GO-MARIE 2022 Campaign Report

Southwest Greenland, July 24-Sept. 19, 2022
The Nippon Foundation-GEBCO Seabed2030 Project Survey Period: July 21-August 18th, 2022

Ocean Research Project:
Principle Investigator Scientist: Nicole Trenholm
contact: *trenholm.orp@gmail.com*
Captain Matthew Rutherford

Map the Gaps:
Hydrographers Tomer Ketter and Marcos Daniel Leite

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1. GO-MARIE Introduction

The GO-MARIE (Glacier-Ocean Mapping and Research Interdisciplinary Effort) is led by Ocean Research Project (ORP), a nonprofit organization based out of Annapolis, Maryland in the United States and conducted onboard the SRV Marie Tharp. GO-MARIE is a decadal initiative to map and characterize the glaciated coastline across the navigable coastal Arctic. GO-MARIE is an exemplary mission in satisfying international polar-ocean mapping and research goals through demonstrating the synergy of science and maritime expertise across academic, government, nonprofit, and business sectors.

The principal investigator (PI) is Nicole Trenholm, field scientist and co-director of ORP. The vessel master Captain Matthew Rutherford is also co-director and founder of ORP.

Figure 1 SRV Marie Tharp undersail in 2022

2. GO-MARIE 2022 Campaign: Southwest Greenland

The first campaign of the GO-MARIE decadal mission was to the glaciated coastline of southwest Greenland onboard the Ocean Research Project's SRV Marie Tharp. Southwest Greenland is home to several small communities and the fishing town of Paamiut. Paamiut is a coastal community of just over 1000 inhabitants. It is a major corridor for ship traffic for tourism and ferry transport navigating between western Greenland ports of the Disko Bay and the capital of Nuuk to southern ports such as Narsaq and Qaqortoq. It is also a port stop for recreational vessels traveling from western Greenland to eastern Greenland and onto northern Europe.

This region has some of the greatest outflows for sediment-rich glacial meltwater stemming from the Greenland Ice Sheet into the Labrador Sea. Seasonal algal blooms are a response from the contact between glacial meltwaters flowing from the fjords to the open ocean. The West Greenland Boundary Current contains ocean water of Atlantic origin. It is both warm and nutrient-rich when in contact with the surface meltwater and can spur coastal biological productivity.

This offshore water mass is known to advance ocean-terminating glacier melt along western Greenland's coastline. New hydrographic insight into the identification of the dominating coastal water masses, the subterranean geometry, and their geochemical composition is critical information necessary to characterize conditions which are driving the current marine food availability in the southwest Greenland region along Narsalik Banke and to show varying degrees of deglaciation. Uncharted glacial fjords identified as missing Greenland Ice sheet topobathymetric model priorities were selected to guide survey activities.

3. GO-MARIE Roles and Relationships

a. Leading Organization

The Ocean Research Project (ORP) is a 501c3 nonprofit organization based in the United States. ORP receives private and public donations to support the operational program of the GO-MARIE annual mission. ORP acknowledges authorizing governing agencies for permission to conduct survey activity within territorial seas. Nonprofit, philanthropic institutes, academic, government and industry partners collaborate in mission objectives providing funding or in-kind support.

b. Authorizing Governing Agencies

The authorizing agencies in approval of the GO-MARIE 2022 Campaign in southwest Greenland included the Royal Danish Ministry of Foreign Affairs, the Danish Defense Authorities, the United States Embassy in Denmark, and the government of Greenland.

ORP will comply with the request from the joint GeoMETOC Support Centre under Danish Defense Department, Materiel and Acquisitions board, for a copy of the bathymetric (incl. relevant metadata e.g. Cruise Reports, Calibration Reports etc.), physical and geochemical data. This material and status of data submission will be shared with POC Johan Mattsson, fmi-ma-chopd@mil.dk after the bathymetric data submission to GEBCO IBCAO and IHO DCDB is submitted. A data-processing and publication plan for ancillary physical and geochemical data will be shared with the POC to indicate expected dates for data availability.

c. Mapping Sponsors and Partners

The Nippon Foundation-GEBCO Seabed2030 is the primary sponsor of the GO-MARIE southwest Greenland 2022 survey. Their support covered the 25 dedicated mapping-day vessel-operation cost for the SRV Marie Tharp as well as the participation of two Map The Gaps IHO-certified hydrographers during a pre-expedition mobilization in the Chesapeake Bay, and then during the Greenland survey as part of the remote polar frontiers program objective pillar.

Map The Gaps provided two trained IHO-certified hydrographers during the 2022 season; these participants were also GEBCO alumni assigned to the southwest Greenland GO-MARIE campaign during the dedicated mapping-day period beginning in mid-July, 2022. The team also aided in the hydrographic system mobilization in the Chesapeake Bay, Maryland of the United States prior to the GO-MARIE mission. GEBCO Alum externally participate in ancillary scientific research led by ORP, associated with the GO-MARIE 2022 multibeam bathymetry dataset.

d. Project Period & Current Ocean Research Sponsors and Partners

University of Maryland Center for Environmental Science Horn Point Laboratory insured the hydrographic technology and provided additional necessary instruments pertaining to the entire GO-MARIE campaign season's extended field research's physical sample acquisition activities, which were coordinated by the principal investigator in conjunction with Horn Point Laboratory faculty. Physical samples are handled, processed, or outsourced for additional processing services at Lamont Doherty Core Repository. Some of these outsourced services are in part supported by the **Isaac Walton League of America Mid-Shore Chapter**. Dr. Andrea Pain is overseeing the biogeochemical analysis of the PI and current doctoral student, Nicole Trenholm. Pre-season field equipment servicing, instrumentation provisioning and boat-lab integration of hardware resources were supported by the **Washington D.C. Explorer's Club** and the **Society of Women Geographers** in 2022. The Society of Women Geographers honored the GO-MARIE 2022 mission by designating the PI as a flag-bearer during the mapping period and also supporting field resource cost needs.

University of Hull provides acoustic and optical scientific instrumentation and field support with Dr. Steven Simmons, in part funded by the Royal Society, and in coordination with the University of Southampton and University of Loughborough. Dr. Simmons collaborates with the PI on the ancillary acoustic data acquisition such as an acoustic doppler current profiler and shipboard flow-through optical data acquisition. He is collaborating in the data-processing of ancillary datasets and the multibeam water column and seabed glacimarine geomorphic data analysis between 2022-2026. During the 2022 summer campaign but after the designated multibeam survey period Dr. Simmons joined the PI to assess the new seabed bathymetry to select the optimal sites for strategic water column observations and physical sample collection.

Massachusetts Institute of Technology supported the field participation of post-graduate Dr. Camila Serra Pompe for the 2022 campaign. She collaborates with the PI on the bio-optical and remote-sensing assessment of the water quality along coastal fjords. Optical observations were in part acquired from continuous flow-through observations into the ship's laboratory during the multibeam survey period but were acquired predominantly after the dedicated mapping days.

e. Project Period and Current Industry Sponsors

R2Sonic provided a loaner Sonic 2026 for the GO-MARIE 2022 campaign to support the testing of new multispectral acoustic survey capacity and of their TruPix™ algorithm compressed water column functionality in a new application. This sonar is capable of surveying to coastal depths of approximately 600 m along priority survey areas and opportunistically in transit. The flexible use of manipulating the gate filters at an optimal angle was of great benefit to ensonify the steep coastal fjords. Seabed bathymetry was the focus of the dedicated multibeam data collection period while backscatter datasets were a secondary opportunistic activity. However, after the dedicated 25 new bathymetric coverage days additional multispectral datasets were acquired.

Universal Sonar Mount provided a mechanical rotating sonar arm MegaTower deck mount capable of efficient deployment and recovery of the multibeam sonar from the bow of the SRV Marie Tharp.

RBR provided a prototype optical sensor for shipboard flow-through sea surface continuous measurements of optical water properties contingent with water quality characteristics including backscatter, chlorophyll and CDOM fluorescence. They also provided a backup CTD probe, the Maestro in the event that our primary loaned CTD sensor experienced any failure. Virginia Institute of Marine Science's Dr. Donglai Gong loaned the RBR CTD Concerto, which was essential in providing water column sound velocity measurements for the dedicated multibeam mapping days. The RBR Concerto CTD is rated at 600 m with an integrated fluorometer and oxygen sensor.

Applanix-A Trimble Co. provided the MarineStar G4+ satellite solution for the best possible navigation and positioning solution for our survey and a trial POSPAC MMS for the PP-RTX post-processed positioning solution. We continue to work out data processing data challenges and product generation into the Spring of 2023.

QPS provided the hydrographic data-acquisition software Qinsy and processing software Qimera to best collect, process, and generate preliminary products of the data. Fledermaus and FM Midwater and FM Geocoder were utilized for further data-processing, assessment, and visualization products of R2Sonic multispectral water column and seabed data. We continue to work out data processing data challenges and product generation into the Spring of 2023.

Echo81 provided mobilization support, expedition remote support and coordination for best navigation acquisition and post processing solutions with Trimble Applanix's MarineStar satellite service solution.

TCARTA provided some samples of satellite derived bathymetry to be cautious of shallow potential shallow coastal fjord waters for reference and for potential depth validation.

4. Hydrographic Equipment

Figure 2 ORP & MTG team deploy R2Sonic on USM Megatower aboard SRV Marie Tharp

The SRV Marie Tharp is a 22-meter steel schooner modified to operate in remote polar coastal regions. The vessel can have a crew of up to nine individuals, and can have an operational distance capacity of 3,300 km between re-fuel events. The SRV Marie Tharp was equipped with a R2Sonic 2026 multibeam echosounder for the duration of the 2022 survey. The multibeam was installed on a Universal Sonar Mount Megatower pole that rotated and locked into position off of the vessel's starboard bow. An Applanix Wavemaster I, an inertial mountain unit system, was utilized for current velocity and water column backscatter not when the multibeam was in use. The RBR Concerto CTD, a sound-velocity profiler, was utilized for sound-velocity correction every few hours. This system was ideal for fjord surveys with limited glacial ice and seas at less than 1 m under power or sail.

The multibeam sounder system was integrated onboard the SRV Marie Tharp with the support of Map The Gaps and Echo81 during a mobilization and sea-trial event in May 17-20, 2022. System offsets were surveyed relative to the vessel geometry and a patch test was conducted. For hydrographic system details and the mobilization patch test, please refer to Appendix II. Cabling Diagram, GNSS Azimuth Measurement Subsystem details can also be found in Appendix II. Please refer to Appendix III for the patch-test site details and multibeam sonar configuration changes relative to the 2022 survey season in southwest Greenland.

5. Southwest Greenland Campaign Objectives

a. The Nippon Foundation-GEBCO Seabed2030 Mapping the Remote Polar Frontiers

1. Multibeam Echosounder Survey Data

The 2022 survey region's northernmost and southernmost points spanned between 63 55.52 N and 61° 24.74 N while the eastern to westernmost points spanned between 52° 04.09 W 48 09.14 W along approximately 321 km of the southwestern Greenland glaciated coastline. The total area surveyed by multibeam sonar is 370 km^2. The most significant port of call in the region is the coastal town of Paamiut. We completed over twenty-five dedicated multibeam mapping-days conducted between July 21-August 18th, 2022 with the support of two hydrographers from Map The Gaps. The lead hydrographer was Tomer Ketter and Marcos Daniel Leite both of whom are IHO certified hydrographers and GEBCO UNH-CCOM post-graduate alumni. The coastal town of Paamiut is home to 1,308 people (as of 2020), a major fishery port, and is a frequent port for cruise ships. The survey region includes some of the Greenland Ice Sheet's greatest meltwater discharge sites and marine terminating glacier fjords where critical fjord bathymetry was missing from topobathymetric models until our survey in 2022.

Fjord	Area (km2)	Max Depth(m)	Min Depth (m)
Equaluit	12.24	344.67	27.49
Kuannersooq	75.91	599.61	4.56
Nerutusooq	30.56	800	21.2
Sermiligaarsok	57.6	602.14	15.97
Allumersat	87.84	579.19	12.69
Sermeq	1.12	27.3	9.77
Transit	42.98	250	12
Neria	23.49	708.93	38.42
Kangerdluarssuk	26.81	523.783	38.56
Kangerdluarssuq	9.88	288	4

Table 1 Multibeam Survey Metrics

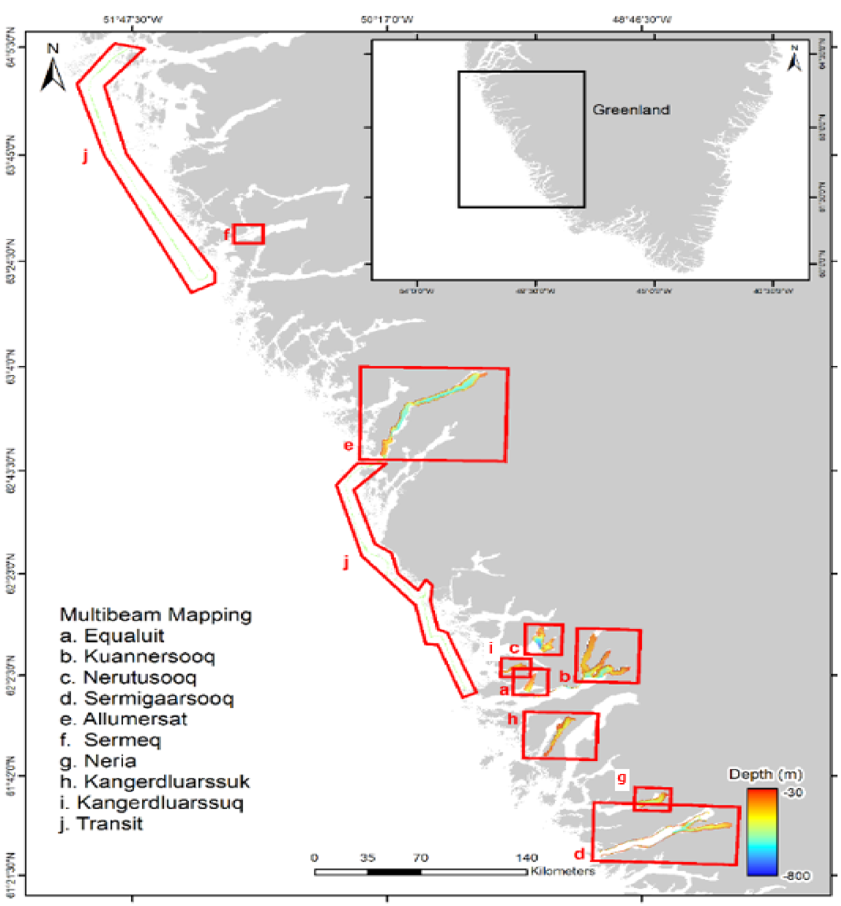


Figure 3 2022 Multibeam Echosounder Survey Data Coverage Map

Refer to individual survey site coverage maps in Appendix I.

1. Singlebeam Echosounder Survey Data

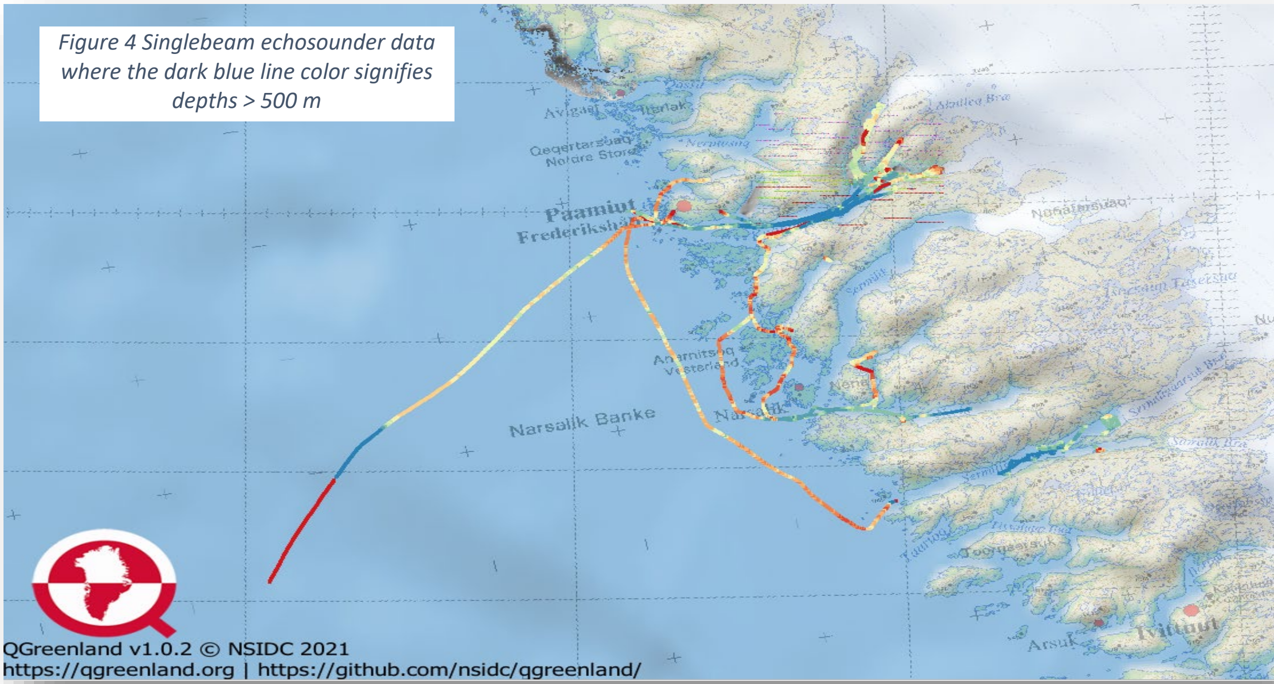


Figure 4 Singlebeam echosounder data where the dark blue line color signifies depths > 500 m

Singlebeam echosounder data was collected with a Raymarine CP 370 and a B260 transducer which is able to map 2,000 meters deep. It was collected in areas where the multibeam echosounder could not detect the seabed accurately in waters greater than 500 m deep and during transit cruises when the sea state did not permit for multibeam echosounder surveying activity.

2. Survey Highlights

Multiple key fjords were occupied in the summer of 2022. Many of which were selected for survey to support the mapping of the limited bathymetry glacial fjords deemed significant towards cryosphere modeling that remain unaddressed in southwest Greenland. We also identified some potential hazards to navigation discussed in the following section.

The targeted uncharted glacial fjords were selected to address under-investigated evidence towards ocean thermal forcing upon the southern Greenland Ice Sheet's ocean terminating glaciers. The role of the boundary current's passage, which comprises warm water of Atlantic origin will be identified along the survey region. These glacial fjords have been ranked in significance as discussed with scientific advisory from their relevance to inform associated Greenland Ice Sheet System models. During the NASA Ocean Melting Greenland (OMG) Mission the southern Greenland glacial fjords were not prioritized to survey with multibeam as they were of a lower priority than other areas of Greenland glacier fjords. Glacier velocity and ice mass loss derived from satellite and sub-orbital remote observations indicated a higher degree of significance to assess for ocean thermal forcing in seasonally accessible Greenland fjords. The seabed shape and maximum fjord channel depth act as a significant control on the degree of boundary current exposure to ocean terminating glaciers. In south Greenland limited bathymetry depicts multiple deep continental shelf-break troughs whereas dedicated survey for high resolution bathymetry could begin to connect these troughs and their subterranean channels to the region's ocean terminating glaciers. The seabed bathymetry and the hydrographic dataset between the outer continental shelf-break troughs and the fjord glaciers also include restrictive seabed sills. These are significant features that can limit boundary current circulation. Bathymetry of significant sills, channels and troughs will greatly improve the resolution of the coastal Greenland Bedmachine/GEBCO/IBCAO grids and will advance Greenland Ice Sheet climate prediction and impact research. Data from these survey can support Danish Charts # 1213, 1210, 1211, 1212 ([Index over grønlandske søkort (danskehavnelods.dk)]).

I. **Multibeam Surveys:** We completed partial multibeam echosounder survey coverage (Reference Figure. 3 of 9 coastal fjords including: a. Eqaluit, b. Kuaanersooq c. Nerutusooq, d. Sermilligaarsook, e. Allumersat, g. Neria, h. Kangerdluarssuk or (Kvanefjord), and i. Kangerdluarssuq. Exploratory reconnaissance multibeam of f. Sermeq and opportunistic transit coverage with multibeam, j. Refer to Appendix I.

II. **Significant Multibeam Fjord Surveys:** 3 of the 9 fjords include fjord branch surveys that contain a total of 5 coastal glaciers whose adjacent fjord branches contain limited or missing bathymetry that is significant relative to the topobathymetric gaps of the Greenland Ice sheet models. Refer to Figure 3 and 4. These include: b. Kuaanersooq: subfjords: 1. Avangnareleq - Branch, 2. Akuliaq - Branch, 3. Nigerlikasik - Branch), d. Sermiligaarsok, e. Allumersat). Refer to Appendix I.

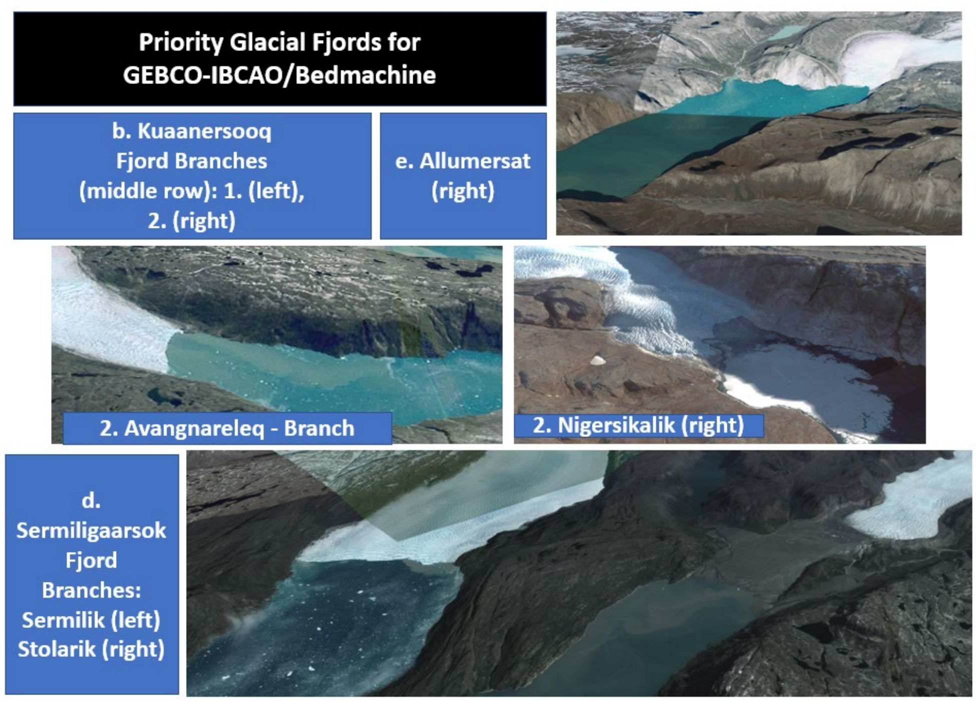


Figure 5 Significant Multibeam Fjord Surveys

III. **Hazardous Ridge and Tidal Peninsula to Large Vessels in Kuannersooq Fjord**: A semi-submerged ledge not visible in satellite imagery or existing charts lies in the main branch of the Kuannersooq fjord system. A ridge poses a hazard to navigation in Kuannersooq fjord, extending to the northeast from the small island in the center of the connecting basin. A shallow ridge connecting an island to a peninsula within Kuaanersooq fjord represents significant subterranean features where three fjord branches come together near an island. A least depth was not identified as it was particularly shallow at the top of the ridge at less than < 30 m. However, multibeam coverage was acquired in parallel with the ridge feature and peninsula. An exploratory survey was conducted to attempt to find a least depth over the gaps of the ridge with a small inflatable dinghy equipped with a mobile 100 m single-beam depth sounder; however, that data may not be available to extract from the Trimble GPS unit and this is still being assessed to include in the final data submission to DCDB. These additional shoal ridge values will be followed up on if they are able to be extracted from the recreational navigation device.

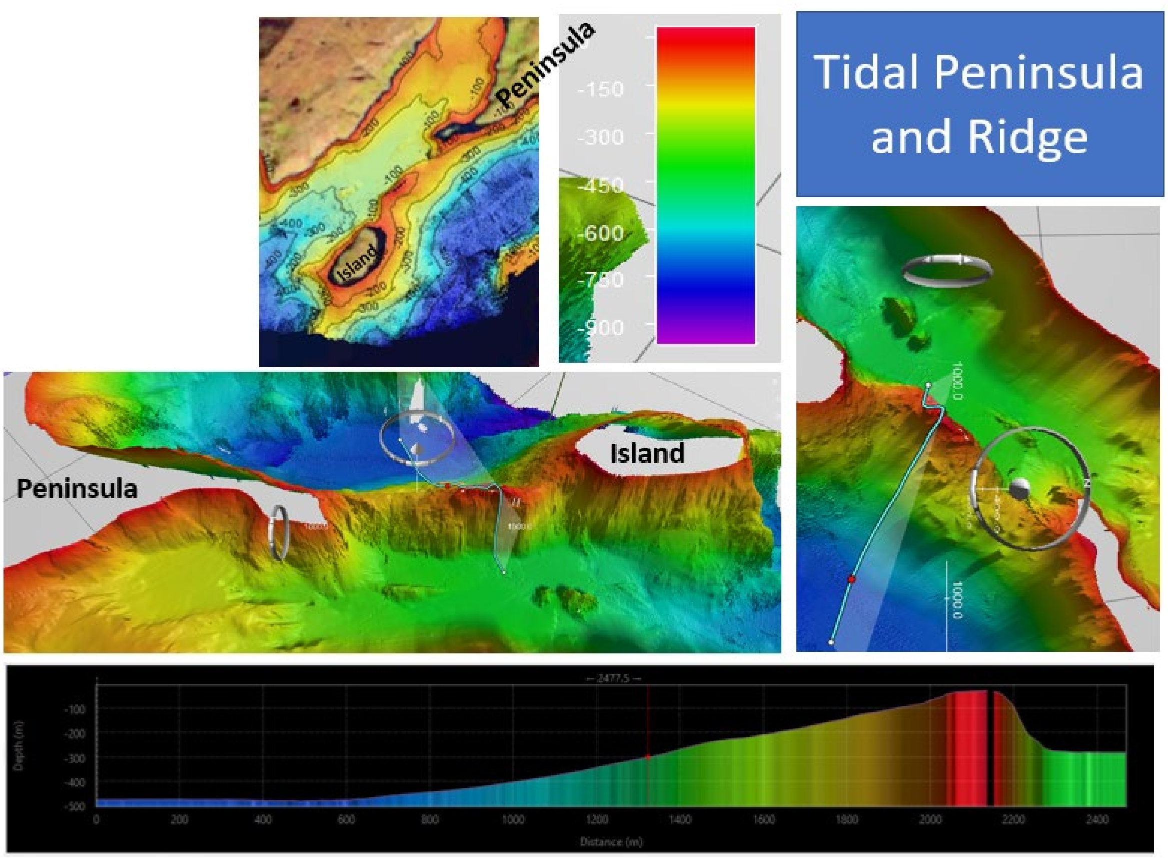


Figure 6 Kuannersooq Fjord Potential Danger to Large Vessels

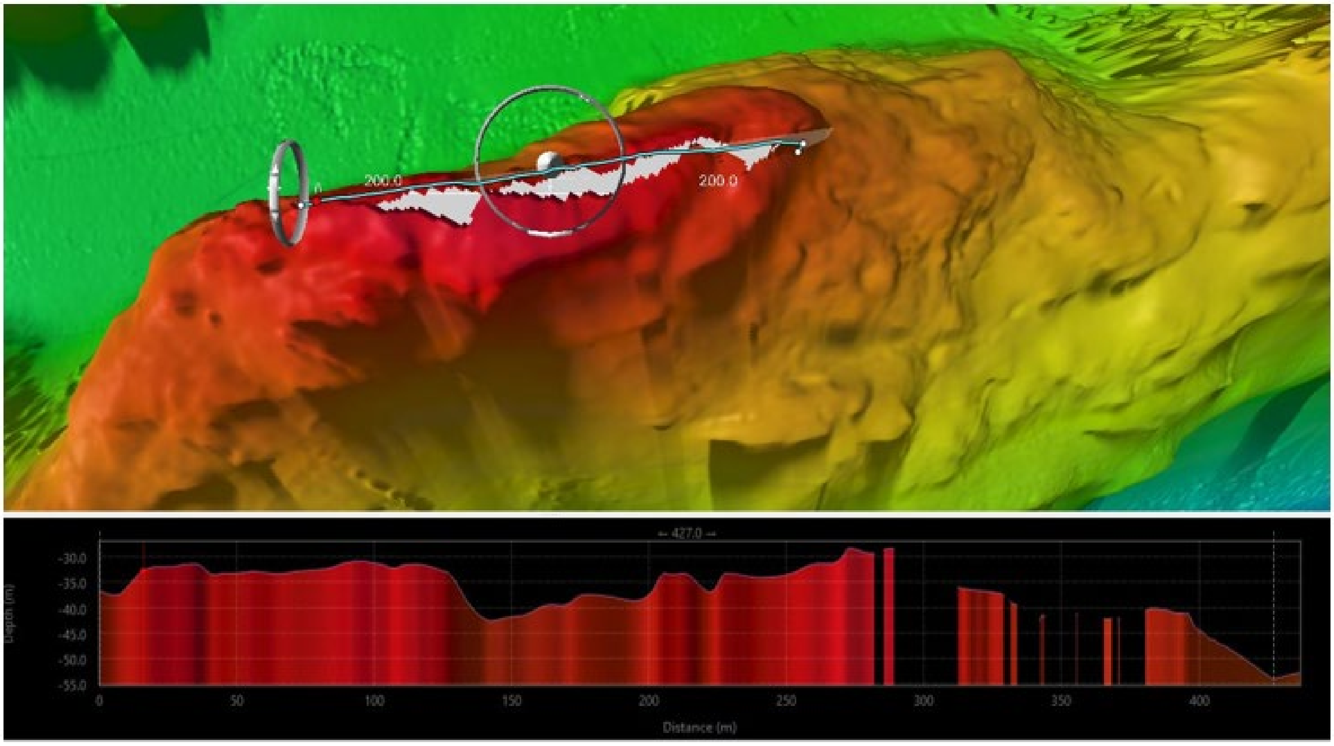


Figure 7 Uncharted Gap over Ridge

IV. **Sermeq fjord depth offse**t: In Sermilik Fjord (Sermeq Glacier, DH chart #2013), the survey has revealed depths ranging 6 m to 21 m where existing soundings indicate 45 m or more, making this fjord unnavigable for larger vessels.

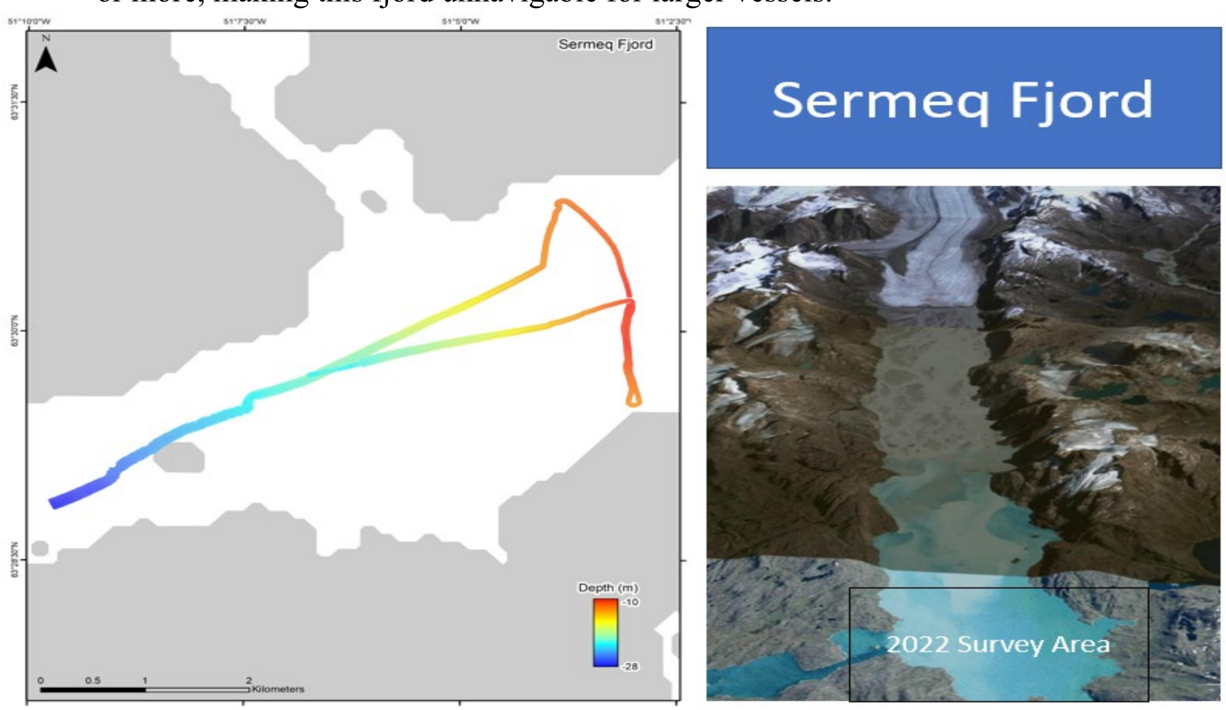


Figure 8 Sermeq Survey

b. Hydrographic Research and Development

An addendum to this section will be provided upon request after May, 2023.

1. Assessing the Best Positioning Processing Options for the southwest Greenland Fjords Multibeam Surveys
    a. Method: POSPAC MMS PP-RTX in Greenland Glacial Fjords

Acquisition: An integrated inertial navigation system (I2NS) was set up using the Trimble CenterPoint RTX corrections to then be modified in Greenland to then use the Fugro Marinestar G4 for GNSS for the positioning operation settings for the hydrographic survey data acquisition for interconnected file management between POSPAC, R2Sonic and QPS Qinsy software. While the Trimble CenterPoint RTX corrections were used successfully for the mobilization period in Maryland, and attempted again in Greenland; ultimately, the RTX didn't work well due to the higher latitude survey where limited satellite detection could be detected by the vessel in the narrow fjords surrounded by steep cliffs.

Processing: A PP-RTX positioning solution is in progress in POSPAC MMS to best correct the positioning of the bathymetric dataset for the purpose of an improved position resolution for the archived bathymetric data, a more accurate submission to the BedMachine Greenland model at NSIDC and for the usage in scientific research publications. The post-processed data does not resolve all navigation offsets that at maximum reach 10 m between overlapping survey lines. All bathymetric and post-navigation processing is a voluntary effort. Therefore, the detailed assessment of the positioning offsets and potential corrections are a timely project.

2. Multi-application of Multibeam Survey Water Column and Seabed Data

    a. Seabed Glacimarine Geomorphology - Evidence of Holocene Glacial Mobility

V. The seabed bathymetry combined with the physical oceanographic profiles within the 5 glacial fjords of significance reveal glaciomarine geomorphology that indicates the historic activity of the fjord glacier position since the last glacial maximum. The dimensions of sills, channels, etc will be analyzed in a publication in progress. For example, Kuannersooq fjord contains a fjord branch with an ocean terminating glacier (1. Avangnareleq – Branch) with a major sill that meets the main fjord stem. Adjacent to this fjord, a present-day land retreated glacial fjord branch also contains a sill that meets the main stem (2. Akuliaq – Branch). However, deep warm boundary current water does partially work its way past each sill but not to the same degree as the third fjord branch which contains no sill feature (3. Nigerlikasik – Branch). Refer to Appendix I.

VI. .

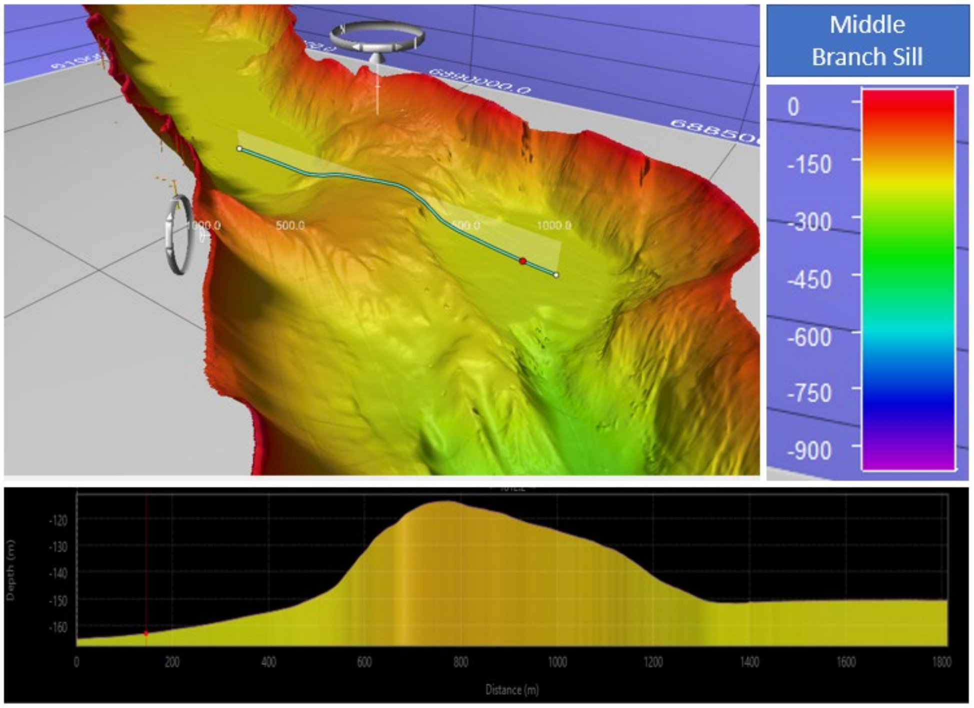


Figure 9 Sill in Kuannersooq Fjord at Avangnareleq - Branch

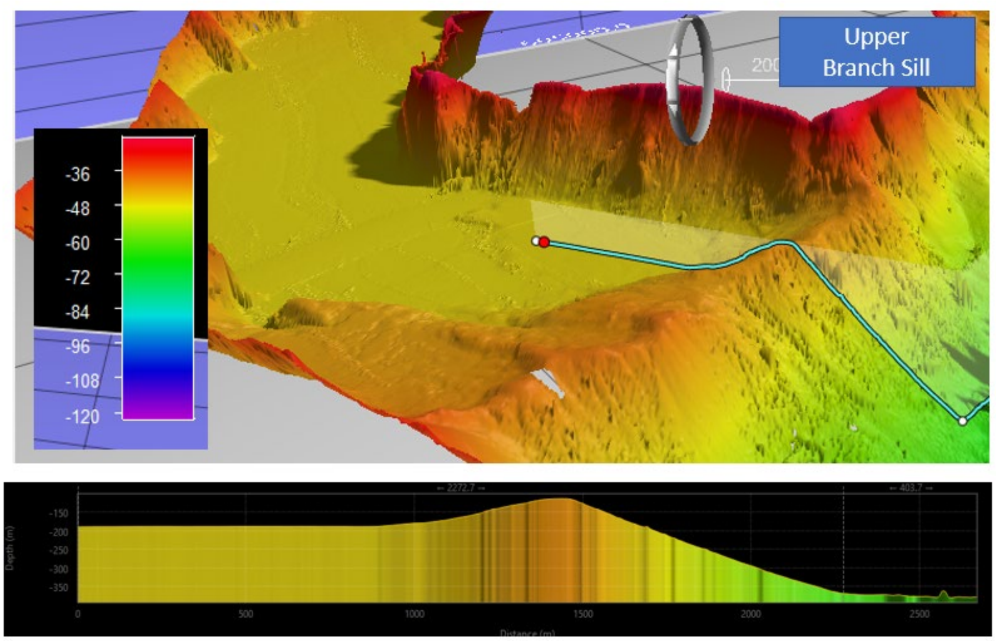


Figure 10 Sill at Kuannersooq Fjord at Akuliaq - Branch

b. Seabed Organic Sediment Composition Characterization – Spatial Mapping of Seabed Carbon Burial Fluctuation Across the Deglaciating Landscape

Acquisition:These multi-application surveys were conducted in Qinsy within the three primary fjord branches of Kuannersooq fjord 1. Avangnareleq - Branch, 2. Akuliaq - Branch, 3.

Nigerlikasik - Branch all influenced by varying degrees of deglaciation and within the completely deglaciated fjord of Nerrutussooq fjord. By collecting seabed backscatter at different frequencies (100, 180, 200, 360 kHz) simultaneously using the R2Sonic 2026 multispectral sonar feature we can begin to assess which frequencies best correspond with the percent organic matter buried on the seabed bottom in glacial fjords impacted by glaciers at different stages of retreat. This project is in progress and is in coordination with collaborating scientists Marcos Daniel Leite of University of New Hampshire and Pedro Menandro of Universidade Federal do Espírito Santo. Seabed samples from cores help to verify the grain size and organic ratio of the survey product area and are being processed at University of Maryland Center for Environmental Science.

Processing: Fledermaus Geocoder, Qimera and open-source programming languages are being used for the project processing, analysis and visualization. ARA and mosaic approach for seabed composition will be conducted for select frequencies such as (100, 180, 200, 360 kHz).

c. Water Column Suspended Sediment Study and Organic Carbon Fraction Analysis – Changes of sediment discharge and suspended organic matter relative to varying stages of coastal glacier retreat

Acquisition: These multi-application surveys were conducted in Qinsy within the three primary fjord branches of Kuannersooq fjord 1. Avangnareleq - Branch, 2. Akuliaq - Branch, 3. Nigerlikasik - Branch all influenced by varying degrees of deglaciation. An assessment of the suspended sediment concentration from fjords impacted by varying degrees of deglaciation is being conducted by measuring water column multibeam backscatter in coordination with Dr. Simmons and by collecting water samples in coordination with Dr. Pain. Water column backscatter data was acquired with the R2Sonic 2026 multibeam sonar at various frequencies (100, 180, 200, 360 kHz). Acoustic Doppler Current Profiler Teledyne Workhorse 600 KHz with a 70 m range and 4 m bin size is used to collect current velocity and water column backscatter in order to have an additional acoustic backscatter derived suspended sediment concentration measurement. Water samples filtered from these sites of suspended sediment were acquired to grountruth the multibeam water column backscatter data derived from suspended sediment concentration and the organic fraction and carbon fraction.

Processing: Water sample analyses are being conducted at present at University of Maryland Center for Environmental Science for sediment and biogeochemical characterization. Seabed bathymetry is being processed with Qimera, Fledermaus Midwater and Python. Ongoing coordination between QPS in regards to data processing efforts. The water column backscatter derived suspended sediment concentration is intended to be extracted and analyzed by frequency by using the R2Sonic algorithm TruePix™, an algorithm that optimizes data volume into snapshots of backscatter return and water column imagery, TruePix™ Compressed Water Column.

6. Products

i. GEBCO IBCAO: Preliminary Processed Data Submission Date: January 5th, 2023, Final Processed Submission Date: tentatively May 2023. The January 5th, 2023 submission entailed 12 grid (.tif) files at Coordinate System: WGS 84, Universal Transverse Mercator Projection - UTM22N at horizontal positioning resolutions between 3-5m. They were submitted to https://seabed.geo.su.se. This report will be submitted to IBCAO to associate with the dataset metadata at the time of submission to Seabed2030 and any addendums after that.

ii. DCDB:

Preliminary Data Submission: March, 2023

Preliminary multibeam echosounder bathymetric grids with the same naming convention with _DCDB added at the end of the file name will be submitted to DCDB along with a singlebeam echosounder file called sb_data_clean_DCDB.txt. This report will also be submitted to DCDB to associate with the dataset metadata.

Final Processed Data Submission: tentatively May, 2023.

Multibeam data will have a significant positioning improvement applied as detailed section b.1.a of this report. The grid updates and updated report will also be submitted to DCDB to associate with the dataset metadata as an addendum..

iii. NSIDC Bedmachine:

Final Processed Data Submission: Tentatively May, 2023.

Point of Contact Dr. Mathieu Morlighem of Dartmouth University. It was suggested for the final processed data to be made available to the Bedmachine model as opposed to preliminary processed or raw data.

iv. US and Danish Embassy:

Preliminary Report Submission Date: January, 2023

Followup Data Report Update Date: May, 2023

Reports are submitted via the Tracking System (RATS) Department of State Bureau of Oceans and International Environmental and Scientific Affairs, Office of Oceans and Polar Affairs (OES/OPA). https://ratsportal.state.gov/

v. GeoMETOC:

Report Submission Date: February, 2023

Report Data Update and Addendum May, 2023

The correspondence is arranged with point of contact at fmi-ma-chopd@mil.dk

7. Communications

Capital Gazette Newspaper Article Print and Digital:

Annapolis-based nonprofit prepares to set sail for Greenland to study climate change on the newly commissioned sailboat, by By Rebecca Ritzel May 14, 2022 at 3:41 pm.

The project was highlighted after the SRV Marie Tharp's Mapping Mobilization Day at a major event in Annapolis, where 100's of passersby boarded the SRV Marie Tharp dockside for boat tours and the Mayor Gavin Buckley set a proclamation to honor the vessel's commissioning on the date of May 13th , 2022 during the first annual Uprigging Event in downtown Annapolis harbor. Local cities highlighted the event promoting the vessel's launch and summer project scope in the Baltimore and Annapolis front page paper. See the article here.

Films:

Three short films were produced and published on the Youtube website (link here) for the Ocean Research Project to highlight the GO-MARIE activity in 2022.

1. The first film highlighted the mobilization event with partnering support from Echo81 and Map The Gaps joining the Ocean Research Project and GO-MARIE crew of 2022 as well as The Nippon Foundation-GEBCO Seabed2030. The film can be viewed here.

Title: Mapping Mobilization Day

Film Abstract: The Ocean Research Project Team along with partners Map the Gaps and sponsor R2Sonic spent a day calibrating the equipment needed for the mapping work we will be conducting in the sub-arctic. It was a busy day working with the equipment and preparing for the expedition.

Filmed and Produced by Michael Desimon.

2. The second film can be found at this link here. It was published to coincide with the Map the Gaps Symposium event October 26-28th, 2022 to honor the hydrographic mapping industry partners who have supported The Nippon Foundation-GEBCO Seabed2030 supported project GO-MARIE.

Title: Together We Map The Seafloor

Film Abstract: Ocean Research Project 501c3 leads a mission (GO-MARIE) to map the uncharted coastline of the Arctic during the ocean decade with a crew of explorers, scientists, top marine tech sponsors, supportive foundations, government and academic partners.

Filmed and Produced by Phineas Alexander at SlyDog Creative Productions while co-written with Nicole Trenholm.

3. The third film is focused on the relationship between The Nippon Foundation-GEBCO Seabed2030 Project and Ocean Research Project relative to their gracious support during the GO-MARIE 2022 campaign. It is published to coincide with final project deliverables submission period in the winter of 2023 while preparing for the 2023 GO-MARIE campaign. The link for the film is here.

Title: The Nippon Foundation-GEBCO Seabed 2030 Project: Go Marie 2022

Film Abstract: Fire in the hole! A new mission launches. The Ocean Research Project and The Nippon Foundation-GEBCO Seabed 2030 Project join hands for the GO-MARIE mission. The project kicks off onboard the SRV Marie Tharp in southwest Greenland and their excitement to map the uncharted waters is unmatched!

Filmed and Produced by Phineas Alexander at SlyDog Creative Productions.

Social Media:

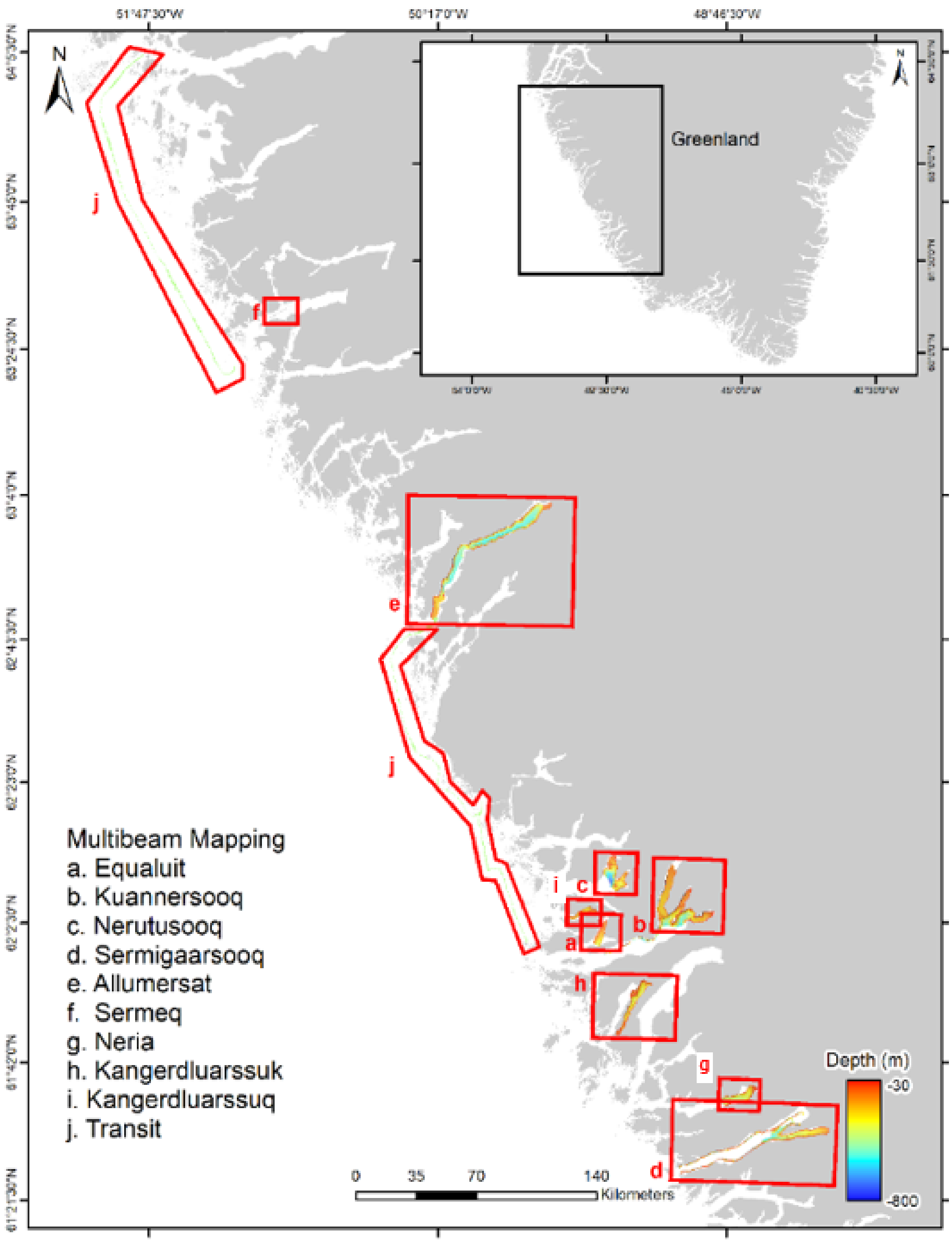
Several social media posts were published on Ocean Research Project's Facebook page to highlight the project lifecycle of the GO-MARIE 2022 mission, the dedicated multibeam echosounder mapping period and the partner hydrographer participation with Map the Gaps between May 2022 and January 2023.

Presentations:

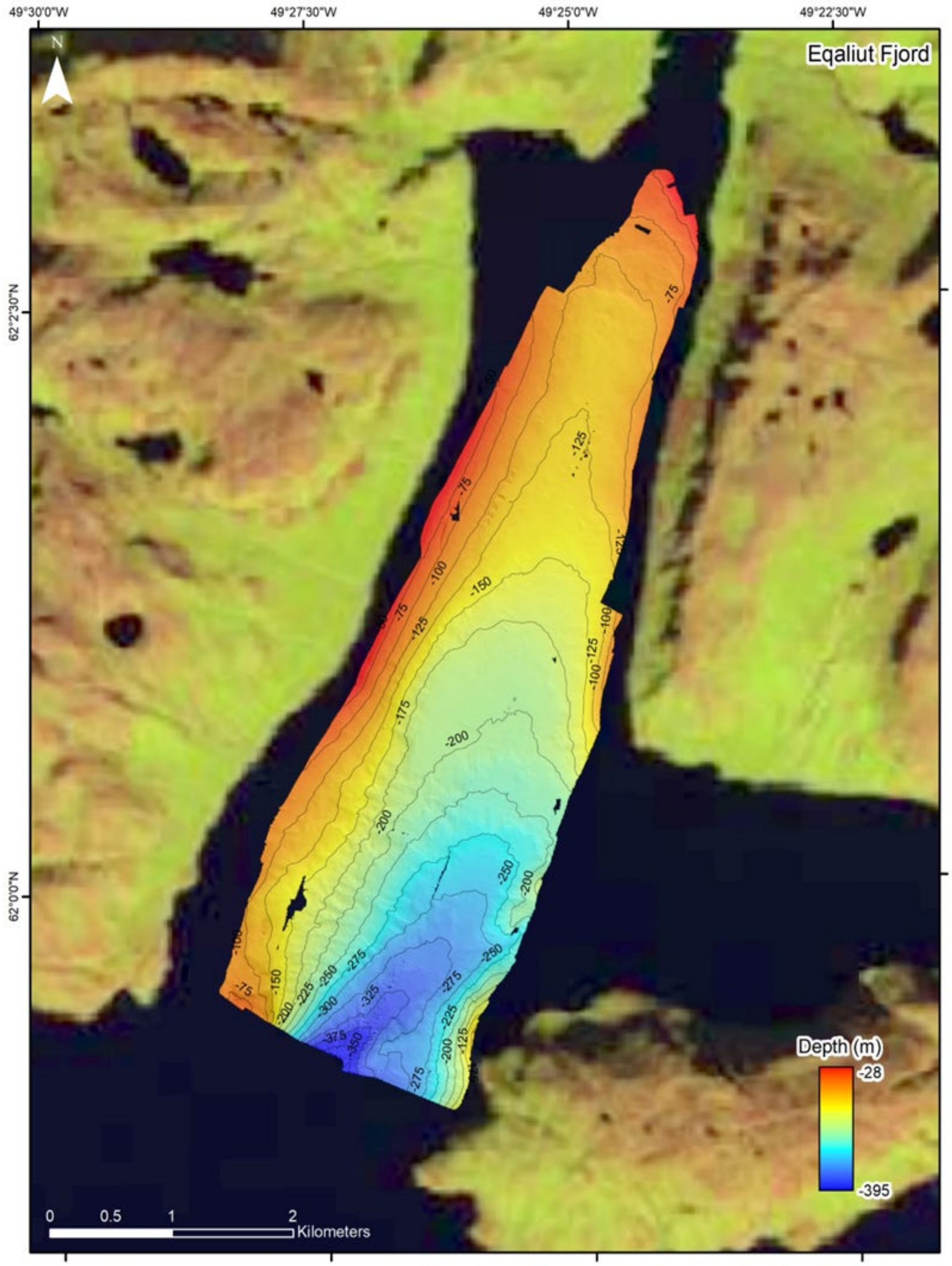
The Principal Scientist presented the work at the Map the Gaps Symposium in Southampton, UK in October 2023, at the University of Loughborough and at the University of Hull in a seminar also in October of 2023. She will also present the collaborative mapping activity at the Future of the Greenland Ice Sheet Science (FOGSS) meeting in March of 2023 at Georgia Tech.

Appendix I:

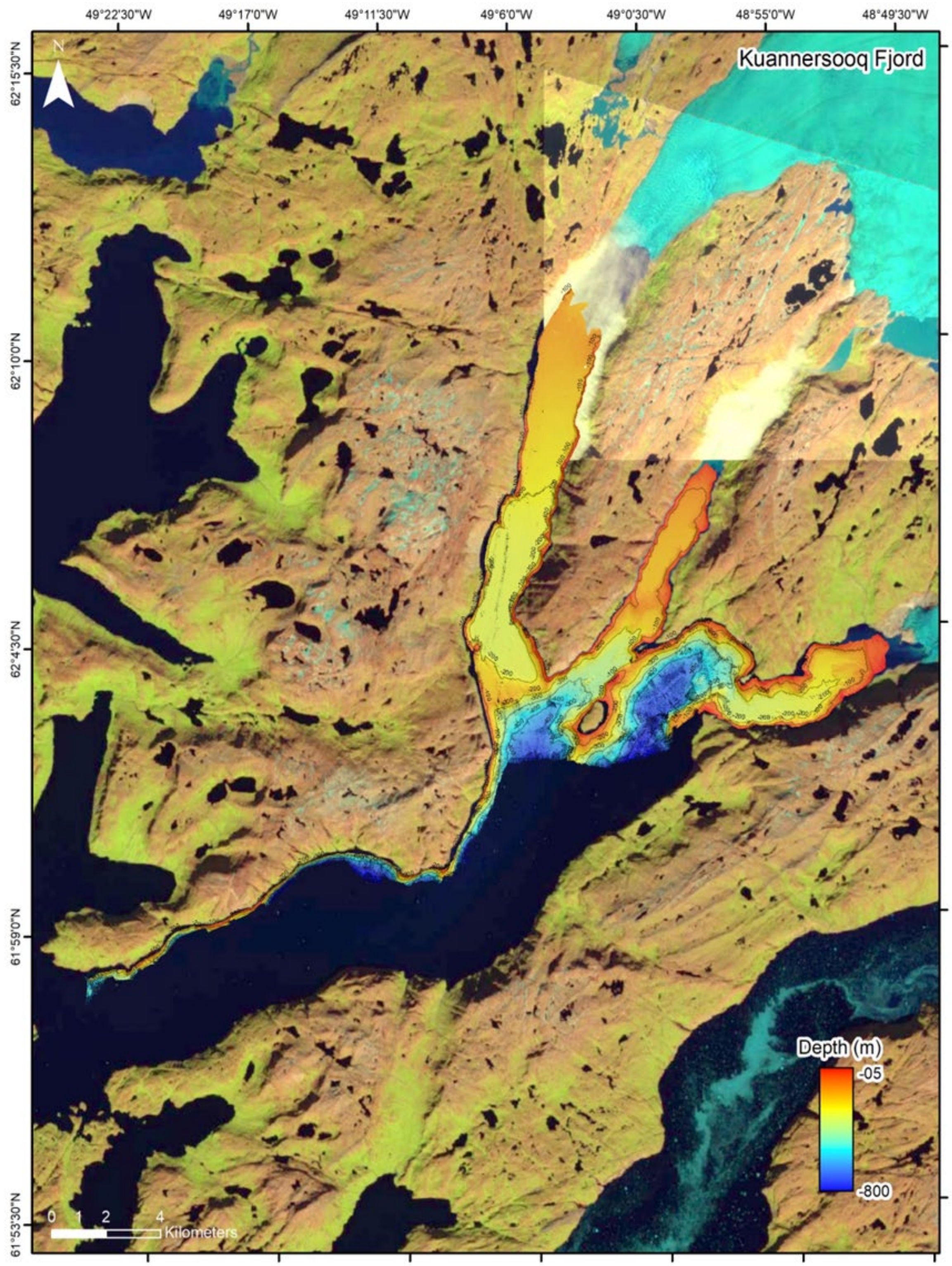
Multibeam Survey Coverage Site Maps



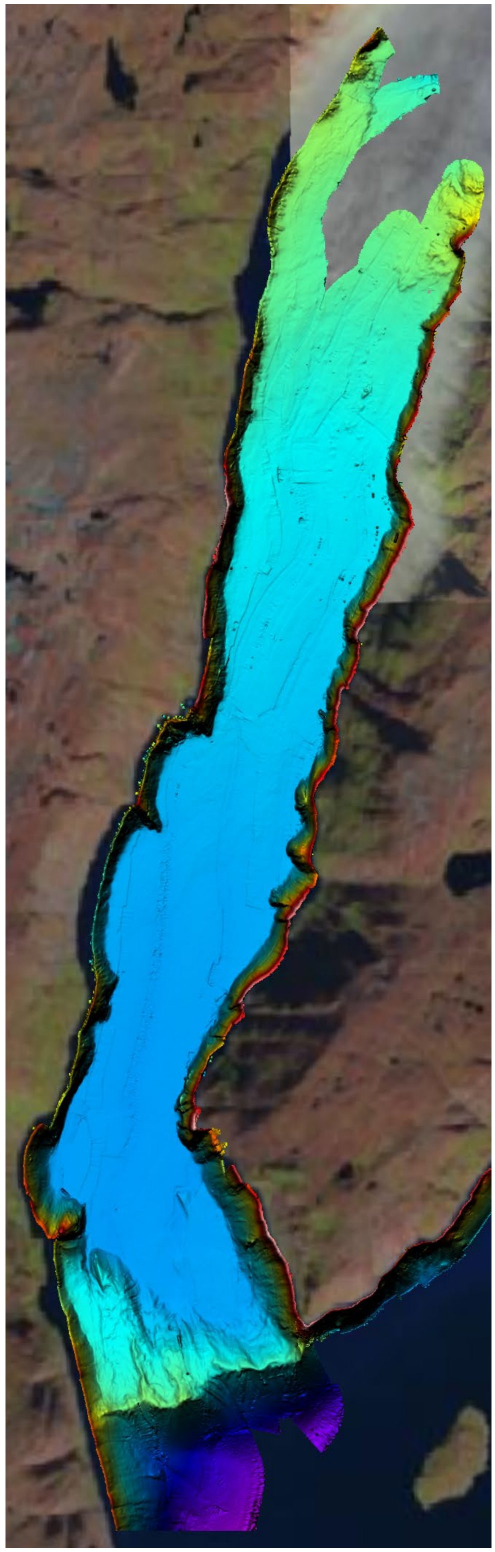
a. Eqaluit Fjord Coverage Map



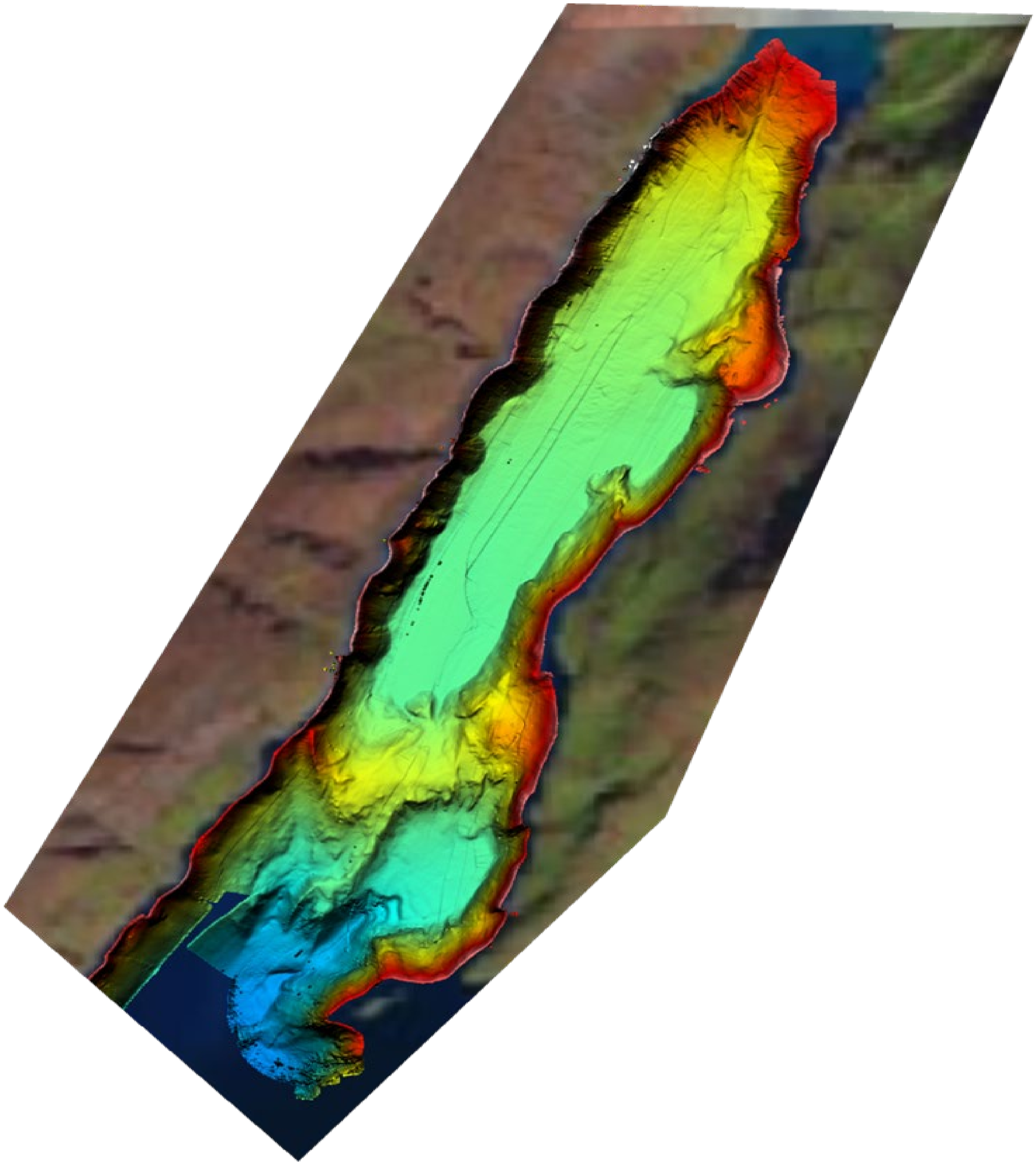
b. Kuannersooq Fjord Multibeam Coverage Map



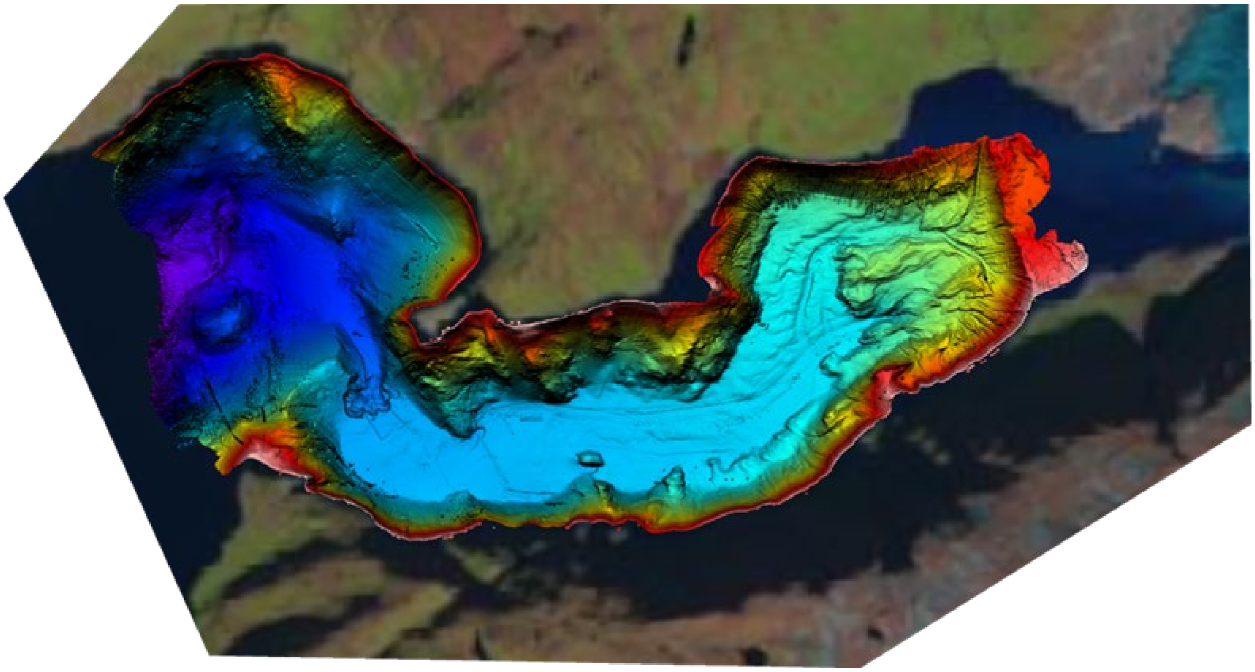
I. Avangnareleq - Branch



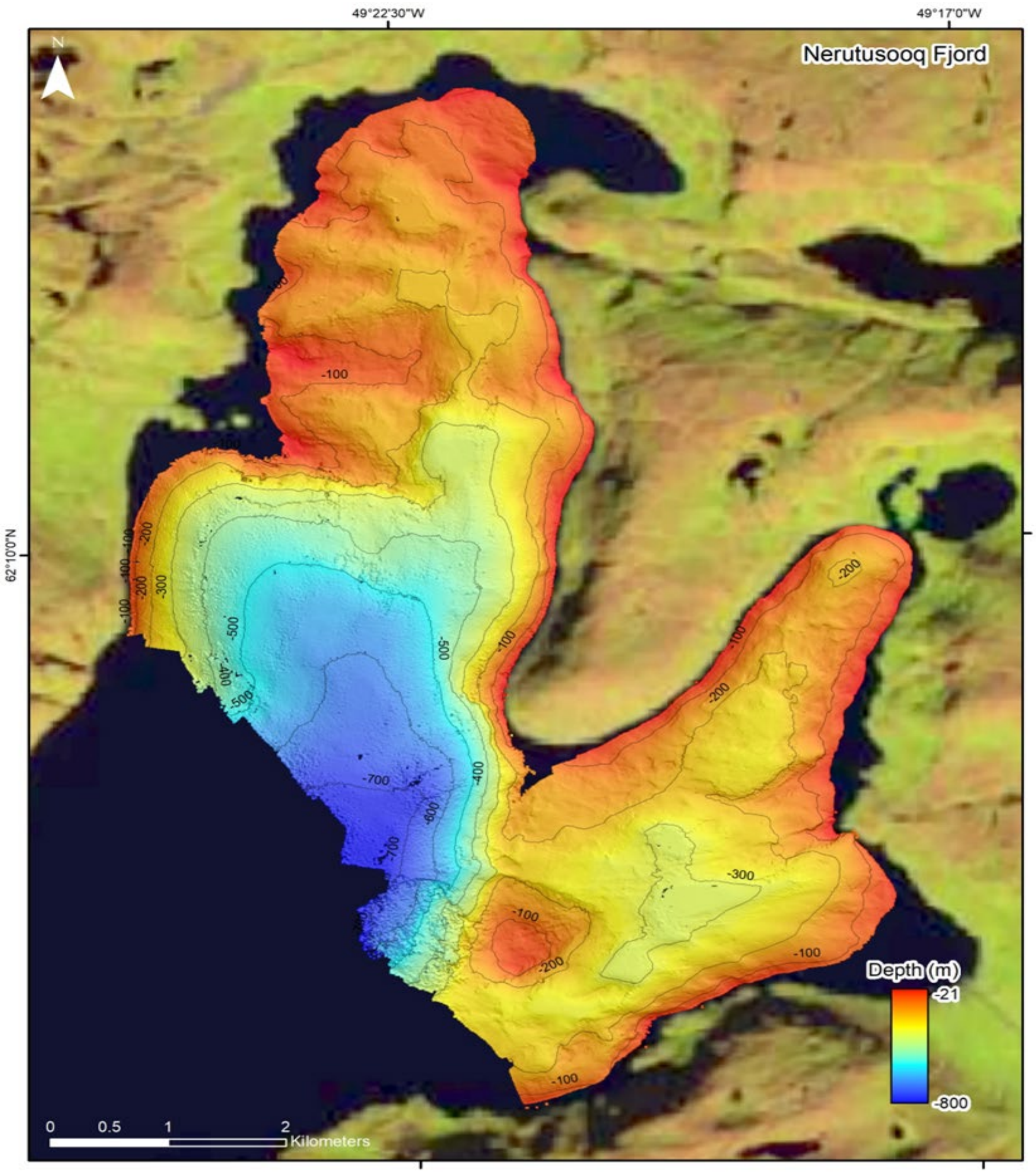
II. Akuliaq - Branch



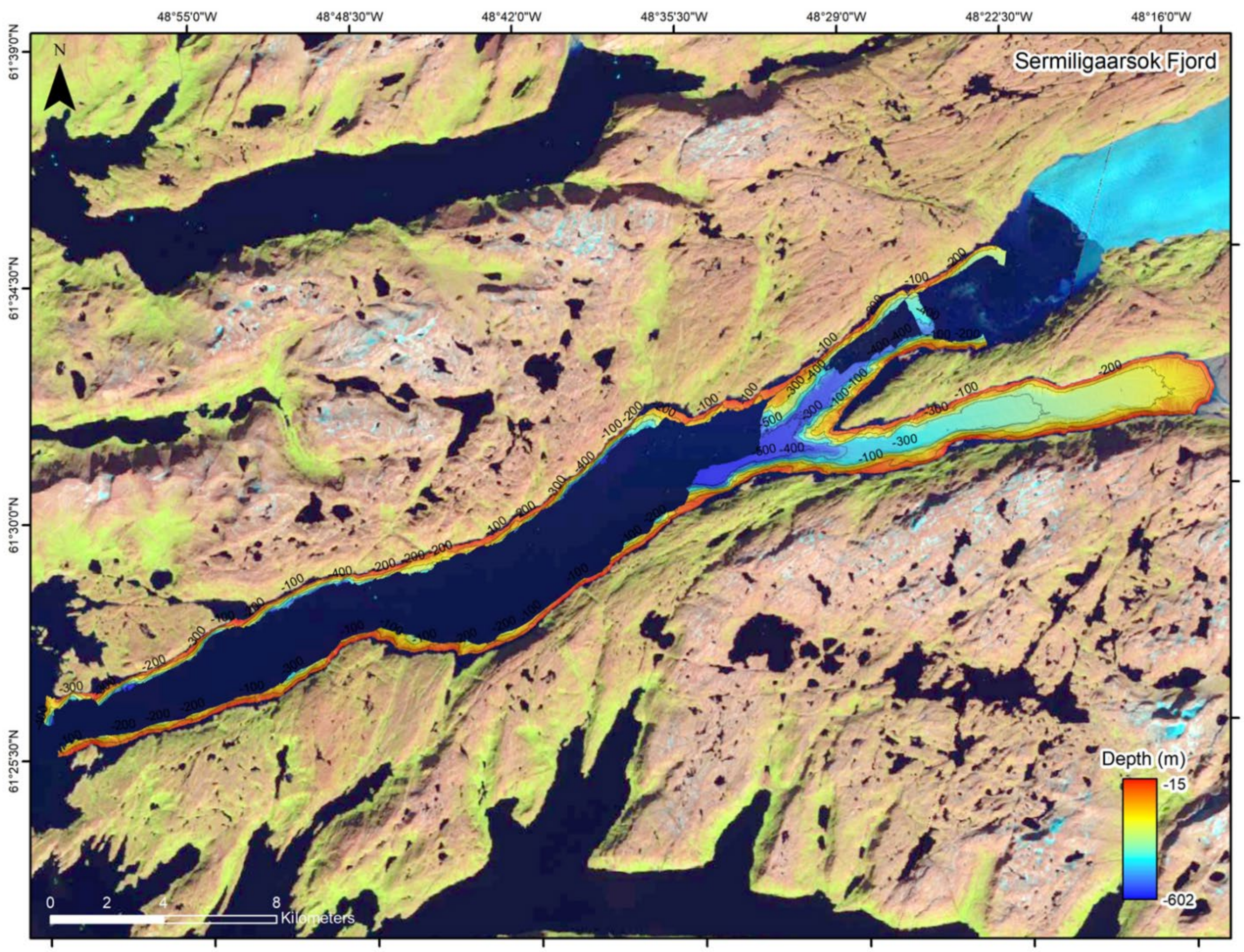
III. Nigerlikasik - Branch



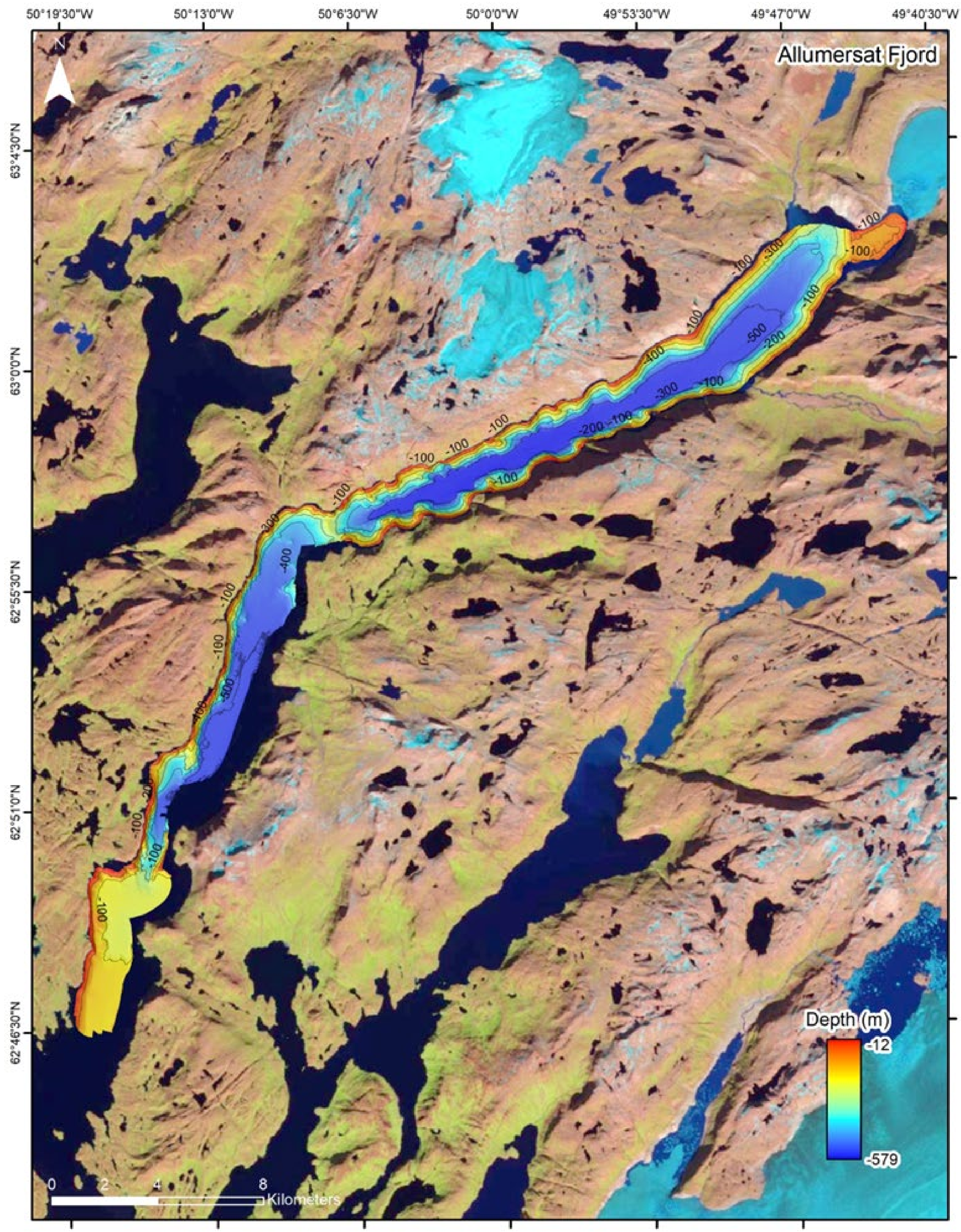
c. Nerutussoq Fjord Multibeam Coverage Map



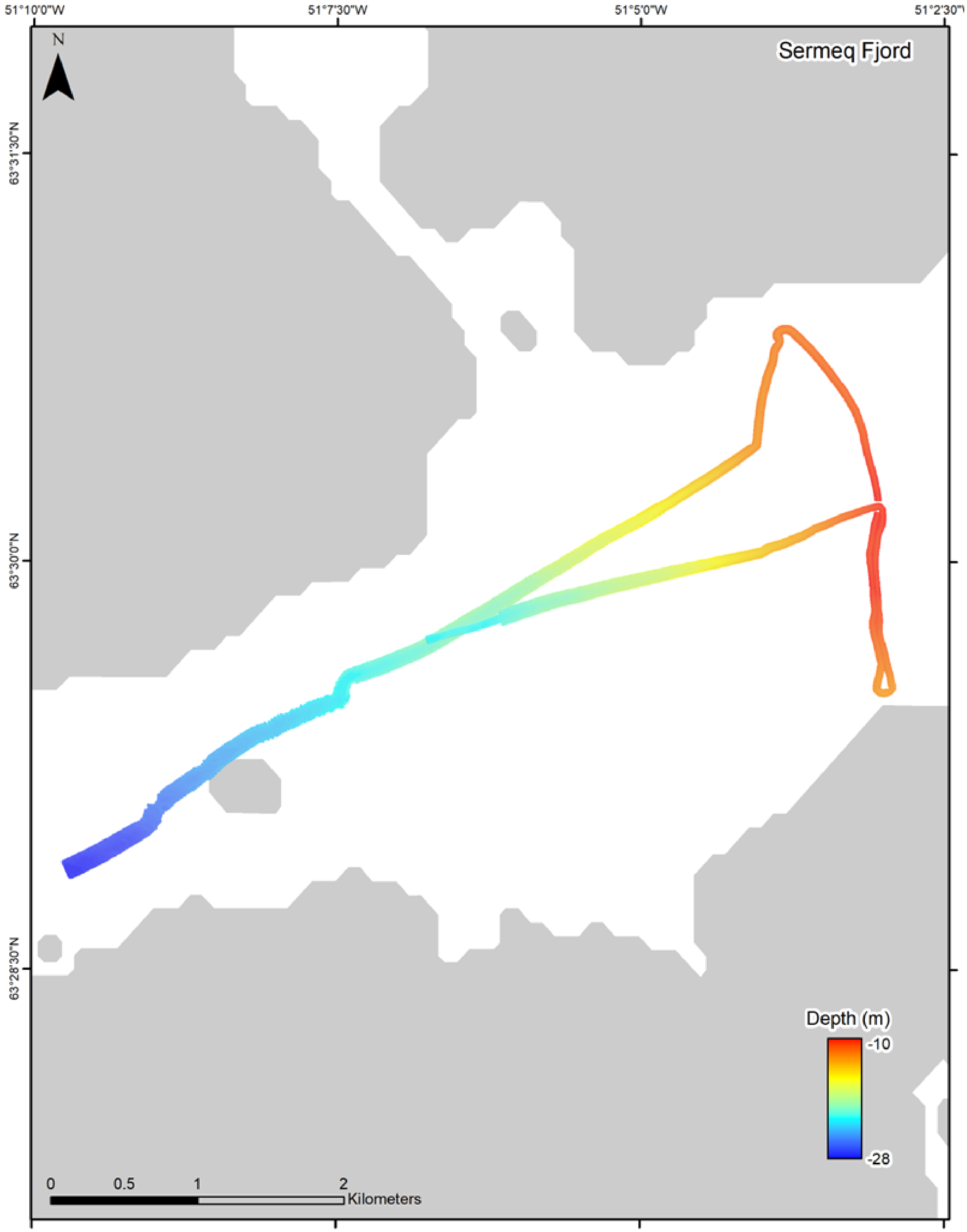
d. Sermiligaarsok Fjord Multibeam Coverage Map



e. Allumersat Fjord Multibeam Coverage Map

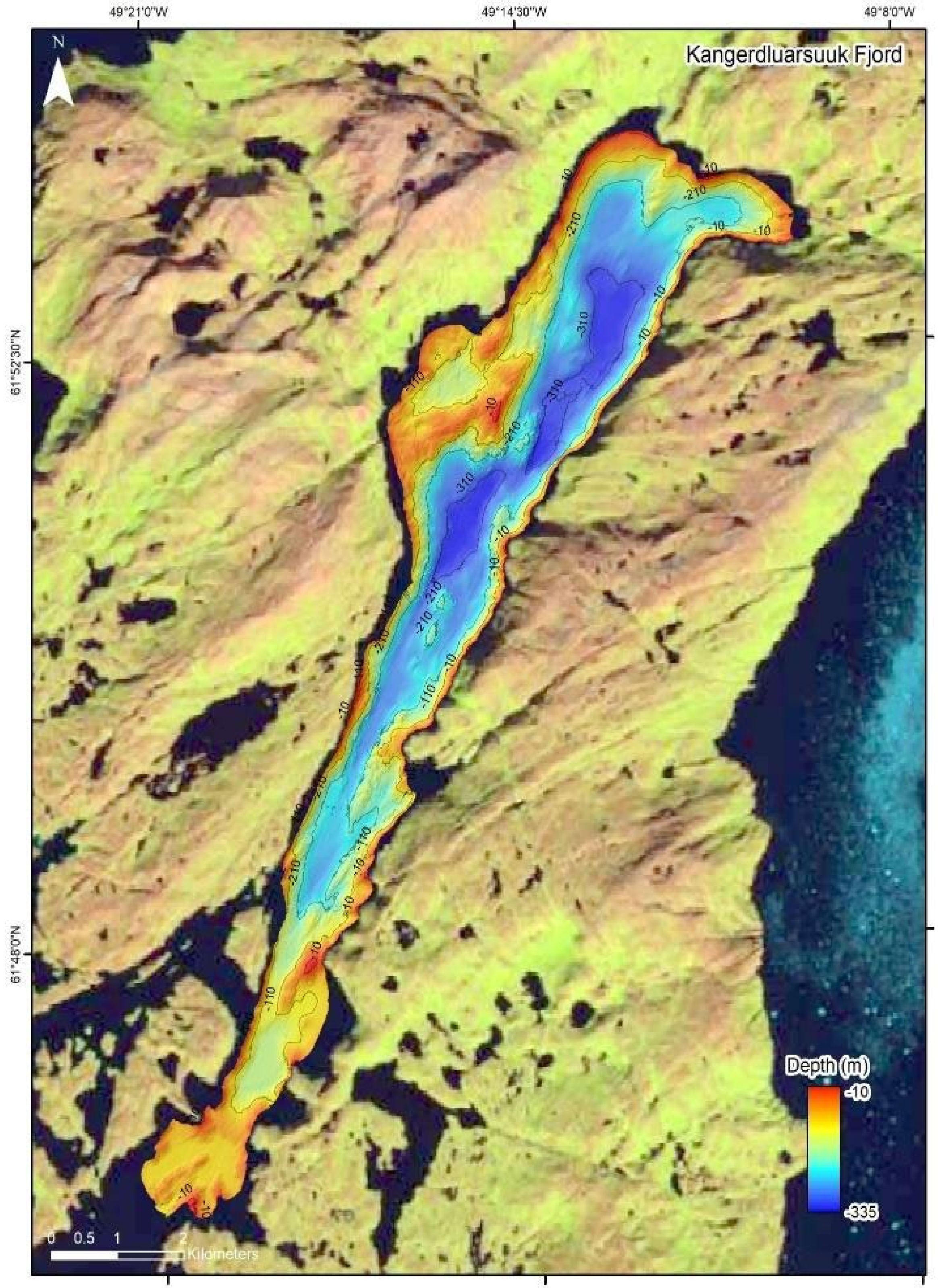


f. Sermeq Fjord Multibeam Coverage Map

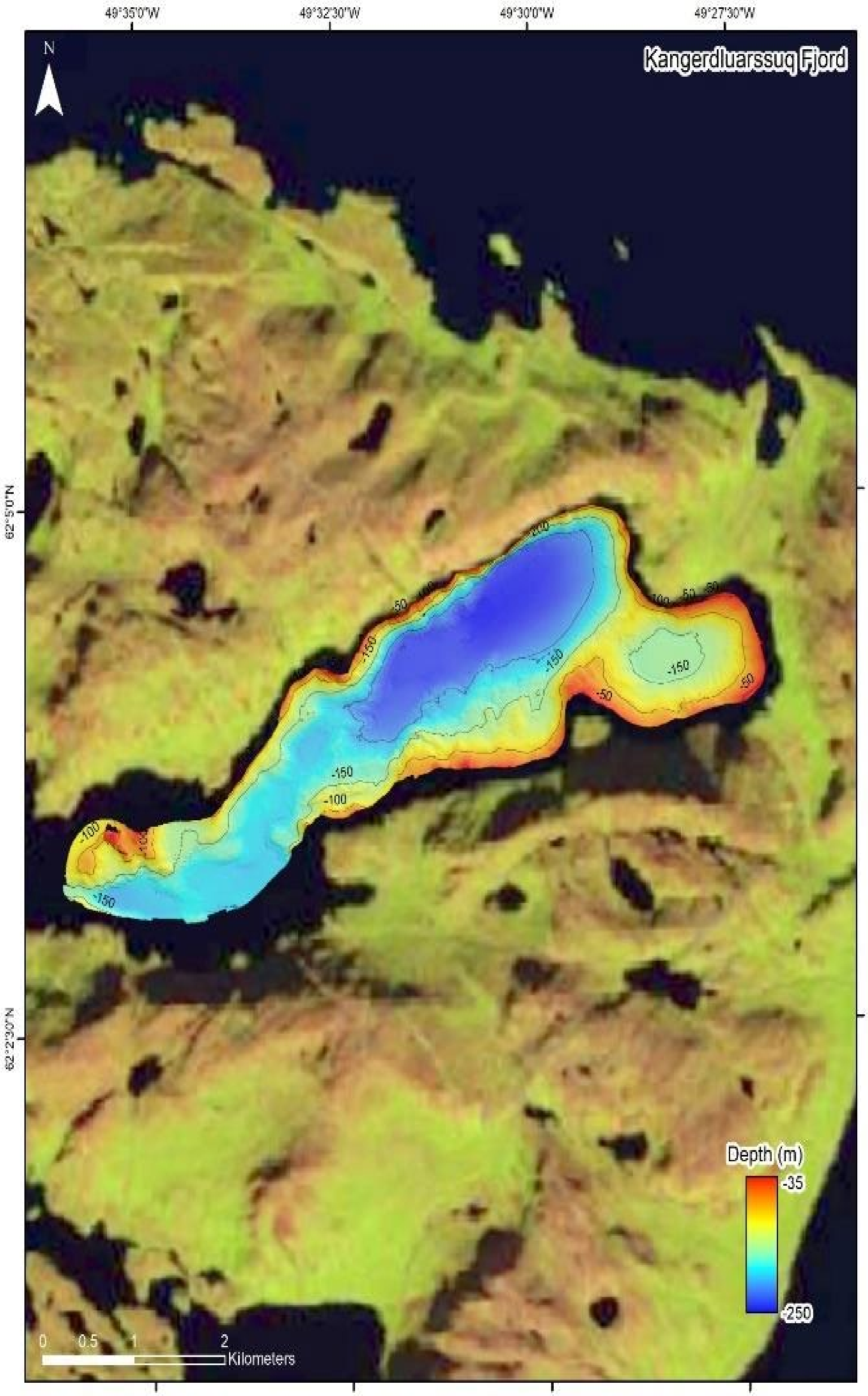


g. Neria Fjord Multibeam Coverage Map

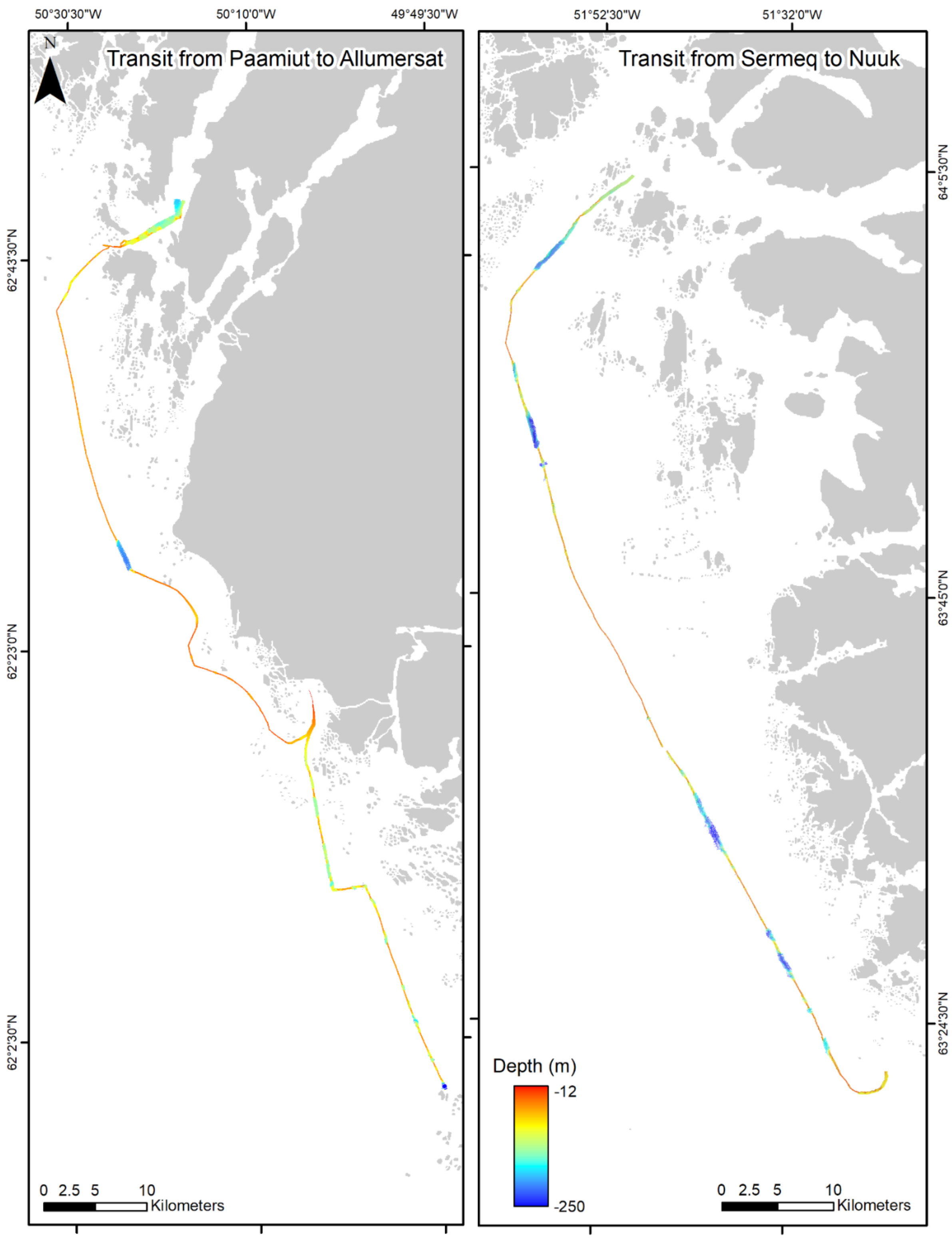
h. Kangerdluarssuk Fjord Multibeam Coverage Map



i. Kangerdluarssuq Fjord Multibeam Coverage Map



j. Transit Multibeam Coverage Map



Appendix II:

Mobilization

Multibeam Integration and Calibration Report: SRV Marie Tharp & R2 Sonic 2026

Map the Gaps

Tomer Ketter

Marcos Daniel de Almeida Leite

Ocean Research Project

Nicole Trenholm

May 2022

Go-Marie Project

Contents

1. Introduction

Tomer and Daniel (MTG's mappers) spent a week in the Chesapeake Bay setting up and testing the multibeam R2 Sonic 2026 onboard the RV Marie Tharp, a 22m overall Bruce Roberts steel schooner. A Patch Test was performed over a shipwreck, and the team surveyed an extra area to validate and achieve the project's goal (Bathymetric and Water Column data). RV Marie Tharp will be the home for the Ocean Research Project 2022 Expedition - GO-MARIE, which will collect bathymetric data on uncharted areas of the Greenland coastline.

2. Marie Tharp Survey System

Multibeam - R2 Sonic 2026

The system was the portable Multibeam Echo sounder (MBES) 2026, manufactured by R2 Sonic. The system was attached to a Universal Sonar Mount (USM), the Extruded Aluminum Foil Z Pole model (12”) on the starboard bow of the Marie Tharp (Figure 1). The IMU was mounted directly on the R2Sonic multibeam system mount bracket. The GNNS antennas were installed over the Marie Tharp’s cockpit. The Sonar Interface Model (SIM) was installed on the Science Lab (Figure 2).

Figure 1: 2026 mounted on the USM pole.

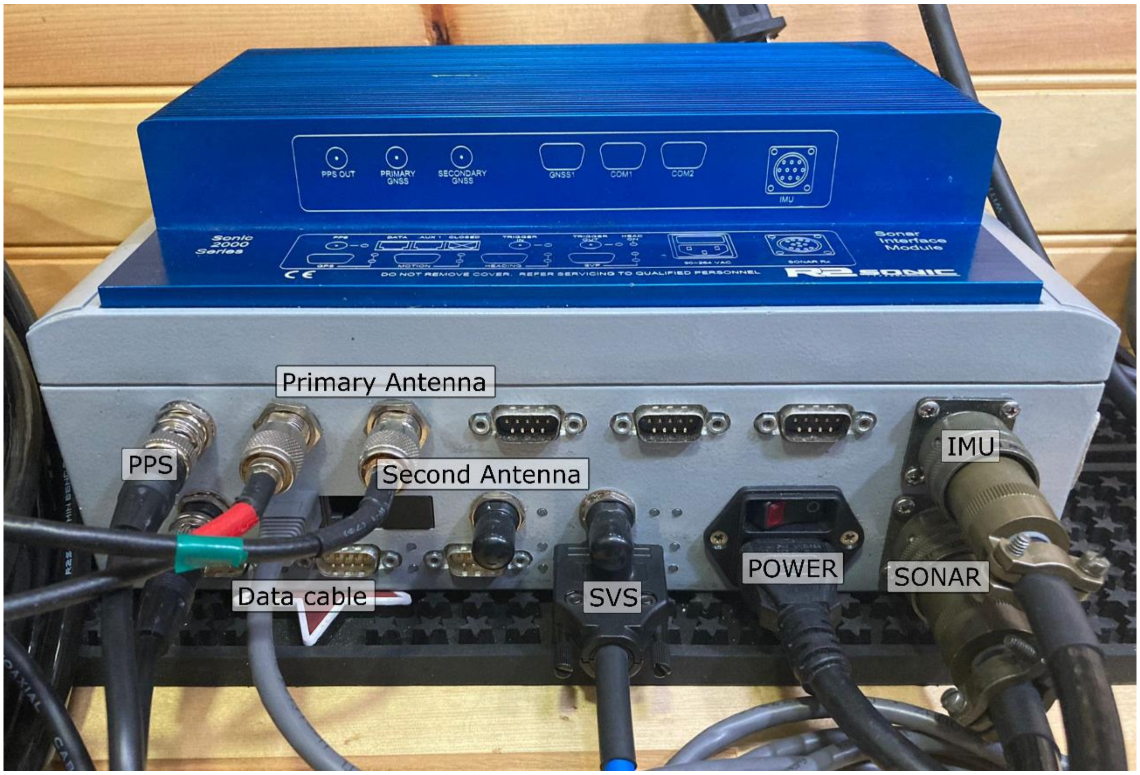


Figure 2: Sonar Interface Model (SIM)

Inertial System – Applanix Wavemaster I

The inertial system was the R2SONIC I2NS SIM Box and IP68 IMU (Figure 3). The R2Sonic I2NS processing and interface are integrated into the SIM. The SIM has connections for the dual GNSS antennas, the IMU, as well as serial input/output ports.

Figure 3. Applanix Wavemaster I; left – SIM; right – IMU.

Sound Velocity Profiler – CTD

Sound velocity profiler was obtained by the RBR *concerto* C.T.D. Which measures conductivity, temperature and depth up to 2000m (dbar) (Figure 4).

Figure 4. CTD

3. Marie Tharp Center of Rotation (CoR) and Offsets

The Vessel CoR was defined on the top of a screw between the cockpit and the mainmast, following the 2/3 rule (Figure 5 – red star). The vertical reference frame established is right-handed: X-axis is +ve forward, Y +ve starboard, and Z +ve downward.

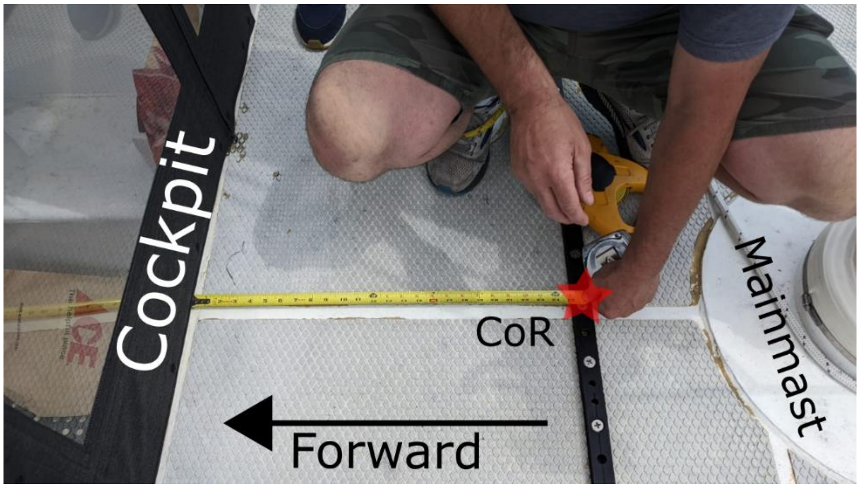


Figure 5. Red star - Vessel CoR

A scheme of the Marie Tharp offset's details is presented in Figure 6. The following points were surveyed using a tape measure, and the units are based on the metric system

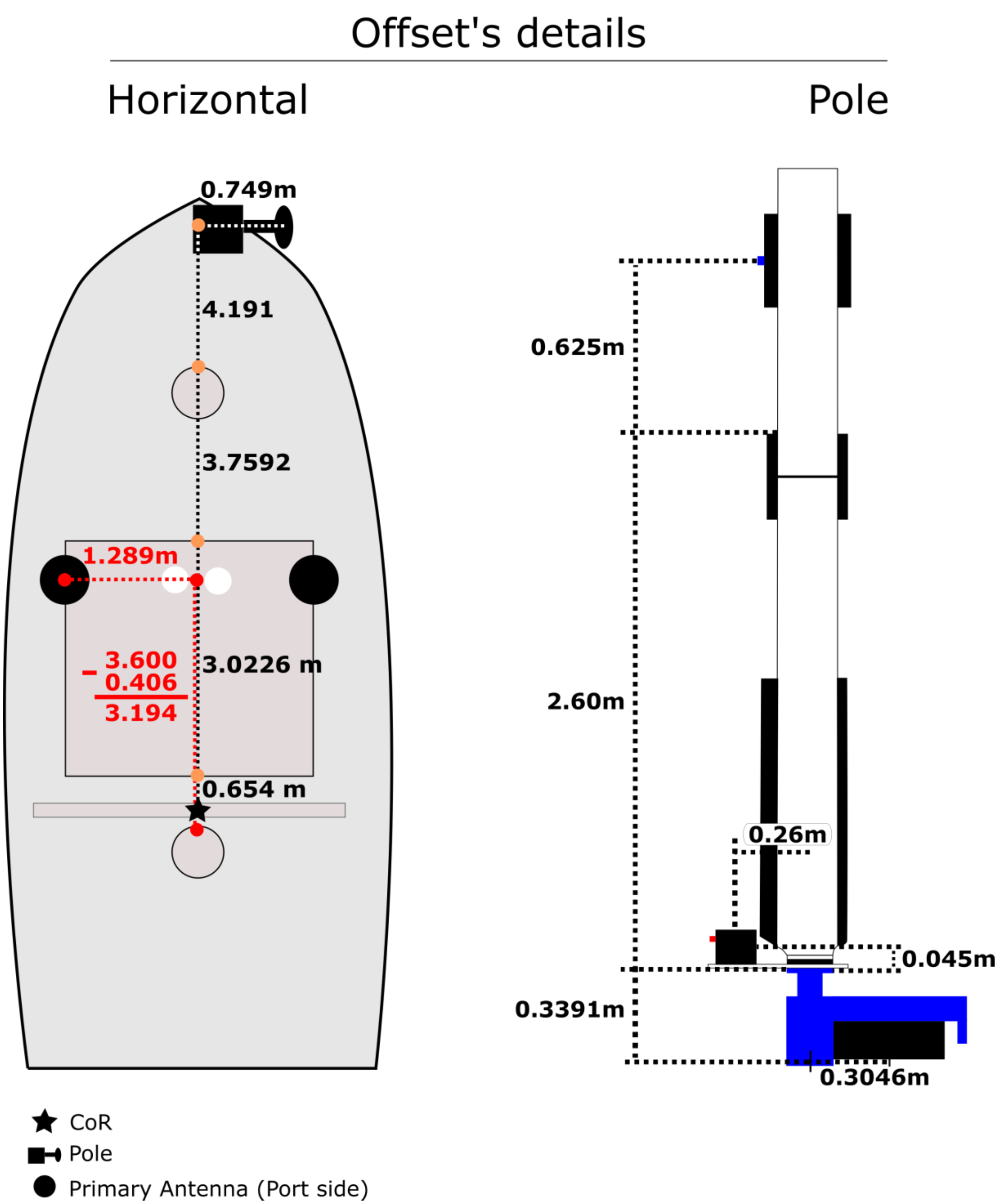


Figure 6. Marie Tharp details offsets.

The final measurements offset for both horizontal and vertical is presented in Figure 7 and Table 1.

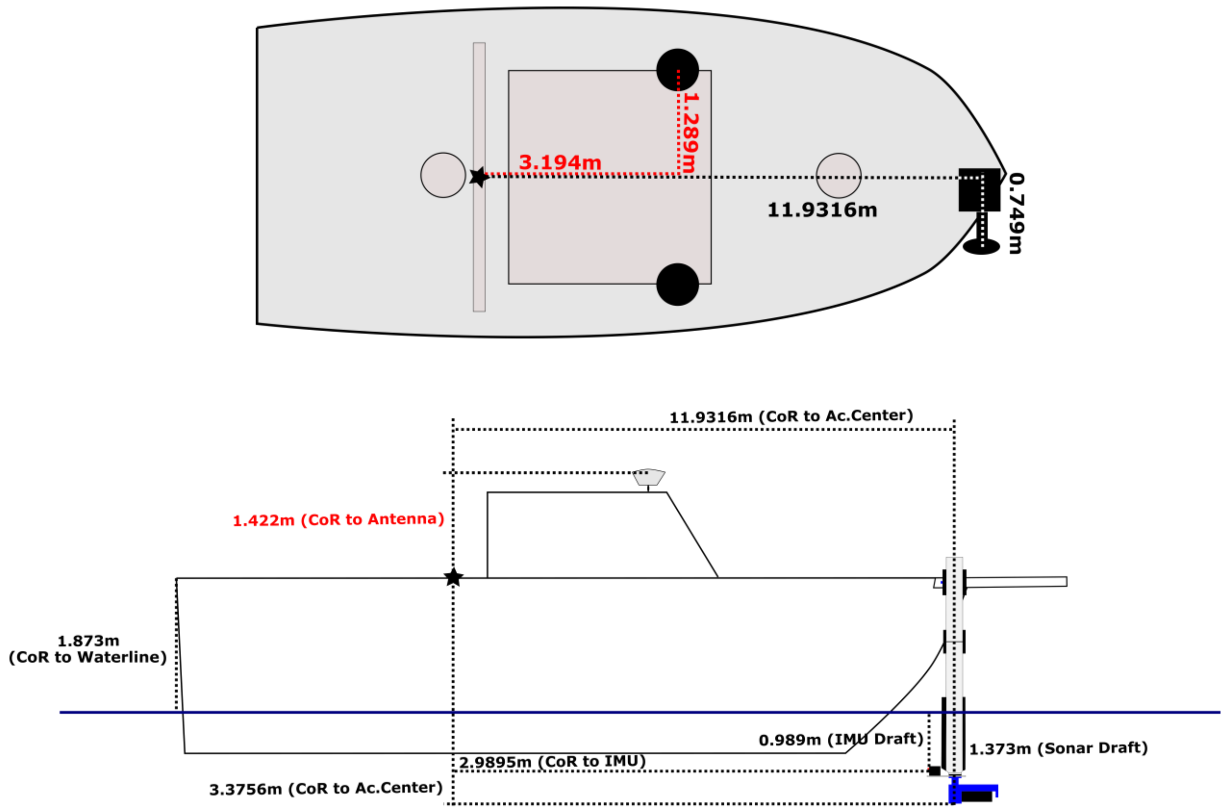


Figure 7. Marie Tharp offset.

Table 1. Marie Tharp offset.

Description	X	Y	Z
Sonar	11.9316	-0.749	3.3756
IMU	11.3668	-0.749	2.9895
Antenna	3.1940	1.2890	-1.422

4. Computer Software

Table 2: Software.

Manufacturer	***Software Name***	***Version***	***Use***
QPS	QINSy	9.3.1	Line planning, navigation, and data acquisition
QPS	Qimera	2.5.3	Patch Test, multibeam data processing, and quality control
Applanix	POS MV/ PosView	10.5	Navigation/Inertial data

Manufacturer	***Software Name***	***Version***	***Use***
RBR	Ruskin	6.13	CTD data converting to suitable for Sound Speed Manager format
HydrOffice	Sound Speed Manager	1.1.7	CTD data processing and conversion to .asvp format.
Esri	ArcGIS Desktop	10.7	Image Creation for Reports
Microsoft	MS Office	2016	Report Writing

5. Wiring Diagram

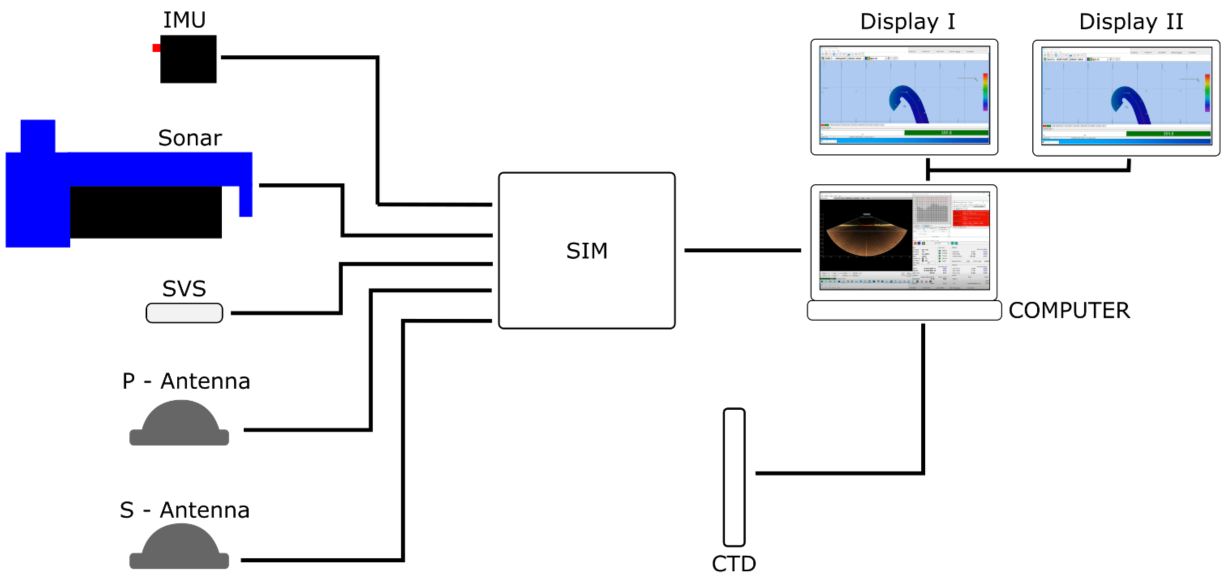


Figure 8. Wiring Diagram

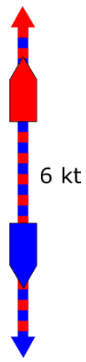
6. System Alignment

GNSS Azimuth Measurement Subsystem (GAMS)

GAMS uses two GNSS receivers and antennas to determine a GNSS-based heading. The leveling occurs in two steps. First, the IMU performs a leveling routine to establish a locally level reference frame. Secondly, the IMU begins to align itself to the true north (gyrocompassing). The gyrocompoassing alignment occurs through maneuvers, such as full turns, S-curves, and figure-of-eight turns. It took around 20 minutes to complete.

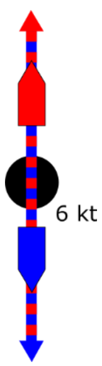
Patch test

Two patch test was carried out to determine the misalignment between the transducer and the IMU. The patch test followed the method presented in Figure 9. The patch test #1 was collected without differential correction, and the Path Test #2 was performed using RTX correction (Figure 10). The location for the patch test was a shipwreck located at the Chesapeake Bay. The depths in the Patch Test area ranged from 10 up to 17m. Before the patch test method, the crew collected a sound speed profile. The patch test was processed in Qimera software, and the result was entered into the QINSy Vessel Configuration file.



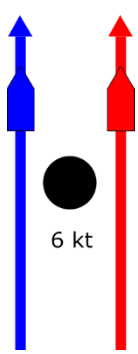
Roll:

- Boat pass above a flat featureless area.
- Opposite directions.
- Same line
- Same vessel speed: 6 knots.



Pitch:

- Boat pass above a feature, e.g. Cod Rock.
- Opposite directions.
- Same line
- Same vessel speed: 6 knots.



Yaw:

- Boat passes next to a feature, e.g. Cod Rock.
- Boat passes above the object but we use the outer beams to capture the slope.
- Boat will go in same directions.
- 2 different lines
- Same vessel speed: 6 knots

Figure 9. Patch test feature method.

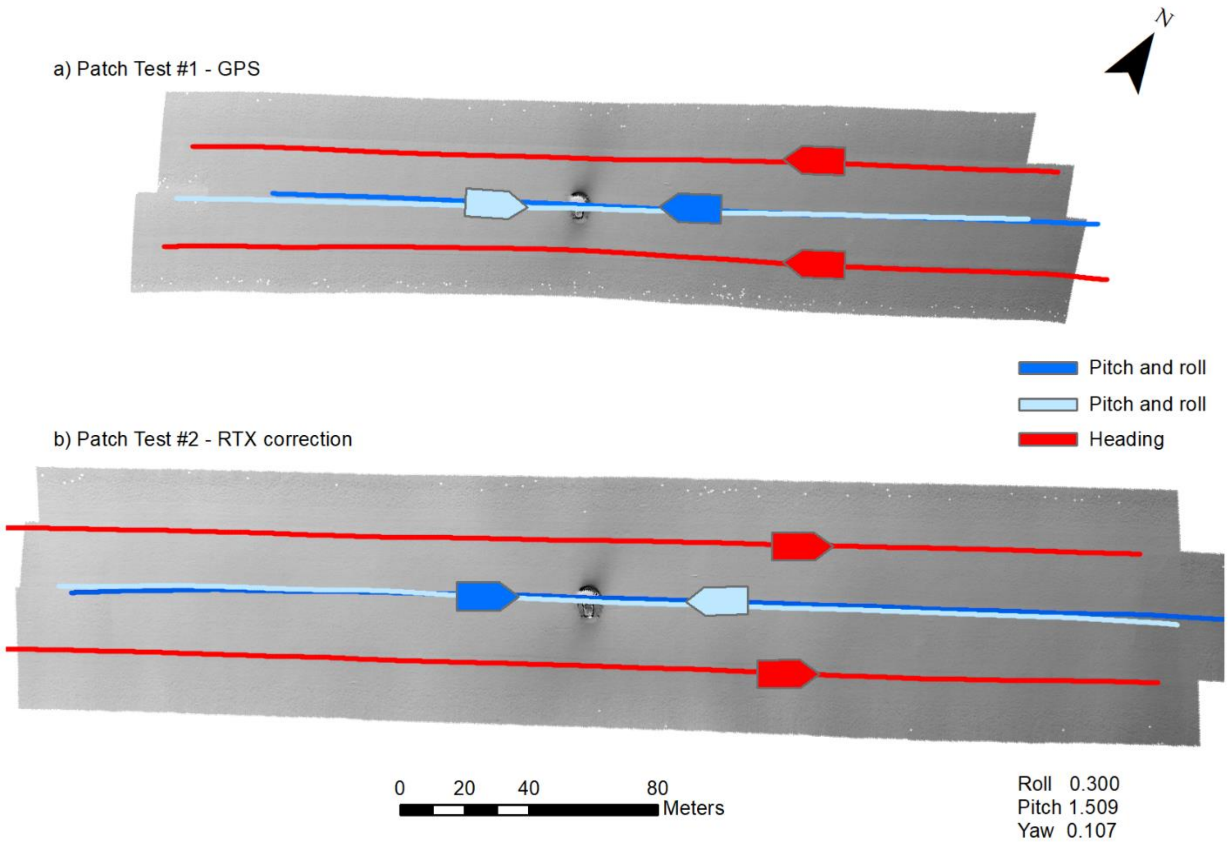


Figure 10. Patch test lines

Table 3: System alignment correctors.

Echosounder	R2 Sonic 2026	
Date	2022-04-19	
Patch Test Values		Corrector
	Pitch	1.509 degrees
	Roll	0.300 degrees
	Yaw	0.107 degrees

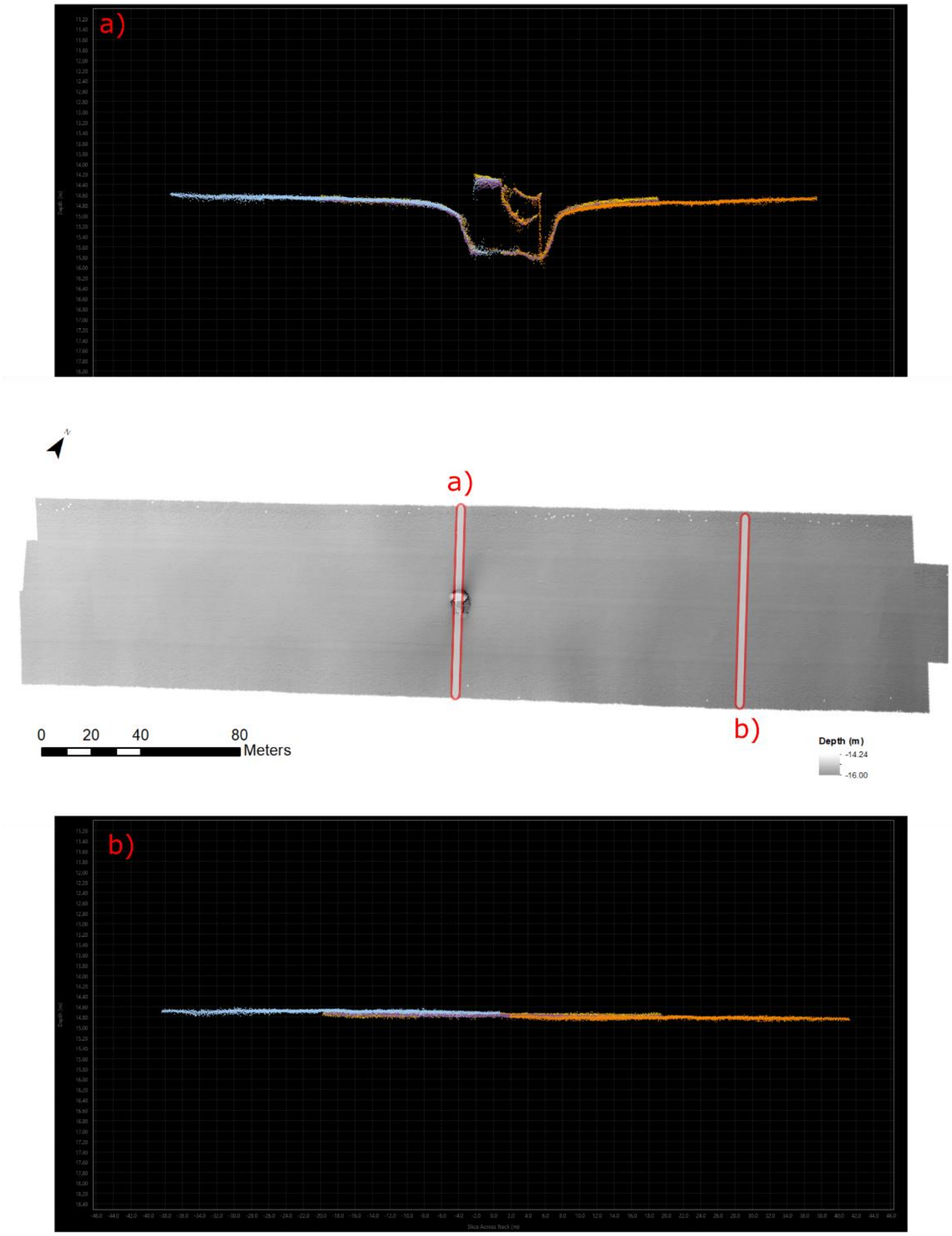


Figure 11: a) Pitch and Heading; b) roll

7. Data Acquisition, Troubleshooting and Quality

The team selected an area to validate the roll, pitch, and yaw angle corrections found. A series of parallel lines (main scheme) and one orthogonal line (crossline) were collected on the chosen site. The chosen location also had a shipwreck (Figure 12 - red box), and the depth ranged from -11 up to -14m.

While surveying, the R2 sonic control software froze a couple of times due to the massive amount of water column data. The troubleshooting was to decrease the sonar ping rate. As a net result, data gridded at 0.25m showed bias and holidays (Figure 12 and 13 - white squares across the main scheme). Besides, when the R2 sonic control software crashed, the log raw sensor data was corrupted, and the heave effect on the data could not be corrected.

The data quality was accepted for IHO Special Order. As you can see, the crossline to main scheme sounding data analysis was performed in Qimera software with the Cross-Check tool (Figure 14). Additionally, two CUBE surfaces were created for the main scheme lines and crossline, where their difference grid was calculated. The statistics output of the Qimera Cross-Check tool is presented in Figure 14. Figure 13 shows the surface difference between the main scheme and the crossline. Both Cross-Check tool statistic output and difference grid statistic revealed a 0.1m mean difference with a standard deviation of about 0.05m.

Overall the team achieved the main goal. However, for the Ocean Research Project 2022 Expedition - GO-MARIE, the team must buy a powerful computer to handle the massive data (water column). The current data did not reach more than 20 meters, and decreasing ping rate resulted in holidays. For Greenland, where the team expects depths to reach up to 800m, keeping the current computer will result in more significant holidays or crashed raw data.

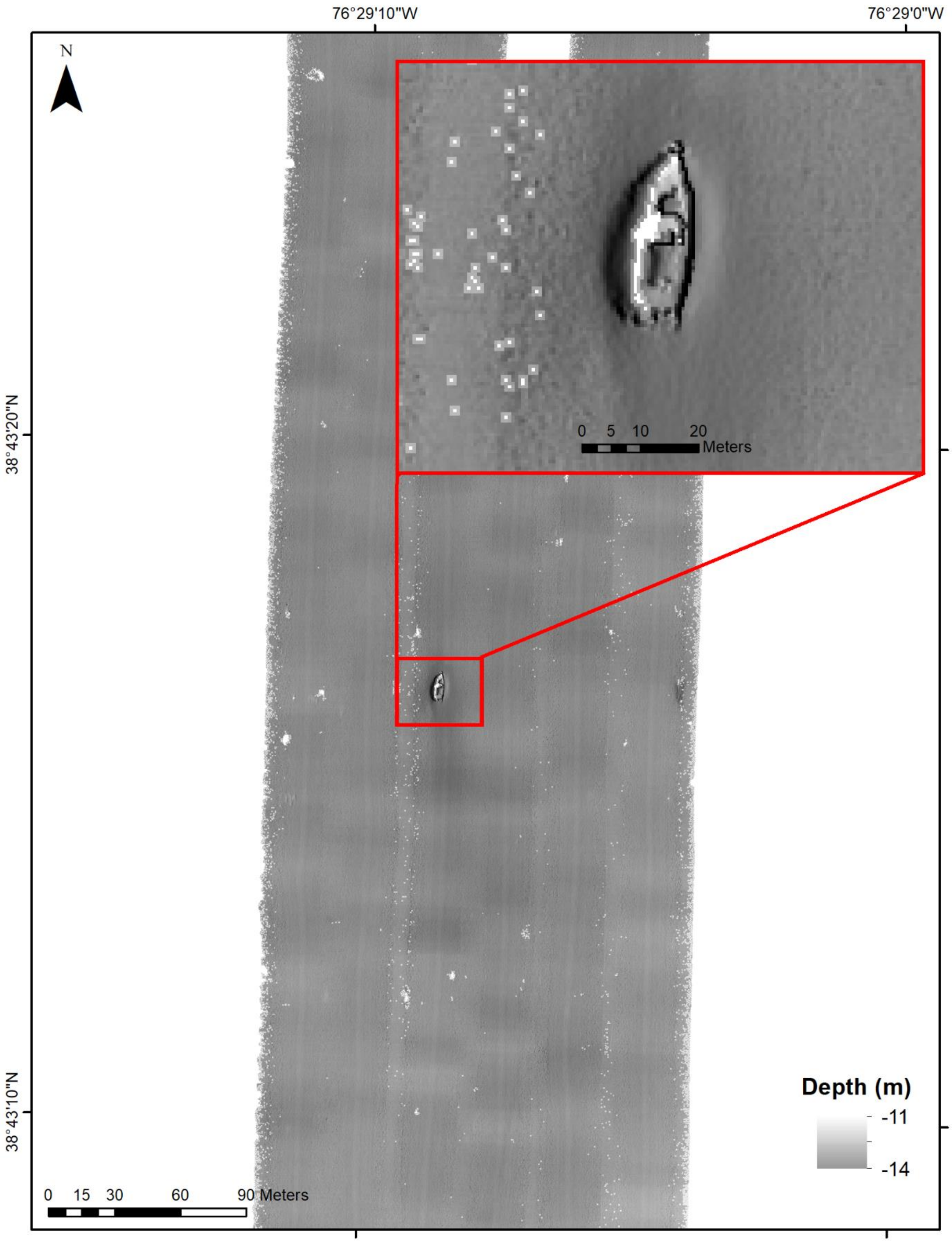


Figure 12: Validation area; Red box - shipwreck

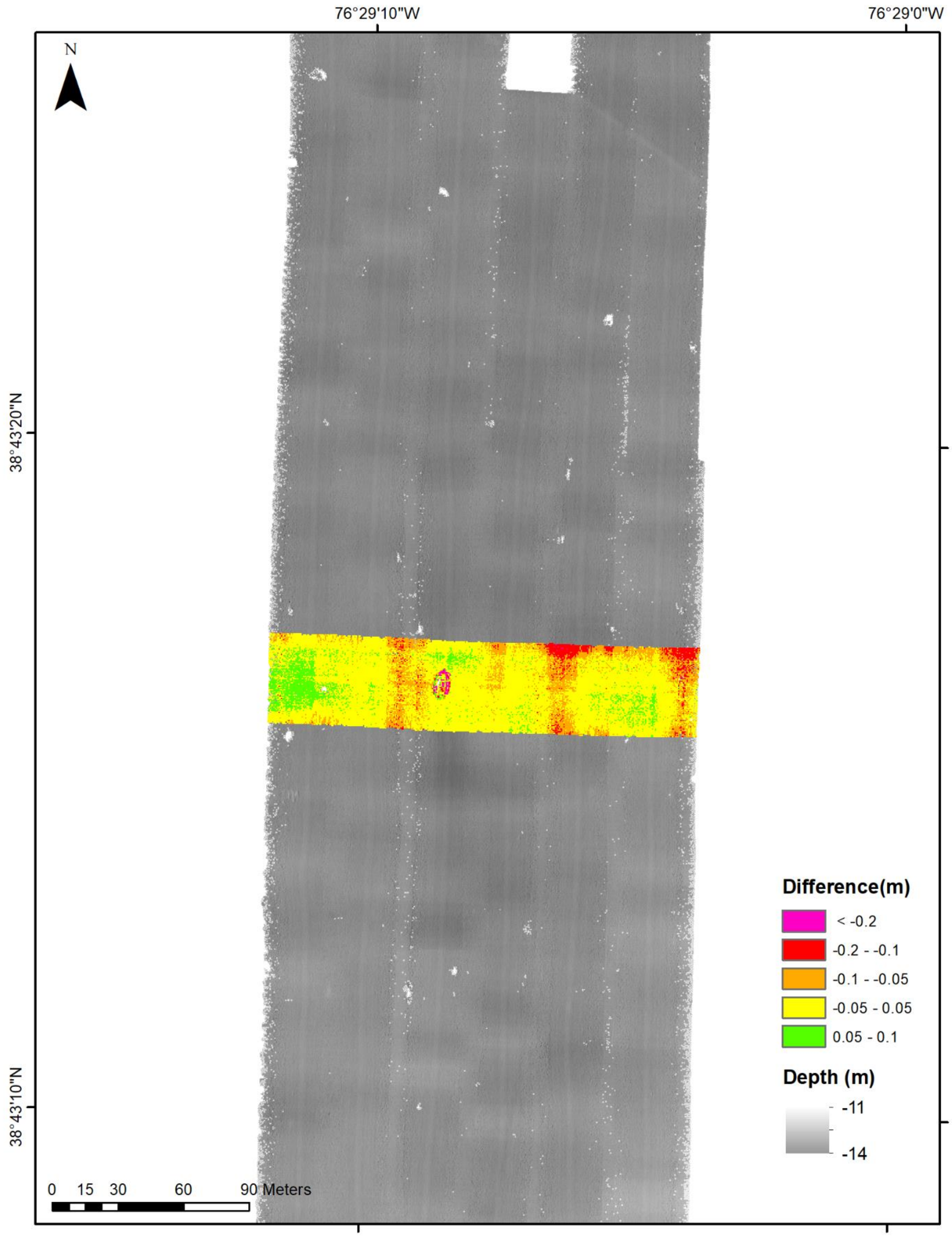


Figure 13: Difference between crossline and main area.

Figure 14: Cross check tool in Qimera. The data was accepted for Special Order.

Appendix III:

Hydrographic Systems Modifications & Patch Test in Greenland

A scheme of the Marie Tharp offset's details is presented in Figure 6. The following points were surveyed using a tape measure, and the units are based on the metric system.

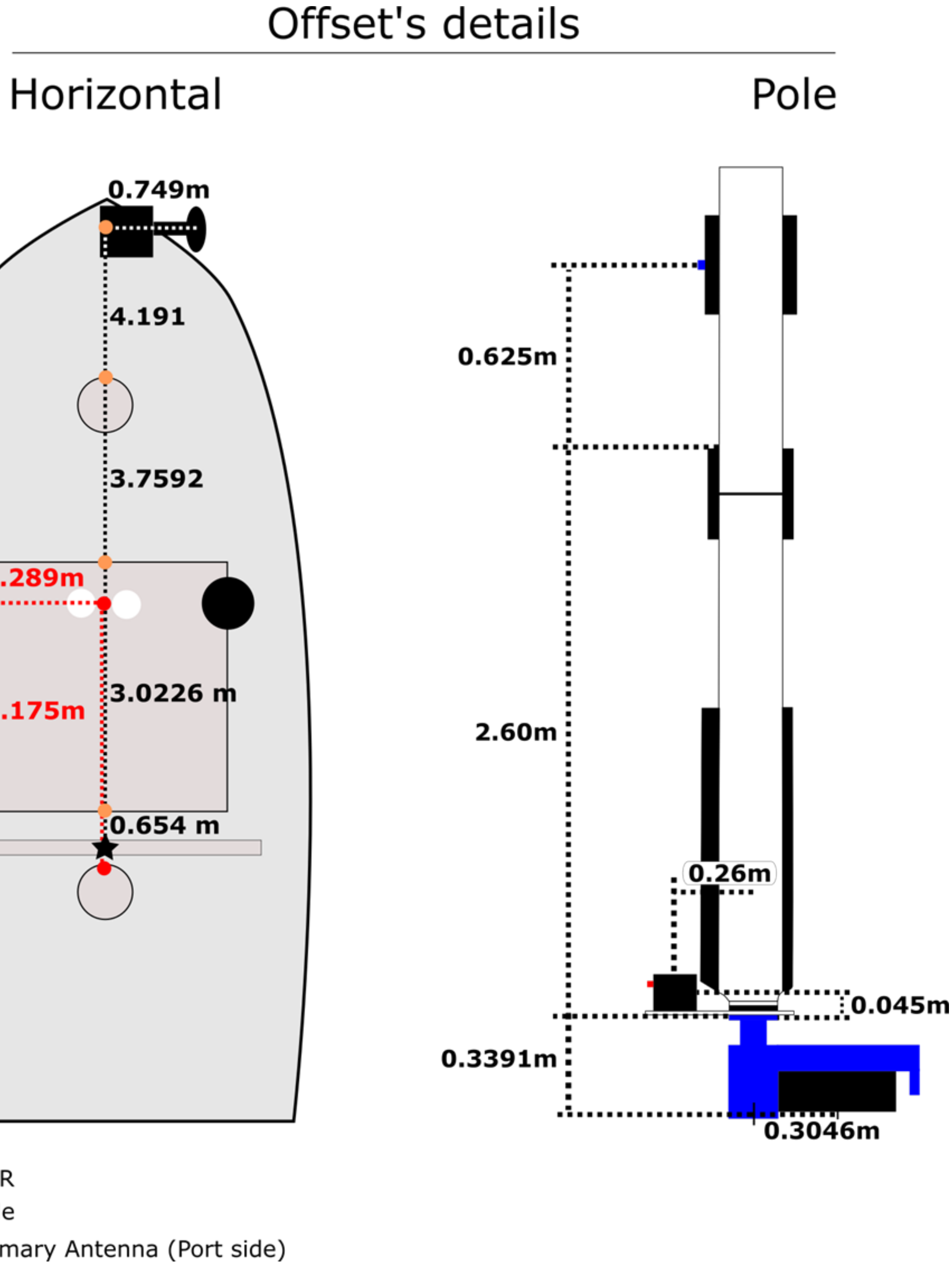


Figure 6. Marie Tharp details offsets.

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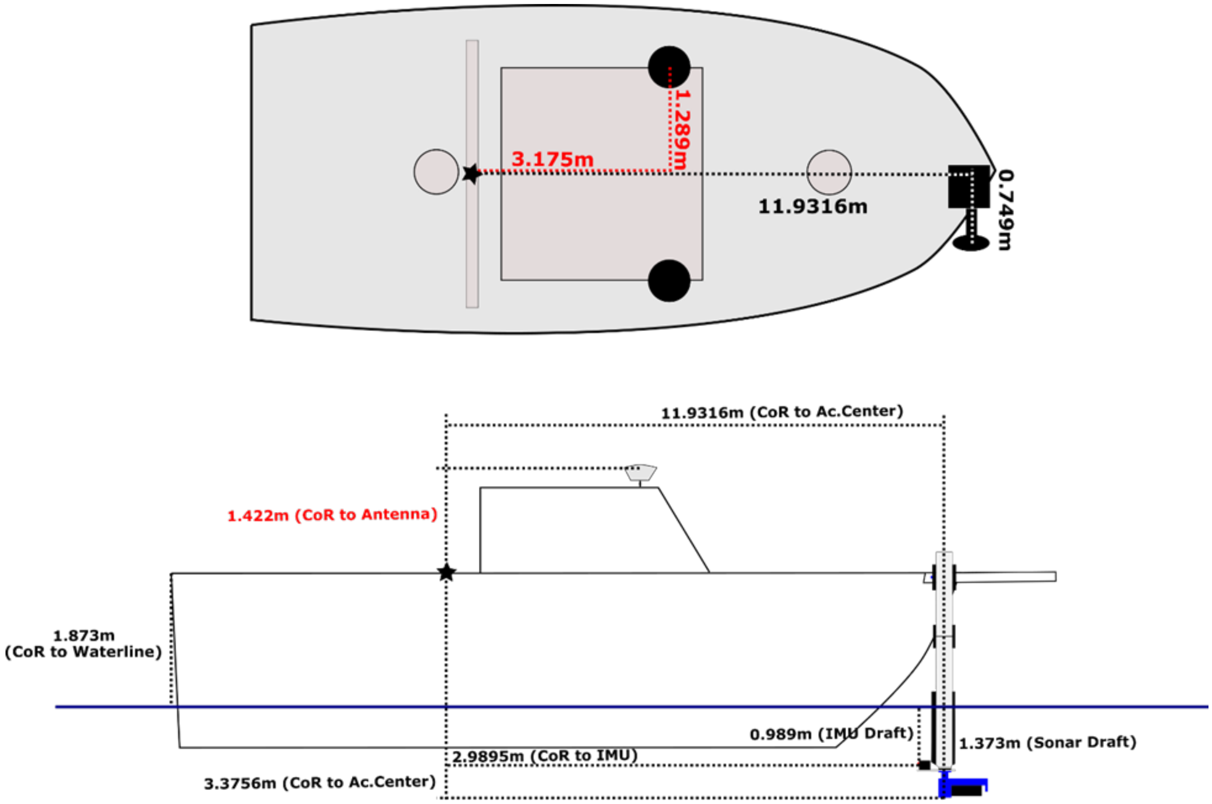


Figure 7. Marie Tharp offset.

Table 1. Marie Tharp offset.

Description	X	Y	Z
Sonar	11.9316	-0.749	3.3756
IMU	11.3668	-0.749	2.9895
Antenna	3.1750	-1.2890	-1.422

1. Cabling Diagram

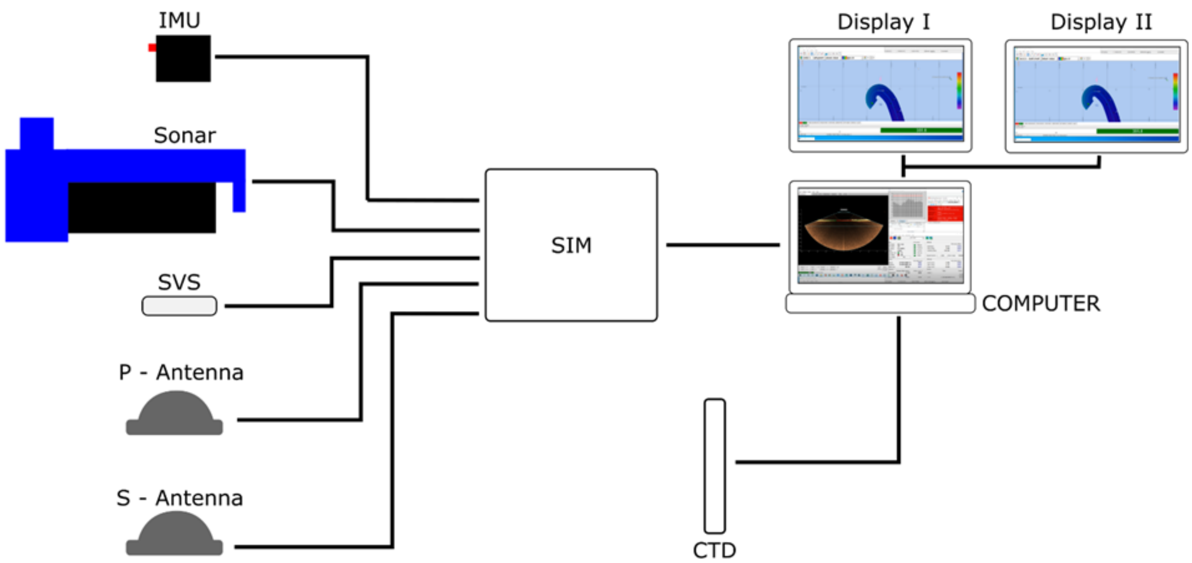


Figure 8. CablingDiagram

2. System Alignment

2.1. GNSS Azimuth Measurement Subsystem

GAMS uses two GNSS receivers and antennas to determine a GNSS-based heading. The levelling occurs in two steps. First, the IMU performs a levelling routine to establish a locally level reference frame. Secondly, the IMU begins to align itself to the true north (gyrocompassing). The gyrocompoassing alignment occurs through manoeuvres, such as full turns, S-curves, and figure-of-eight turns. It took around 35 minutes to complete.

2.2. Patch test

The patch test was carried out to determine the misalignment between the transducer and the IMU. The patch test followed the method presented in Figure 9. The location for the patch test was a channel close to Paamiut and flat bottom at the Kuannersooq

Vanefjord. The depths in the Patch Test area ranged from 50 up to 295m. Before the patch test method, the crew collected a sound speed profile. The patch test was processed in Qimera software.

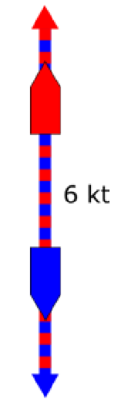
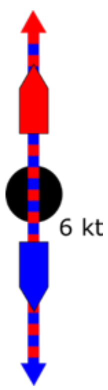
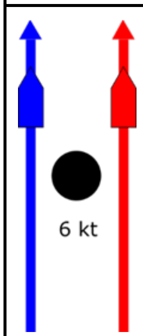
<table>
<tr><td></td><td>Roll :
Boat pass above a flat featureless area.
Opposite directions.
Same line
Same vessel speed: 6 knots</td></tr>
<tr><td></td><td>Pitch:
Boat pass above a feature, e.g. Rock.
Opposite directions.
Same line
Same vessel speed: 6 knots</td></tr>
<tr><td></td><td>Yaw:
Boat passes next to a feature, e.g. Cod Rock.
Boat passes above the object but we use the outer beams to capture the slope.
Boat will go in same directions.
2 different lines
Same vessel speed: 6 knots</td></tr>
</table>

Figure 9. Patch test feature method

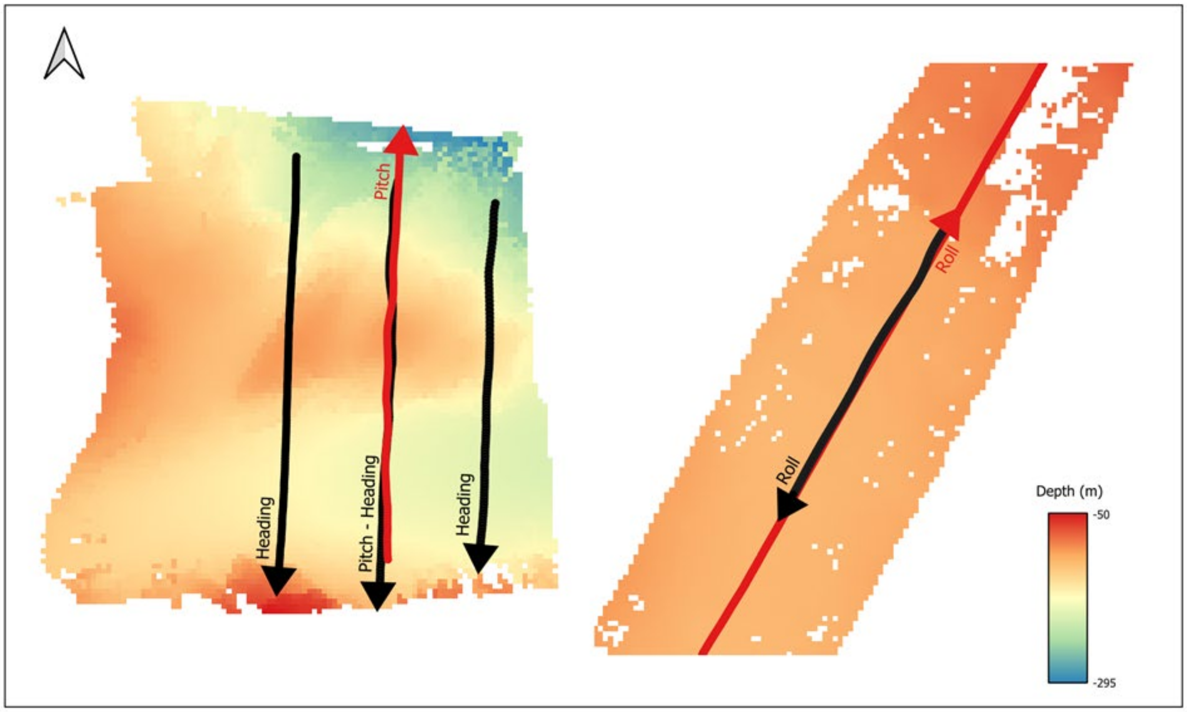


Figure 10. Patch test lines

- SVP

Table 3: System alignment correctors

Echosounder	R2 Sonic 2026	
Date	2022-07-23	
Patch Test Values		Corrector
	Pitch	0.800 degrees
	Roll	0.230 degrees
	Yaw	-0.100 degrees

3. General Bathymetric Processing Parameters

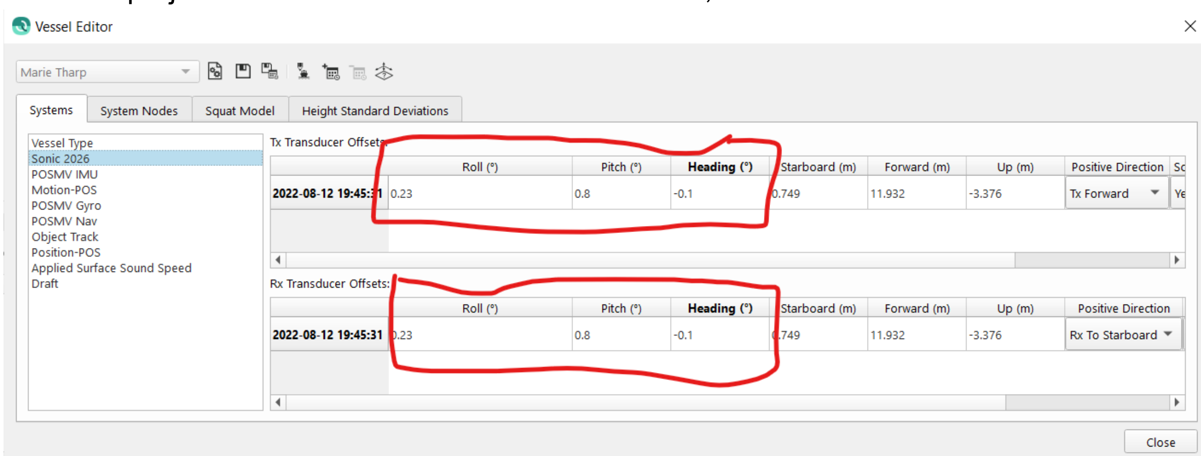
Preliminary processing and QC was done on board the vessel in times surveying was not possible due to weather or other considerations. Specific processing notes and exclusions are reported below for each survey area where applicable.

3.1. Data import

Raw multibeam data from the R2Sonic is logged by QINSY in proprietary .db format including all datagrams from the sounder, including beam angle, range, TruePix, Intensity (seafloor backscatter), snippets (sidescan) and full-trace water column amplitudes (during our survey we only collected water column in certain locations due to the large network throughput and storage requirements of 1gb per minute).
The various QINSY projects from this survey are opened natively in Qimera and a .qpd file is created for each .db file. The QPD holds all the navigation, processing and edits applied to each sounding.

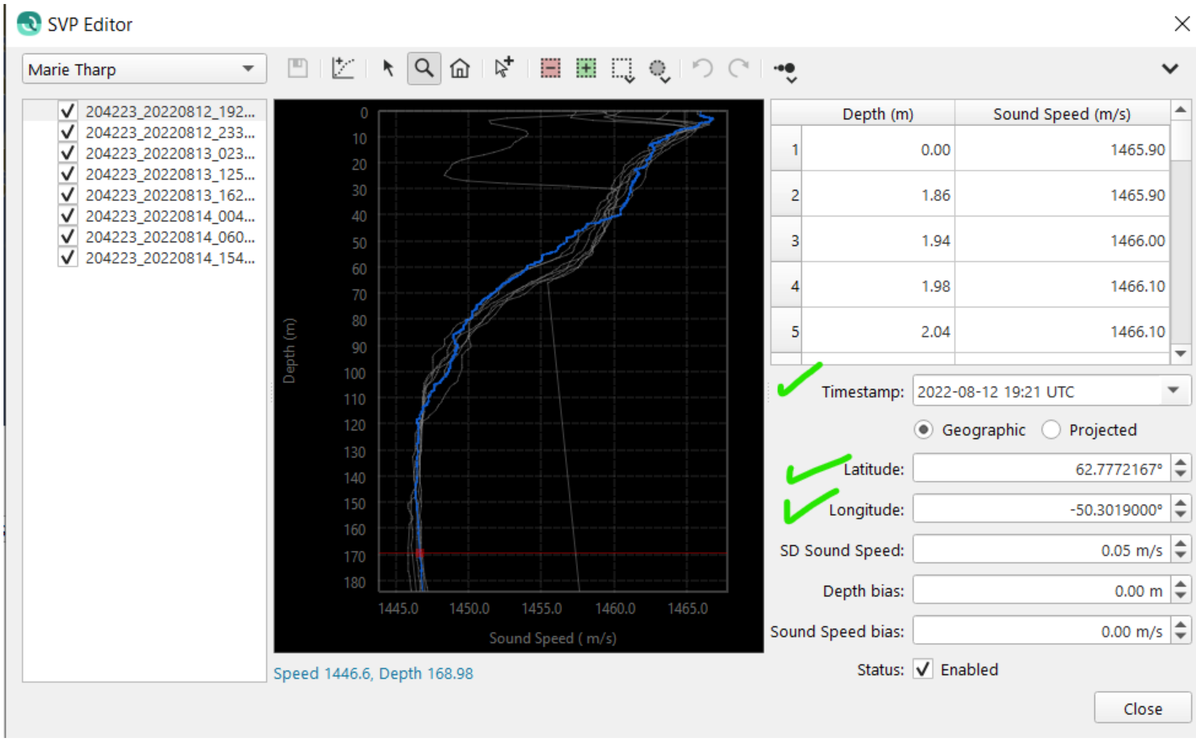
3.2. Vessel configuration

Lever arms are pre-configured in QINSY however patch test calibration values are input in each QIMERA project for the Sonic 2026 Tx and Rx for Roll, Pitch and Yaw as below:

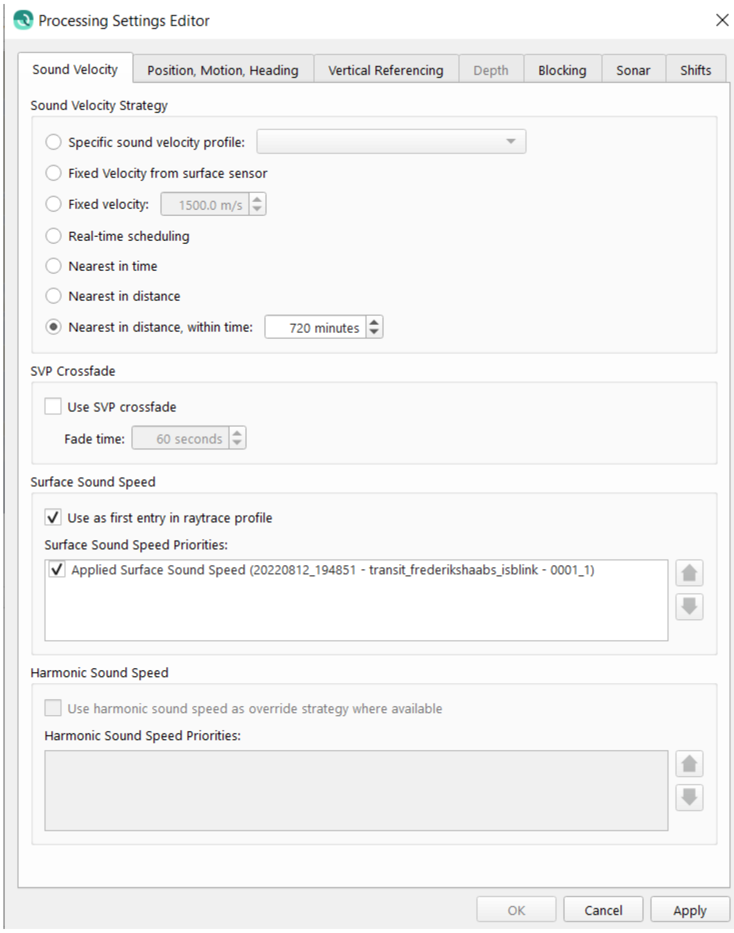


3.3. SVP

CTD casts acquired by the RBR were downloaded from the instrument via wireless link and exported in comma delimited text files which were subsequently imported and processed in Sound Speed Manager. Each cast was exported in the Kongsberg .asvp format which is readable by Qimera, and tagged with UTC time and date as well as Lat/Lon coordinates when imported into Qimera.



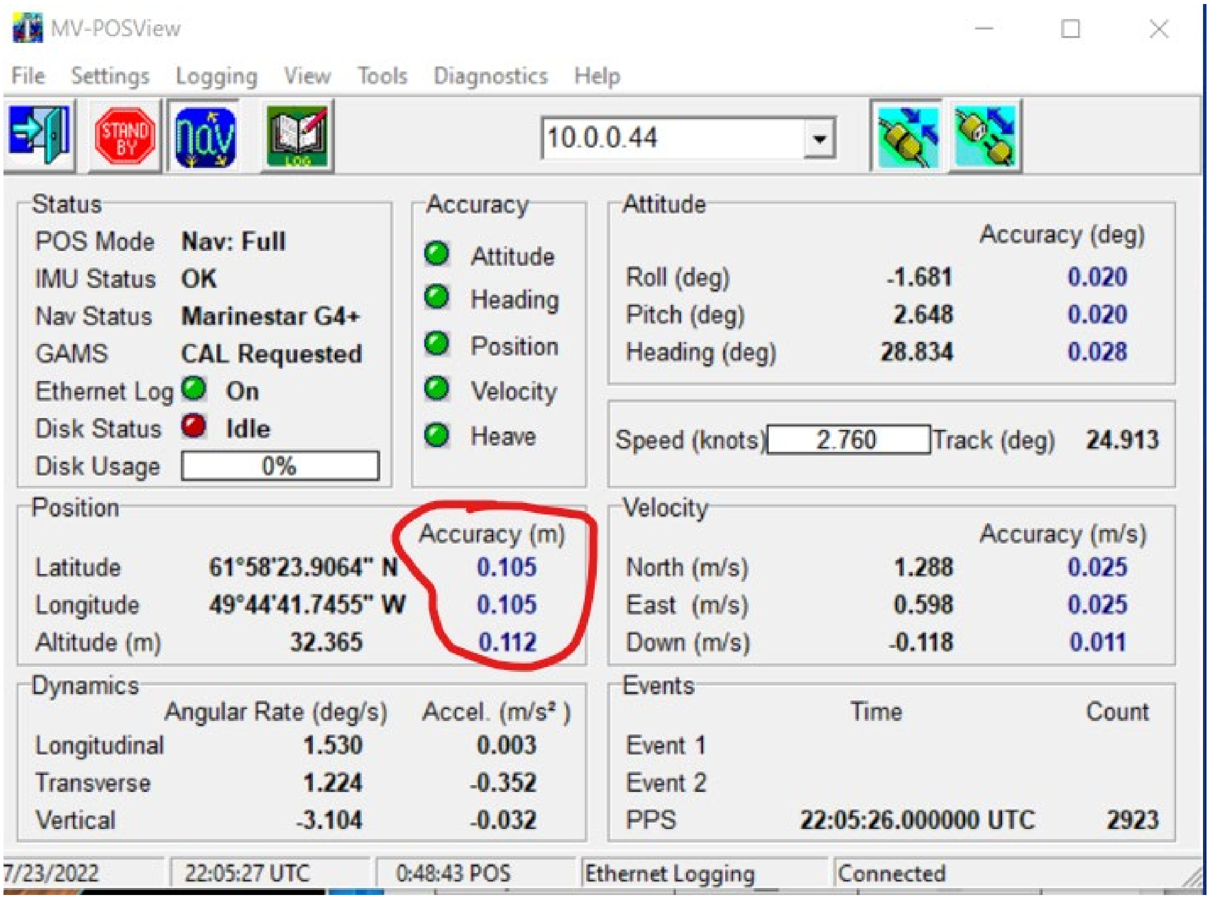
Sound Velocity strategy applied is Nearest in Distance within time (720min).



3.4. Navigation & Motion

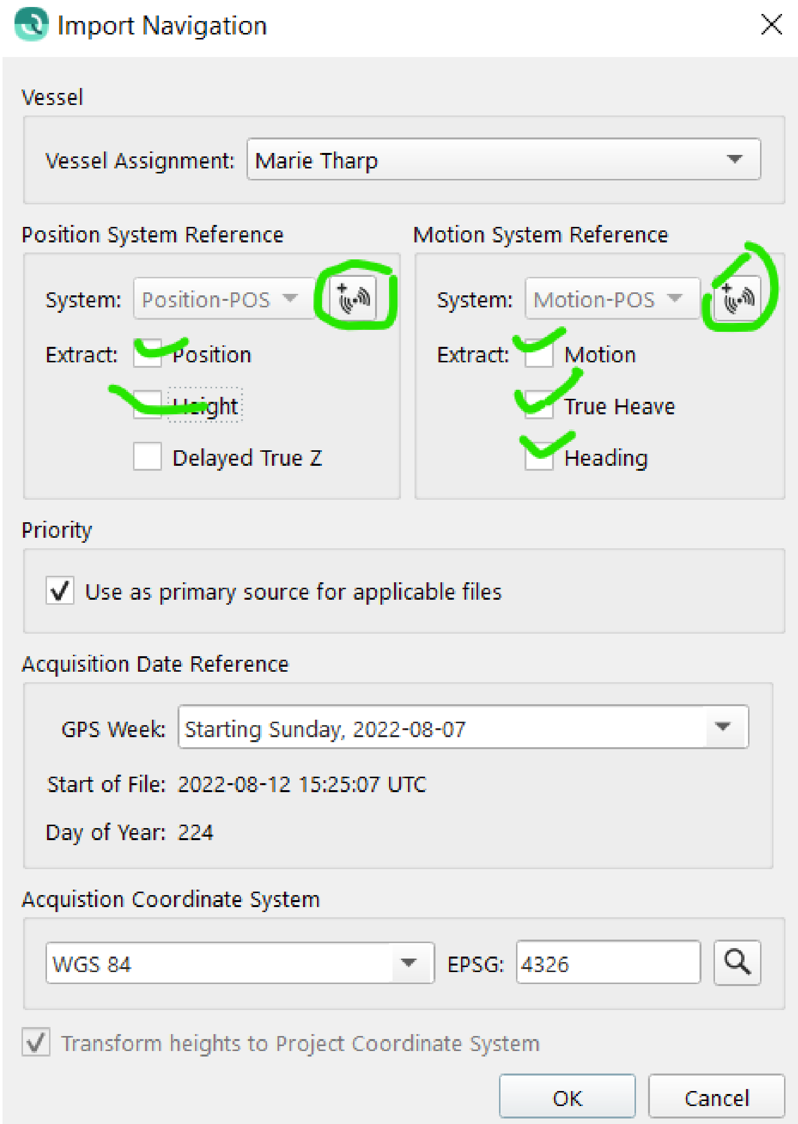
The R2sonic has an integrated POS-MV board with WaveMaster II specification level (0.02º) providing real-time horizontal position and heading, as well as delayed heave (after logging) and Height when RTK solution is available.

For this survey we had an integrated DGNSS Trimble MarineSTAR G4+ subscription which provided us with 0.1m (decimeter) level accuracy in X, Y and Z axes. When available, the



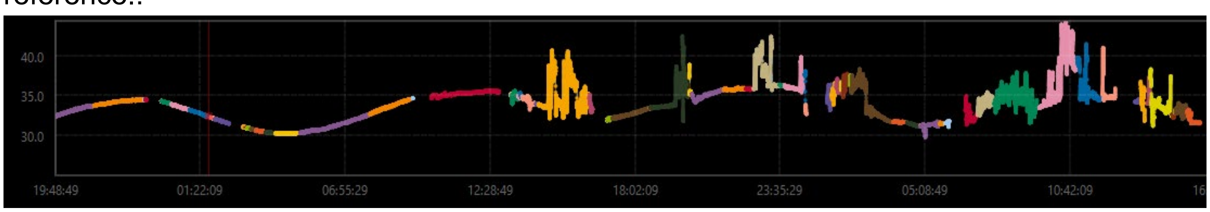
MarineSTAR G4+ may be used for vertical referencing, however due to the high latitudes surveyed, the DGNSS signal was blocked on many occasions while surveying in narrow and steep fjords surrounded by cliffs rising at times to 1,000m above sea level. The satellite broadcasting the correction is about 20 degrees above the horizon in the south.

The import process in Qimera (Source> add binary navigation files) requires the user to define a new system for positioning and one for motion, by simply entering a name and uncertainty levels (0.02deg for this system). Check the boxes shown:



3.5. Vertical Reference

While the G4 signal is good we can use this method as vertical reference to the WGS84 ellipsoid. However, when the signal is lost, there are large errors in the elevation measurement. See here (Qimera NAV editor) the 4m tide cycle while reception is clear and the spikes when the signal is lost. this might require more work in PosPac to be able to apply ellipsoid vertical reference.:



Hydrographic Systems Modifications & Patch Test in Greenland

For now we are using instantaneous water level and that will require PP-RTX post processing solution for a better accuracy in vertical positioning solution.