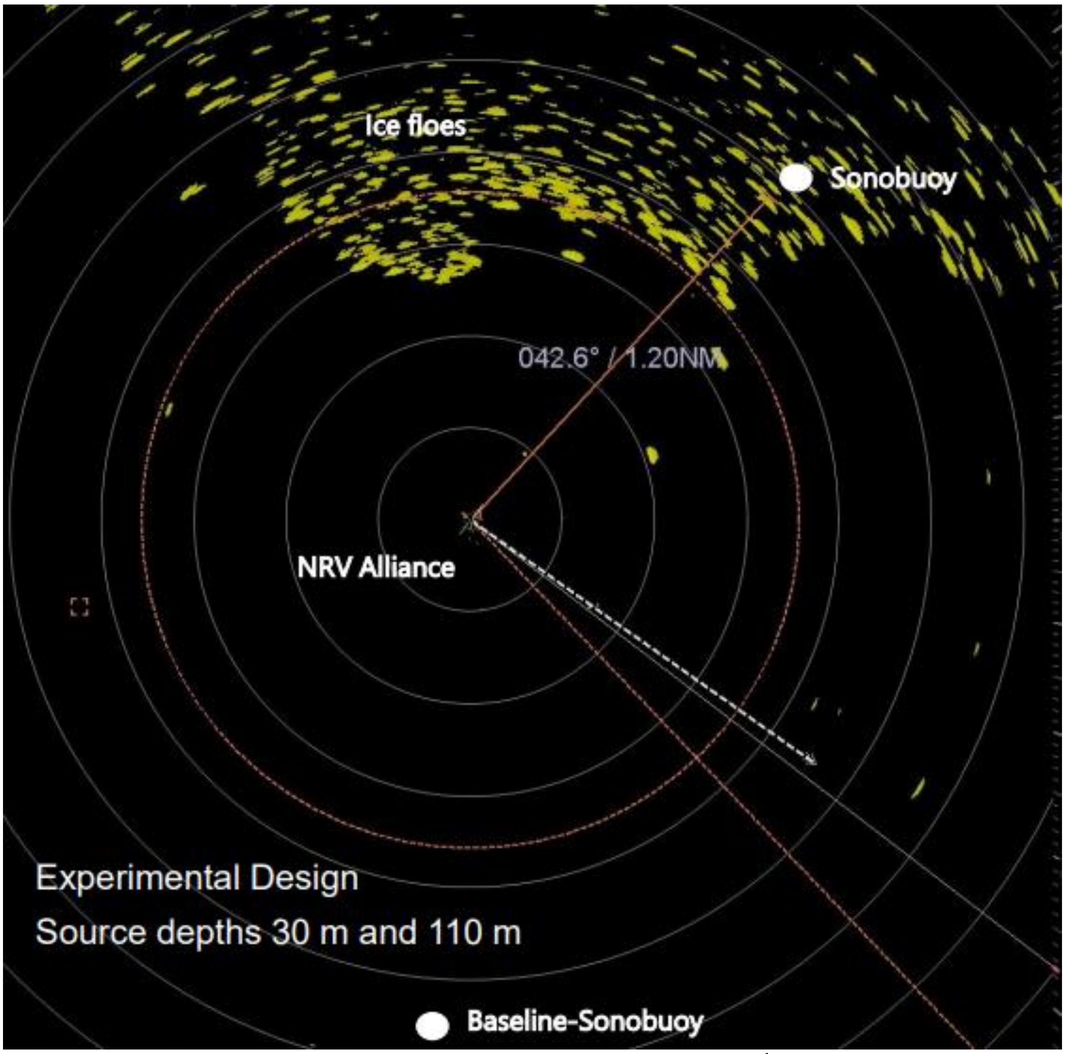


Figure 37: Experimental design of the acoustic experiment done the 29th June 2023.

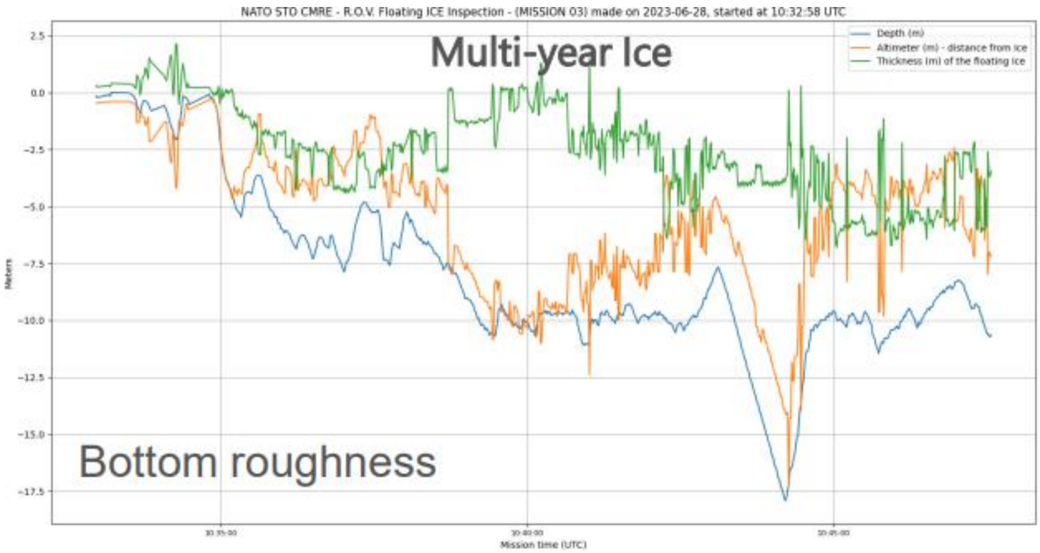


Figure 38: Bottom roughness final plot.

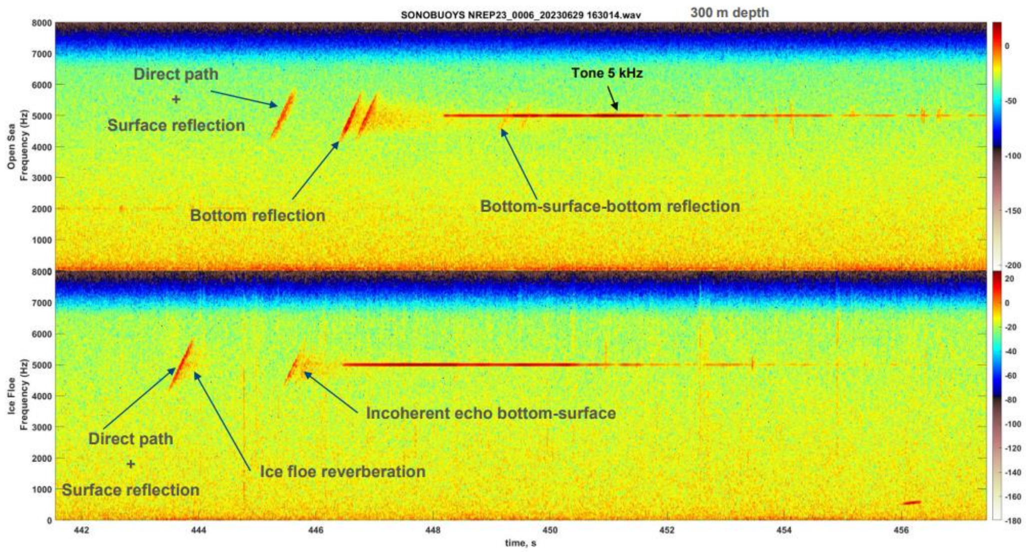


Figure 39: Sonobuoys 300 m depth.

Considering the following hypothesis:

- Near constant velocity profile for near surface transmissions (30 m);
- High frequency-> geometric optics approximation (GOA);
- Specular reflection by sea surface and sea ice bottom roughness;
- Sound Speed=1440 m/s;
- Beaufort 0 (SITREP).

The scattering angle (θ_{cut}) was estimated from the geometric schematization displayed in Figure 40 from which results $\theta_{cut} = 25^{o}$.

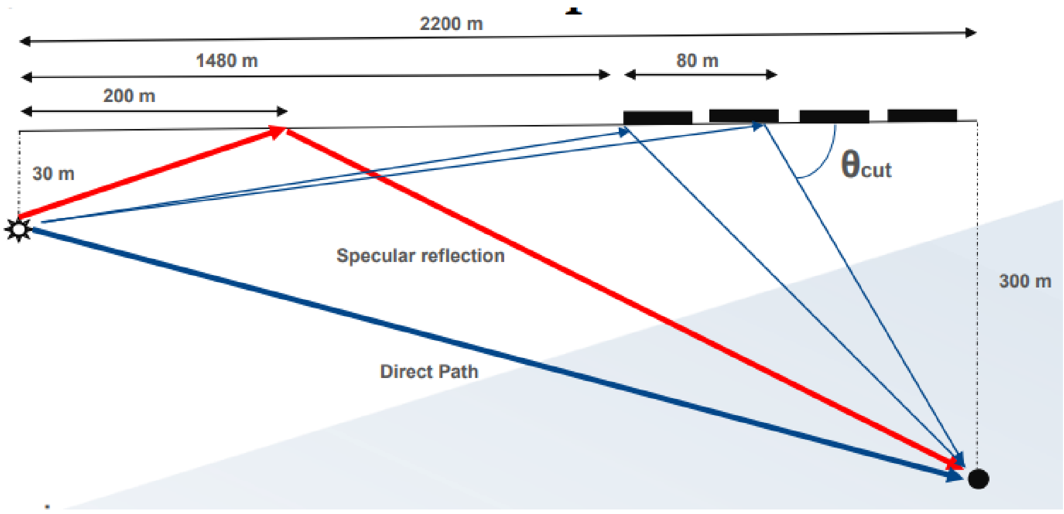


Figure 40: Geometric scheme to retrieve the scattering.

1 July 2023

The goal of the acoustic experiment done the 1st July 2023 was the single floe forward scattering characterization of the ice floe ice floe schematized in Figure 41 and photographed below the surface by the ROV (left side of Figure 42) and above the surface by the drone (Figure 42 right side).

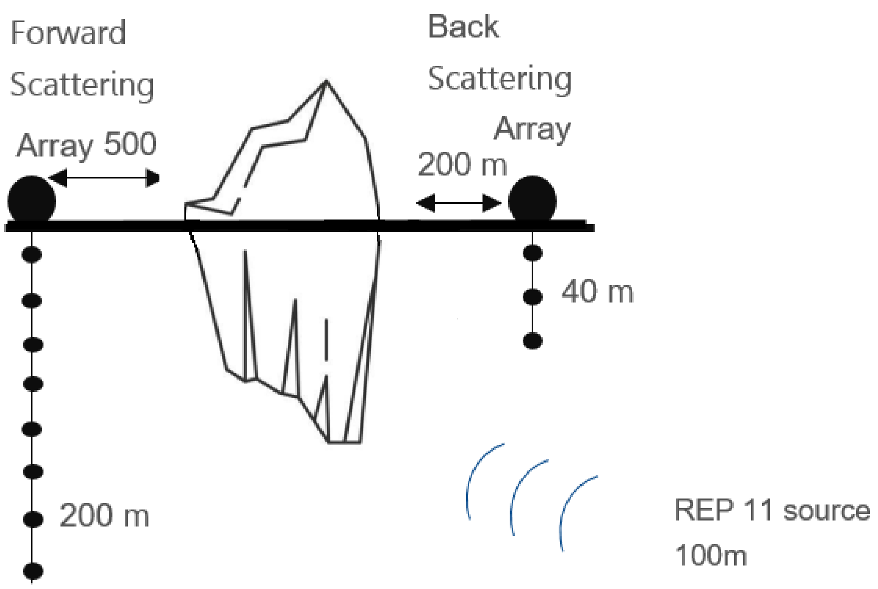


Figure 41: Geometric scheme of the ice floe used to perform the acoustic analysis done the 1st July 2023.

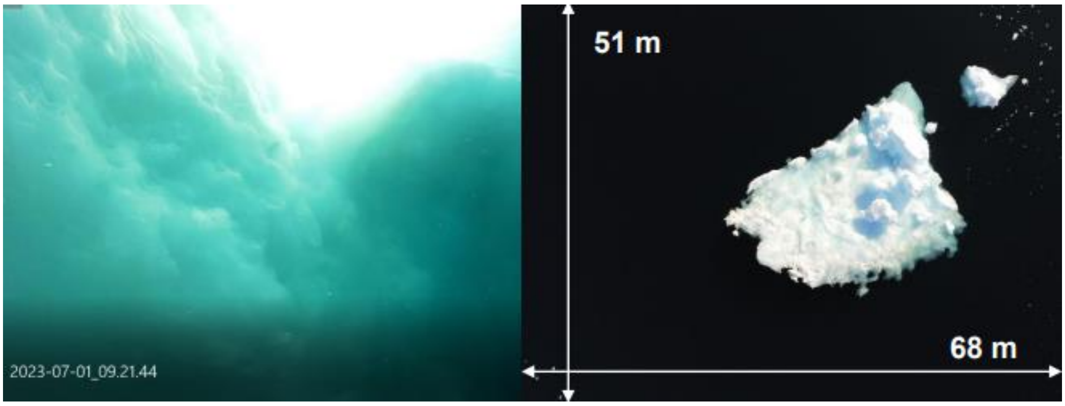


Figure 42: Pictures of the ice floe taken with the ROV (left side) and with the ROV (right side).

Annex B: Drone data

This Annex reports the details of the drone tracks performed during NREP23 and on the available orthorectified products.

Flight I: 24th June 2023 h 14:00 – 14:10

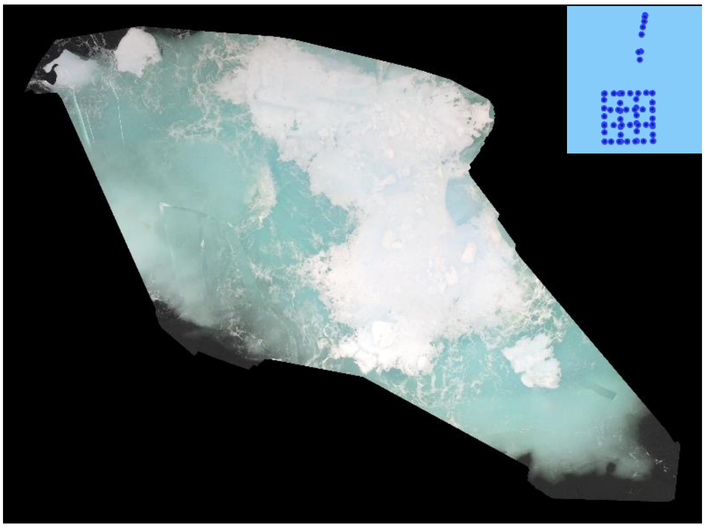


Figure 43: Orthomosaic product retrieved from the drone total track (upper right blue dots) performed on 24 June 2023. The final size of the swath is 24 m x 30m.

Flight II: 25th June 2023 h 10:06 – 10:10

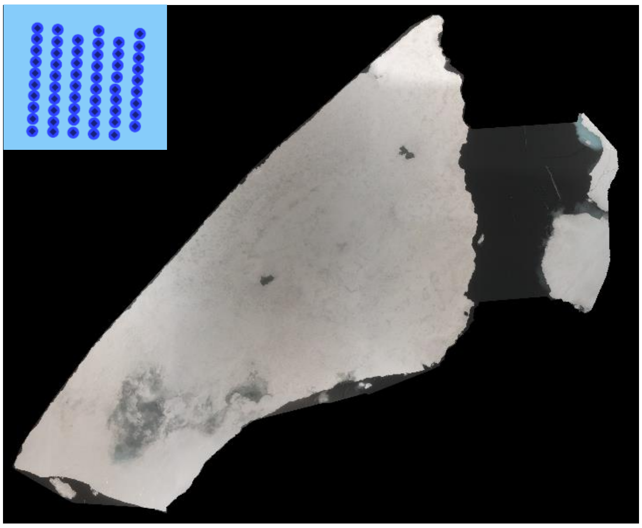


Figure 44: Orthomosaic product retrieved from the drone total track (upper left blue dots) performed on 25 June 2023. The final size of the swath is 56 m x 70 m (lon, lat).

Flight III: 25th June 2023 h 10:18 – 10:23

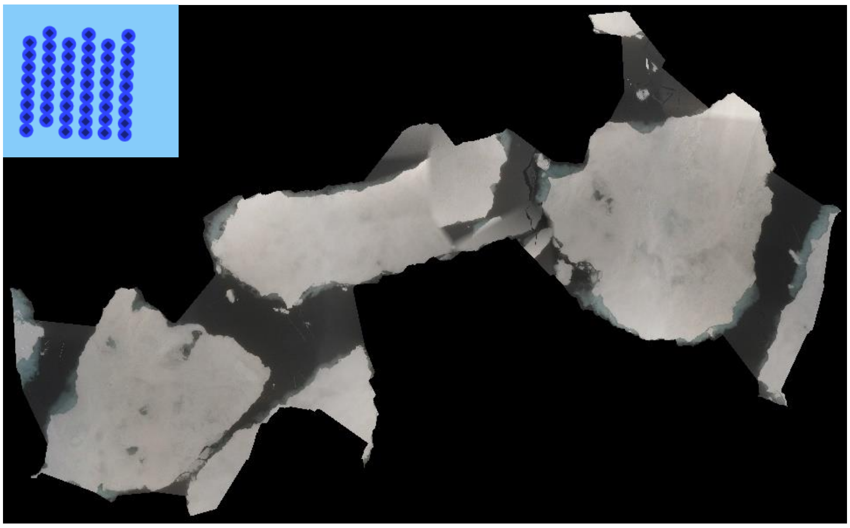


Figure 45: Orthomosaic product retrieved from the drone total track (upper left blue dots) performed on 25 June 2023. The final size of the swath is 85 m x 142 m (lon, lat).

Flight IV: 25th June 2023 h 10:33 – 10:37 and 16:41-16:48

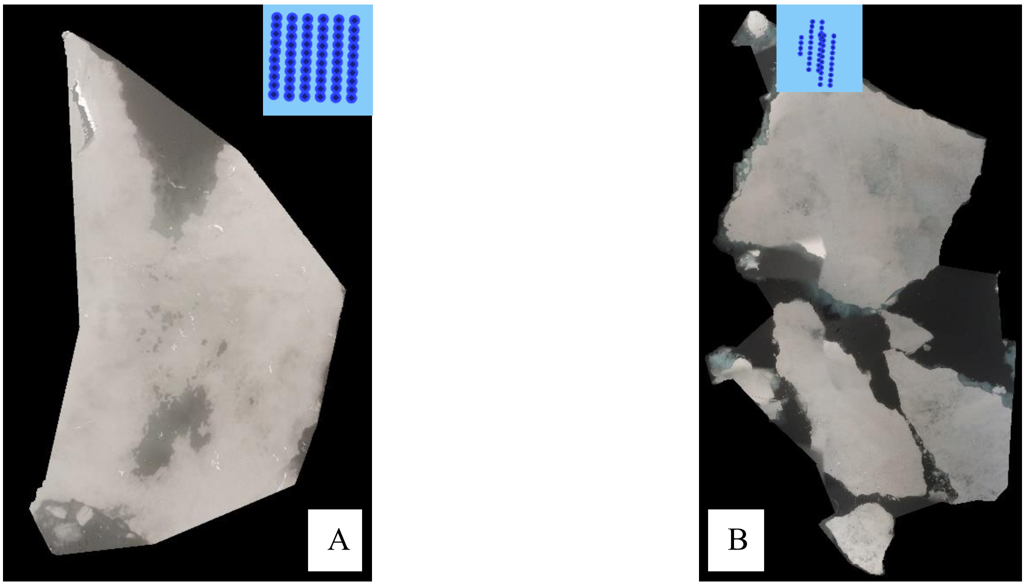


Figure 46: Orthomosaic product retrieved from the drone total track (upper left blue dots) performed on 25 June 2023 at *(a)* 10 am and *(b)* 4pm. The final size of the swaths are *(a)* 22 m x 14 m (lon, lat) and *(b)* 99 m x 57 m (lon, lat).

Flight V: 25th June 2023 h 16:54-16:57

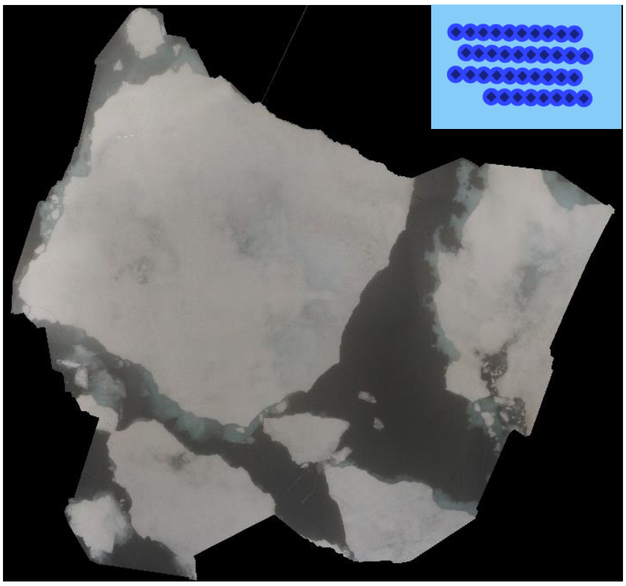


Figure 47: Orthomosaic product retrieved from the drone total track (upper left blue dots) performed on 25 June 2023 4pm. The final size of the swath is 75 m x 77m (lon, lat).

Flight VI: 28th June 2023 h 13:40-13:45

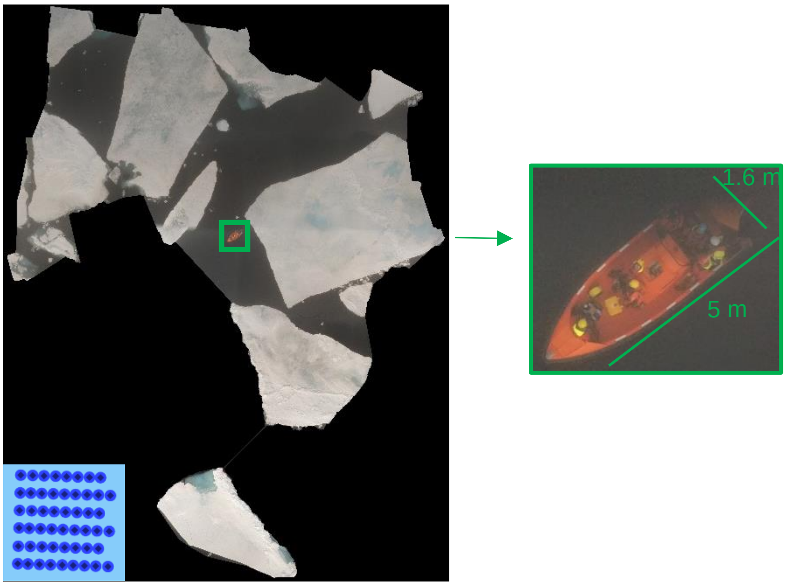


Figure 48: Orthomosaic product retrieved from the drone total track (lower left blue dots) performed on 29th June 2023 1pm. The final size of the swath is 168 m x 124m (lon, lat).

Flight VII: 28th June 2023 h 14:07-14:11

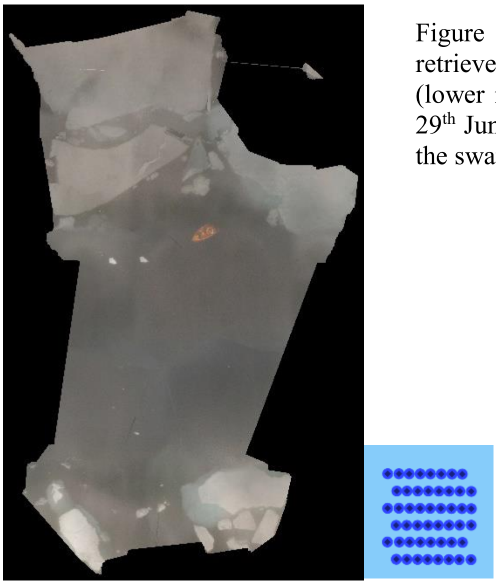


Figure 49: Orthomosaic product retrieved from the drone total track (lower right blue dots) performed on 29th June 2023 2pm. The final size of the swath is 98 m x 61 m (lon, lat).

Flight VIII: 29th June 2023 h 14:07-14:11

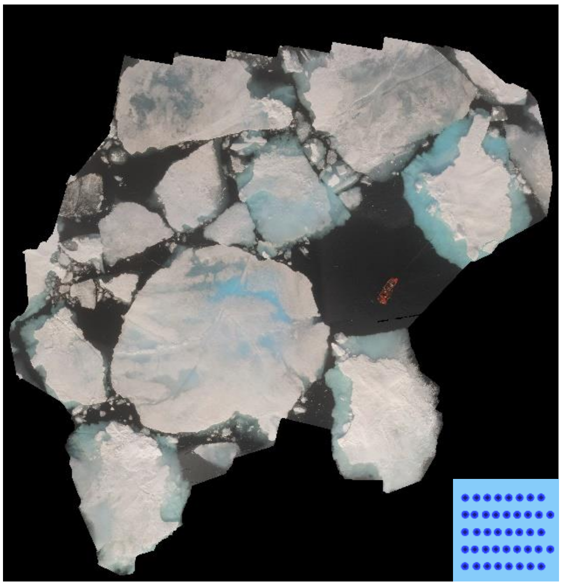


Figure 50: Orthomosaic product retrieved from the drone total track (lower right blue dots) performed on 29th June 2023 2pm. The final size of the swath is 110 m x 102 m (lon, lat).

Flight VIV: 30th June 2023 h 14:35-14:42

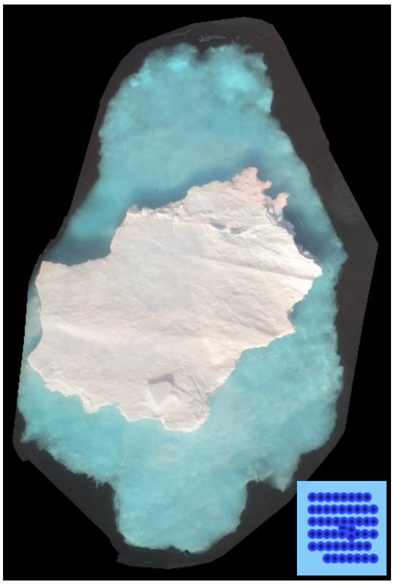


Figure 51: Orthomosaic product retrieved from the drone total track (lower right blue dots) performed on 30th June 2023 2pm. The final size of the swath is 60 m x 40 m (lon, lat).

Flight X: 1st July 2023 h 10:49-10:59

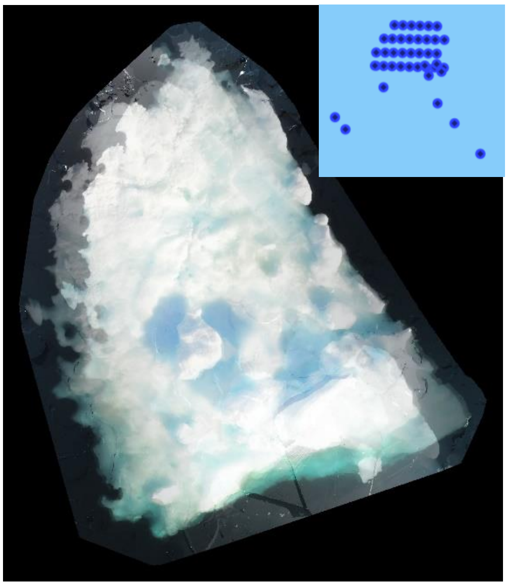


Figure 52: Orthomosaic product retrieved from the drone total track (lower right blue dots) performed on 1st July 2023 10am. The final size of the swath is 35 m x 30 m (lon, lat).

Document Data Sheet

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Title

NREP23 Cruise Report and Data Catalogue

Abstract

The Nordic Recognized Environmental Picture 2023 (NREP23) sea trial was performed in the Fram Strait, where ice floes are still present during the summer season. The sea trial was designed to measure the scattering of such structures as well as their integrated effect on acoustic propagation. Environmental observations, including sea ice distribution, were gathered along an acoustic transmission line defined by a source and receivers. These measurements are expected to conclude the research initiated in NREP21 (and followed in NREP22) to study and to quantify the impact of different physical phenomena on Arctic Sonar and underwater communications (UComms) operations.

This Memorandum Report (MR) provides a detailed overview of the oceanographic and acoustic measurements collected by both the NRV Alliance and autonomous platforms during the NREP23 sea trial. It also summarizes the raw and processed data available in the CMRE data repository.

Keywords

Arctic Ocean; acoustic data; oceanographic data; NREP; ice.

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