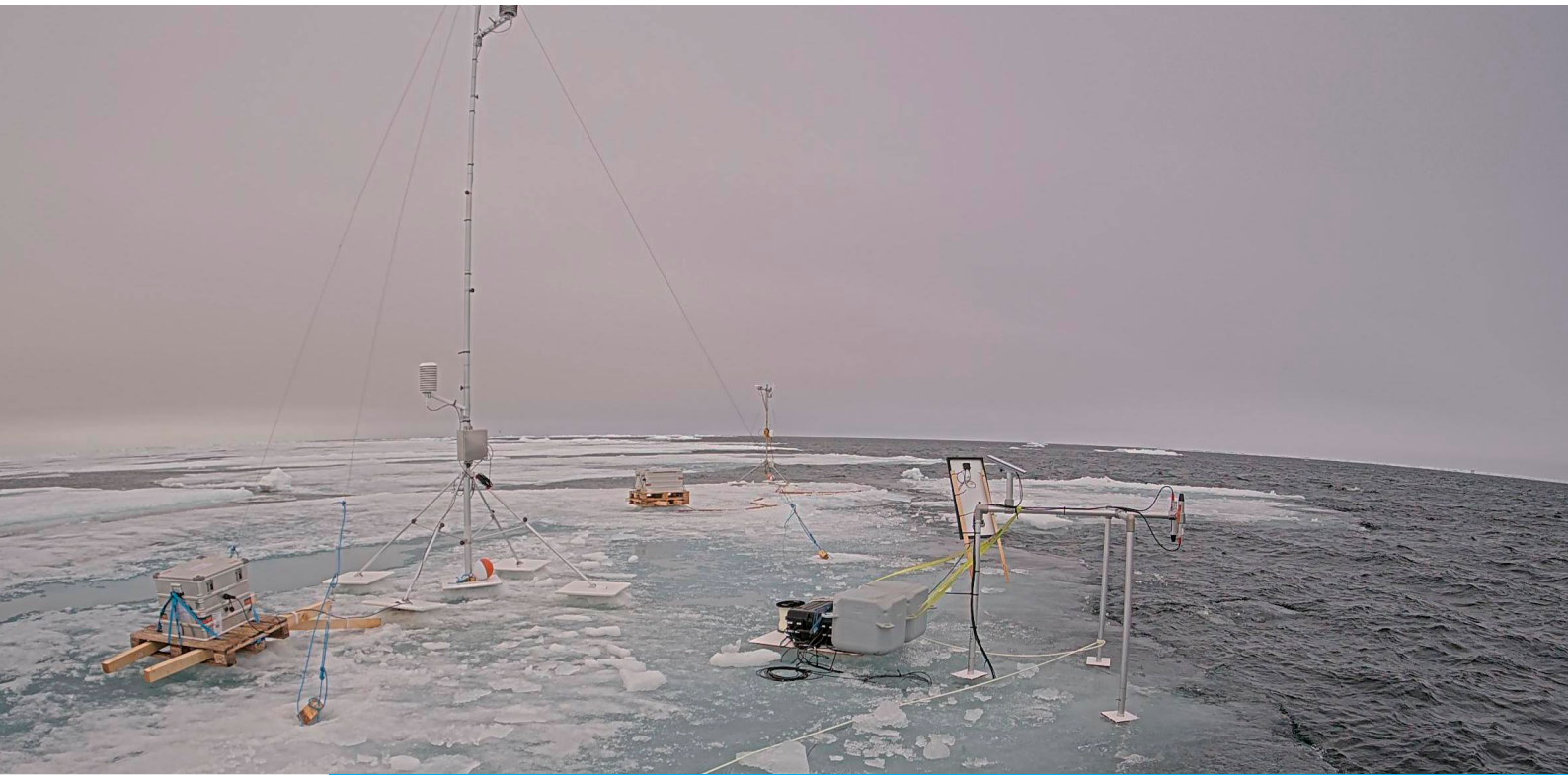




808
2026

Berichte

zur Polar- und Meeresforschung

Reports on Polar and Marine Research

**The Expedition PS149
of the Research Vessel POLARSTERN
to the Arctic Ocean in 2025**

Edited by
Marcel Nicolaus

with contributions of the participants

Die Berichte zur Polar- und Meeresforschung werden vom Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) in Bremerhaven, Deutschland, in Fortsetzung der vormaligen Berichte zur Polarforschung herausgegeben. Sie erscheinen in unregelmäßiger Abfolge.

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Titel: Das Foto zeigt den 10-m hohen Wettermasten (links), die Energiebilanzstation (im Hintergrund) und eine Strahlungsstation (rechts) auf der Eisstation in Regime 1. Dies ist das letzte Foto von der autonomen Kamera vom 5. August um 15:29 UTC. Danach ist die Scholle weiter geschmolzen und zerfallen.

Title: The photo shows the 10 m high weather mast (left), the energy balance station (in the background) and a radiation station (right) on the ice station in Regime 1. This is the last photo taken by the autonomous camera on 5 August at 15:29 UTC. After that, the floe continued to melt and disintegrate.

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Please cite or link this publication using the identifiers

<https://epic.awi.de/id/eprint/60779/>

https://doi.org/10.57738/BzPM_0808_2026

ISSN 1866-3192

PS 149 / CONTRASTS

02 July 2025 – 01 September 2025

Tromsø – Longyearbyen



CONTRASTS

**Chief scientist
Marcel Nicolaus**

**Coordinator
Ingo Schewe**

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1. ÜBERBLICK UND EXPEDITIONSVERLAUF

Marcel Nicolaus¹, Thomas Krumpen¹

¹DE.AWI

Einleitung

Der Arktische Ozean ist durch eine stark heterogene Meereisschicht geprägt, die einem ausgeprägten saisonalen Zyklus unterliegt. Dieser Zyklus wird durch die Wechselwirkungen von Atmosphäre und Ozean bestimmt und führt zu erheblichen regionalen und zeitlichen Unterschieden in Ausdehnung, Dicke, Struktur und Eigenschaften des Eises. Besonders für die Sommermonate bestehen große Unsicherheiten in Eiseigenschaften und deren Verteilung in der Arktis, während diese den Jahresgang besonders stark beeinflussen. Diese Unsicherheiten sind von zentraler Bedeutung für die zukünftige Entwicklung der Arktis und ihre Rolle im globalen Klimasystem.

Die Expedition CONTRASTS wurde durchgeführt, um diese Prozesse anhand unterschiedlicher Meereisregime systematisch zu untersuchen. Unter einem Regime wird die Kombination aus Bildungsort, Alter, Dicke und den jeweiligen atmosphärischen und ozeanischen Randbedingungen verstanden. Im Fokus standen drei charakteristische Regime: (1) einjähriges Eis nahe der Eisrandzone, das den Sommer zum Großteil nicht übersteht, (2) mehrjähriges Eis in der Transpolardrift mit einer Lebensdauer von zwei oder mehr Jahren, sowie (3) älteres, besonders dickes Eis, das vorwiegend aus dem Bereich nördlich von Kanada oder dem Beaufortwirbel stammt. Übergänge und Gradienten zwischen diesen Regimen konnten durch Beobachtungen entlang von Drift- und Stationsarbeiten identifiziert werden.

Während die MOSAiC Expedition 2019/20 einen einzigartigen ganzjährigen Datensatz lieferte, war dieser im Wesentlichen auf eine Scholle und damit auf ein einzelnes Regime beschränkt. CONTRASTS erweiterte diesen Ansatz, indem die räumliche Dimension systematisch berücksichtigt wurde. Ziel dieser Expedition war es, die zeitliche Entwicklung und die Unterschiede der Regime im Hinblick auf Strahlungsbilanz, Schmelzprozesse, Eisdicke, Energieflüsse und biologische Wechselwirkungen zu charakterisieren. Damit sollten die Prozesse, die zur regionalen und saisonalen Variabilität des Meereises beitragen, besser verstanden und quantifiziert werden.

Ein zentrales Element des Untersuchungsprogramms war der interdisziplinäre Ansatz. Bei jedem Stationsaufenthalt wurde ein identisches Beobachtungsprogramm durchgeführt, während in den Abwesenheitsphasen autonome Messsysteme weiter Daten aufzeichneten. Dies ermöglichte es, das Atmosphäre–Eis–Ozean-System während der Schmelzzeit in jedem Regime über einen Zeitraum von etwa sechs Wochen kontinuierlich zu erfassen. Das multidisziplinäre Arbeitsprogramm umfasste die Meereisphysik, atmosphärische Wissenschaften, physikalische Ozeanographie und Ökosystemstudien sowie ein ergänzendes Programm zur Kommunikation und Öffentlichkeitsarbeit.

Darüber hinaus stand CONTRASTS in direktem Zusammenhang mit früheren Expeditionen des Forschungseisbrechers Polarstern in den zentralen Arktischen Ozean, insbesondere mit MOSAiC 2019/20 sowie ArcWatch-1 (2023) und ArcWatch-2 (2024).

Die aktuelle Arbeit knüpfte unmittelbar an diese Expeditionen an und erweiterte sie durch den gezielten Vergleich verschiedener Meereisregime. CONTRASTS profitierte von einem etablierten interdisziplinären und internationalen Forschungsteam an Bord und an Land, das die gewonnenen Beobachtungen in einen größeren Kontext einordnete und damit eine wesentliche Grundlage für die Weiterentwicklung der Arktisforschung schuf.

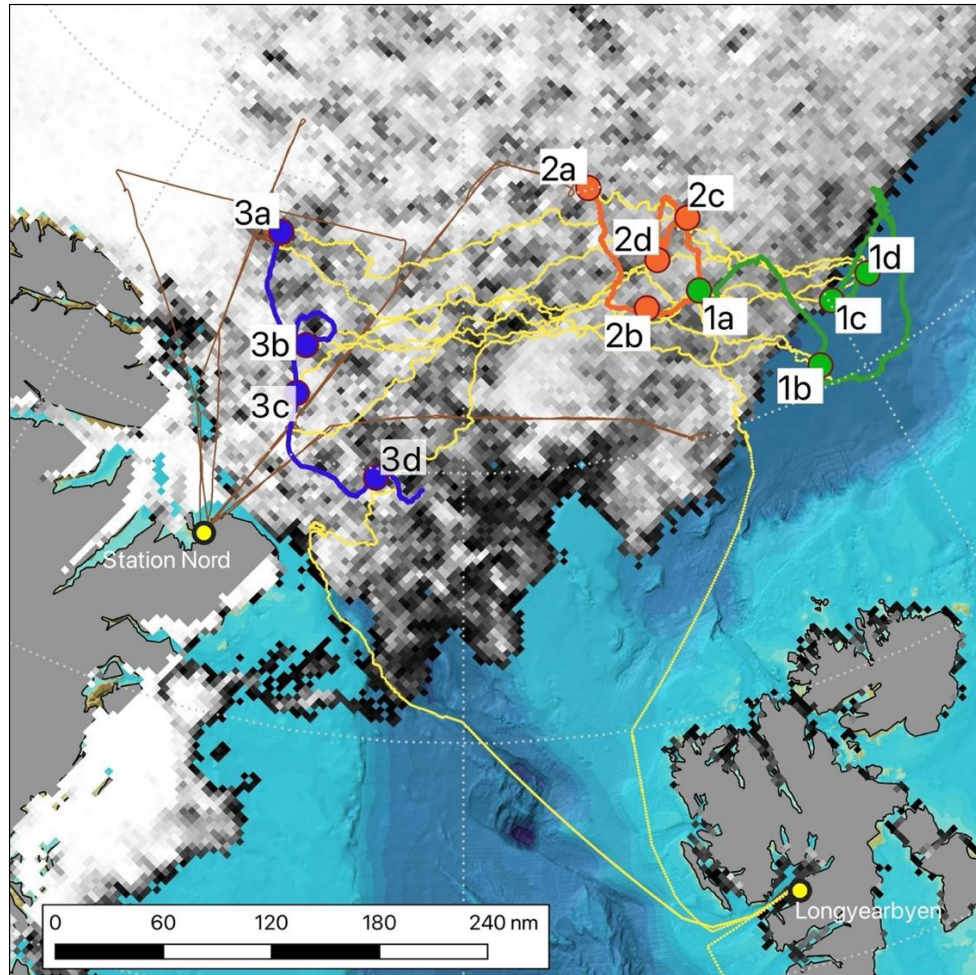


Abb. 1.0.1: Fahrtroute der Expedition CONTRASTS (PS149, ArcWatch-3). Die Polarstern Fahrtroute (gelb) ist zusammen mit der Drift der drei Eisregime (blau, orange, grün) dargestellt. Die farbigen Punkte zeigen die Eisstationen (Tab. 1.0.1). Die braunen Linien zeigen die Flüge der IceBird Summer 2025 Kampagne mit direktem CONTRASTS Bezug. Im Hintergrund ist die Meereiskonzentration vom 30. August 2025 dargestellt (www.meereisportal.de). Die Reise begann am 2. Juli 2025 in Tromsø und endete am 1. September 2025 in Longyearbyen. Siehe <https://doi.pangaea.de/10.1594/PANGAEA.987133> für eine Darstellung des master tracks in Verbindung mit der Stationsliste für PS149.

Fig. 1.0.1: Route of the CONTRASTS expedition (PS149, ArcWatch-3). The route of Polarstern (yellow) is shown together with the drift of the three ice regimes (blue, orange, green). The colored dots represent the ice stations (Tab. 1.0.1). The brown line shows the flight tracks of the aircraft campaign IceBird Summer 2025 with direct connection to CONTRASTS. The sea ice concentration on 30 August 2025 is shown in the background (www.meereisportal.de). The voyage began in Tromsø on 2 July 2025 and ended in Longyearbyen on 1 September 2025. See <https://doi.pangaea.de/10.1594/PANGAEA.987133> to display the Master track in conjunction with the station list for PS149.

Fahrtverlauf

Die CONTRASTS-Expedition begann am 2. Juli 2025 in Tromsø, Norwegen und endete am 1. September 2025 in Longyearbyen, Spitzbergen (Abb. 1.0.1). Insgesamt wurden 62 Tage auf See verbracht und eine Strecke von 4.805 Seemeilen (8.730 km) zurückgelegt. An Bord befanden sich 100 Personen, 57 Wissenschaftler:innen und 43 Besatzungsmitglieder (Anhang A.2 und A.3, Abb. 1.0.2). Der „CONTRASTS Kalender“ in Abbildung 1.0.3 gibt eine Übersicht über die wesentlichen Ereignisse und Stationsarbeiten der Expedition. Zusammen mit der Fahrtroute in Abbildung 1.0.1 lässt sich ein Überblick über den Fahrtverlauf gewinnen.



Abb. 1.0.2: Gruppenfoto der 53 wissenschaftlichen Teilnehmer:innen der Expedition CONTRASTS (PS149, ArcWatch-3). (Foto: Katharina Naundorf)

Fig. 1.0.2: Group photo of the 53 scientific participants in the CONTRASTS expedition (PS149, ArcWatch-3). (Photo: Katharina Naundorf)

Abb. 1.0.3 (**nächste Seite**): Kalender der CONTRASTS (PS149) Aktivitäten. Die farbigen Balken geben die Aufenthalte an den einzelnen Stationen an (Farben passend zu denen in Abb. 1.0.1).

Neben den Kalenderdaten sind die Tage auf See gegeben. Die Zahlen oben rechts in den Kalenderfeldern geben die Stationsnummern an, die an dem Tag begonnen wurden (siehe Anhang A.4, A.7 und A.8). Weitere spezielle Events sind als Kommentar vermerkt.

Fig. 1.0.3 (**next page**): Calendar of CONTRASTS (PS149) activities. The colored bars indicate the stays at the individual stations (colors correspond to those in Fig. 1.0.1). In addition to the calendar dates, the days at sea are also given. The numbers at the top right of the calendar fields indicate the station numbers that were started on that day (see Appendices A.4, A.7, and A.8). Other special events are noted as comments.

[illegible]

Nach dem Auslaufen wurde zunächst Longyearbyen auf Spitzbergen für einen logistischen Stopp angefahren, bevor die eigentliche Expedition begann und am 5. Juli die ersten Stationsarbeiten ausgeführt wurden. Vom 6. Juli bis 30. August fand die gesamte Expedition innerhalb des eisbedeckten arktischen Ozeans statt. Vom 6. Bis 7. Juli (bei 82,25°N / 020,17°O) hat *Polarstern* die neue französische *Tara Polar Station* für ihre erste Expedition ins Meereis geleitet (Abb. 1.0.4) und erstmalig ein anderes Schiff gezielt ins Eis geführt. Dies war ein Meilenstein für das französische Team auf dem Weg zu ihrer ersten Arktisdrift *Polaris 1* im Jahr 2026/27. Anschließend wurde *Tara Polar Station* für ihre eigene Drift und Expedition zurückgelassen.



Abb. 1.0.4: *Polarstern* und *Tara Polar Station* an der Eiskante bei 82,25°N / 020,17°O am 6. Juli 2025
(Foto: AWI)

Fig. 1.0.4: *Polarstern* and *Tara Polar Station* at the ice edge 82.25°N / 020,17°E on 6 July 2025
(Photo: AWI)

Der Hauptteil der CONTRASTS Stationsarbeiten wurde auf insgesamt 12 Eisstationen ausgeführt (Tab. 1.0.1, Abb. 1.0.1). Die erste Eisstation (Station 1a) fand vom 9. bis 12. Juli in Regime 1 (Kapitel 1.1) statt. Anschließend wurde jedes Regime 4-mal angefahren, bis die Eisarbeiten mit der Station 3d vom 26. bis 27. August abgeschlossen wurden. Dabei konnten in den Regimen 2 und 3 bei jedem Besuch die identischen Schollen angefahren werden. Bei Regime 3 war es sogar möglich den identischen Anlegepunkt 4-mal zu verwenden. Bei Regime 2 mussten nur geringe Veränderungen vorgenommen werden, da Teile der Eiskanten im Verlauf geschmolzen und abgebrochen sind (Abb. 1.0.6). Dagegen ist die Drift von Regime 1 wesentlich weiter gen Osten verlaufen, als erwartet und in russische Hoheitsgebiete gedriftet. Damit war diese Station für den dritten Besuch (Station 1c) nicht erreichbar. Stattdessen wurde eine andere Scholle im gleichen Regime gewählt. Anschließend ist die ursprüngliche Station während der Drift komplett zerfallen und geschmolzen, so dass Besuch 1d nur noch zum Abbergen von Geräten in der Eisrandzone genutzt werden konnte. Die Zeitreihen der Beobachtungen innerhalb der Regime / Stationen umfasste im Endeffekt ca. 6 Wochen in jeder Region (Region 1: 43 Tage, Region 2: 41 Tage, Region 3: 39 Tage). Region 3 soll im Rahmen der EGC-Sources (PS150) Expedition noch einmal besucht werden. Dort

wurden verschiedene autonome Geräte über das Expeditionsende hinaus hinterlassen. Kapitel 1.1 beschreibt die Auswahl der Eisstationen sowie die allgemeinen Eisbedingungen. Kapitel 1.2 beschreibt die Wetterbedingungen während der Eisstationen. Karten aller Eisstationen sind in Anhang A.5 zusammengefasst.

Parallel fand die Flugkampagne des Polarflugzeugs *Polar 6* von Station Nord (Grönland) aus statt. Hier konnten zwei Überflüge der *Polar 6* an einer der Eisstationen von CONTRASTS realisiert werden, während gleichzeitig auch Vergleichsmessungen auf dem Eis, per Drohne und Helikopter durchgeführt wurden (Abb. 1.0.3 und 1.0.5). Darüber hinaus konnte *Polar 6* auf zwei weiteren Messflügen die CONTRASTS Region und deren Eisstationen überfliegen und wertvolle Daten aus der Luft gewinnen (Abb. 1.0.1).



Abb. 1.0.5 Das Polarflugzeug Polar 6 fliegt am 22. Juli 2025 über die Eisstation 3a. Der Flug ist Teil der Zusammenarbeit zwischen CONTRASTS und den IceBird-Sommerkampagne 2025. Das Flugzeug schleppt den EM-Bird für Messungen der Meereisdicke (siehe Kapitel 2.9). (Foto: Evgenii Salganik)

Fig. 1.0.5 The polar aircraft Polar 6 flying over Ice Station 3a on 22 July 2025. The flight is part of the collaboration between CONTRASTS and the IceBird Summer 2025 campaign. The aircraft is towing the EM-Bird for sea ice thickness measurements (see Chapter 2.9). (Photo: Evgenii Salganik)

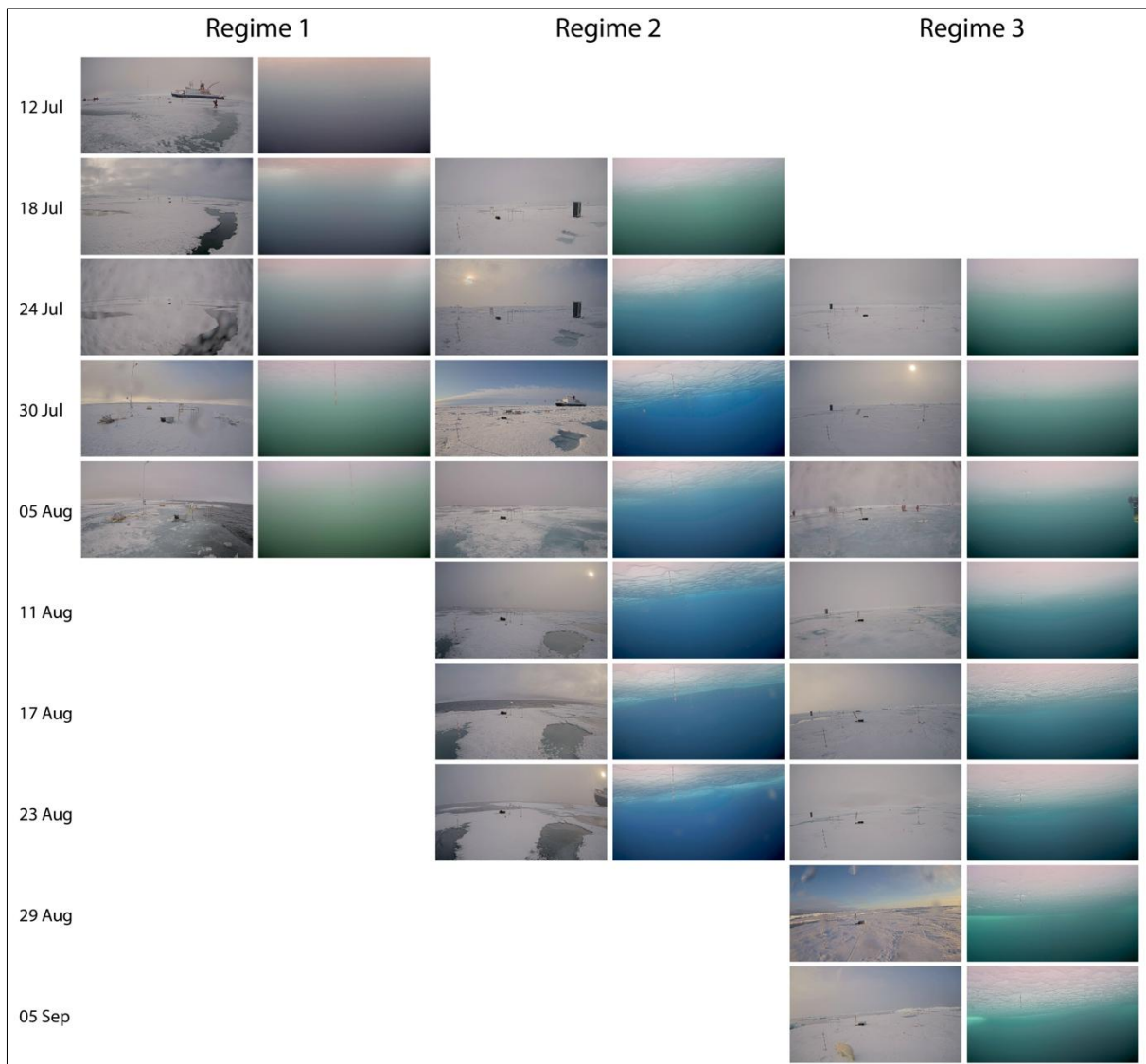


Abb. 1.0.6: Entwicklung der drei Eisregime anhand von Fotos der autonomen Kameras (siehe Kapitel 2.14). Die Fotos zeigen die Bedingungen alle 6 Tage oberhalb und unter dem Meereis. Die Fotos stammen vom jeweiligen Tag gegen Mittag, jedoch wurden bei wechselnden Witterungsbedingungen Fotos ausgewählt, die eine möglichst gute Sicht erlauben. Die Unterwasserfotos sind zum gleichen Zeitpunkt entstanden. Veränderungen von Aufbauten sind teilweise den Eisarbeiten geschuldet. Fehlende Fotos liegen daran, dass dann keine Kamera an der Station aktiv war.

Fig. 1.0.6: Development of the three ice regimes based on photos taken by autonomous cameras (see Chapter 2.14). The photos show the conditions above and below the sea ice every 6 days. The photos were taken around noon on the respective day, but in case of changing weather conditions, photos were selected that allow for the best possible visibility. The underwater photos were taken at the same time. Changes in structures are partly due to ice work. Missing photos are due to the fact that no camera was active at the station at that time.

Tab. 1.0.1: Eisstationen während CONTRASTS (PS149)**Tab. 1.0.1:** Ice stations during CONTRASTS (PS149)

Station	ID	Start Date	Start Position	End Date	End Position
Station 1a	PS149_13-1	09.07.2025 06:32	83.805 N 020.753 E	12.07.2025 18:25	83.857 N 024.251 E
Station 2a	PS149_16-1	14.07.2025 12:36	85.021 N 013.512 E	17.07.2025 17:58	84.687 N 013.945 E
Station 3a	PS149_18-1	19.07.2025 17:45	84.482 N 017.876 W	22.07.2025 18:00	84.348 N 017.885 W
Station 1b	PS149_21-1	25.07.2025 16:30	82.701 N 027.118 E	28.07.2025 16:40	82.490 N 028.418 E
Station 2b	PS149_25-1	30.07.2025 07:00	83.757 N 015.899 E	01.08.2025 20:45	83.749 N 019.038 E
Station 3b	PS149_30-1	04.08.2025 07:28	83.586 N 012.566 W	06.08.2025 19:30	83.719 N 011.012 W
Station 1c	PS149_32-1	09.08.2025 13:00	83.228 N 033.739 E	10.08.2025 22:07	83.327 N 034.147 E
Station 2c	PS149_36-1	12.08.2025 06:52	84.474 N 022.172 E	14.08.2025 17:22	84.613 N 021.575 E
Station 3c	PS149_41-1	16.08.2025 19:55	83.079 N 012.948 W	18.08.2025 22:30	82.721 N 012.853 W
Station 1d	PS149_44-1	21.08.2025 16:15	83.188 N 030.226 E	22.08.2025 01:00	83.246 N 033.253 E
Station 2d	PS149_46-1	23.08.2025 06:51	84.201 N 018.150 E	24.08.2025 18:32	84.213 N 017.325 E
Station 3d	PS149_47-1	26.08.2025 07:10	82.424 N 006.163 W	27.08.2025 20:15	82.339 N 004.657 W

Arbeiten auf See

Insgesamt wurden auf der Expedition 661 Stunden (27,5 Tage) an den 12 Eisstationen verbracht und dazu 37 weitere Stationen vom Schiff aus durchgeführt. Die Eisstationen dauerten meist um 60 Stunden (2,5 Tage), so dass an 3 Tagen auf dem Eis gearbeitet werden konnte (Tab. 1.0.1). Während die Eisgangway achtern an Backbord ausgebracht wurde, fand an 1 bis 2 Tagen das Windenprogramm über Steuerbord statt. *Polarstern* wurde bei jeder Eisstation (Ausnahme Station 1d) mit 4 Leinen an der Scholle verankert. Die Arbeiten mit dem Multicorer (MUC) fanden zumeist nach Abschluss der Arbeiten auf dem Eis in einer Entfernung >0,5 Seemeilen von der Scholle statt, um zu verhindern, dass Sedimente die oberen Wasserschichten oder das Meereis beeinflussen. Auf dem Meereis wurden Wege markiert, um möglichst große Teile der Oberflächen der Schollen für wissenschaftliche Arbeiten, vor allem auch bei späteren Besuchen, unberührt zu lassen. Wann immer möglich, wurden die identische Regionen und Profile auf und unter dem Meereis für die Wiederholungsmessungen genutzt. Andernfalls wurden möglichst ähnliche Standorte gesucht. Bei der Einrichtung der Messpunkte auf dem Eis wurden räumliche Abhängigkeiten verschiedener Geräte und Methoden bestmöglich berücksichtigt. Alle Arbeiten auf dem Eis wurden basierend auf Luftbildern und GPS-Positionen dokumentiert. Die Karten aller Eisstationen sind im Anhang A.5 enthalten.

Highlights und übergreifende Ergebnisse

Insgesamt konnte im Rahmen der CONTRASTS (PS149) beobachtet werden, wie stark sich das Meereis im Laufe des Sommers verändert und wie stark es schmilzt. Es ist gelungen die unterschiedlichen Meereisregime im atlantischen Teil der Arktis zu charakterisieren und klare Unterschiede, sowie einige Gemeinsamkeiten, dieser Regime während der Schmelze zu beschreiben. Insgesamt ist das Meereis in der Region sehr stark zurückgegangen, die Eiskante hat sich weit nach Norden verschoben und innerhalb der eisbedeckten Region ist die Eiskonzentration stark gesunken (siehe Kapitel 1.1). Dabei war das Meereis insgesamt überraschend dünn, insbesondere wenn man die Eisdrift der vorherigen Monate berücksichtigt. Auch die physikalischen Eigenschaften des Meereises innerhalb der drei Regime haben sich stark verändert und beschreiben die Hauptschmelze des Jahres (Kapitel 2)

Die atmosphärischen Messungen (Kapitel 3) zeigten deutliche Unterschiede zwischen den verschiedenen Regimen. Gleiche Wetterbedingungen führten zu unterschiedlichen Reaktionen, abhängig von Eisdicke, Oberflächenfarbe und Schmelzstatus. Die Energieflüsse wurden durch Regen, Schnee, Schmelztümpel und die Oberflächenstruktur entscheidend beeinflusst. In 300 m Höhe wurden Lufttemperaturen von +13 °C gemessen – ungewöhnlich warm für die Region. Durch den langen Aufenthalt in allen drei Regimen konnten sehr repräsentative Datensätze zu den synoptischen Bedingungen gesammelt werden.

Auch im Ozean zeigten sich deutliche Unterschiede (Kapitel 4): Während die Last Ice Area (Region nördlich von Grönland und dem Kanadischen Archipel) kältere und frischere Wassermassen überdeckte, fungierte der offene Ozean als Wärmespeicher und beeinflusste sogar die Luftmassen darüber. Mit Messungen bis in 1.000 Meter Tiefe konnten Strömungen und Wirbel dokumentiert werden, die das Schmelzgeschehen wesentlich mitbestimmen.

Überraschend war für das Forschungsteam, dass während der gesamten Expedition kaum Meereisalgen in oder unter den Schollen gefunden wurden – selbst in der Last Ice Area, wo zu Beginn noch wenig Schmelze eingesetzt hatte (Kapitel 5). Ein ähnlicher Befund war schon zwei Jahre zuvor, während ArcWatch 1-Expedition festgestellt worden, während ältere Expeditionen meist von einer Dominanz von Eisalgen berichteten. Ob dies auf einen drastischen Rückgang oder auf ein früheres Abschmelzen des Meereises zurückzuführen ist, wird derzeit anhand von Sedimentproben aus 4.000 Metern Tiefe untersucht. Mit Hilfe der Mikroskopie und dem neuen Planktoskop-System konnten nur wenige Eisalgenzellen unter Millionen von Phytoplankton nachgewiesen werden. Stattdessen prägten Bakterien und reichlich vorhandenes Zooplankton das Ökosystem und sorgten dafür, dass organisches Material in die Tiefe transportiert wurde.

Ein besonderes Merkmal von CONTRASTS war der vielseitige Einsatz autonomer Messsysteme. Zahlreiche Bojen haben kontinuierlich das Schmelzen des Meereises beobachtet und vermessen. Ein besonderes Highlight waren neue Kamerabojen, die über und unter dem Meereis die Veränderungen in Bilder erfasst haben (Abb. 1.0.6). So konnte das Eis sowohl von oben als auch von unten während der Abwesenheit des Forschungsteams beobachtet werden, was die Auswertung der Datensätze wesentlich unterstützen wird. Während das etablierte ROV BEAST das Meereis auf allen Stationen von unten vermessen hat, wurden zusätzlich noch autonomere ROVs erprobt. Diese können „vom Büro aus“ gesteuert werden und sollen so in Zukunft ermöglichen, dass auch räumliche Messungen unter dem Meereis in Abwesenheit von Forschungsteams durchgeführt werden können. Bislang war dies nur stationär während der Messkampagnen möglich. Auch das neue autonome Oberflächenfahrzeug „Otter“ absolvierte seine erste Erprobung im Meereis während der CONTRASTS Expedition. Zukünftig soll es für ozeanographische Messungen in Rinnen sowie in küsten- und gletschernahen Bereichen eingesetzt werden. Die ersten umfangreichen Messungen sind im Rahmen der im Anschluss an die CONTRASTS Expedition laufenden Expedition (PS150) vorgesehen. Über dem Eis profitierte die Expedition von der Weiterentwicklung von Drohnen. Auf jeder Station konnten damit hochauflösende digitale

Geländemodelle des Meereises erstellt, zusätzliche horizontale und vertikale Luftprofile erfasst und die Oberflächenalbedo kartiert werden. Mit dem neuen Planktoskop stand zudem erstmals ein KI-gestütztes Analysewerkzeug zur Verfügung, das direkt an Bord die Zusammensetzung und Häufigkeit der Planktongemeinschaft bestimmt – Messungen, die auf einem fahrenden Forschungsschiff bislang kaum realisierbar waren.

SUMMARY AND ITINERARY

The Arctic Ocean is characterized by a highly heterogeneous sea ice layer that is subject to a pronounced seasonal cycle. This cycle is determined by the interactions between the atmosphere and the ocean and leads to considerable regional and temporal differences in the extent, thickness, structure and properties of the ice. For the summer months in particular, there are major uncertainties in ice properties and their distribution in the Arctic, while these have a particularly strong influence on the annual cycle. These uncertainties are of central importance for the future development of the Arctic and its role in the global climate system.

The CONTRASTS expedition was carried out to systematically investigate these processes using different sea ice regimes. A regime is understood to be the combination of formation location, age, thickness and the respective atmospheric and oceanic boundary conditions. The focus was on three characteristic regimes: (1) one-year-old ice near the ice edge zone, most of which does not survive the summer, (2) multi-year ice in the transpolar drift with a lifespan of two or more years, and (3) older, particularly thick ice, which originates mainly from the division north of Canada or the Beaufort Gyre. Transitions and gradients between these regimes could be identified by observations along drift and station work.

While the 2019/20 MOSAiC expedition provided a unique year-round data set, this was essentially limited to a floe and thus to a single regime. CONTRASTS extended this approach by systematically considering the spatial dimension. The aim of this expedition was to characterize the temporal development and the differences between the regimes regarding radiation balance, melting processes, ice thickness, energy fluxes and biological interactions. The aim was to better understand and quantify the processes that contribute to the regional and seasonal variability of sea ice.

A central element of the research program was the interdisciplinary approach. An identical observation program was carried out during each station visit, while autonomous measuring systems continued to record data during the absence phases. This made it possible to continuously record the atmosphere-ice-ocean system during the melting period in each regime over a period of around six weeks. The multidisciplinary work program included sea ice physics, atmospheric sciences, physical oceanography and ecosystem studies as well as a complementary communication and outreach program.

In addition, CONTRASTS was directly linked to previous expeditions of the research icebreaker *Polarstern* to the central Arctic Ocean, in particular MOSAiC 2019/20 as well as ArcWatch-1 (2023) and ArcWatch-2 (2024). The current work directly followed on from these expeditions and extended them by specifically comparing different sea ice regimes. CONTRASTS benefited from an established interdisciplinary and international research team on board and on land, which placed the observations obtained in a larger context and thus created an essential basis for the further development of Arctic research.

Course of the journey

The CONTRASTS expedition began on 2 July 2025 in Tromsø, Norway and ended on 1 September 2025 in Longyearbyen, Svalbard (Fig. 1.0.1). A total of 62 days were spent at sea and a distance of 4,805 nautical miles (8,730 km) was travelled. There were 100 people on board, 57 scientists and 43 crew members (Appendix A.2 and A.3, Fig. 1.0.2). The "CONTRASTS calendar" in Figure 1.0.3 provides an overview of the main events and station

work of the expedition. Together with the route in Figure 1.01, an overview of the journey can be obtained.

After setting sail, the ship first called at Longyearbyen on Svalbard for a logistical stop before the actual expedition began and the first station work was carried out on 5 July. From 6 July to 30 August, the entire expedition took place within the ice-covered Arctic Ocean. From 6 to 7 July (at 82.25°N / 020.17°E), *Polarstern* guided the new French *Tara Polar Station* into the sea ice for its first expedition (Fig. 1.0.4) and for the first time guided another ship specifically into the ice. This was a milestone for the French team on the way to their first Arctic drift *Polaris 1* in 2026/27, after which *Tara Polar Station* was left behind for its own drift and expedition.

The main part of the CONTRASTS station work was carried out at a total of 12 ice stations (Tab. 1.0.1, Fig. 1.0.1). The first ice station (Station 1a) took place from 9 to 12 July in regime 1 (Chapter 1.1). Subsequently, each regime was visited 4 times until the ice work was completed with station 3d from 26 to 27 August. In Regimes 2 and 3, the identical floes could be approached on each visit. In Regime 3, it was even possible to use the identical mooring point four times. In Regime 2, only minor changes had to be made, as parts of the ice edges melted and broke off in the process (Fig. 1.0.6). In contrast, the drift of Regime 1 was much further east than expected and drifted into Russian territory. As a result, this station was not accessible for the third visit (Station 1c). Instead, another floe in the same regime was chosen. Subsequently, the original station completely disintegrated and melted during the drift, so that visit 1d could only be used to retrieve equipment in the ice edge zone. The time series of observations within the regimes/stations ultimately comprised approx. 6 weeks in each region (region 1: 43 days, Region 2: 41 days, Region 3: 39 days). Region 3 will be visited again as part of the EGC-Sources (PS150) expedition. Various autonomous devices were left there beyond the end of the expedition. Chapter 1.1 describes the selection of the ice stations and the general ice conditions. Chapter 1.2 describes the weather conditions during the ice stations. Maps of all ice stations are summarized in Appendix A.5.

The flight campaign of the polar aircraft *Polar 6* from Station North (Greenland) took place in parallel. Here, two overflights of the *Polar 6* were realized at one of the CONTRASTS ice stations, while at the same time comparative measurements were carried out on the ice by drone and helicopter (Fig. 1.0.3 and 1.0.5). In addition, *Polar 6* was able to fly over the CONTRASTS region and its ice stations on two further measurement flights and obtain valuable data from the air (Fig. 1.0.1).

Work at sea

A total of 661 hours (27.5 days) were spent at the 12 ice stations during the expedition, and 37 additional stations were carried out from the ship. The ice stations usually lasted around 60 hours (2.5 days), so that work could be carried out on the ice on 3 days (Tab. 1.0.1). While the ice gangway was deployed aft on the port side, the winch program took place over the starboard side on 1 to 2 days. *Polarstern* was anchored to the floe with 4 lines at each ice station (with the exception of station 1d). Work with the multicorer (MUC) usually took place after the work on the ice had been completed at a distance of >0.5 nautical miles from the floe to prevent sediment from affecting the upper water layers or the sea ice. Paths were marked on the sea ice to leave as much of the floe's surface as possible untouched for scientific work, especially during subsequent visits. Whenever possible, identical regions and profiles on and under the sea ice were used for repeat measurements. Otherwise, similar locations were sought wherever possible. When setting up the measuring points on the ice, spatial dependencies of different devices and methods were taken into account as far as possible. All work on the ice was documented on the basis of aerial photographs and GPS positions. The maps of all ice stations are included in Appendix A.5.

Highlights and overall results

Overall, CONTRASTS (PS149) was able to observe how much the sea ice changes over the course of the summer and how much it melts. It was possible to characterise the different sea ice regimes in the Atlantic part of the Arctic and to describe clear differences, as well as some similarities, between these regimes during melting. Overall, the sea ice in the region has declined significantly, the ice edge has shifted far to the north and the ice concentration within the ice-covered region has fallen sharply (see Chapter 1.1). Overall, the sea ice was surprisingly thin, especially when the ice drift of the previous months is taken into account. The physical properties of the sea ice within the three regimes have also changed considerably and describe the main melting of the year (Chapter 2)

The atmospheric measurements (Chapter 3) showed clear differences between the different regimes. The same weather conditions led to different reactions, depending on ice thickness, surface color and melting status. The energy fluxes were decisively influenced by rain, snow, melt ponds and the surface structure. Air temperatures of +13 °C were measured at an altitude of 300 meters - unusually warm for the region. Due to the long stay in all three regimes, very representative data sets on the synoptic conditions could be collected.

There were also clear differences in the ocean (Chapter 4): While the Last Ice Area (region north of Greenland and the Canadian Archipelago) covered colder and fresher water masses, the open ocean acted as a heat reservoir and even influenced the air masses above it. Measurements down to a depth of 1,000 meters were able to document currents and eddies, which play a significant role in determining the melting process.

It was surprising for the research team that hardly any sea ice algae were found in or under the floes during the entire expedition - even in the Last Ice Area, where little melting had started at the beginning (Chapter 5). A similar finding had already been observed two years earlier during the ArcWatch 1 expedition, while older expeditions usually reported a dominance of ice algae. Whether this is due to a drastic decline or an earlier melting of the sea ice is currently being investigated using sediment samples from a depth of 4,000 meters. With the help of microscopy and the new planktoscope system, only a few ice algae cells could be detected among millions of phytoplankton. Instead, bacteria and abundant zooplankton characterized the ecosystem and ensured that organic material was transported to the depths.

A special feature of CONTRASTS was the versatile use of autonomous measuring systems. Numerous buoys continuously monitored and measured the melting of the sea ice. A particular highlight was the new camera buoys, which recorded the changes in images above and below the sea ice (Fig. 1.0.6). This allowed the ice to be observed both from above and below during the research team's absence, which will significantly support the analysis of the data sets. While the established ROV BEAST surveyed the sea ice from below at all stations, more autonomous ROVs were also tested. These can be controlled "from the office" and should enable spatial measurements to be carried out under the sea ice in the absence of research teams in future. Until now, this has only been possible in a stationary position during measurement campaigns. The new autonomous surface vehicle "Otter" also completed its first sea ice trials during the CONTRASTS expedition. In future, it will be used for oceanographic measurements in channels and in coastal and glacier areas. The first extensive measurements are planned for the expedition following the CONTRASTS expedition (PS150). Above the ice, the expedition benefited from the further development of drones. This enabled high-resolution digital terrain models of the sea ice to be created at each station, additional horizontal and vertical aerial profiles to be recorded and the surface albedo to be mapped. The new planktoscope was also the first AI-supported analysis tool to determine the composition and frequency of the plankton community directly on board - measurements that were previously almost impossible to realize on a moving research vessel.

1.1 Sea ice regimes and conditions

Sea ice age, drift trajectories and origins

To identify different ice regimes as well as the origin and drift trajectories of the surveyed sea ice, we used two different satellite-based estimates of sea ice age and motion. The first method for determining ice age and origin is based on a Lagrangian drift model called IceTrack, which tracks points on a 25×25 km grid back in time. Drift trajectories are computed using the OSI-405-c motion product (Ocean and Sea Ice (OSI) Satellite Application Facility (SAF), Lavergne et al., 2016). The tracking approach works as follows: sea ice is tracked backward from a grid point on a daily basis, halting when the ice reaches the coastline or fast ice edge, or when the satellite-based ice concentration (provided by OSI-430-a and OSI-450-a, OSI SAF) at a given location falls below 20%. The ice age is then inferred from the temporal length of the trajectories (Krumpen et al., 2020). A detailed description of IceTrack is provided in Krumpen et al. (2025). Figure 1.1.1 provides an overview of the sea ice age north of Fram Strait derived from IceTrack for July 1st and 15th 2025, as well as for August 1st, and 15th 2025.

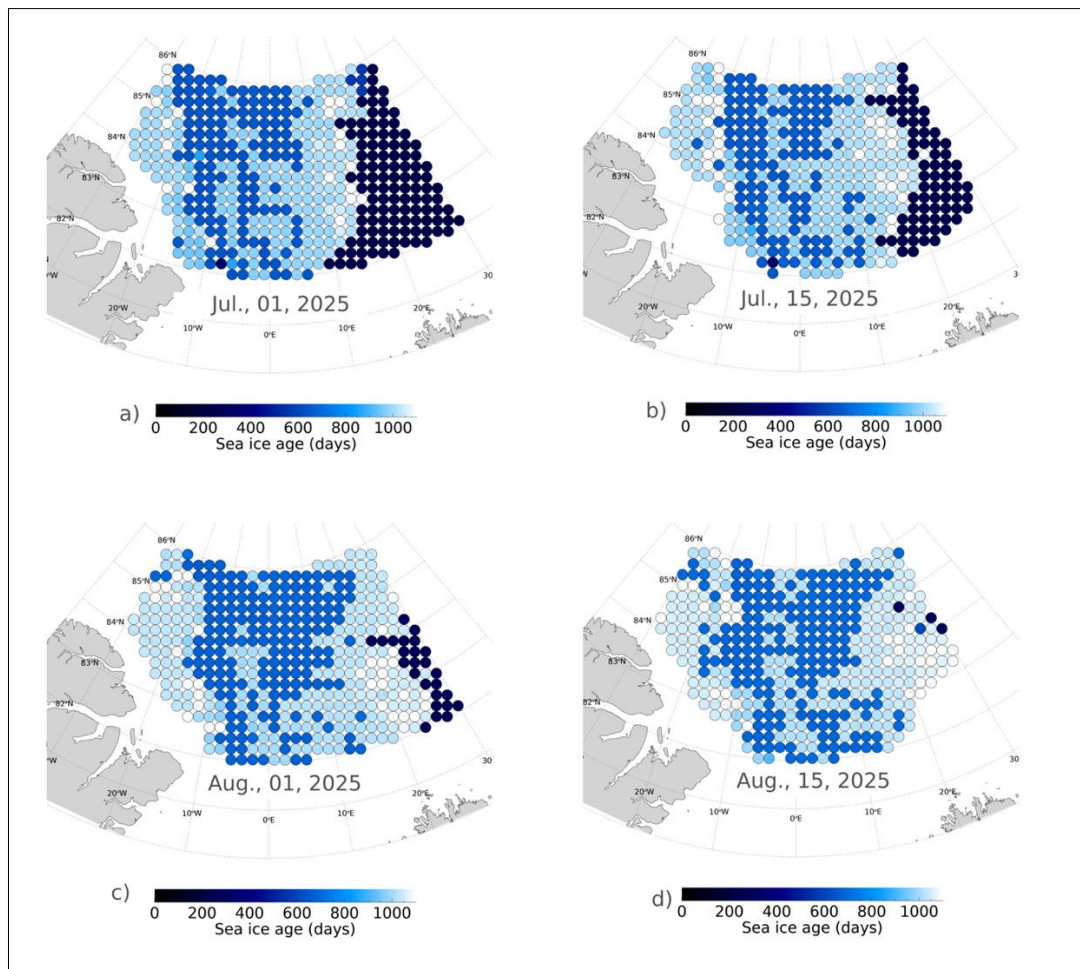


Fig. 1.1.1: Sea ice age at four different times during the expedition, derived from IceTrack, a Lagrangian trajectory model. Values are given in days.

In addition, the NSIDC ice age product was used for the identification of different ice regimes. The NSIDC product is based on a similar Lagrangian tracking approach, using weekly gridded ice motion vectors (v.4.1, Tschudi et al., 2020). The weekly product is provided on a 12.5×12.5 km grid. Figure 1.1.2 presents the weekly sea ice age in Fram Strait, displayed at two-week intervals throughout the expedition. Its physical approach differs slightly from IceTrack and follows the principle of “oldest ice age assignment”: if two parcels of different ages are advected into the same grid cell, the oldest age is assigned to that cell, under the assumption that younger ice is more easily deformed than older ice (Regan et al., 2023). The NSIDC sea ice age product is a widely used reference for monitoring changes in the Arctic sea ice cover because of its high consistency and extensive temporal and spatial coverage (e.g., Ye et al., 2023). We gratefully acknowledge Scott Stewart, Mark Tschudi, and Walt Meier for providing accelerated access to the NSIDC sea ice age data during our cruise.

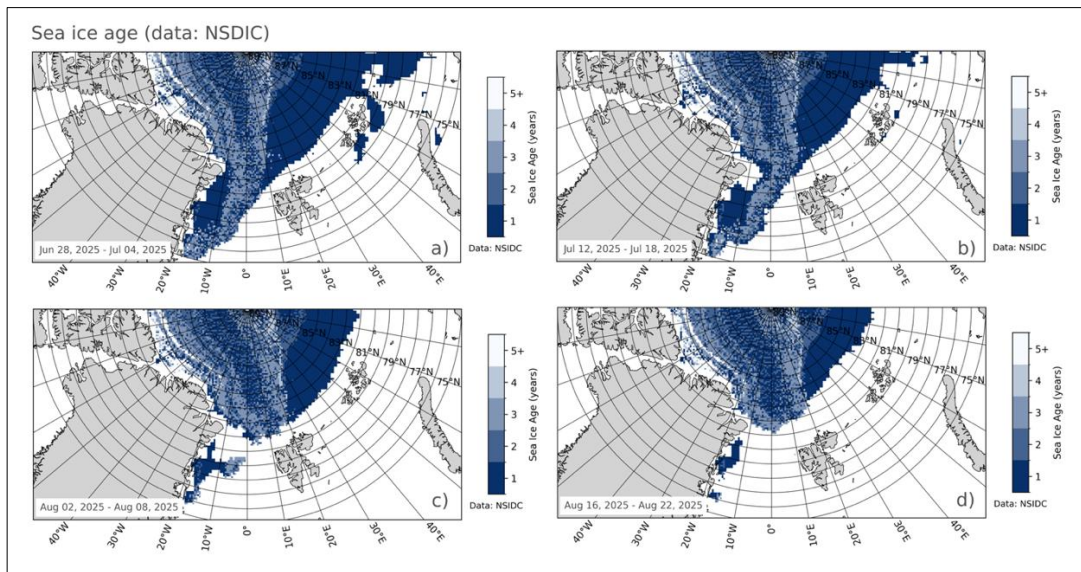


Fig. 1.1.2: Sea ice age estimates derived from the NSIDC product, expressed in years (source: Scott Stewart, NSIDC)

To identify ice regimes beyond those defined solely by ice age, we additionally used sea ice surface roughness information derived from the ICESat-2 satellite. These data were provided by Kyle Duncan and Sinead Farrell for February 2025, which we gratefully acknowledge. In addition to surface roughness, the dataset includes information on sail frequency (n/km) and the height of pressure ridges at the basin scale (for details see Duncan & Farrell, 2022). To make the February data applicable to the summer months, we used IceTrack to advect the ICESat-2 observations forward by 120 days, thereby obtaining an impression of the morphological regimes at the beginning of the expedition. The results of the forward-advected ICESat-2 data from February are presented in Figure 1.1.3.

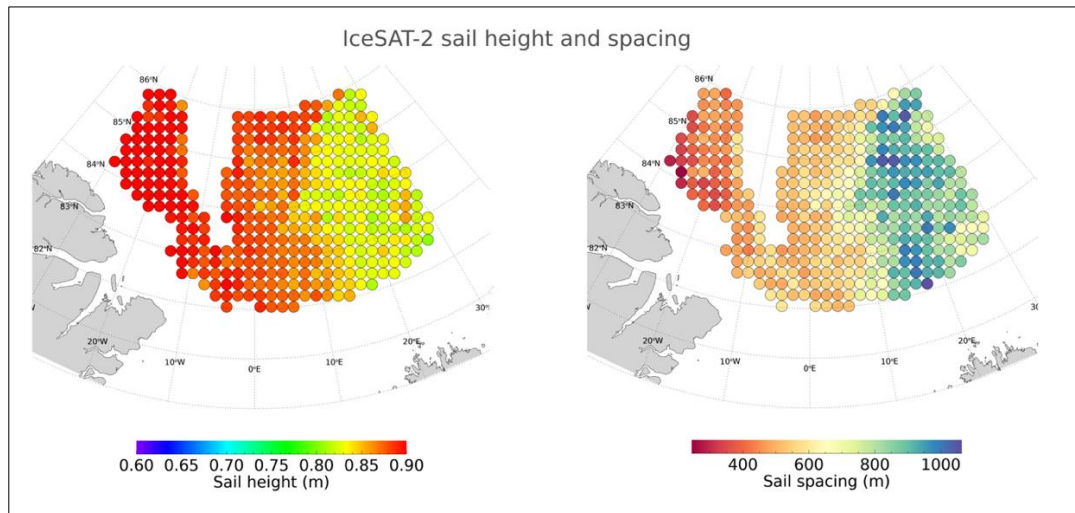


Fig. 1.1.3: Sail spacing and sail height derived from ICESat-2 observations in February 2025. To enable their use for expedition planning, the data were advected 120 days forward with IceTrack to 1 July^t 2025.

Satellite data to support ice navigation and floe selection

Near-real-time synthetic aperture radar (SAR) data were acquired and integrated into the onboard MapViewer to support navigation and decision-making between stations. The widest spatial coverage of the expedition region was provided by ESA Sentinel-1 imagery, with acquisition frequency temporarily increased for the duration of the cruise. In combination with data from the Radarsat Constellation Mission (RCM), this ensured near-complete SAR coverage of the study area (see Fig. 1.1.4). Sentinel-1 and RCM are C-band radar satellites with an image resolution of approximately 30 m. Additionally, TerraSAR-X data (DLR) were received daily via DLR Bremen. These high-resolution acquisitions were primarily used over ice floes R1–R3 and along transit routes between stations to facilitate navigation.

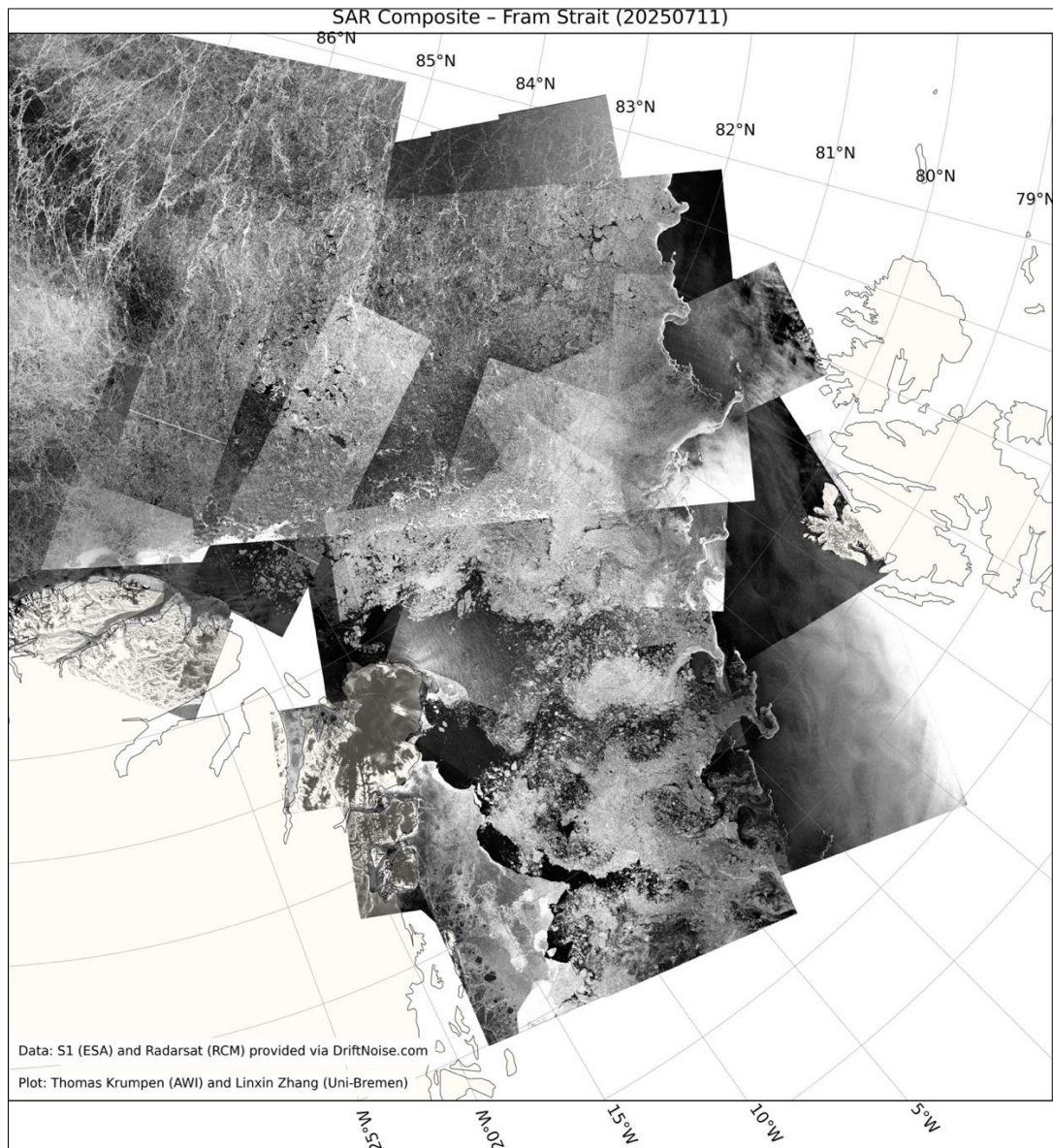


Fig. 1.1.4: Daily composite of SAR data (Sentinel-1 and Radarsat) acquired over the expedition area on 11 July. Owing to the particularly high acquisition frequency of the ESA Sentinel-1 satellite, multiple scenes covering the ship's position were available on some days.

Sea ice age distribution in the working area (early July)

At the beginning of July, both age products reveal a pronounced west–east gradient in sea-ice age across northern Fram Strait (see Fig. 1.1.2 panel a, and Fig. 1.1.1 panel b). The drift paths and source regions associated with the main age zones at expedition start are summarized in Figure 1.1.5.

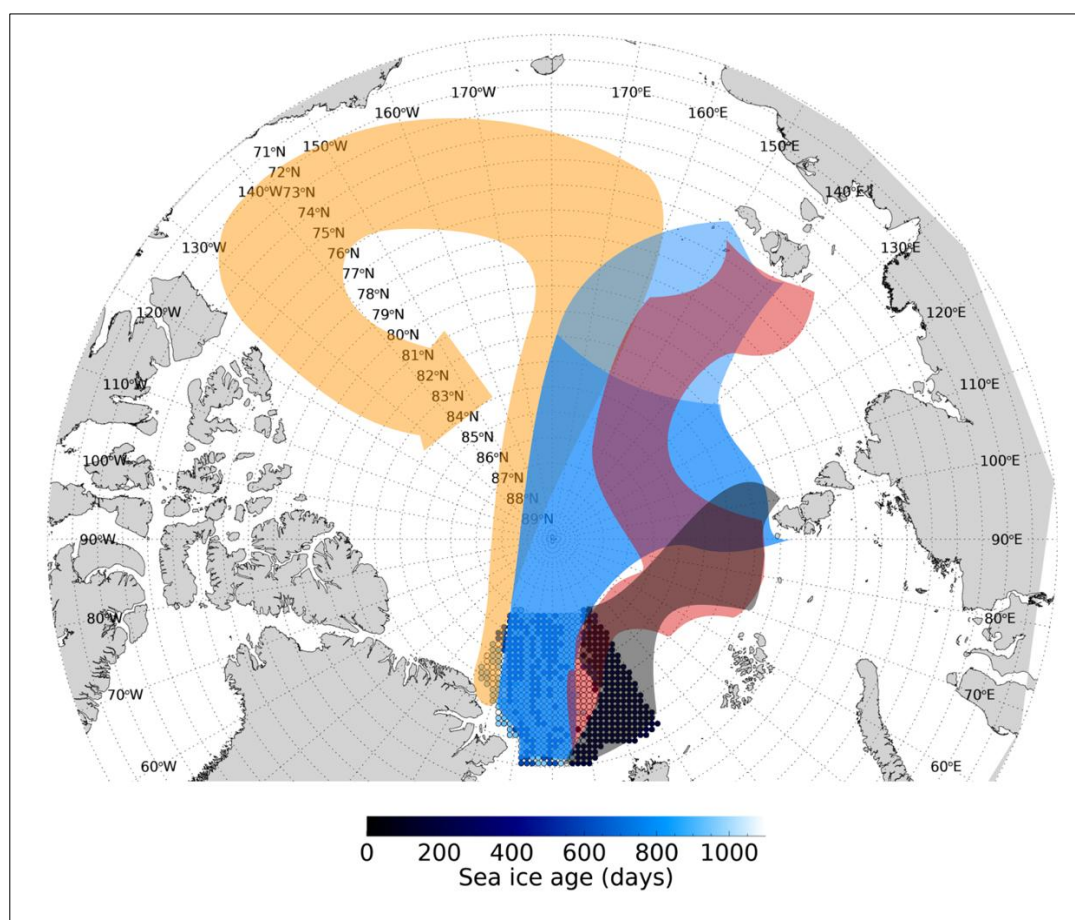


Fig. 1.1.5: Approximate drift pattern and source region of the individual sea ice regimes present in the CONTRASTS area at the beginning of the expedition.

- **Regime 1: First-year ice / marginal ice zone (FYI/MIZ)**

The eastern part of the study area was dominated by first-year ice originating primarily from the Kara Sea, where the first ice station was established. The approximate drift route of this FYI, reconstructed with IceTrack, is shown as a black arrow in Figure 1.1.5. Owing to its younger age, this ice exhibits markedly lower pressure ridge frequencies and reduced sail heights (see Fig. 1.1.3), a pattern confirmed by observations in the field. During the expedition, this FYI band drifted strongly eastward, particularly in July, in response to passing cyclones. Farther west the eastward deflection was weaker, creating a divergent drift pattern across the study region and contributing to locally reduced ice concentration (see Fig. 1.1.6).

- **Regime 2: Second- and multi-year ice of Siberian origin (SYI/MYI)**

Central parts of the expedition area were characterized mainly by second- and multi-year ice that formed largely offshore to the north of the Laptev Sea and the New Siberian Islands (Fig. 1.1.5, blue and red arrows). SYI constitutes the bulk of the pack within the study domain. It transited from its formation areas across the central Arctic into Fram Strait; western SYI zones are sourced predominantly from the New Siberian Islands sector, whereas the eastern SYI zones trace back toward the Laptev Sea sector. Occasional patches of older, three- to four-year ice of Siberian origin are also present and are unusual compared with the last two decades. During 2022–2023, an extended

Beaufort Gyre and suppressed Transpolar drift limited the sea ice export from the Laptev Sea, allowing ice to persist and recirculate there for two years. In October 2024, the influence of the Beaufort Gyre diminished and strong offshore winds finally exported portions of this older ice toward the pole. Part of it is currently being incorporated into the Last Ice Area (LIA), while a smaller fraction turned towards Fram Strait. The second ice station (R2) was set on this latter branch. Icebergs embedded in the pack near that station contained substantial sediment, likely entrained when the ice was near Severnaya Zemlya; sediment found on floe R2 and in its vicinity further supports a shallow-shelf origin or repeated shelf contact.

- **Regime 3: Old ice linked to the Last Ice Area (MYI)**

The third and smallest regime consists of old multiyear ice (MYI), concentrated mainly in the near-coastal sectors north of Greenland and Canada (the Last Ice Area, LIA). This coastal MYI was not directly accessible during the expedition. However, just northeast of these zones, an offshoot of this area had formed a long, narrow band that connected directly to the second-year ice (SYI) zone to the east. This band of ice was reachable by ship and provided the basis for Regime 3 (R3). The ice had previously transited through the Beaufort Gyre and was continuing its drift toward Fram Strait, with its approximate trajectory shown by the orange arrow in Figure 1.1.5. In contrast to the first-year ice (FYI) zones, the western sectors exhibit substantially higher sail frequency and greater sail heights (Fig. 1.1.3). During the final phase of the expedition and upon the floe's entry into Fram Strait, the narrow band of older ice dispersed, leaving the surroundings of floe R3 dominated by younger and significantly less deformed ice.

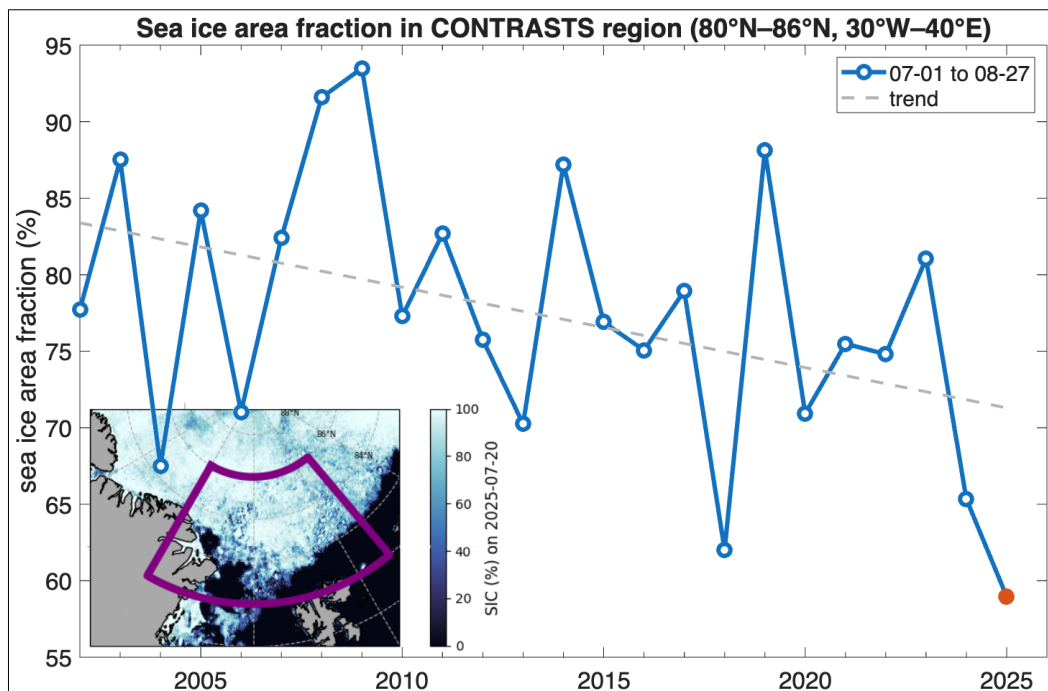


Fig. 1.1.6: Area covered by sea ice in the survey region (see small map). Unlike sea-ice extent, this view only considers the percentage of overall surface that is covered by ice. The time series shows the period surveyed for all available years since 2002. (Figure: Gunnar Spreen / University of Bremen)

Origins and drift patterns of R1–R3

Below, the likely origins of the individual floes, as derived from backtracking with IceTrack, are summarized:

- **Regime 1:** As shown in Figure 1.1.7, Regime 1, together with the alternate floe used in the third rotation, originated in the Kara Sea and is ~1 year old.
- **Regime 2:** The second station (Fig. 1.1.7, Regime 2) originated in the Siberian marginal seas, likely in the vicinity of the New Siberian Islands. Because export toward the central Arctic was intermittently suppressed in 2022–2023, the ice recirculated north of Severnaya Zemlya for an extended period before progressing toward the central Arctic and, eventually, Fram Strait.
- **Regime 3:** The Regime 3 floe traces back to the Beaufort Gyre and possibly to sectors of the LIA north of Canada (Fig. 1.1.7, Regime 3). Sediments incorporated within the ice are extremely fine; we infer they were entrained from the Mackenzie River plume/delta during freeze-up and subsequently transported within the pack.

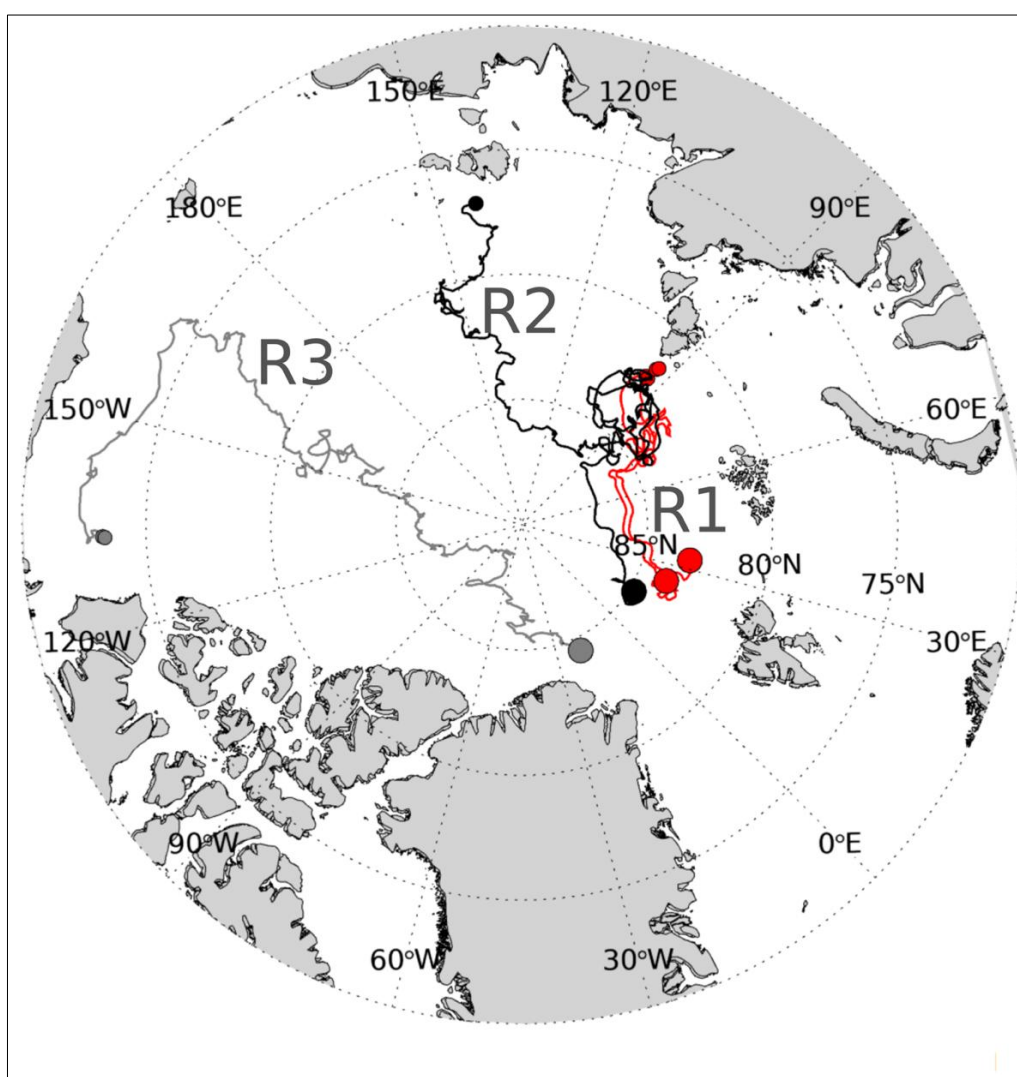


Fig. 1.1.7: Back-trajectories of the three floes in Regime 1 (R1), Regime 2 (R2), and Regime 3 (R3) using IceTrack

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1.2 Weather conditions during PS149

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Journey to the Arctic

After having left the Grøtsund harbour near Tromsø and having crossed the adjacent Norwegian fjord landscape in the evening of 2 July 2025, the research vessel *Polarstern* encountered the swell field of a low-pressure system that had just moved across the Norwegian Sea into the Fram Strait, causing two swells from the west and southwest and a significant wave height of 2 m. While the low-pressure system over the north-eastern coast of Greenland (4 July) moved westward in an arc towards the North Pole to the Queen Elizabeth Islands (7 July), an independent high developed from an Azores high over the Norwegian Sea and shifted its centre of gravity across Franz Josef Land (6 July) to the East Siberian Sea (8 July). Thus, a southerly wind flow dominated throughout the entire voyage from Tromsø via Longyearbyen to the first days in the sea ice north of Svalbard. In the coastal area northwest of Svalbard, coastal guidance and jet effects caused a temporary increase of the usually weak to moderate wind to 5 Bft on 5 July.

Figures of weather conditions for all ice stations, as described below, are shown in Appendix A.6.

Ice station 1a – fog and low stratus

When reaching the Arctic sea ice north of Svalbard on 6 July, the *Polarstern* encountered a prolonged period of fog. The fog thinned considerably for a few hours on 6 July (with a relative humidity above 99%) and on 7 and 8 July it became at times so dense that the horizontal visibility fell below 300 m. On 9 July, we reached the first ice station at 83.8° north, 20.7° east. When, on the same day, a low-pressure system coming from the Kara Sea was located just east of us over Franz Josef Land, the wind temporarily shifted to the northwest and briefly increased to 6 Bft, allowing the moist ground layer to slowly mix and the cloud base to rise to very low stratus during the night into 10 July. The low-pressure system crossed the North Pole on the morning of 10 July, and during the day, the wind shifted to the southeast and decreased to 4 Bft.

A low-pressure system that moved north along the east coast of Greenland being located over the western part of the Fram Strait on 10 July brought another inflow of milder, moist air, causing the cloud base to drop again and the cloud cover to eventually turn into fog in the late afternoon. In the evening and during the night into 11 July, its frontal system moved across the working area, causing freezing rain (temperature below 0°C) and dissolving the fog for a few hours. On 11 July, however, the fog was temporarily so thick that the visibility dropped to less than 150 m, with a southerly wind of 5 to 6 Bft, which veered southwest during the course of the day as the low-pressure system moved further west. On 12 July, the low-pressure system had merged with the previously mentioned low-pressure system to form a larger low-pressure complex over Ellesmere Island, causing a temporary increase in wind speed to 7 Bft and lifting the fog to very low stratus clouds on the same day and during the entire night into 13 July. The low then moved very slowly to the northwest and weakened significantly over the following days.

Ice station 2a – sun, fog, stratus

In the meantime, on the evening of 12 July, the *Polarstern* left the first ice station, which had drifted slightly to the east, continued its journey northwest through the ice and reached the second ice floe to be investigated at 85.0° north, 13.5° east on 14 July. Originating from a high-pressure system centred over the Norwegian Sea, a ridge built up to the north across the Fram Strait and moved eastward, resulting in the first day of extended favourable flying conditions

and much sunshine on 14 July. It was not until late in the evening that low stratus clouds reached us, turning into fog during the night. This was caused by a low-pressure system that had formed just north of Greenland and was moving eastward. The low-pressure system was directly above us on the morning of 15 July (temporary northwestern wind of 6 Bft) and filled up just north of Franz Josef Land by 17 July. From 15 to 17 July, fog and low stratus clouds dominated, with the fog becoming temporarily so dense on the morning of 17 July that the visibility dropped to 150 metres.

When we left the second ice floe on the evening of 17 July and continued our journey westwards to find a third floe to investigate just northeast of Greenland, the visibility improved significantly for a few hours as further cloud layers moved over the fog and dissolved it.

Ice station 3a – the sunny ice floe

From 17 July to 20 July, a low-pressure system from Russia moved from the Laptev Sea across the North Pole to Greenland, carrying a moist air mass to the central Arctic. At the same time, the low weakened and filled up over the northeastern part of Greenland by 21 July. On 18 July and 19 July, fog and low stratus clouds were once again prevailing. From the evening of 19 July to the evening of 22 July, the *Polarstern* anchored at the third ice floe, which was initially located at 84.5° north, 17.9° west, northeast of Greenland, and drifted very slowly southwards due to the weak wind. On 20 July, the visibility improved significantly as the moist ground layer became thinner beneath several layers of medium-high clouds, allowing fog patches to form only in certain areas (relative humidity remained at 100% throughout the day), one of which did not reach us until the evening. At the same time, an intermediate high formed north of the Fram Strait, slowly shifting southwards, so that weak winds from land (on 21 July from southerly and on 22 and 23 July from westerly directions) brought significantly drier air from Greenland, counteracting the formation of new fog and resulting in almost three sunny days with only isolated patches of fog (21 July to 23 July in the morning).

Ice station 1b – fog and freezing rain

From 23 July onwards, three low-pressure systems coming from Russia via Severnaya Zemlya successively transported mild, moist air into the central Arctic, causing a prolonged period of fog with only brief interruptions. The first relatively weak low moved from 21 July on from Severnaya Zemlya, weakening, to Ellesmere Island (23 July), closely followed by a second, stronger low, which moved from Severnaya Zemlya (23 July) to Franz Josef Land, where it slowly filled up from 24 July onwards. The transit from the third ice station near Greenland back to the first ice station north of Svalbard (23 July in the evening to 25 July in the afternoon) therefore took place mostly with a tailwind (with mostly moderate winds from the west to north). On 24 July, the occlusion front of the second low pressure system passed over us, causing freezing rain (due to the warm air mass in upper air levels) and a brief northeast wind of 5 Bft. When we entered the area of the occlusion again on 25 July, the fog was interrupted by snowfall with a northnorthwest wind of 5 Bft. On 25 July, a low formed over Severnaya Zemlya, moved northwest and was located on 27 July between the first ice station north of Svalbard, where we stayed from the afternoon of 25 July to the afternoon of 28 July, and the North Pole. The wind therefore shifted to the west during the night into 27 July and increased to 6 Bft by the following night. As the low slowly moved eastwards around the North Pole from 28 July onwards, the wind calmed down to 1 Bft by the evening of 29 July. At the same time, the fog became so thin that the clouds above and the sun were clearly visible.

Ice station 2b – the melting ice floe

During the second visit of the second ice floe from 30 July in the morning to 1 August in the evening fog and low stratus were still prevailing. On 30 July, a high-pressure system built up

over Svalbard, while the low near the North Pole deepened again far north of the East Siberian Sea, causing the westerly wind to increase during the day and blow from the southwest with 6 Bft during the night into 31 July and on the same day. A large gap in the shallow fog reached us on the evening of 30 July and provided about five hours of perfect flying weather. The high moved southeastwards across the Barents Sea to the Kara Sea (2 August), causing the wind to decrease from the night into 1 August on.

From 31 July onwards, a low from Iceland moving northwards along the east coast of Greenland transported a mild air mass through the Fram Strait into the research area, so that from the night of 1 August onwards, positive temperatures were measured not only in upper air levels (+5°C at 700 m) but also at ground level (+1°C). At the same time, the associated warm front brought rain, with continued dense fog or at times very low cloud bases and poor visibility.

On 2 August, as we were heading west back to the third ice floe, the low over the northwestern part of the Fram Strait filled up. The wind was weak, the fog remained thick, and the rain stopped in the afternoon.

Ice station 3b – warm air intrusions from the south

On 2 August, a temporary high formed over the Norwegian Sea and moved northeastwards across the Barents Sea (3 and 4 August) to Severnaya Zemlya (5 August). The wind therefore shifted to the south during the night into 3 August and increased to 7 Bft by the following evening (during the night the average wind speed briefly rose to 8 Bft). This caused the foggy area above our cruise path to shift northwards, resulting in good flying weather conditions on the afternoon of 3 August. On the same day, however, there was a warm air intrusion from the south, so that on the evening of 3 August, a low stratus cloud cover reached us again, which turned into dense fog during the night into 4 August (with continuous 7 to 8 Bft south wind).

On the morning of 4 August, the research work started on the third ice station, which was now located at 83.6° north, 12.6° west, just northeast of Greenland. At the occlusion point of an Icelandic low, a secondary low formed over the Norwegian Sea on 4 August, moved northwest and crossed the northeast coast of Greenland during the night into 6 August. The south wind therefore backed east by 5 August and decreased to 4 to 5 Bft. Within the area of the low it rained from the evening of 4 August until midday on 5 August, and there was a brief clearing of the fog in the morning of 5 August. The low transported a very mild air mass with an air temperature of just below +10°C at a height of 200 to 250 m (radiosonding data on 5 August at 06 UTC) and +2°C near the ground. The low then moved to the Beaufort Sea until 8 August. During the night into 6 August, the wind veered again south and, under the influence of a high-pressure ridge, the fog became significantly thinner in the afternoon of the same day. After leaving the ice station on the evening of 6 August, the fog finally cleared completely.

Ice station 1c – more warm air intrusions from the south

On the way from the third ice station eastwards to the region of the first ice station, there were several warm air intrusions to the north between a low-pressure complex over the Norwegian Sea and the Greenland Sea and a high-pressure system near Severnaya Zemlya.

On the morning of 7 August, as a weak warm front from a low over the Fram Strait moved westward (east wind at 3 to 4 Bft), we found ourselves in a strip of fog stretching from southwest to northeast, which we had already crossed in the afternoon.

The following night, we were crossed by an occlusion front that brought rain and widespread fog. On 9 August, work began on a new ice floe northeast of Svalbard near the sea ice edge in the region of the first ice floe, which had drifted too far east in the meantime and was therefore no longer accessible to us. The fog only thinned significantly later that day and shifted

northeastward with the moderate southwest wind, supported by lee effects from Svalbard, so that good flying conditions once again occurred in the afternoon and evening.

During the night into 10 August, the wind backed south and brought in a new large-scale and long-lasting foggy area. We were situated at the edge of the high just west of Severnaya Zemlya. The temperature above the fog, directly at the upper limit of the inversion, rose to just below +13°C by 11 August (radiosonde ascent on 11 August at 7 UTC).

Ice station 2c – fog

Late in the evening of 10 August, we left the ice station 1c and reached the second ice floe between Svalbard and the North Pole for the third time on the morning of 12 August. With a southerly air flow (mostly 3 to 4 Bft) at the edge of a high just southeast of Franz Josef Land, mild air masses continued to be transported into the Arctic. The fog was freezing on the night of 12 August and caused ice to form on the ship and the measuring instruments. By 13 August, the high had shifted southeast to Severnaya Zemlya, and the low-pressure complex over the Greenland Sea had slowly weakened, causing the wind to calm to 1 to 2 Bft during the night into 13 August.

On 13 August, a small-scale low formed just north of Svalbard, south of our current position. The wind therefore shifted east and temporarily increased to 5 Bft during the following night. At the same time, the low caused freezing rain on the evening of 13 August and the night. As the low moved northwest, the wind veered south by the morning.

Ice station 3c – strong northwest wind, fog, sun

In the meantime, an Icelandic low moved northeast and crossed Svalbard on 15 August. From the evening of 14 August to the evening of 16 August, the *Polarstern* travelled westward from the second ice station to the third ice station, passing through the occlusion front of the low, where fog and intermittent freezing rain occurred. From 16 August onwards, the low was located east of us, while at the same time a high over Greenland intensified. Therefore, on 15 August, the wind, which had previously been predominantly southerly, backed north, increased to 6 Bft by the evening of 16 August (when reaching ice floe 3) and continued backing northwest. As the low and its occlusion front moved further northeast, the wind decreased to 4 Bft by 18 August and backed west at the edge of a high-pressure ridge extending northward. With the inflow of drier air from Greenland, the possibility of fog also decreased significantly, so that the 18 August, the last day on the ice floe, was completely fog-free.

After leaving the third ice floe late in the evening of 18 August, the wind veered northwest during the night and increased to 6 to 7 Bft by the morning, due to a low moving north of Greenland southeastwards and bringing in low stratus clouds that changed into fog during the course of the day. The ridge, which extended from a high over Iceland along the east coast of Greenland northward and in front of which the *Polarstern* was travelling eastward, shifted very slowly towards the east. As a result, the wind veered north on 19 August and decreased to 4 Bft. In the night of 20 August, the fog cleared for a few hours.

Ice station 1d – rescue of the lost floe during sunny conditions

While the previous low slowly weakened, a secondary low formed on 17 August at the occlusion front over the Barents Sea. It deepened as it moved westward, lay just southeast of Svalbard on 19 August, then moved southward and merged with another low over the Kola Peninsula. Due to the prevailing northeastern wind over ice floe 1, which had broken into pieces by then, it drifted back across the border of the Russian EEZ (exclusive economic zone) into the Norwegian EEZ by 20 August, making it accessible to us again.

The high-pressure ridge extending northeast through the Fram Strait (and on whose eastern flank we were located) caused widespread fog dissipation, resulting in sunny conditions from

the night into 21 August onwards. This facilitated the search and recovery of the remains of the first ice floe in the area of the sea ice edge at 83.2° north 30.2° east to 33.3° east, which took place from the afternoon of 21 August until late into the night. Here, for the first time, a swell from the east with a wave height of 1.5 m could be observed again.

Ice station 2d – snow fall

On the way to the second ice station on 22 August, the weather remained sunny with only a few shallow fog patches as we travelled northwest through the central area of the high-pressure ridge. The previously moderate north wind calmed down and backed southwest during the course of the day. In the evening, we reached an occlusion of a large-scale low-pressure system between the North Pole and the Beaufort Sea, which extended around the North Pole to the southwest towards Greenland and only slowly moved eastwards as it slowly dissipated. As a result, from the night into 23 August onwards, there was once again persistent fog with only brief interruptions.

From the morning of 23 August to the afternoon of 24 August, we were for the last time at the second ice floe at 84.2° north, 18.1° east, north of Svalbard. A low from northern Greenland moved northeast and passed over us during the night into 25 August, so that on the afternoon of 24 August, as we left the ice floe, there was freezing rain, which turned to snowfall in the evening and left a snow layer of about 3 cm on the ship. At the same time, the wind veered from southeast to southwest during the night and temporarily increased to 4 Bft.

Afterwards, a high-pressure ridge built up to the north over Svalbard and moved eastwards on 25 August. As a result, the wind backed south during the voyage from the second to the third ice floe on 25 August and increased to 5 Bft. At the same time, a low over the northeast coast of Greenland brought light snowfall once again while moving northwards. Only a few thin fog patches remained at the back side of the low.

Ice station 3d – sun

Reaching the third ice floe just northeast of Greenland at 82.4° north 6.1° west for a last time on the morning of 26 August, we got into the area of a weak low that had been moving in the meanwhile from Iceland to the northeast, crossing the Fram Strait on 26 August and being situated north of Svalbard on 27 August. Afterwards, a ridge that was extending from a high over the Norwegian Sea to the north moved eastwards across the Fram Strait and crossed Svalbard on 28 August. On its front side the low moved from 27 to 28 August to the southeast to the Barents Sea and filled up. Thus, the southern wind calmed down to 2 to 3 Bft on 26 August and shifted northwest. On 26 August isolated fog patches still occurred, but the air mass generally became dryer on 27 August due to the high pressure influence. Therefore, on 27 and in the morning of 28 August it was mostly sunny. In the evening of 27 August we left the third ice floe and stayed northeast of Greenland until 29 August evening.

2. SEA ICE PHYSICS

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Grant-No. AWI_PS149_01 and AWI_PS149_05

Outline and objectives

Sea ice acts as an integrator of fluxes and exchange processes between the atmosphere and the ocean and provides a unique habitat that is rapidly changing. The study of sea ice physics is therefore closely linked to all other scientific groups participating in CONTRASTS. Our main goal is to investigate the physical properties and key processes of different sea ice regimes:

- Characterize different sea ice regimes in the central Arctic, which are the focus of CONTRASTS.
- Quantify summer (melt) processes of sea ice as functions of atmospheric and oceanic boundary conditions.
- Advance understanding of ongoing changes in summer sea ice, building on results from previous expeditions (e.g., MOSAiC 2019/2020; Nicolaus et al., 2022).
- Improve knowledge of atmosphere-ice-ocean interactions, with particular emphasis on thermodynamic processes and sea ice's role as both a habitat and a barrier.
- Enhance observational capabilities, testing new instruments and measurement systems in challenging Arctic conditions.

These objectives are addressed through the following thematic sub-programs.

Topic 1: Energy Budgets

We aim to quantify how energy is distributed and used for sea ice melt in different regimes over space and time. This focus includes understanding:

- The partitioning of shortwave radiation (broadband, spectral and hyperspectral), specifically in how it is reflected, absorbed, and transmitted.
- Formation and evolution of melt ponds and their contribution to surface, lateral, and bottom ice melt.
- Changes in sea ice surface conditions (e.g., surface scattering layer, deteriorated ice) and internal ice structure.

These studies will build on insights from previous expeditions (e.g., MOSAiC and ArcWatch-1/2) and help validate satellite retrievals and improve model parameterizations. A key aspect is linking the mass and energy budgets to understand the fate of meltwater both at the surface (melt ponds) and directly beneath the ice, which can rapidly transition toward refreezing later in the season.

Topic 2: Mass Balance

During CONTRASTS, we investigated sea ice mass balance, thickness, and snow distribution on various spatial scales and in different ice regimes throughout the summer. The observations (airborne, floe-level, shipborne) complement the long-term IceBird survey program carried out with *Polar5/6* every summer. We are particularly interested in thickness differences among sea ice of varying ages. By combining thickness measurements with satellite-derived ice drift, we can estimate volume fluxes across Fram Strait region.

Topic 3: Remote Sensing of Sea Ice*Hyperspectral Imaging of Melt Ponds and Sea Ice*

The color and spectral signature of melt ponds evolve throughout the melt season, influenced by factors such as pond depth, trapped bubbles, and impurities. Meanwhile, the reflectance of summer sea ice is largely determined by the presence of snow and the surface scattering layer. By measuring spectra in the range of 400–1000 nm, we seek to refine satellite retrievals of surface albedo, melt pond fraction, and possibly melt pond bottom ice thickness.

Microwave Emission of Sea Ice

Satellite-borne microwave radiometers have monitored Arctic sea ice area since the 1970s. Although many parameters can be retrieved in the freezing season, summer melt (with abundant liquid water on or in the ice) complicates interpretations. We study the variability in microwave emission at common satellite frequencies (19, 37, and near 90 GHz), as well as at 1.4 GHz (used for thin ice thickness retrievals) and atmospheric absorption regions (around 23, 56, 183, 243, and 340 GHz). This work aims to improve summer retrieval methods and extend current satellite remote sensing capabilities.

Helicopter-Borne Thermal Infrared Surface Imaging

During summer, temperature differences between ocean, sea ice, and melt ponds often drop below 5 K, but local variations still occur. Helicopter-based thermal infrared imaging will capture this surface temperature variability, helping us characterize melt pond fractions and the thermal CONTRASTS between different ice features and open water.

Topic 4: Bio-Physical Linkages

Optical Cryomineral Detection and Sea ice Biophysical Properties (WISELIGHT Project)

When sea ice melts or breaks up, cryogenic minerals like gypsum can be released into the upper ocean and potentially transported to great depths (Wollenburg et al., 2020). The abundance and formation regime of these minerals remain cryptic. WISELIGHT tests a novel hyperspectral imaging (HI) technique to detect these minerals in extracted ice cores or melted filtered ice core samples (800–1700 nm, SWIR range) with the goal to fill a critical methodological gap in how we observe and quantify cryomineral precipitation in sea ice. The project has three main objectives:

- Develop a novel efficient optical method to directly image cryogenic gypsum in sea ice core or filtered melted core samples using SWIR hyperspectral imaging.
- Obtain a baseline of gypsum content in different ice regimes of the Central Arctic Ocean during the melt season.
- Link optical measurements and cryomineral content with ice physicochemical and biophysical properties including temperature, salinity, density, meltwater chemistry, ice structure and ice biological properties such as Chl-*a*, suspended particulate matter, and transparent exopolymeric substances, TEP).

Additional observations, such as under-ice sediment traps and ROV sampling, aimed to help determine whether gypsum influences biological material aggregation, and the underlying interconnection between the sea ice and any nutrient/carbon fluxes under-ice.

Topic 5: Surface Properties of Sea Ice

Snow and ice surfaces become highly heterogeneous during Arctic summer, with melt ponds, leads, ridges, and roughness features all affecting energy and momentum transfer and stability of the boundary layer. Within topic 5 we will focus on the following aspects:

- Quantifying snow/ice surface properties – including albedo, roughness, and melt pond development – influencing the turbulent exchange at the atmosphere-ice interface.
- Assessing near-surface Arctic boundary layer processes caused by surface heterogeneities. We will examine how thermal vs. topographic drivers influence local wind systems and turbulent energy exchange.
- Improving model parameterizations of small-scale boundary layer processes in climate models.

A key component is understanding the ice-albedo feedback. We will integrate airborne (e.g., drones, helicopters, airplanes) and surface-based observations to map melt pond fraction, bathymetry, sea ice thickness, and surface albedo in multiple ice regimes. Surface data will validate bathymetry measurements from airborne sensors (including a scanner with a green laser on aircraft *Polar 6*). We will also evaluate the utility of drones as a complement or alternative to helicopters for broad-scale melt pond observations under various weather conditions.

Topic 6: Operations in Ice-Covered Waters

We are conducting a project called IceWise to evaluate the added value of using satellite data for navigation in ice-covered waters. To number the added value, we compared transits made through ice with and without satellite-support (MapViewer). During transit, the following parameters were monitored:

- Engine parameters (fuel consumption, engine load)
- Progress through ice (speed, route efficiency)
- Time saved (overall transit duration)
- Ice type (ice thickness using the SIMs and optical data from Panomax)

By analyzing operational metrics under these different navigation strategies, we aim to quantify the benefits of state of the art satellite data (Sentinel-1, TerraSAR-X, RADARSAT) integration for more efficient passage through different ice types and regimes.

Topic 7: Sea Ice Dynamics

Finally, we investigated sea ice dynamics using a network of GPS-equipped buoys deployed in Fram Strait and further north. This region experiences heavy deformation and dynamic thickening, and satellite-derived motion or deformation parameters can be unreliable. The buoy network:

- Provides high-resolution drift data
- Captures deformation events across spatial scales
- Improves understanding of how ice in this region evolves under strong dynamic forcing

These insights will be especially valuable for refining satellite-based motion and deformation products in areas where existing methods face large uncertainties.

Surface Measurements during Ice Stations

2.1 Surface albedo

Work at sea

Spectral and broadband albedo measurements were collected on three ice stations during the 2025 CONTRASTS expedition. Broadband albedo measurements were performed with a Kipp and Zonen albedometer (Fig. 2.1.1, left). It consisted of two pyranometers recording the incoming and reflected radiation in the form of an electrical signal measured with a multimeter. Spectral albedo measurements were made with an ASD FieldSpec3 spectroradiometer (Fig. 2.1.1, right). The ASD measures radiant energy with a spectral range of 350-2,500 nm. Albedos were calculated using the ratio of incident (incoming) to reflected energy at each wavelength. The unit was housed in a backpack with a fiber optic cable extending to the sensor. The sensor was mounted on the end of a 1 m long arm in a gooseneck aimed at a spectralon cosine collector. During every albedo survey, coincident photographs and snow, surface scattering layer, and melt pond depth were recorded every 5 m using a ruler.



Fig. 2.1.1: Left: A Kipp and Zonen albedometer was used to measure broadband albedo, photo from 22 July 2025 on R3a. Right: An ASD FieldSpec3 spectroradiometer was used to measure spectral albedo, photo from 1 August 2025 on R2b.

Table 2.1.1 gives an overview of the albedo measurements including the device names and event ID numbers. At Station 1, there was a total of two albedo lines: (1) “Nanuk Transect”, a 200-m transect established on R1a to complement optics measurements with the ROV program, and (2) “Main2 Transect”, a new 200 m survey line established on R1b due to the melt-out of the Nanuk Transect. At Station 2, there was a total of three shorter albedo surveys: (1) “Oogruk Transect”, a 90 m survey facing southward and within the ROV optics grid, (2) the level ice portion of the “Main Transect”, extending 85 m on the ROV optics grid, and (3) the “Rafted Ice Transect”, extending 90 m along the Main Transect within the ROV optics grid. At Station 3, two 100 m albedo surveys were established on both sides of the ROV optics grid: (1) “Aiviq Transect” and (2) the “Main Transect”. At all stations, opportunistic albedo measurements were made in collaboration with other activities (e.g., melt pond surveys) and surface scattering layer (SSL) experiments.

Tab. 2.1.1: An overview of the spectral and broadband measurements collected during the 2025 CONTRASTS expedition

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
R1a	20250710-r1a-nanuq-transect	20250710	ASD, Kipps	PS149_13-1-Dart_ASD-01, PS149_13-1-Dart_Kipps-01, PS149_13-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive, ablation stakes
R1a	20250711-r1a-nanuq-transect	20250711	ASD, Kipps	PS149_13-1-Dart_ASD-02, PS149_13-1-Dart_Kipps-02, PS149_13-1-ruler-02	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive, ablation stakes
R1a	20250711-r1a-ponds-library	20250711	ASD, Kipps	PS149_13-1-Dart_ASD-03, PS149_13-1-Dart_Kipps-03, PS149_13-1-ruler-03	Ablation stakes
R1a	20250712-r1a-ssl-experiment	20250712	ASD, Kipps	PS149_13-1-Dart_ASD-04, PS149_13-1-Dart_Kipps-04, PS149_13-1-ruler-04; PS149_13-1-Dart_ASD-05, PS149_13-1-Dart_Kipps-05, PS149_13-1-ruler-05; PS149_13-1-Dart_ASD-06, PS149_13-1-Dart_Kipps-06, PS149_13-1-ruler-06; PS149_13-1-Dart_Kipps-07, PS149_13-1-ruler-07	Hyperspectral camera, snow characterization, transmittance
R1a	20250712-r1a-ponds-colocated	20250712	Kipps	PS149_13-1-Dart_Kipps-08	MagnaProbe (PS149_13-1-magnaprobe-marcel-02), drone survey

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
					(PS149_13-1-Mavic3-03)
R2a	20250715-r2a-oogruk-transect	20250715	ASD, Kipps	PS149_16-1-Dart_ASD-01, PS149_16-1-Dart_Kipps-01, PS149_16-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive, ablation stakes
R2a	20250715-r2a-ssl1-experiment	20250715	ASD, Kipps	PS149_16-1-Dart_ASD-02, PS149_16-1-Dart_Kipps-02, PS149_16-1-ruler-02; PS149_16-1-Dart_ASD-03, PS149_16-1-Dart_Kipps-03, PS149_16-1-ruler-03; PS149_16-1-Dart_ASD-04, PS149_16-1-Dart_Kipps-04, PS149_16-1-ruler-04	Transmittance, snow characterization
R2a	20250715-r2a-main-transect	20250715	ASD, Kipps	PS149_16-1-Dart_ASD-05, PS149_16-1-Dart_Kipps-05, PS149_16-1-ruler-05	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ablation stakes
R2a	20250716-r2a-ssl1-experiment	20250716	ASD, Kipps	PS149_16-1-Dart_ASD-06, PS149_16-1-Dart_Kipps-06, PS149_16-1-ruler-06; PS149_16-1-Dart_ASD-07, PS149_16-1-Dart_Kipps-07, PS149_16-1-ruler-07	Transmittance, snow characterization
R2a	20250717-r2a-ponds-library	20250717	ASD, Kipps	PS149_16-1-Dart_ASD-09, PS149_16-1-Dart_Kipps-09,	

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
				PS149_16-1-ruler-09	
R2a	20250717-r2a-raftedice-transect	20250717	ASD, Kipps	PS149_16-1-Dart_ASD-08, PS149_16-1-Dart_Kipps-08, PS149_16-1-ruler-08	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive, ablation stakes
R2a	20250717-r2a-ssl-colocated	20250717	ASD	PS149_16-1-Dart_ASD-10, PS149_16-1-Dart_Kipps-10, PS149_16-1-ruler-10	Snow characterization (PS149_16-1-snowpit_016)
R2a	20250717-r2a-ssl1-experiment	20250717	ASD, Kipps	PS149_16-1-Dart_ASD-11, PS149_16-1-Dart_Kipps-11, PS149_16-1-ruler-11; PS149_16-1-Dart_ASD-12, PS149_16-1-Dart_Kipps-12, PS149_16-1-ruler-12	Snow characterization
R3a	20250720-r3a-aiviq-transect	20250720	ASD, Kipps	PS149_18-1-Dart_ASD-01, PS149_18-1-Dart_Kipps-01, PS149_18-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive
R3a	20250720-r3a-main-transect	20250720	ASD, Kipps	PS149_18-1-Dart_ASD-02, PS149_18-1-Dart_Kipps-02, PS149_18-1-ruler-02	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ablation stakes
R3a	20250721-r3a-ssl-experiment	20250721	ASD, Kipps	PS149_18-1-Dart_ASD-03, PS149_18-1-Dart_Kipps-03, PS149_18-1-ruler-03; PS149_18-1-Dart_ASD-04, PS149_18-1-Dart_Kipps-04,	Transmittance, snow characterization

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
				PS149_18-1-ruler-04; PS149_18-1-Dart_ASD-05, PS149_18-1-Dart_Kipps-05, PS149_18-1-ruler-05	
R3a	20250722-r3a-ponds-colocated	20250722	ASD, Kipps	PS149_18-1-Dart_ASD-06, PS149_18-1-Dart_Kipps-06, PS149_18-1-ruler-06	
R3a	20250722-r3a-ssl-experiment	20250722	ASD, Kipps	PS149_18-1-Dart_ASD-07, PS149_18-1-Dart_Kipps-07, PS149_18-1-ruler-07; PS149_18-1-Dart_ASD-08, PS149_18-1-Dart_Kipps-08, PS149_18-1-ruler-08	Transmittance, snow characterization, hyperspectral camera
R3a	20250722-r3a-ponds-colocated	20250722	Kipps	PS149_18-1-Dart_Kipps-09	Drone surveys (PS149_18-1-Mavic3-03, PS149_18-1-Mavic3-04)
R1b	20250726-r1b-ponds-library	20250726	ASD, Kipps	PS149_21-1-Dart_ASD-02, PS149_21-1-Dart_Kipps-02, PS149_21-1-ruler-02	
R1b	20250726-r1b-main2-transect	20250726	ASD, Kipps	PS149_21-1-Dart_ASD-01, PS149_21-1-Dart_Kipps-01, PS149_21-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization
R1b	20250727-r1b-metcity-colocated	20250727	ASD, Kipps	PS149_21-1-Dart_Kipps-03	Met City
R1b	20250727-r1b-ponds-library	20250727	ASD, Kipps	PS149_21-1-Dart_ASD-04, PS149_21-1-Dart_Kipps-04,	

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
				PS149_21-1-ruler-04; PS149_21-1-Dart_ASD-05, PS149_21-1-Dart_Kipps-05, PS149_21-1-ruler-05	
R1b	20250727-r1b-rov2-transect	20250727	ASD, Kipps	PS149_21-1-Dart_ASD-06, PS149_21-1-Dart_Kipps-06, PS149_21-1-ruler-06	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive,
R1b	20250727-r1b-snow-colocated	20250727	ASD	PS149_21-1-Dart_ASD-07	Snowpit (PS149_21-1-snowpit_031)
R1b	20250727-r1b-ponds-colocated	20250727	ASD, Kipps	PS149_21-1-Dart_ASD-08, PS149_21-1-Dart_Kipps-08, PS149_21-1-ruler-08	Hyperspectral camera, transmittance
R1b	20250728-r1b-ponds-colocated	20250728	Kipps	PS149_21-1-Dart_Kipps-09	Drone surveys (PS149_21-1-Mavic3-01; PS149_21-1-Mavic3-02; PS149_21-1-Matrice_350_RTK-03 PS149_21-1-Matrice_350_RTK-04), magnaprobe
R2b	20250730-r2b-oogruk-transect	20250730	ASD, Kipps	PS149_25-1-Dart_ASD-01, PS149_25-1-Dart_Kipps-01, PS149_25-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ablation stakes, ROV optics dive
R2b	20250731-r2b-ponds-library	20250731	ASD, Kipps	PS149_25-1-Dart_ASD-03, PS149_25-1-Dart_Kipps-03, PS149_25-1-ruler-03	
R2b	20250731-r2b-metcity-colocated	20250731	Kipps	PS149_25-1-Dart_Kipps-02	Met City

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
R2b	20250731-r2b-ponds-colocated	20250731	Kipps	PS149_25-1-Dart_Kipps-06	Drone survey (PS149_25-1-Mavic3-02)
R2b	20250731-r2b-raftedice-transect	20250731	ASD, Kipps	PS149_25-1-Dart_AS-04, PS149_25-1-Dart_Kipps-04, PS149_25-1-ruler-04	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ablation stakes, ROV optics dive
R2b	20250731-r2b-ssl2-experiment	20250731	ASD, Kipps	PS149_25-1-Dart_AS-05, PS149_25-1-Dart_Kipps-05, PS149_25-1-ruler-05	Hyperspectral camera, snow characterization
R2b	20250801-r2b-oogruk-transect	20250801	ASD, Kipps	PS149_25-1-Dart_AS-07, PS149_25-1-Dart_Kipps-07, PS149_25-1-ruler-07	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ablation stakes, ROV optics dive
R2b	20250801-r2b-ponds-library	20250801	ASD	PS149_25-1-Dart_AS-08, PS149_25-1-ruler-08	
R2b	20250801-r2b-raftedice-transect	20250801	ASD, Kipps	PS149_25-1-Dart_AS-09, PS149_25-1-Dart_Kipps-09, PS149_25-1-ruler-09	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive, ablation stakes
R2b	20250801-r2b-ssl2-experiment	20250801	ASD, Kipps	PS149_25-1-Dart_AS-10, PS149_25-1-Dart_Kipps-10, PS149_25-1-ruler-10	Snow characterization
R2b	20250801-r2b-main-transect	20250801	ASD, Kipps	PS149_25-1-Dart_AS-11, PS149_25-1-Dart_Kipps-11, PS149_25-1-ruler-11	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ablation stakes, ROV optics dive
R3b	20250804-r3b-main-transect	20250804	ASD, Kipps	PS149_30-1-Dart_AS-01, PS149_30-1-	Hyperspectral camera, GEM, ARIEL,

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
				Dart_Kipps-01, PS149_30-1-ruler-01	MagnaProbe, snow characterization, ablation stakes
R3b	20250804-r3b-ponds-colocated	20250804	ASD, Kipps	PS149_30-1-Dart_ASD-02, PS149_30-1-Dart_Kipps-02, PS149_30-1-ruler-02	Transmittance, hyperspectral camera
R3b	20250804-r3b-ssl-experiment	20250804	ASD, Kipps	PS149_30-1-Dart_ASD-03, PS149_30-1-Dart_Kipps-03, PS149_30-1-ruler-03	Snow characterization
R3b	20250805-r3b-aiviq-a-transect	20250805	ASD, Kipps	PS149_30-1-Dart_ASD-07, PS149_30-1-Dart_Kipps-07, PS149_30-1-ruler-07	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive
R3b	20250805-r3b-aiviq-b-transect	20250805	ASD, Kipps	PS149_30-1-Dart_ASD-10, PS149_30-1-Dart_Kipps-10, PS149_30-1-ruler-10	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive
R3b	20250805-r3b-ponds-colocated	20250805	Kipps	PS149_30-1-Dart_Kipps-06	Magnaprobe, drove survey (PS149_30-1-Matrice_350_RTK-03)
R3b	20250805-r3b-ssl-experiment	20250805	ASD, Kipps	PS149_30-1-Dart_ASD-04, PS149_30-1-Dart_Kipps-04, PS149_30-1-ruler-04; PS149_30-1-Dart_ASD-05, PS149_30-1-Dart_Kipps-05, PS149_30-1-ruler-05	Snow characterization, hyperspectral camera
R3b	20250806-r3b-metcity-colocated	20250806	Kipps	PS149_30-1-Dart_Kipps-08	Met City
R3b	20250806-r3b-ponds-colocated	20250806	ASD	PS149_30-1-Dart_ASD-11	Transmittance

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
R3b	20250806-r3b-ssl-experiment	20250806	ASD, Kipps	PS149_30-1-Dart_ASD-09, PS149_30-1-Dart_Kipps-09, PS149_30-1-ruler-09	Snow characterization
R1c	20250809-r1c-main3-transect	20250809	ASD, Kipps	PS149_32-1-Dart_ASD-01, PS149_32-1-Dart_Kipps-01, PS149_32-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ablation stakes
R1c	20250810-r1c-coring-colocated	20250810	ASD, Kipps	PS149_32-1-Dart_ASD-02, PS149_32-1-Dart_Kipps-02, PS149_32-1-ruler-02	Density core, transmittance
R1c	20250810-r1c-main3-transect	20250810	ASD, Kipps	PS149_32-1-Dart_ASD-03, PS149_32-1-Dart_Kipps-03, PS149_32-1-ruler-03	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization
R1c	20250810-r1c-ponds-colocated	20250810	Kipps	PS149_32-1-Dart_Kipps-04	Magnaprobe, drone surveys (PS149_32-1-Mavic3-01; PS149_32-1-Matrice_350_RTK-01)
R1c	20250810-r1c-rov-transect	20250810	ASD, Kipps	PS149_32-1-Dart_ASD-05, PS149_32-1-Dart_Kipps-05, PS149_32-1-ruler-05	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive
R2c	20250812-r2c-raftedice-transect	20250812	ASD, Kipps	PS149_36-1-Dart_ASD-01, PS149_36-1-Dart_Kipps-01, PS149_36-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive, ablation stakes
R2c	20250812-r2c-ssl3-experiment	20250812	ASD, Kipps	PS149_36-1-Dart_ASD-03, PS149_36-1-Dart_Kipps-03, PS149_36-1-ruler-03	Snow characterization, ARIEL, hyperspectral camera

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
R2c	20250812-r2c-t-transect	20250812	ASD, Kipps	PS149_36-1-Dart_ASD-02, PS149_36-1-Dart_Kipps-02, PS149_36-1-ruler-02	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization
R2c	20250813-r2c-ponds-colocated	20250813	ASD	PS149_36-1-Dart_ASD-04, PS149_36-1-Dart_Kipps-04, PS149_36-1-ruler-04	Density core, transmittance
R2c	20250813-r2c-ssl3-experiment	20250813	ASD	PS149_36-1-Dart_ASD-05, PS149_36-1-Dart_Kipps-05, PS149_36-1-ruler-05	Snow characterization, ARIEL, hyperspectral camera
R2c	20250814-r2c-coring-colocated	20250814	ASD	PS149_36-1-Dart_ASD-06, PS149_36-1-Dart_Kipps-06, PS149_36-1-ruler-06	Density core, transmittance
R2c	20250814-r2c-snow-colocated	20250814	ASD	PS149_36-1-Dart_ASD-07, PS149_36-1-Dart_Kipps-07, PS149_36-1-ruler-07	Snowpit (PS149_36-1-snowpit_076), ARIEL, hyperspectral camera
R2c	20250814-r2c-ssl3-experiment	20250814	ASD, Kipps in morning only.	PS149_36-1-Dart_ASD-08, PS149_36-1-Dart_Kipps-08, PS149_36-1-ruler-08; PS149_36-1-Dart_ASD-09, PS149_36-1-ruler-09	Snow characterization, ARIEL, hyperspectral camera
R3c	20250817-r3c-aiviq-transect	20250817	ASD, Kipps	PS149_41-1-Dart_ASD-02; PS149_41-1-Dart_Kipps-02; PS149_41-1-ruler-02	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive
R3c	20250817-r3c-main-transect	20250817	ASD, Kipps	PS149_41-1-Dart_ASD-01; PS149_41-1-Dart_Kipps-01; PS149_41-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization,

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
					ROV optics dive, ablation stakes
R3c	20250817-r3c-ponds-colocated	20250817	ASD	PS149_41-1-Dart_ASD-03	Density core, transmittance
R2d	20250823-r2d-beartracks-library	20250823	ASD, Kipps	PS149_46-1-Dart_ASD-02; PS149_46-1-Dart_Kipps-02; PS149_46-1-ruler-02	
R2d	20250823-r2d-coring-colocated	20250823	ASD	PS149_46-1-Dart_ASD-03; PS149_46-1-ruler-03	Density core, transmittance
R2d	20250823-r2d-raftedice-transect	20250823	ASD, Kipps	PS149_46-1-Dart_ASD-01; PS149_46-1-Dart_Kipps-01; PS149_46-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization, ROV optics dive, ablation stakes
R2d	20250823-r2d-ponds-library	20250823	ASD, Kipps	PS149_46-1-Dart_ASD-04; PS149_46-1-Dart_Kipps-04; PS149_46-1-ruler-04	
R2d	20250823-r2d-t-transect	20250823	ASD, Kipps	PS149_46-1-Dart_ASD-05; PS149_46-1-Dart_Kipps-05; PS149_46-1-ruler-05	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization
R2d	20250824-r2d-remotesensing-colocated	20250824	ASD	PS149_46-1-Dart_ASD-06; PS149_46-1-ruler-06	Remote sensing, snow pit, snow transect, ARIEL
R2d	20250824-r2d-snow-colocated	20250824	ASD	PS149_46-1-Dart_ASD-07; PS149_46-1-ruler-07	ARIEL, snow characterization
R3d	20250827-r3d-aiviq-transect	20250827	ASD, Kipps	PS149_47-1-Dart_ASD-01; PS149_41-1-Dart_Kipps-01; PS149_41-1-ruler-01	Hyperspectral camera, GEM, ARIEL, MagnaProbe, snow characterization
R3d	20250827-r3d-main-transect	20250827	ASD, Kipps	PS149_47-1-Dart_ASD-02; PS149_41-1-	Hyperspectral camera, GEM, ARIEL,

Station	Site / Albedo Folder	Date (YYYYMMDD)	Instrument	Event ID	Colocated measurements
				Dart_Kipps-02; PS149_41-1- ruler-02	MagnaProbe, snow characterization, ROV optics dive, ablation stakes
R3d	20250827- r3d-ponds- colocated	20250827	ASD	PS149_47-1- Dart_ASF-03	Density core, transmittance

Preliminary (expected) results

The spectral and broadband albedo surveys were performed at all ice stations and contribute to the long-term record of albedo measurements in the central Arctic. These observations will augment observational gaps from the 2019-2020 MOSAiC expedition (Fig. 2.1.2) and advance understanding on the spatio-temporal variability and evolution of surface albedo across three contrasting sea ice regimes during the melt season.

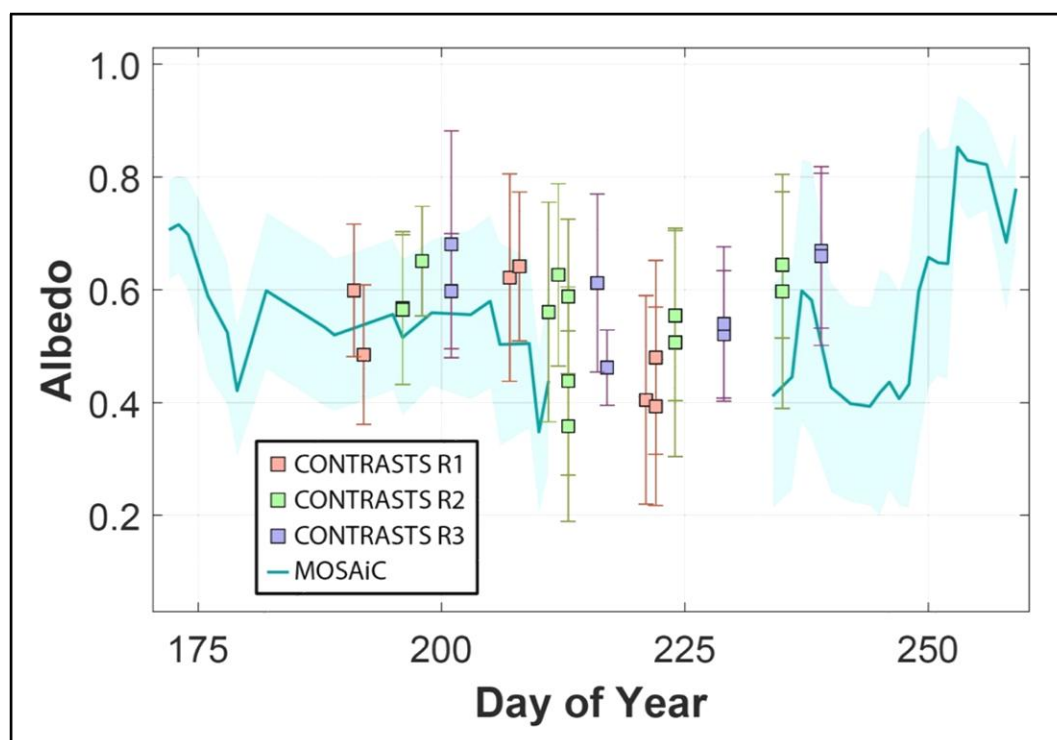


Fig. 2.1.2: A comparison of broadband albedos between the three CONTRASTS ice stations (R1, R2, R3) and spring-autumn measurements in 2020 during the MOSAiC expedition. CONTRASTS augments the observational gap in the MOSAiC time-series.

In Figure 2.1.3, spectral albedos are compared from the first visit at each ice station. R1 exhibited the lowest spectral albedo, whereas R3 exhibiting the highest albedo. Similarly, R1 had the darkest melt ponds whereas R3 had the lightest melt ponds, owing to differences in their sea ice thicknesses.

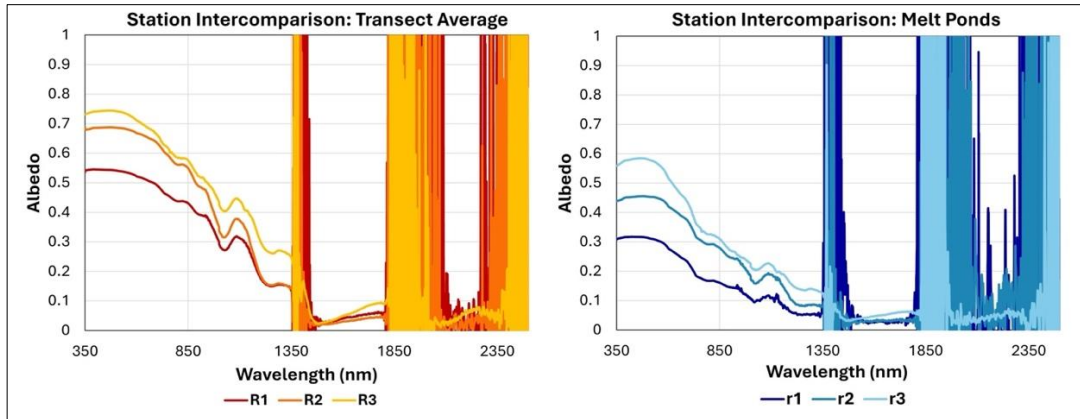


Fig. 2.1.3: Spectral albedos compared across Stations 1-3 (R1, R2, R3). Left: The transect-average spectral albedo across the three ice stations. Right: The average spectral albedo from melt ponds along the transects at each ice station.

In Figure 2.1.4, the time-series of broadband albedos along the Oogrük Transect shows temporal and spatial variability. In between the first (R2a) and second (R2b pre-rain) visits, the albedo increased on unpounded surfaces with fresh snowfall (0.65 to 0.69), whereas over melt ponds, the albedo decreased due to thinning ice (0.35 to 0.23). After heavy rainfall (R2b post-rain), the albedo over unpounded sea ice decreased substantially (0.69 to 0.56). The most dramatic decrease occurred in areas bordering melt ponds (-0.21).

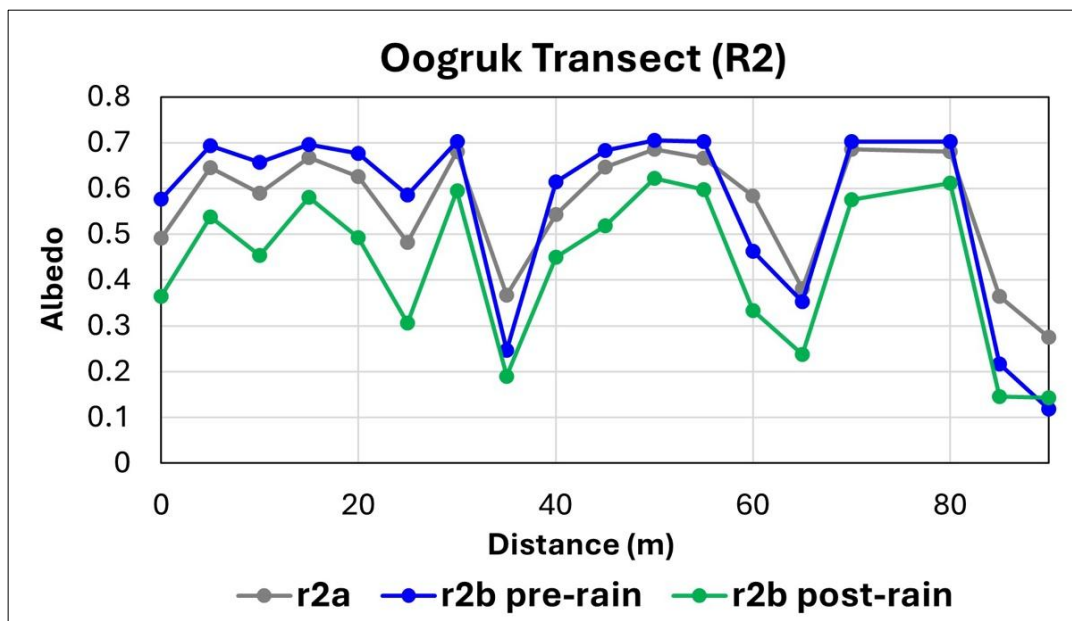


Fig. 2.1.4: The broadband albedo time-series along the Oogrük Transect at R2, where R2a was measured on 15 July 2025, R2b pre-rain on 30 July 2025, and R2b post-rain on 1 August 2025.

2.2 Ablation stakes

Work at sea

Sea ice thickness, draft, surface ablation, and snow/surface scattering layer or pond depth were manually measured at ablation stakes. Stakes also indirectly record basal melt, by subtracting the surface ablation from the total thickness change. The stakes were 3 meter long plastic tubes, designed to float with approximately 1 meter above the water surface. Stakes were deployed during the first visit at each station by drilling holes in the ice with a 2 inch Kovacs augur, measuring the ice thickness and draft, and then placing the stake in the hole. The position of the surface-air interface was then marked on the stake with electrical tape. As with most deployments in the ice, drilling a hole provided a conduit for fresh meltwater, which then froze the stake in the hole due to cold temperatures in the ice (e.g., see ice coring results, Section 2.11). On subsequent visits, if the stake were still frozen in, then the measurement from the tape mark to the new surface records surface ablation. When the stakes were no longer frozen in surface ablation was not measured. On repeat visits ice thickness and draft were measured by drilling a new hole within approximately 50 centimeters of the stake. Stakes were deployed along the main transect, where many co-located measurements were made. During the first visit when stakes were deployed, it was undesirable to drain melt ponds. So the stakes primarily record the evolution of bare ice. On floe 1, all but one ablation stake was inaccessible by the second visit (list of stake measurement events are provided in the station plan, appendix)

Preliminary (expected) results

Floe 2 experienced 60 cm of total melt from 15 July to 24 August and floe 3 experienced 29 cm of total melt from 21 July to 26 August (Fig. 2.2.1). Between visits 1 and 3, surface melt predominated at both floes. Between visits 3 and 4, floe 2 experienced accelerated basal melt and near-zero surface melt, whereas melt ceased at floe 3.

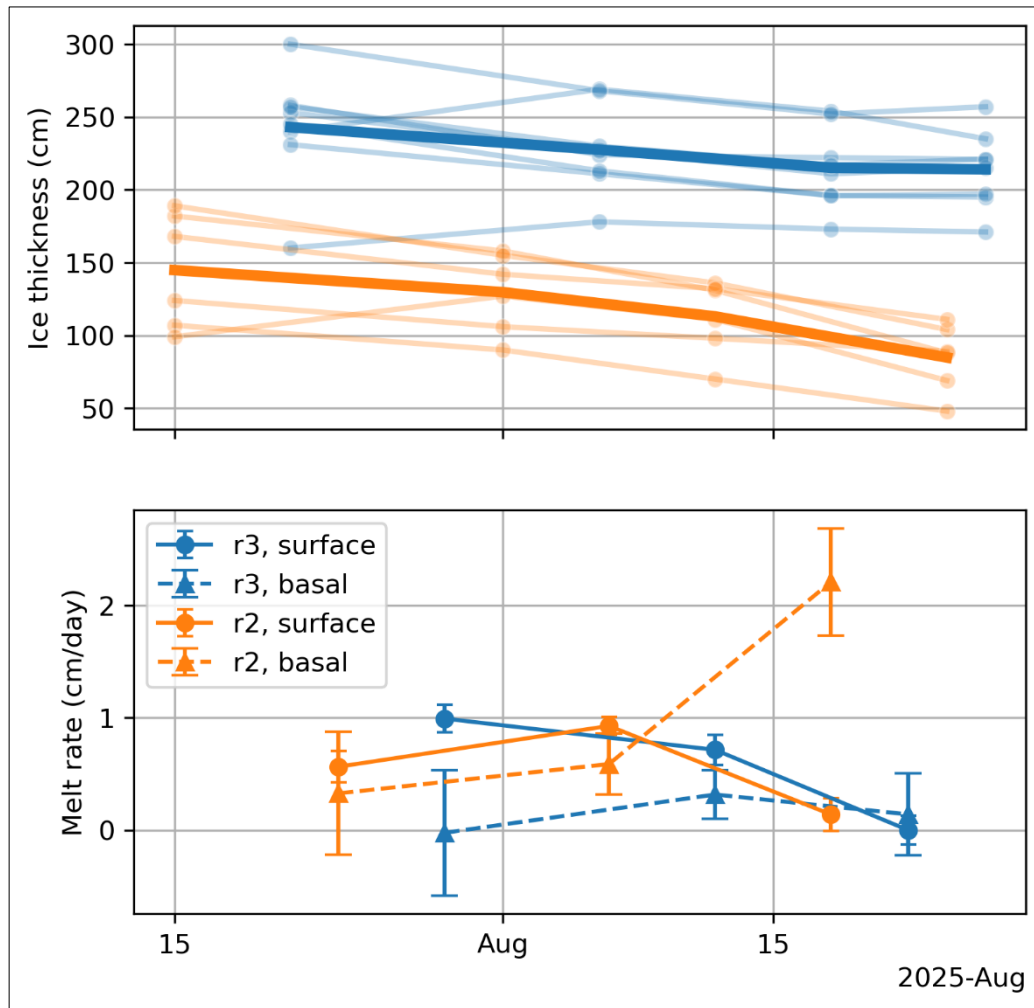


Fig. 2.2.1: Snow and ice thickness evolution (top) and implied surface and basal melt rates (bottom) for floe 2 (orange) and floe 3 (blue). In the top panel each faint line represents the measurement at an individual stake while the bold lines are the means for each floe. In the bottom panel, the error bars show the standard error of the mean for the surface melt rate. For the basal melt rate, the error bars are the sum in quadrature of the standard errors of the mean for the surface melt rate and total melt rate (basal melt rate is the difference of those two quantities). The horizontal positions of the melt rate points in the bottom panel is halfway between station visits.

2.3 Repeated measurements of snow and surface scattering layer

Work at sea

Data collection and events

All snow and events are recorded as PS149_xx-1-snowpit_xxx events. “Snowpit” is a parent device to all other “snow” devices. Each “snowpit” event is shown in Table 2.3.1. All events are recorded as device “snowpit” (PS149_xx-1-snowpit_xxx). The “optional label” indicates the location, and whether the event was an actual snowpit (“_snowpit”), a transect (“_transect”) or a special event. Metadata and detailed description of each event is in the AWI CONTRASTS logbook (<https://spaces.awi.de/spaces>), and are tagged as “snow”. The logbook will be downloaded as pdf and published with the data.

“Snowpit” measurements were collected on three ice stations/regimes during the 2025 CONTRASTS expedition. At each station, we established sites that were repeated at each station visit. The sites were chosen to support major installations and measurements on the floe, in coordination with other teams, namely: coring, remote sensing, albedo, ROV and transmittance, drones, and surface-atmosphere interactions.

Each snowpit was accompanied by a short transect, unless the snowpit was right next to other main transect locations. Snowpit transects were also done at main transect locations, where they were collocated with albedo or remote sensing measurements.

In total, performed 108 events, of which 38 are snowpits, 55 are transects, and 15 “other” events, most of which were specific collocated measurements with other teams.

Snow/SSL/interface Sampling

- 38 samples for microCT measurements in the lab in Davos.
- 30 samples of the snow/SSL interface and 5-10 cm below the interface. Those samples were cut in the freezer lab on board, measured for Salinity/Conductivity (Fig. 2.3.6) and bottled in vials for dO18 measurements.
- Samples of 3 frozen pond lids during station 2d and 3d, where our SnowImager transects crossed frozen ponds were sampled for microCT measurements in the lab in Davos.
- 150 samples for volumetric density (only in case of snow/SSL), salinity, dO18, and black carbon (BC). Density was measured in the field, salinity was measured on board, dO18 samples and BC samples will be sent to AWI Potsdam. Snow/SSL dO18 and were collected in the original frozen form in falcon tubes. Cut ice samples (glass vials) were melted and bottled in 20ml glass vials.
- We have under pond ice core samples for microCT measurements in Davos. The samples were collected by David Clemens-Sewall to better understand pond transmittance. Twin cores were processed on board by David and Dmitry Divine (CORING).

Field instruments

We use the following instruments:

- Density cutter and weighing scale (volumetric *density*)
- Wooden ruler (snow height), rectangular square profile of 2 mm x 15 mm)
- Avalanche probe (snow height), cylindrical cone profile with a diameter of 14 mm
- Thermometer (snow temperature)

- Metashape targets taped onto a builder's square to calculate small-scale roughness of the surface and the snow-ice interface by using photogrammetry
- Sonyalpha camera for overview pictures and photogrammetry
- SnowImager: For taking near infrared reflectance images of a snow surface or profile. It consists of a near infrared (850nm and 940 nm, separately) illumination system and two cameras to capture the reflected light. The housing of the SnowImager acts as a sun (light) shield. The imageable area is approximately 300 mm x 400 mm. A top and a bottom image of reflectance and dark (no illumination) images from two cameras are captured and stitched together in post processing. (specific surface area + density)

Snowpits and sampling

We followed a standard protocol for the snowpits, which consisted of:

1. Describing weather and surface conditions
2. Overview pictures of each site
3. Photogrammetry with targets of the surface (~1x1 m)
4. SnowImager SSA (specific surface area) measurements of the surface (3 sets)
5. SnowImager density (with grid) measurements of the surface (3 sets)
6. 5 snowheights in each SnowImager footprint, cm-accuracy. With ruler or avalanche probe or both
7. 16 snow/SSL height measurements of snow/SSL height measurements along 4.5m, every 0.3m with ruler and avalanche probe at the snowpit.
8. Snowpit "excavation" or scraping of the surface scattering layer with a shovel.
9. SnowImager measurement of the interface for SSA and density (1-3 sets)
10. SnowImager measurement of the snowpit wall for SSA and density, if there was enough height to do so.
11. Photogrammetry of the interface roughness.
12. Temperature profile (every cm)
13. Density, salinity, dO18, Black carbon sampling, (3 cm resolution)
14. microCT sample, max. sample height of 12cm whereas the snow surface is always included. With the 12 cm sample height we likely always captured the interface even though it was clear bare ice for all samples, especially on 2d, 3d when the ice column was dry, drained and mostly frozen
15. Thick section sample (only on floe 1a, 2a)
16. ice interface and below sample for salinity and dO18

Snow transects

We followed a standard protocol for the snowpits, which consisted of:

1. Overview pictures of each transect
2. SnowImager SSA surface measurements is either every 1 m (if it's a transect that accompanies a snowpit) or every 2-5 m if it is the Main Transect.
3. 5 snowheights in each SnowImager footprint, cm-accuracy. With ruler or avalanche probe or both
4. SnowImager density (with grid) measurements of the surface (usually offset by 0.5 m to the SSA transect). The density transect was not always done
5. Photogrammetry for surface roughness at 5-25 m intervals

Note: If melted ponds were part of our transects, we measured with the SnowImager next to the pond. If the ponds were frozen, we measured on top of the pond.

Collocated measurements

Most measurements were collocated with albedo, ARIEL, Hyperspectral Camera, the cloud radiometer on the peildeck (Vampire), GEM, MagnaProbe, ROV (along regular transects), Coring, RS, transmittance (dedicated snowpits and transects). We had targeted events (Snowbusters) for collocated measurements to describe specific surfaces with albedo, ARIEL or Hyperspectral camera, where we tried to establish a library of different surfaces and made coordinated measurements in more or less exact footprints of each other.

Comparing snow height measurements with ruler and avalanche probe

We noticed that the snow height measurements with the ruler were inconsistent with our snowpit height measurements, so after floe 2b, we started doing all our snow/SSL height measurements with both the ruler and the avalanche probe, which has a similar cone diameter like the MagnaProbe, so the measurements are more representative. These measurements will benefit from the microCT samples in trying to determine what the relevant quantity of “snow/SSL height” is. We took 7000+ of these comparative measurements to try and quantify biases due to different snow height measurements. The measurements should also be compared to MagnaProbe measurements at a later stage.

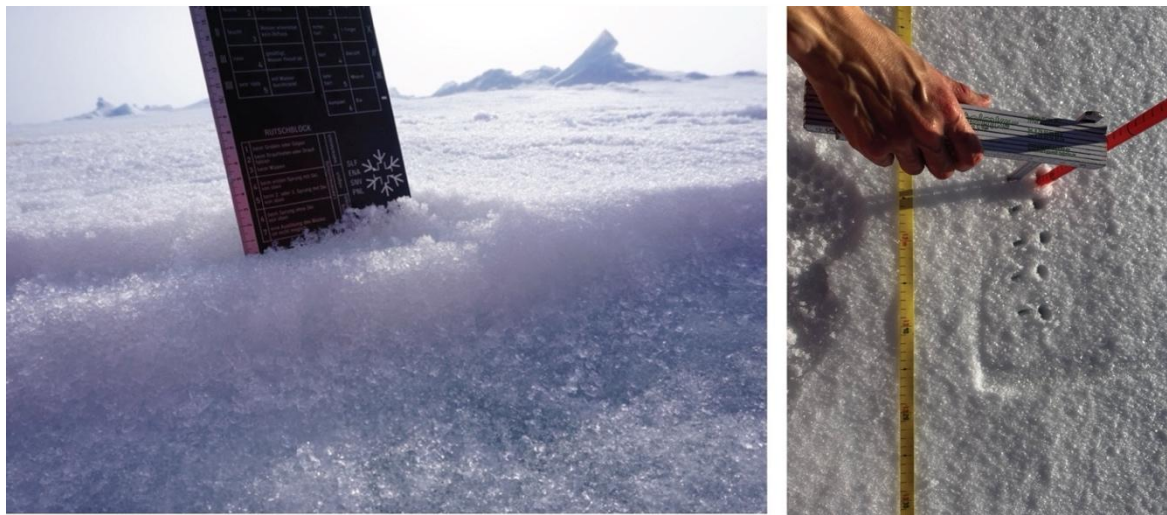


Fig. 2.3.1: Left image: Surface scattering layer, with maybe some snow on top at the EndOfMainTransect site (snowpit event 035). Only top part is soft and penetrable by the folding ruler. We compared the measurements of snow/SSL height to avalanche probe measurements (right image). Pictures by Ruzica Dadic

Tab. 2.3.1: List of „snowpit“ events that were measured during CONTRASTS. Broadly collocated events, such as drones, ROV, radiation station or atmospheric measurements are not specifically mentioned.

Event ID	Optional label	Collocation with
PS149_13-1-snowpit_001	snow_1a_RS_site_snowpit	VAMPIRE
PS149_13-1-snowpit_002	snow_1a_RS_site_transect	VAMPIRE
PS149_13-1-snowpit_003	snow_1a_RS_site_transect	VAMPIRE

Event ID	Optional label	Collocation with
PS149_13-1-snowpit_004	snow_1a_MainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_13-1-snowpit_005	snow_1a_RS_site_transect	VAMPIRE
PS149_13-1-snowpit_006	snow_1a_ThickIce_transect	
PS149_13-1-snowpit_007	snow_1a_RS_site_snowpit	VAMPIRE
PS149_13-1-snowpit_008	snow_1a_ThickIce_snowpit	
PS149_16-1-snowpit_009	snow_2a_SSL_experiment	Albedo, transmittance
PS149_16-1-snowpit_010	snow_2a_CORING_site_snowpit	Coring, transmittance
PS149_16-1-snowpit_011	snow_2a_CORING_site_transect	Coring, transmittance, albedo
PS149_16-1-snowpit_012	snow_2a_RS_site_transect	VAMPIRE
PS149_16-1-snowpit_013	snow_2a_RS_site_snowpit	VAMPIRE
PS149_16-1-snowpit_014	snow_2a_RS_site_transect	VAMPIRE
PS149_16-1-snowpit_015	snow_2a_MainTransect_transect_extended	Remote sensing, albedo, GEM, MagnaProbe
PS149_16-1-snowpit_016	snow_2a_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_18-1-snowpit_017	snow_3a_RS_site_transect	VAMPIRE
PS149_18-1-snowpit_018	snow_3a_RS_site_snowpit	VAMPIRE
PS149_18-1-snowpit_019	snow_3a_RS_site_transect	VAMPIRE
PS149_18-1-snowpit_020	snow_3a_CORING_site_snowpit	Coring, transmittance, albedo
PS149_18-1-snowpit_021	snow_3a_CORING_site_transect	Coring, transmittance, albedo
PS149_18-1-snowpit_022	snow_3a_SSL_experiment	Albedo, transmittance
PS149_18-1-snowpit_023	snow_3a_albedotransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_18-1-snowpit_024	snow_3a_MainTransect_transect_extended	Remote sensing, albedo, GEM, MagnaProbe
PS149_18-1-snowpit_025	snow_3a_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_21-1-snowpit_026	snow_1b_ThickIce_snowpit	GEM, Magnaprobe
PS149_21-1-snowpit_027	snow_1b_ThickIce_transect	GEM, Magnaprobe
PS149_21-1-snowpit_028	snow_1b_RS_site_snowpit	VAMPIRE
PS149_21-1-snowpit_029	snow_1b_RS_site_transect	VAMPIRE
PS149_21-1-snowpit_030	snow_1b_BeginningOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_21-1-snowpit_031	snow_1b_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_21-1-snowpit_032	snow_1b_MainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_25-1-snowpit_033	snow_2b_CORING_site_snowpit	Coring, transmittance, albedo
PS149_25-1-snowpit_034	snow_2b_CORING_site_transect	Coring, transmittance, albedo
PS149_25-1-snowpit_035	snow_2b_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_25-1-snowpit_036	snow_2b_EndOfMainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_25-1-snowpit_037	snow_2b_EndOfMainTransect_2_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_25-1-snowpit_038	snow_2b_RS_site_snowpit	VAMPIRE

Event ID	Optional label	Collocation with
PS149_25-1-snowpit_039	snow_2b_RS_site_transect	VAMPIRE
PS149_25-1-snowpit_040	snow_2b_MainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_25-1-snowpit_041	snow_2b_CORING_site_snowpit	Coring, transmittance, albedo
PS149_25-1-snowpit_042	snow_2b_CORING_site_transect	Coring, transmittance, albedo
PS149_25-1-snowpit_043	snow_2b_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_25-1-snowpit_044	snow_2b_EndOfMainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_25-1-snowpit_045	snow_2b_RS_site_snowpit	VAMPIRE
PS149_25-1-snowpit_046	snow_2b_RS_site_transect	VAMPIRE
PS149_25-1-snowpit_047	snow_2b_RS_site_2_snowpit	VAMPIRE
PS149_30-1-snowpit_048	snow_3b_RS_site_snowpit	VAMPIRE
PS149_30-1-snowpit_049	snow_3b_RS_site_transect	VAMPIRE
PS149_30-1-snowpit_050	snow_3b_CORING_site_transect	Coring, transmittance, albedo
PS149_30-1-snowpit_051	snow_3b_MainTransect_transect	transect
PS149_30-1-snowpit_052	snow_3b_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_30-1-snowpit_053	snow_3b_SedimentTrapPondNorth_snowpit	GEM, MagnaProbe
PS149_30-1-snowpit_054	snow_3b_SedimentTrapPondNorth_transect	GEM, MagnaProbe
PS149_30-1-snowpit_055	snow_3b_albedo_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_30-1-snowpit_056	snow_3b_MainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_30-1-snowpit_057	snow_3b_SedimentTrapPondNorth_snowpit	GEM, MagnaProbe
PS149_30-1-snowpit_058	snow_3b_SedimentTrapPondNorth_transect	GEM, MagnaProbe
PS149_30-1-snowpit_059	snow_3b_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_30-1-snowpit_060	snow_3b_MainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_30-1-snowpit_061	snow_3b_albedo_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_32-1-snowpit_062	snow_1c_CORING_site_snowpit	Coring, transmittance, albedo
PS149_32-1-snowpit_063	snow_1c_CORING_site_transect	Coring, transmittance, albedo
PS149_32-1-snowpit_064	snow_1c_MainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_32-1-snowpit_065	snow_1c_RS_site_snowpit	VAMPIRE
PS149_32-1-snowpit_066	snow_1c_RS_site_transect	VAMPIRE
PS149_32-1-snowpit_067	snow_1c_ROVTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_32-1-snowpit_068	snow_1c_turbulence_snowpit	
PS149_32-1-snowpit_069	snow_1c_turbulence_transect	
PS149_36-1-snowpit_070	snow_2c_CORING_site_snowpit	Coring, transmittance, albedo
PS149_36-1-snowpit_071	snow_2c_CORING_site_transect	Coring, transmittance, albedo

Event ID	Optional label	Collocation with
PS149_36-1-snowpit_072	snow_2c_MainTransect_transect_extended	Remote sensing, albedo, GEM, MagnaProbe
PS149_36-1-snowpit_073	snow_2c_Tline_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_36-1-snowpit_074	snow_2c_EndOfMAinTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_36-1-snowpit_075	snow_2c_EndOfMAinTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_36-1-snowpit_076	snow_2c_CoordinatedSurfaceMeasurements	Remote sensing, albedo, VAMPIRE
PS149_36-1-snowpit_077	snow_2c_RS_site_snowpit	VAMPIRE
PS149_36-1-snowpit_078	snow_2c_RS_site_transect	VAMPIRE
PS149_36-1-snowpit_079	snow_2c_precipitation_collection	Precipitation collection
PS149_36-1-snowpit_080	snow_2c_precipitation_collection	Precipitation collection
PS149_41-1-snowpit_081	snow_3c_SedimentTrapPondNorth_snowpit	GEM
PS149_41-1-snowpit_082	snow_3c_SedimentTrapPondNorth_transect	GEM
PS149_41-1-snowpit_083	snow_3c_RS_site_snowpit	VAMPIRE
PS149_41-1-snowpit_084	snow_3c_RS_site_transect	VAMPIRE
PS149_41-1-snowpit_085	snow_3c_MainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_41-1-snowpit_086	snow_3c_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_41-1-snowpit_087	snow_3c_albedo_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_41-1-snowpit_088	snow_3c_CoordinatedSurfaceMeasurements	Remote sensing
PS149_41-1-snowpit_089	snow_3c_CORING_site_snowpit	Coring, transmittance, albedo
PS149_41-1-snowpit_090	snow_3c_CORING_site_transect	Coring, transmittance, albedo
PS149_46-1-snowpit_091	snow_2d_MainTransect_transect_extended	Remote sensing, albedo, GEM, MagnaProbe
PS149_46-1-snowpit_092	snow_2d_CORING_site_snowpit	Coring, transmittance, albedo
PS149_46-1-snowpit_093	snow_2d_CORING_site_transect	Coring, transmittance, albedo
PS149_46-1-snowpit_094	snow_2d_EndOfMAinTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_46-1-snowpit_095	snow_2d_EndOfMainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_46-1-snowpit_096	snow_2d_Tline_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_46-1-snowpit_097	snow_2d_CoordinatedSurfaceMeasurements	Remote sensing, albedo
PS149_46-1-snowpit_098	snow_2d_RS_site_transect	VAMPIRE, Remote sensing, albedo
PS149_46-1-snowpit_099	snow_precipitation_collection	Precipitation collection
PS149_47-1-snowpit_100	snow_3d_SedimentTrapPondNorth_snowpit	

Event ID	Optional label	Collocation with
PS149_47-1-snowpit_101	snow_3d_SedimentTrapPondNorth_transect	
PS149_47-1-snowpit_102	snow_3d_MainTransect_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_47-1-snowpit_103	snow_3d_EndOfMainTransect_snowpit	Remote sensing, albedo, GEM, MagnaProbe
PS149_47-1-snowpit_104	snow_3d_albedo_transect	Remote sensing, albedo, GEM, MagnaProbe
PS149_47-1-snowpit_105	snow_3d_CORING_site_snowpit	Coring, transmittance, albedo
PS149_47-1-snowpit_106	snow_3d_CORING_site_transect	Coring, transmittance, albedo
PS149_47-1-snowpit_107	snow_3d_RS_site_snowpit	VAMPIRE
PS149_47-1-snowpit_108	snow_3d_RS_site_transect	VAMPIRE

Preliminary (expected) results

The objective of our measurements is to quantitatively describe the physical properties of summer snow and the surface scattering layer, including the statistical spatial variability.

On this expedition, we mainly characterized the surface scattering layer (Fig. 2.3.2), but some sites had snow until relatively late. Figure 2.3.3 is as an example for comparison of SnowImager reflectance at sites with different SSL/snow thickness.



*Fig. 2.3.2 Very anisotropic surface scattering layer at flow 2c, snowpit event 070.
Pictures by Ruzica Dadic.*

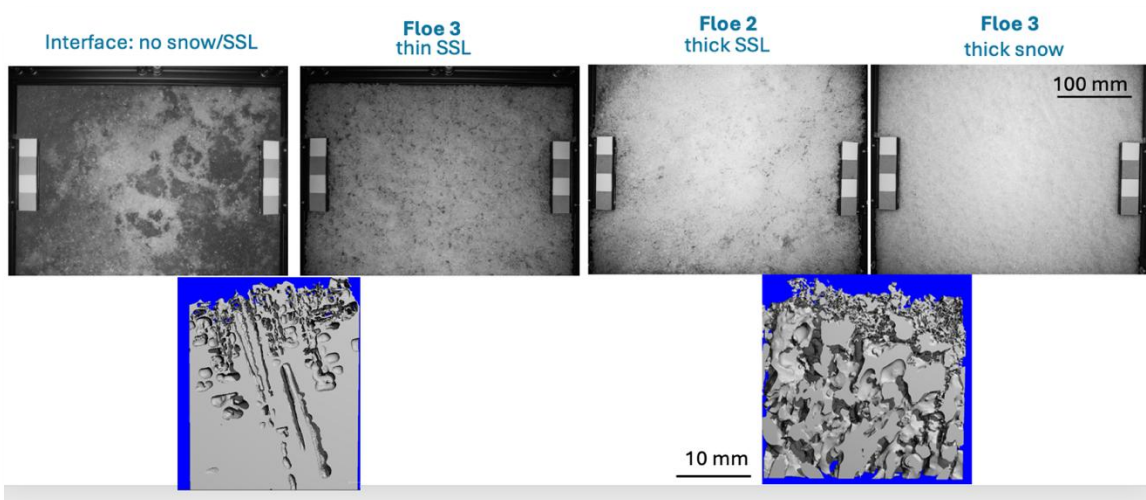


Fig. 2.3.3 Example of SnowImager images (reflectivity at 940 nm) at the ice interface, two different types of SSL and relatively thick snow. The microCT images below are from MOSAiC and just for orientation of how the microstructure may look.

- *Snow/SSL height:*
 - The snow/SSL height, which we could sample with the density cutter varied between 2-25 cm (Fig. 2.3.4.). The highest surface layer was found on station 3a, where the snow had not melted yet on the rafted ice of the “EndOfMain-Transect” snowpit. For the remainder of the cruise, the “softer” surface layer was between 5-10 cm. On station 2d and 3d, the SSL was frozen, with station 3d having a 3 cm new snow layer on top. The snow cores we collected for the microCT, however, did not, at least visually show a difference between the soft and hard layer. Snow/SSL densities varied between 180-550 kg/m³.
- *Snow/SSL density:*
 - Densities below 200 kg/m³ were very loose surface scattering layer crystals, while densities over 450 were wet samples which were either measured after rainfall or on wet snow, which could retain the meltwater (Fig. 2.3.5).
- *Snow/SSL salinity/conductivity:*
 - All but a few salinities were zero (including the top ~10 cm of ice), so we chose to show the measured conductivity, where we can see a clear signal of increasing conductivity from the surface into the top of the sea ice (Fig. 2.3.6).
- *Snow/SSL temperature:*
 - Most snow/SSL profile temperatures were between 0 - -0.2 C. At station 3d, where we had ~2-3 cm of snow and relatively clear skies, the surface got as cold as -1.5C.

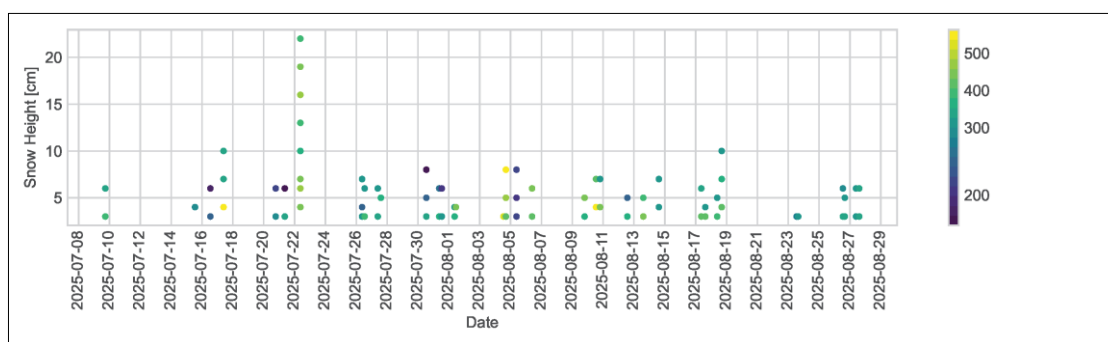


Fig. 2.3.4 Snow/SSL height from our snowpits during CONTRASTS. The colour bar represents the volumetric density in kg/m^3

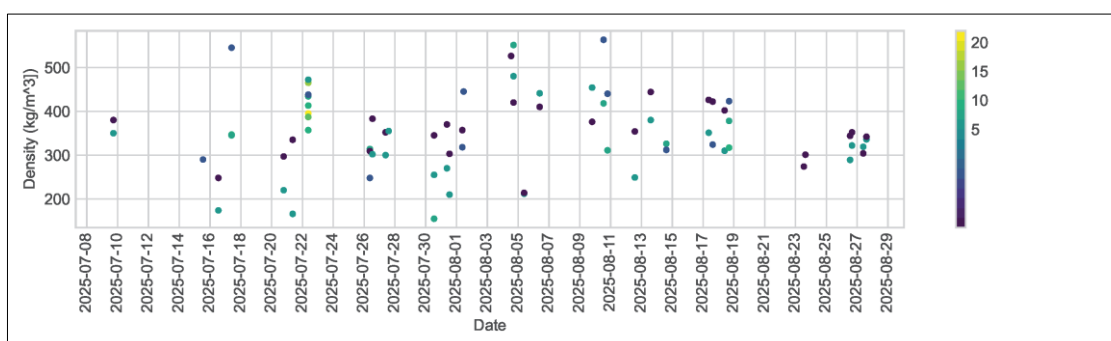


Fig. 2.3.5: Snow/SSL density from our snowpits during CONTRASTS. The colour bar represents the snow/SSL height.

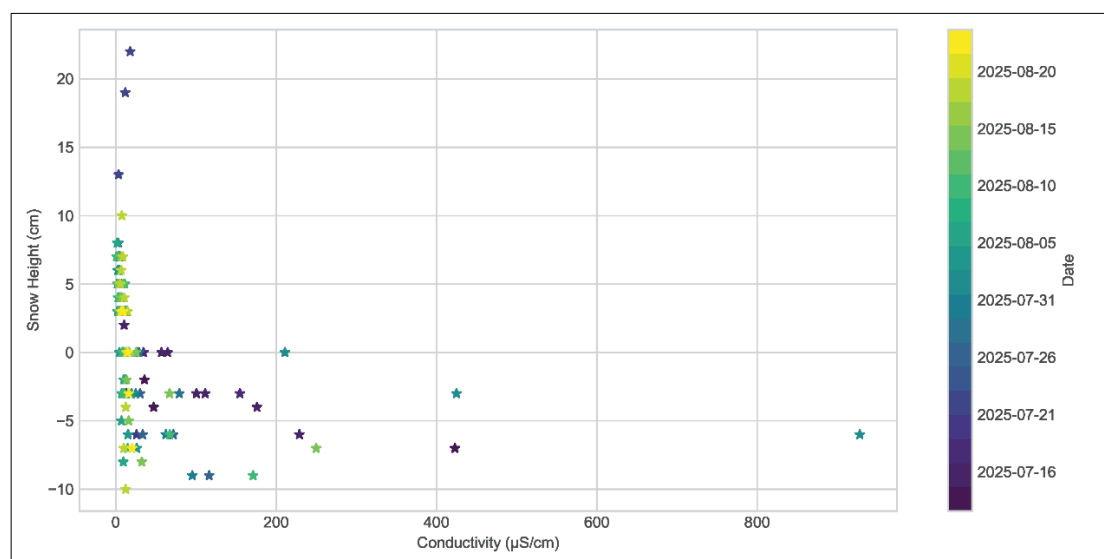


Fig. 2.3.6: Conductivity with snow/SSL height. The colour bar indicated the date of the snowpit sampling. This figure is still missing 10 interface samples of the top 10-15 cm of the ice. They could not be processed in time for this report.

The surface scattering layer showed relatively large temporal and also spatial variability, which we hope to quantify with the many Snowmager measurements. There were also many rain events and a few snow events, which we captured, and an example of which can be seen in Snowmager transect data in Figure 2.3.7. The figure shows a statistical distribution of reflectance (at 940 nm) and the resulting specific surface area (SSA) values along the CORING transect (20 m, measurements every 1 m). The small-scale spatial variability (within each image) is significantly larger before the rain event, which seems to “smooth out” the reflectance, which is also visible in the left part of the figure that shows two different Snowmager footprints. After the rain, the surface is darker and shows less small-scale spatial variability. The spatial variability along the 20m of the transect may depend on ponding, especially after the rain (pictures on the right side of Fig. 2.3.7).

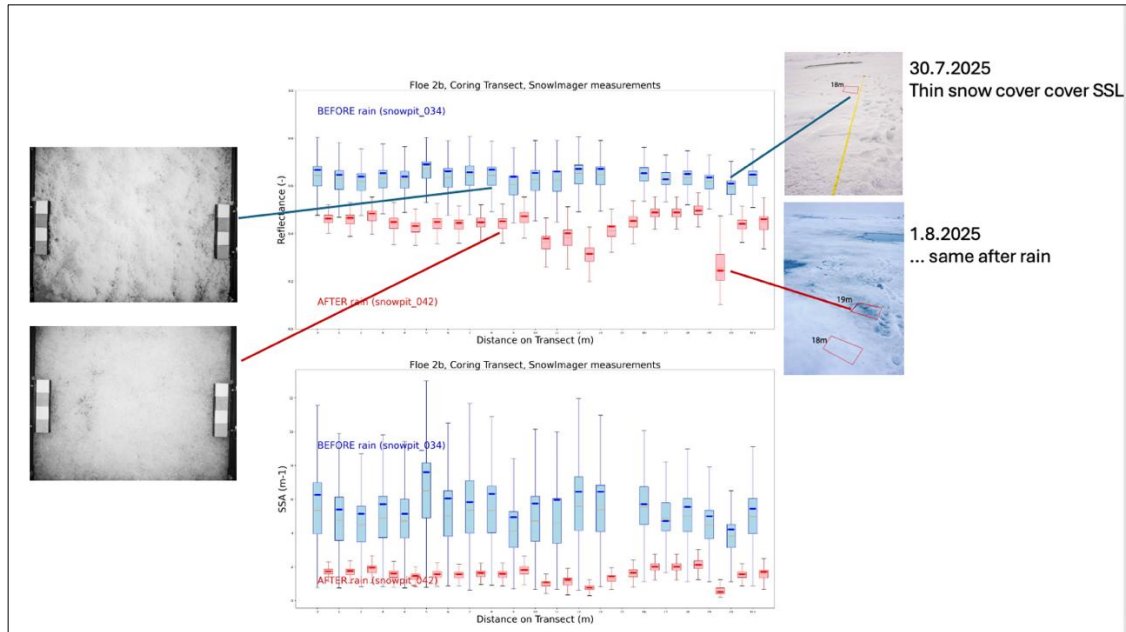


Fig. 2.3.7: Comparison of the 940 nm reflectance and the resulting SSA along the CORING transect before and after the rain, events 034 (blue) and 042 (red). The shaded area is the interquartile range, with the mode as dark line, and the median in orange. Left are two examples of Snowmager footprints, where the smaller spatial variability after the rain is observable. The photographs on the right show the same surface before and after the rain event. Pictures by Michael Haugeneder, Matthias Jaggi and Ruzica Dadic.

2.4 Sea ice thickness, and snow and melt pond depth transects

Work at sea

Sea ice thickness as well as snow and melt pond depth were measured along transects across the floe during each ice station. Here “snow depth” refers to both the thickness of the surface scattering layer (SSL) and the thickness of the snow.

The total thickness, i.e. ice thickness plus snow/SSL, is measured with a GEM instrument (ground electromagnetic induction device, GEM-2 from Geophex Ltd.) installed in a pulka sled. The GEM sled can swim and be pulled over melt ponds. In case the melt pond water is fresh (i.e. not melted through), the thickness of the melt pond ice bottom plus the depth of the melt pond is measured by the GEM. The GEM uses the strong CONTRASTS in electrical conductivity between sea ice and seawater to determine the height of the device above the underside of the ice. A transmitter coil in the GEM emits an electromagnetic signal at 5 frequencies between 1.5 kHz and 93 kHz. This field induces eddy currents in the seawater directly below the underside of the ice. These eddy currents create a secondary electromagnetic field that can be used to determine the height of the GEM device above the ocean-sea ice boundary, i.e., it measures the sea ice plus snow/SSL thickness or ice plus melt pond depth. The strength of the secondary field decreases exponentially with the distance between the generator (underside of the sea ice) and the receiver (GEM). To establish this exponential relationship between the ice thickness and measured EM field, a calibration with an 8-step ladder was performed during each ice station. The GEM is put on all ladder steps and its height is measured. In addition, the ice thickness under the ladder is measured in five drill holes. Thereafter an exponential fit is applied to the calibration measurements. This fit-function is then used to convert the GEM measurements obtained during the transects into ice thicknesses. During measurement, the GEM is pulled manually across the ice in a pulka. The GEM was used along long transects as part of floe surveys and for the shorter joint transects and individual measurements in the central observatory close to the ship.

The depth of the snow and/or SSL on top of the sea ice is measured with a MagnaProbe (MP; from Snow-Hydro LLC). The probe consists of a 1.5 m long measuring rod with a flat basket at the lower end. During the measurement, the rod is inserted into the snow, with the basket remaining on the snow surface. The basket was adapted with a flotation made of extruded polystyrene foam. This adaptation allows to measure the depth of melt ponds as the basket floats and stays on top of the water surface. The difference between the sensor tip (ice surface) and the basket (snow/water surface) gives the snow or melt pond depth. In addition, the GPS position is recorded for each measurement. All measured data is stored in a data logger in the backpack carried by the operator and can be read out later on a PC. MagnaProbe profiles along transects were always measured in conjunction with ice thickness measurements from the GEM (see above). The difference between the GEM measurements and the snow depth measured by the MagnaProbe then gives the actual sea ice thickness. During transect measurements melt ponds were marked in the dataset by a double-measurement, i.e., pushing the MP button two times at the same location. In addition to the transect work, detailed melt pond depth surveys were conducted (see Chapter 2.7).

Table 2.4.1 summarizes all GEM and MP data obtained during the long transects during the floe surveys. Snow/melt pond measurements were taken every 2–5 m. These surveys had a total length between 2 to 3 km. The floe surveys consisted of 3 to 4 straight transect lines crossing through different regimes of the floe with the aim to be most representative for the floe conditions. The corners of the transect were marked by flags and the same transect was repeated during the next floe visit. Small differences occurred due to bad visibility or if the edges of the floe broke away or were not accessible anymore. All floe surveys were performed by walking and pulling a pulka with the GEM device and probing the snow and melt ponds with a MagnaProbe.

Tab. 2.4.1: Summary of all long transect GEM and MagnaProbe floe surveys.

Visit	Floe 1	Floe 2	Floe 3
a	2025-07-10 GEM & MP “Marcel” Length: 2.1 km	2025-07-15 GEM & MP “Marcel” Length: 3.2 km	2025-07-22 GEM & MP “Marcel” Length: 3.1 km
b	2025-07-27 GEM & MP “Marcel” Length: 2.2 km	2025-07-31 GEM & MP “Marcel” Length: 3.0 km	2025-08-05 GEM & MP “Anja” Length: 3.1 km
c	2025-08-10 (different floe) GEM & MP “Anja” Length: 2.5 km	2025-08-13 GEM & MP “Anja” Length: 2.9 km	2025-08-17 GEM & MP “Anja” Length: 3.1 km
d	Only floe pieces left; no access	2025-08-24 (floe edge not accessible) GEM & MP “Anja” Length: 2.4 km	2025-08-27 (different GEM) GEM-556 & MP “Anja” Length: 2.9 km

With the GEM further measurements were performed within the central observatory close to the ship. These measurements were focused on shorter transects, usually 100-200 m straight lines, which have been measured by several different instruments (often also referred to as “main transect”). In addition, more specific transects as e.g. the snow transects of Chapter 2.3 as well as specific melt ponds which were surveyed with the hyperspectral camera (see Chapter 2.5) were measured. From here on these transects will be called “short transects”. The GEM ice thickness data serves as an additional important information for different measurements of e.g. the ARIEL L-Band microwave radiometer (see Chapter 2.6). For the measurements of the hyperspectral camera (see Chapter 2.5) it is a crucial part of the experimental set-up to investigate the relation between spectral reflectance and melt pond ice thickness. Although for some melt ponds the ice thickness was measured directly in 2-inch auger holes, the GEM was used specifically for ice thickness measurements of melt ponds which could not be drilled due to other co-located measurements. While at some melt ponds the ice thickness was measured at distinct locations within the ponds, at other melt ponds the ice thickness was measured along a transect line across the pond to obtain melt pond depth statistics. However, all specific melt pond ice thickness surveys using the GEM are referred to as pond measurements in Table 2.4.2.

Tab. 2.4.2: Number of all short transect and melt pond GEM surveys of each ice station.

Visit	Floe 1	Floe 2	Floe 3
a	1 pond	2 ponds	2 short transects 4 ponds
b	1 short transect 1 pond	2 short transects 1 pond	3 short transects 3 ponds
c	2 short transects 1 pond	3 short transects	3 short transects
d			3 short transects

Preliminary (expected) results

GEM long transect ice thickness measurements

The long transect measurements of sea ice plus snow thickness for each floe will be referred to as “floe thickness” from here on. The data shown here is not yet spatially binned. However, all timeslots which obviously show stationary measurements are filtered out. Therefore, the statistics shown and discussed here will not change significantly after the spatial binning. The spatial binning of the data will be done before data publication.

Figure 2.4.1 shows the probability distributions obtained by kernel density estimation (KDE) from the measured floe thicknesses for each floe during all ice stations. The different shapes and modes of these distributions give valuable insight into the melt evolution of each floe and sea ice regime.

During the first round of ice stations (1a-3a) the distribution of floe 1 and floe 2 look similar, which is also reflected in a very similar modal value of 1.55 m and 1.51 m, respectively. Nonetheless, floe 1 has a bimodal distribution with a smaller second peak at around 0.8 m. The distribution of floe 2, in contrast, shows higher probabilities for floe thicknesses between 2 m and 3 m. So, despite the similar modal value of both floes, floe 2 is composed of thicker ice. The floe thickness distribution of floe 3 has a significantly higher modal value of 1.90 m and a more pronounced tail towards ice thicknesses of more than 2.5 m. This agrees with the backtracking of the floe history, which showed that floe 3 is composed of multiyear ice.

During the second round of ice stations (1b-3b) the long transect measurements show a decrease in floe thickness for all floes. Compared to floe 2 and floe 3 with a similar melt rate of about -0.25 m during the about two weeks between the visits, floe 1 melted much stronger between the first two rounds with -0.41 m. It should be noted here that some of the very thin floe parts near the floe edge of floe 1 (0.8 m thickness) within the central observatory melted during this time and were not accessible anymore during visit 2. However, this very thin ice at the floe edge represented only a rather small part of the long transect. All floe thickness distributions are less bimodal during the second visit round. They lost either thin or thick second modes identifiable during the first visits. Only floe 3 still had an extended tail towards higher floe thicknesses. This points to enhanced melting of the thick ice ridges, which makes sea ice flatter and more uniform during the summer melt season.

The floe thickness measurements of the third round of ice stations (1c-3c) show the strongest melt rates again for floe 1 with -0.43 m. Although ice station 1c was not at the same floe as 1a and 1b their ice regime was similar and can be seen as representative for most floes in this area. The floe of station 1c consisted mostly of ice less than 1 m thick. Large parts of the floes were not accessible for the long transect due to this very thin ice. Contrasting to this strong melt rate of floe 1, the floe thickness of floe 2 and floe 3 only changed very slightly from visit two to visit three based on the shown distributions, which is surprising considering the overall melting temperatures. This might be due to drainage of meltwater from the sea ice surface towards the sea ice bottom. As the GEM cannot differentiate between solid sea ice and liquid meltwater, a layer of fresh meltwater below the sea ice could indeed compensate the melt rate of the sea ice itself in the GEM measurements. Although there are several indications for such a meltwater layer (e.g. camera buoys), this hypothesis has to be further investigated.

The fourth round of ice stations (2d-3d) shows again a stronger melting rate of -0.38 m for floe 2. This indicates stronger melting processes for the time between stations 2d and 2c than for the time between stations 2b and 2a (-0.24 m). Due to a technical malfunction of the GEM-730, at the moment of writing, unreasonable GEM-556 measurements there is no floe thickness distribution shown for station 3d although a long transect was done. There is hope that the GEM-566 measurements can be successfully analysed at a later stage.

All of the floe thickness measurements discussed here have to be considered preliminary. Besides the mentioned spatial binning, the GEM measurements should also be compared to other ice thickness measurements as well as oceanographic measurements for the under-ice

melt water layer. Only then solid conclusions can be drawn for the melt evolution of the different ice floes.

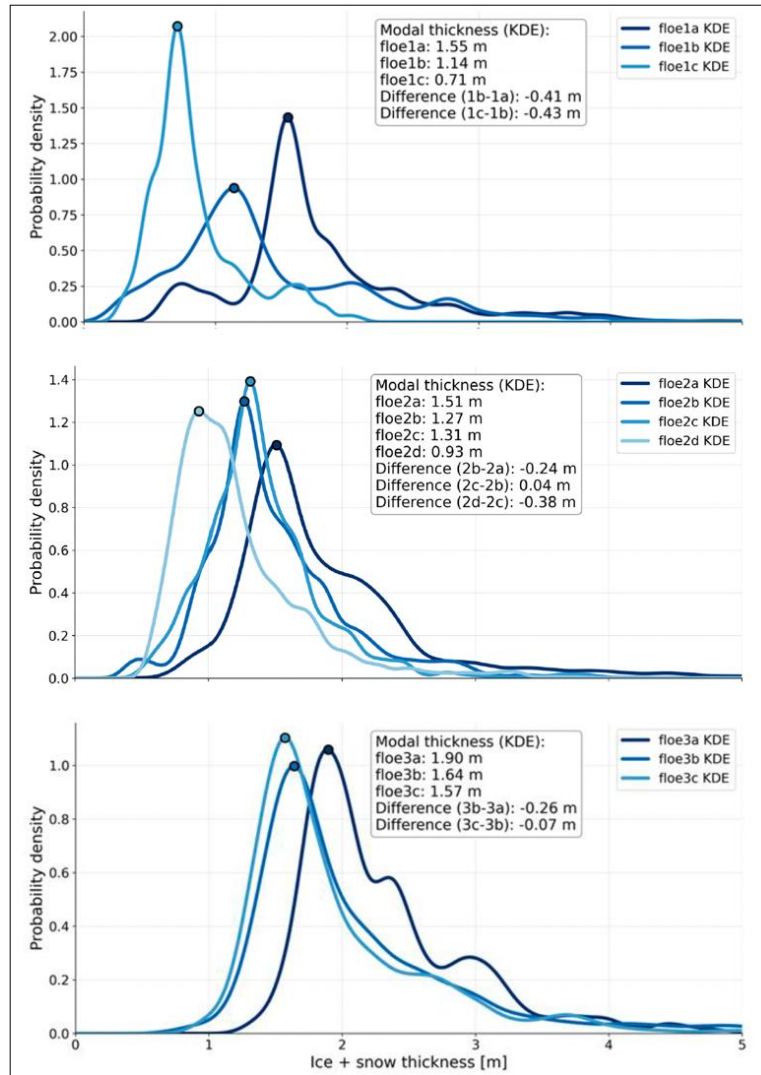


Fig. 2.4.1: Probability density distributions of the ice and snow thicknesses measured by the GEM-730 during the long transects at each ice station. The dots on the lines mark the corresponding modal thickness of the distributions.

The GEM measurements within the central observatory are not yet analysed and, therefore, not shown here.

MagnaProbe long transect snow and melt pond depth measurements

Figure 2.4.2 show the histogram of the snow and/or surface scattering layer (SSL) measurements for all ice floe visits as obtained by the MagnaProbe during the long transects. The long transects should provide representative values for the whole floe. Overall, the mean and median snow depth do not vary significantly between the three floes. At later visits and after rain events there is a tendency towards thinner snow/SSL values. However, the main difference between the different ice floes and over time is the change in the histogram shape. During the first round of visits (1a to 3a) the snow/SSL distributions are much wider than during the following visits. Especially for visits c and d the distributions are much more confined and the long tail of thicker values got reduced.

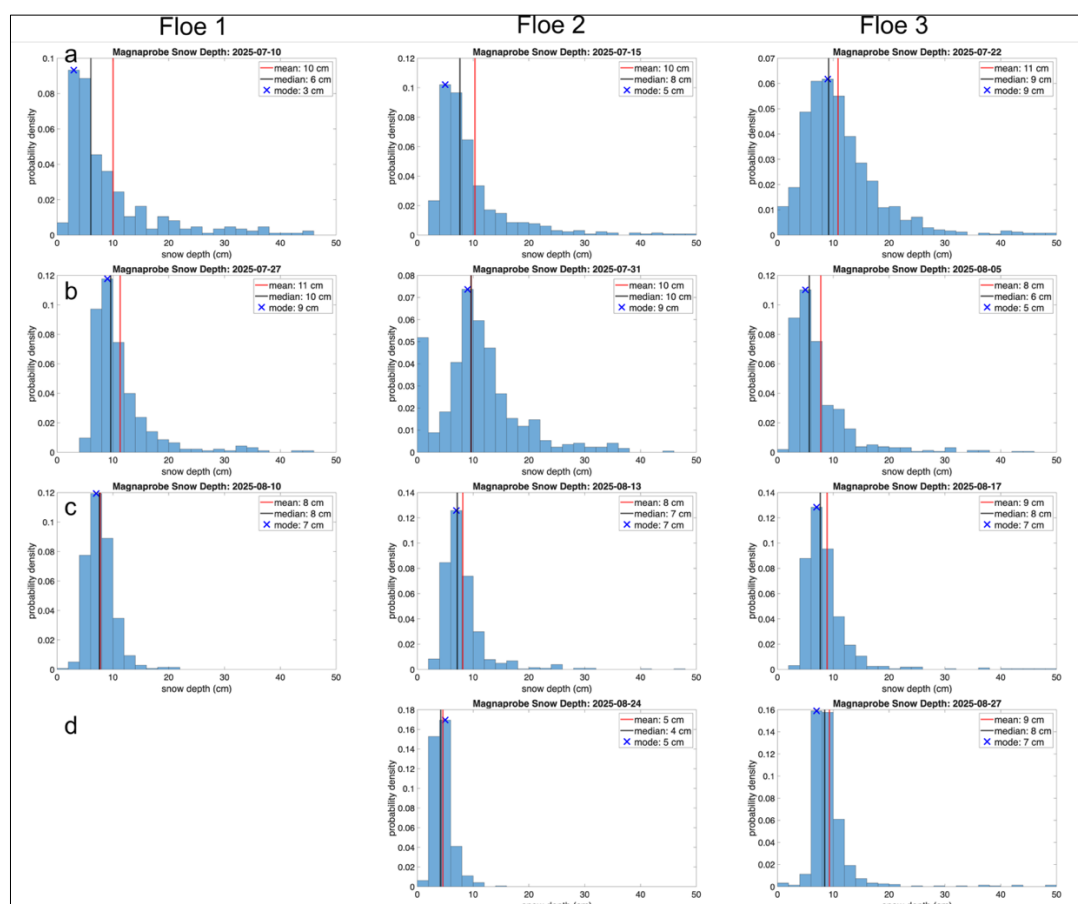


Fig. 2.4.2: Histograms displayed as probability density distributions of the snow and surface scattering layer (SSL) depth for all ice stations as measured during the long transects by the MagnaProbe.

Red lines mark the mean, black lines the median, and blue crosses the 1st modal value of the distributions, respectively. Floes 1 to 3 are shown as columns and the respective visits a to d as separate rows. The histogram is cut at 50 cm snow/SSL depth but in most cases some higher values at low probability do occur.

The SSL is usually developing only to a certain maximum thickness, which is dominating the modal value of the histograms. The higher values are then mainly found close to ridges and in the beginning (i.e. visits a) apparently still contained some snow. The rain events and the almost continuous surface melting during the expedition reduced these high snow values while the SSL depth remained mainly unchanged. However, during the last visits d also some new snow contributed to the measurements.

Figure 2.4.3 show the histogram of the of the melt pond depths as obtained by MagnaProbe measurements during the long transects. Floe 1 shows overall the smallest melt pond depths (mean and median). However, during the first two visits a and b, differences are not very significant. More interesting is that the older and more deformed floes 2 and 3 show a second (or third) mode at much higher melt pond depth. Here the oldest and most deformed floe 3 has the deepest secondary mode, which can be attributed to the many melt ponds in-between ridges. These often have higher melt pond depths, especially later in the season, when the melt ponds on thinner ice reach their maximum depth and drain or their bottom floats up and thereby reduces the melt pond depth.

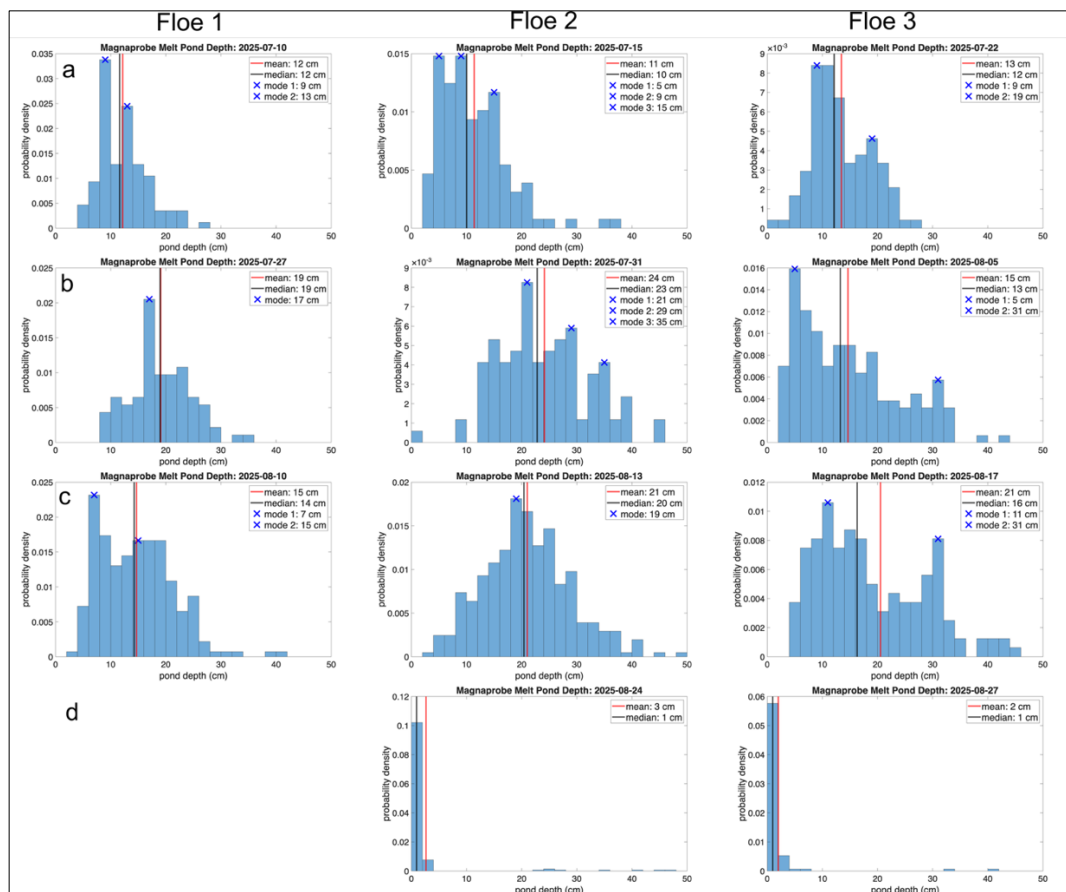


Fig. 2.4.3: Histograms displayed as probability density distributions of the melt pond depth for all ice stations as measured during the long transects by the MagnaProbe. Red lines mark the mean, black lines the median, and blue crosses the dominant modal values of the distributions, respectively. Floes 1 to 3 are shown as columns and the respective visits a to d as separate rows. The histogram is cut at 50 cm melt pond depth but in most cases some higher values at low probability do occur. Mind that the melt ponds during visit d were frozen over and that the lid could not be penetrated.

During the last visit of floes 2 and 3 the melt ponds were frozen over and the MagnaProbe could not penetrate this mainly 4-5 cm thick ice. Therefore, these distributions do not represent real melt pond depths and can only be used to obtain the average melt pond fraction of the floes. Melt pond fractions are not presented here as their processing needs spatial averaging, which is not performed yet.

2.5 Hyperspectral imaging of melt ponds and sea ice

Work at sea

2-D hyperspectral imaging of surface areas during all ice stations was conducted with the Specim IQ camera in a portable system setup. The Specim IQ records 204 spectral bands within the spectral range of 400 to 1000 nm with an image resolution of 512×512 pixel (thus the result is a $204 \times 512 \times 512$ points data cube). However, at the applied low integration time of, in most cases, 2 ms the near-infrared (NIR) range (>900 nm) has a poor signal-to-noise ratio. This low integration time is necessary to avoid saturation in the other parts of the spectrum. For some melt pond images additional images with longer integration times of about 18-24 ms were taken. Anyway, for >900 nm the spectrum appears noisy and is thus not further used in the following discussion. The focal length was set to a constant value of 2 m for the entire expedition. The maximum opening angle of the camera and thus the field of view is 31° . The Specim IQ camera is installed in a Peli case to protect it from the environments (and heat it at colder temperatures) which also contains a power bank for extending the operation time. The basic setup comprises the Specim IQ camera mounted on a tripod, a Panasonic Toughbook to remotely operate the camera and a white reference plate. The white reference is a ceramic plate which is assumed to reflect all incoming diffuse sunlight. Measured spectral reflectivity values shown and discussed here are always relative to the spectral reflectivity measured at the white reference. The white reference plate is mounted on a small tripod and placed horizontally in the lower right corner of every measured image as visible in Figure 2.5.1. In the following, images of the hyperspectral camera will sometimes also be referred to as measurements.

The hyperspectral measurements were conducted in two different set ups, each serving a specific analysis purpose:

1. *Transect Measurements*: Transect measurements in a straight line crossing usually 200 m of each floe. The measurements were taken at constant distances of 20 m (measured by tapes), perpendicular to the walking direction to the right side using a small Manfrotto tripod of about 1.45 m height. The incidence angle was measured by a hand-held angle meter and always set to about 40° . The roll angle of the camera was set to 0° (horizontal alignment) by eye. The viewing direction was measured by a compass. The transects were re-measured at each floe visit to enable statistical surface reflectance studies of, e.g., melt evolution or surface scattering layer changes at the same locations.
2. *Nadir Pond Measurements*: Specifically chosen ponds were measured using a Nedo tripod with a Manfrotto lateral side arm mounted on top of it. On one side of the arm the Peli case including the Specim IQ camera was mounted while on the other side another Peli case including a counter weight of 4.4 kg was mounted. This tripod set up provides a camera height of up to 2.80 m in its full extension and about 0.5 m lateral displacement from the tripod head. The incidence and roll angle were manually aligned to about 0° (nadir view) and 0° , respectively. The nadir view reduces the number of pixels influenced by forward or backward scattering peaks as well as specular reflection, which would prevent meaningful analysis. Measurements using this set up are used for analysis of the relation between melt pond reflectance and the ice thickness of the melt pond bottom. Co-located ice thickness measurements were either conducted by drillings or GEM ice thickness measurements (see Chapter 2.4). Additionally pond water salinity and temperature were measured for most melt ponds. The measured melt ponds were selected to cover a wide range of pond bottom ice thicknesses. For the selection on site, the pond color was used as an indicator for their

thickness. This kind of pond measurements were either performed at specific locations within the ponds or along straight lines through the ponds (pond transects) marked by tapes. All of these pond measurements were repeated (if possible) at each floe visit.

For future campaigns either digital protractors or a water level could be mounted on the Peli case of the camera to alleviate the camera alignment. A water level on the white reference would also be helpful as the tilt of the white reference strongly influences its brightness (especially during clear sky conditions).



Fig. 2.5.1: Examples for the two different camera set ups. Left images: Transect measurement on small tripod with 40° incidence angle. Right images: Nadir pond measurement (90° incidence angle) with co-located drill hole in the image center. The white square marks the extend of the hyperspectral measurement. The white plate is the white reference.

On floe visits 2c and 3c coordinated measurements with other teams were conducted (see Tab. 2.5.1). For these measurements distinct homogenous surfaces were selected and – additional to the hyperspectral images - different instruments as e.g. the microwave radiometer ARIEL (see Chapter 2.6 and 2.17), the snowimager (see Chapter 2.3) as well as pyranometers (see Chapter 2.1) were measuring the same overlapping footprint. This will give possibilities for extended studies of different kinds of surface scattering layers or snow covers.

On floe visits 3a and 3b the surface scattering layer experiment, described in Chapter 2.1, was measured.

Table 2.5.1 shows a summary of all conducted measurements on the different ice floes including the additional measurements mentioned in the previous paragraph and comments on changes in the transect lines.

Tab. 2.5.1: List of hyperspectral measurements

Ice station	Station number	Dates	Transect obs.	Nadir pond obs.	Additional obs.	Comments
1a	PS149_1 3-1	2025-07-09 – 2025-07-12	9 at 1 transect	12 (4 ponds)		200 m transect
2a	PS149_1 6-1	2025-07-14 – 2025-07-17	10 at 1 transect	6 (2 ponds)		200 m transect
3a	PS149_1 8-1	2025-07-19 – 2025-07-22	11 at 2 transects	13 (3 ponds)	1 (Surface scattering layer experiment)	One outer and one inner transect (both 100 m)
1b	PS149_2 1-1	2025-07-25 – 2025-07-28	10 at 1 transect	20 (4 ponds)		New 200 m transect as old one melted
2b	PS149_2 5-1	2025-07-30 – 2025-08-01	22 at 2 transects	25 (4 ponds)		Main 200 m transect measured twice due to rain event
3b	PS149_3 0-1	2025-08-04 – 2025-08-06	12 at 2 transects	24 (4 ponds)	1 (Surface scattering layer experiment)	
1c	PS149_3 2-1	2025-08-09 – 2025-08-10	18 at 2 transects	18 (2 ponds)		New floe. Two 100 m transects.
2c	PS149_3 6-1	2025-08-12 – 2025-08-14	11 at 2 transects	24 (3 ponds)	7 (Coordinated surface measurements with other groups)	First 100m of main transect lost due to melting. New additional 100 m transect.
3c	PS149_4 1-1	2025-08-16 – 2025-08-18	12 at 2 transects	19 (4 ponds)	9 (Coordinated surface measurements with other groups)	
2d	PS149_4 6-1	2025-08-23 – 2025-08-24	6 at 1 transect	11 (2 ponds)		Refrozen ponds.
3d	PS149_4 7-1	2025-08-26 – 2025-08-27	8 at 2 transects	10 (4 ponds)		Refrozen ponds.

Preliminary (expected) results

The recorded images are saved as raw data cubes together with a dark frame and a white reference frame. Instead of using the internal created white reference frame, for each image a pixel within the white reference covered area within the image is selected and used as the white reference. With the help of these dark and white references the raw data is converted into reflectance data which, in case of diffuse illumination, can be assumed to be an approximation of surface albedo.

Sub-footprint reflectance variability

The left image of Figure 2.5.2 shows a RGB image of a hyperspectral measurement composed of a surface scattering layer (SSL) and a melt pond towards the right. Three regions representing three different surface types are selected for further hyperspectral reflectance analysis. Region 1 (red) is covered by a homogenous SSL and region 2 (blue) by a melting SSL through which the melt pond below is shining through already. The latter region can be seen as a transition from a SSL to a melt pond. Region 3 (green) consists of a homogenous melt pond surface.

The reflectance spectra averaged over each of these regions are shown in the right plot of Figure 2.5.2. Area averaged spectra are statistically more representative for these surface classes and are less noisy compared to single pixel spectra. It is clearly visible that the SSL (region 1) has the highest reflectivity over all wavelengths. The reflectivity of the mixed region 2 has the same spectral signature shape as region 1 but about 0.1 less in intensity. So, even small patches of melted areas can significantly reduce the overall reflectivity of the SSL. Region 3 has very low reflectivity values compared to region 1 and 2. Also the shape of the spectral signature is different. The decrease in reflectivity between 550 nm and 700 nm of the melt pond surface is more pronounced than for the SSL. This is typical for melt pond surfaces as water absorbs sunlight in the near-infrared wavelengths stronger than ice or snow surfaces. Further, the spectrum of melt pond reflectivity is smoother than the SSL spectrum, as the SSL has much higher surface variability. The peak at about 760 nm for all cases is caused by oxygen absorption (oxygen A-band), which can be seen in all measurements.

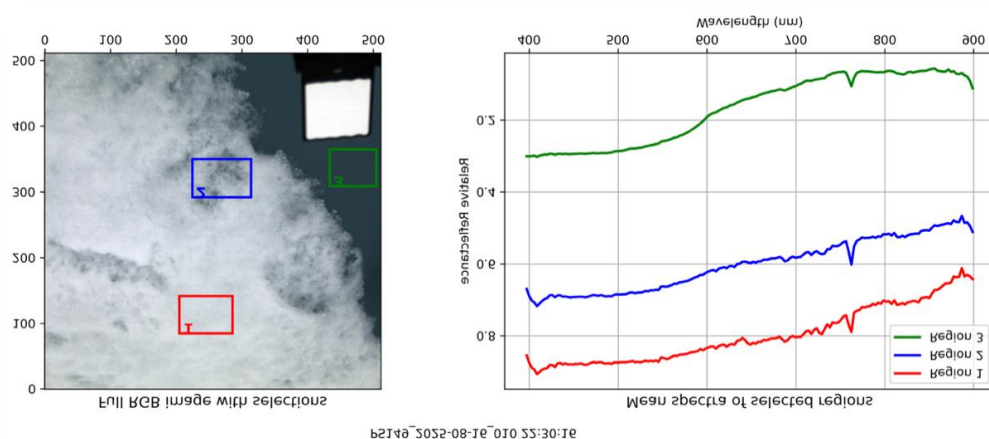


Fig. 2.5.2: The left image shows an RGB image of a hyperspectral reflectance measurement. It was taken using the transect set up (small tripod, 40° incidence angle) on the inner transect of floe 3c at 61.30m looking towards 318°. The right plot shows the relative reflectance values averaged over the corresponding regions.

However, melt pond surfaces are not always homogenous as in the previously shown case. Figure 2.5.3 (left) shows a contrasting example of a highly heterogenous melt pond surface. In the brighter areas towards the left and the upper right corner of the image the melt pond bottom consisted of many small air bubbles enclosed in the ice. The light scattering caused by these bubbles leads to a much higher reflectivity in region 1 (red) and 3 (green) than seen in the pure ice melt pond bottom of region 2 (blue, Fig. 2.5.3 right). This difference in reflectivity is most pronounced towards the lower frequencies, where the bubbly areas (region 1 and 3) show roughly a three times higher reflectivity than the pure ice bottom (region 2). The general shape of the spectral signature seems to be consistent over all three regions with two steep slopes between 550 nm – 600 nm and 700 nm – 750 nm. However, these slopes are much stronger in the bubbly areas. After about 810 nm the spectral signature of region 1 and 3 differs from region 2 with another decrease in reflectivity. The ice thickness measured at the drill hole visible in the left image of Figure 3.5.3 is 63.4 cm which is about 10 cm thicker than the rest of the pond bottom with about 50 cm ice thickness. Although, this slightly higher ice thickness might also contribute to the higher reflectivity of region 1 and 3 compared to region 2, the ice thickness is probably not the major factor causing the higher reflectivity in this case. It is more probably the light scattering of the entrapped air bubbles which leads to the higher reflectivity and, therefore, the brighter appearing surfaces of region 1 and 2. So, this example case shows that air bubbles within the ice of melt pond bottoms can significantly increase their spectral reflectivity, especially at lower wavelengths. In this case the bubbles caused an increase in reflectivity of roughly 2-3 times the reflectivity of pure ice bottom.

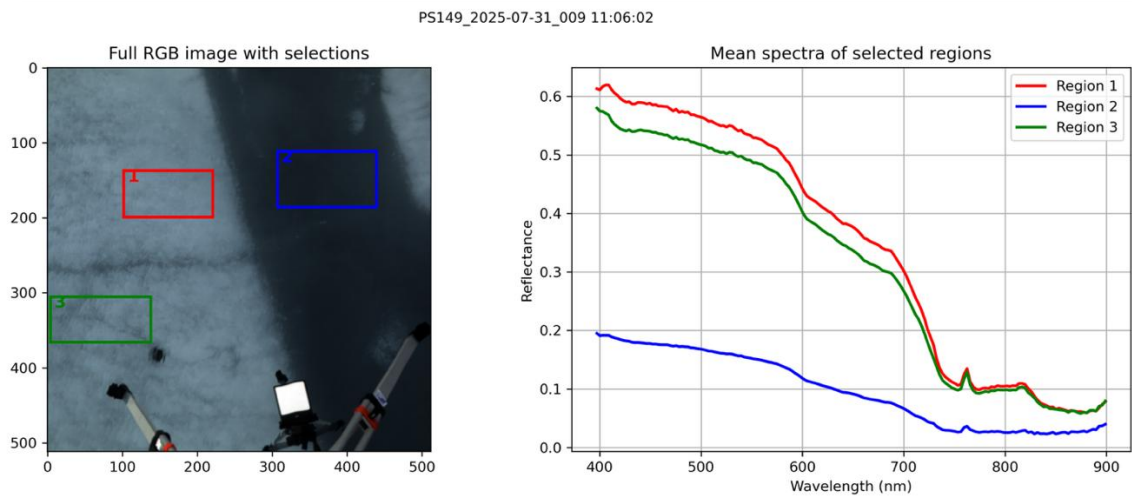


Fig. 2.5.3: The left image shows an RGB image of a hyperspectral reflectance measurement. It was taken using the nadir set up (big tripod, 0° incidence angle) at the “Milka Pond” of floe 2b. The right plot shows the relative reflectance values averaged over the corresponding regions.

Relation between spectral reflectance and melt pond ice thickness

To gain more insight into the relation between spectral melt pond reflectance and melt pond ice thickness, nadir hyperspectral pond measurements together with co-located ice thickness measurements were performed. Figure 2.5.4 shows images of 4 different ponds with different pond bottom ice thicknesses reaching from 0.02 m to 1.79 m. The mean melt pond depths (water depth) for these ponds have been, respectively: 1.50 cm, 7.90 cm, 14.25 cm, 29.00 cm.

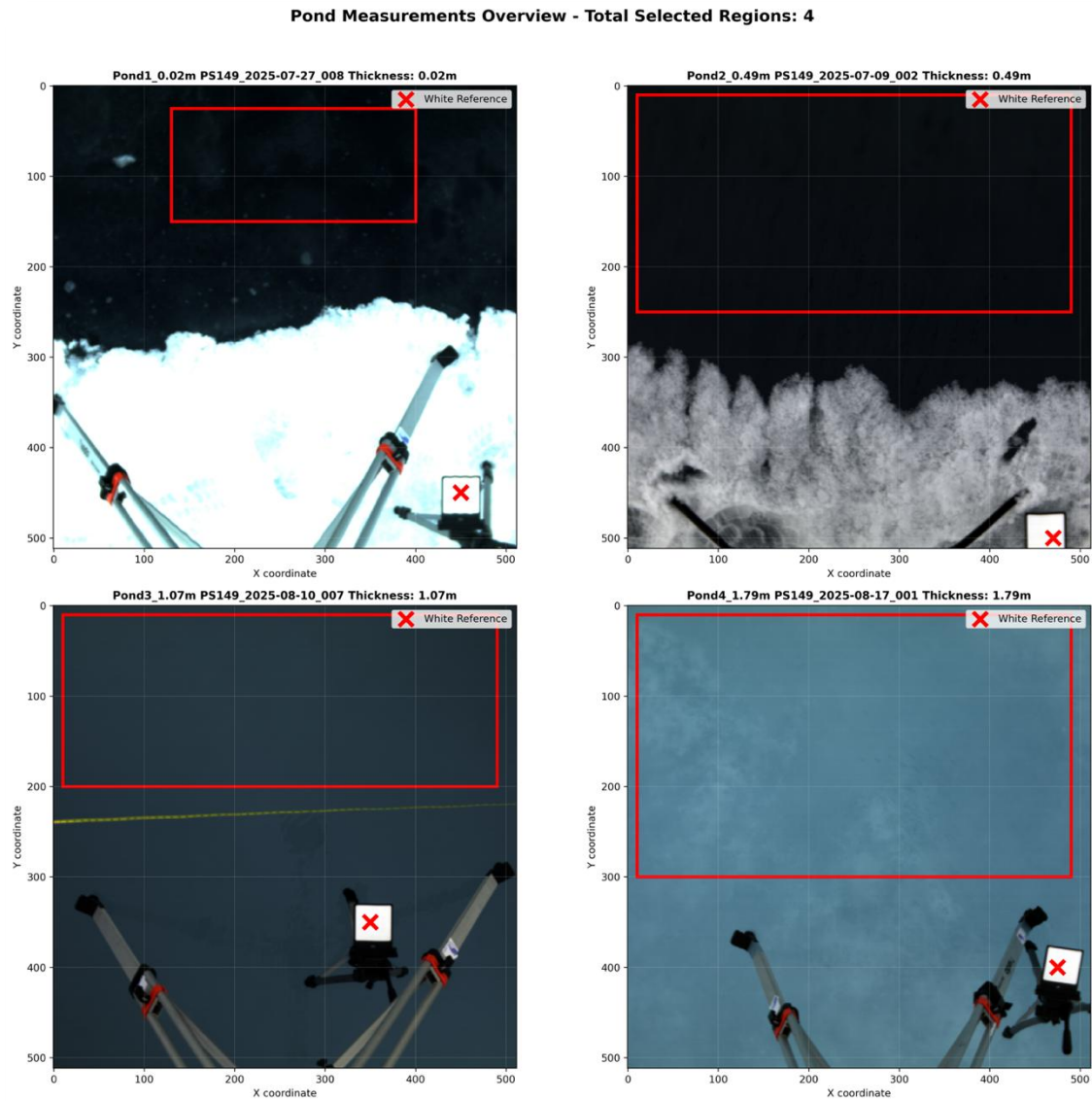


Fig. 2.5.4: RGB images of four different melt ponds captured by the SpecimIQ hyperspectral camera. The red rectangles mark the area over which the spectral reflectances shown in Figure 2.5.4 are averaged. The red cross highlights the pixel which was used as the white reference for the corresponding image.

For each of the red rectangles the areal mean spectral reflectance is calculated and shown in Figure 2.5.5 (left), color coded with the respective pond ice thickness. It is clearly visible that, for wavelengths below 700 nm, the reflectance increases strongly with increasing ice thickness. This clear correlation is also visible in the right plot of Figure 2.5.5 which shows the relative reflectance versus the ice thickness for 400 nm, 500 nm, 600 nm, 700 nm, 800 nm and 900 nm. Especially for 400-600 nm the relation seems to have an exponential shape. At 700 nm and especially at 800 nm there's no clear correlation between ice thickness and reflectivity anymore. Pond 3 has the lowest spectral reflectances even though the ice below was more than twice as thick as at pond 2. Also pond 2 does not show a significant increase in reflectivity compared to pond 1 above 700 nm, even though the ice below pond 2 was about 24 times thicker than pond 1. The hypothesis for this is that – due to the increasing absorption of sunlight from liquid water towards the NIR – above 700 nm the increase in melt pond depth (mentioned

above) is the more dominant factor than the increase in ice thickness. A study of König and Oppelt (2020) underlines this, as they show a clear sensitivity of optical measurements at 700 nm to melt pond depth and derive a melt pond depth retrieval for this wavelength.

More detailed studies after the cruise will further investigate this relation between spectral melt pond reflectance and ice thickness. Also, the relation between spectral reflectance and melt pond depth will be further analysed.

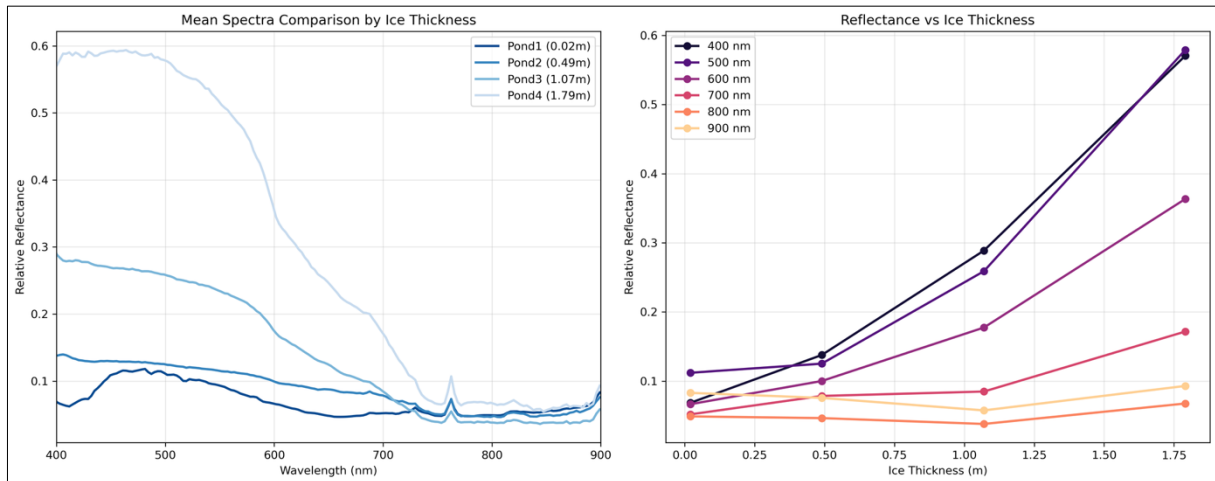


Fig. 2.5.5: Left: Area averaged spectral reflectances of the marked areas within the four melt ponds shown in Figure 2.5.3. Right: Relative spectral reflectance versus melt pond ice thickness for six different wavelengths. The dots mark the points of measured data, the lines in between are linearly interpolated between the measured datapoints.

2.6 Microwave emission (L-band) of the sea ice surface

Work at sea

The L-band microwave radiometer (ARIEL) (Fig. 2.6.1), providing an invisible microwave perspective on variations in sea ice surface properties. This instrument operates at 1.413 GHz with a 20 MHz bandwidth in horizontal (H) and vertical (V) polarization. It has a radiometric accuracy of 1 K at 1 Hz, and uses a 2×2 antenna patch array with a 36° beam width at 3 dB. It measures the emitted power from the surfaces and, through hot and cold load calibration, derives vertical and horizontal brightness temperatures. With its longer wavelength (~21 cm), it has larger penetration depth and potentially can retrieve thin ice thickness under cold conditions. During CONTRASTS the surface emission signal variability is mainly dominated by the various melting processes in the snow, surface scattering layer, and sea ice. Their impact is largely not known in detail and explored here. During freezing conditions, L-band radiometry can measure sea ice thickness for thin ice <1 m, depending on salinity and temperature. Thus, it is complementary to radar altimetry, which is less sensitive to thin ice and gets more accurate above approximately 1m ice thickness. However, in summer, the wetness in the snow and the surface scattering layer strongly affects the measurements. Our objective is to fill this gap in order to improve satellite retrievals and current satellite monitoring capabilities, advance sea ice thickness retrievals from L-band radiometer satellites (such as Soil Moisture Ocean Salinity (SMOS) and Soil Moisture Active Passive (SMAP)), and improve estimates of Arctic sea ice thickness changes on a larger scale.

During 9 ice stations, the ARIEL microwave radiometer (produced by MWSE S.L.) was mounted on a stand made from aluminum tubes, fixed to a sledge at a height of approximately 150 cm (Fig. 2.6.1). Each measurement took about 1–2 minutes, and photographs documenting the general surface conditions were taken at every stop. ARIEL has a build in IR photodiode, which provides surface temperature information. Table 2.6.1 shows a summary of all conducted measurements on the different ice floes including comments on changes for each one. The measurements can be grouped into two main categories:

1. Transect measurements

Most microwave emission measurements were carried out jointly with observations of the physical properties of sea ice and snow along the transect lines in the Central Observatory (CO). ARIEL was pulled along the transect lines (1 or 2), with measurements taken every 10–20 m at an incidence angle of about 50°. These were combined with measurements of surface albedo (Chapter 2.1), snow and surface scattering layer (Chapter 2.2), and sea ice thickness by drilling and GEM (Chapter 2.4), .

2. Local measurements

The remote sensing (RS) site was usually located next to *Polarstern* on the port side. During ice stations, microwave radiometers from the VAMPIRE-2 project (see Chapter 3.2) looked towards this site, and complementary measurements such as ice cores (salinity and temperature profiles), grain size analysis, and small-scale snow and ice surface topography/roughness were conducted within the radiometer footprints. At this site, ARIEL typically performed 1–2 measurements for comparison.

In addition, at each ice station, a range of surface types were measured, e.g. homogeneous ice, surface scattering layer (SSL) survey areas, ice ridges etc. Some experiments were carried out in cooperation with albedo and snow measurements (see Chapter 2.3 and Chapter 2.1). These complementary multi-instrument observations on the same surface provide essential information for a more comprehensive understanding and interpretation of the brightness

temperature measurements. A varying-incidence-angle experiment with ARIEL was also conducted.



Fig.2.6.1: ARIEL deployed on a plastic sled during ice station work, measuring a homogeneous ice surface

Tab. 2.6.1: Overview of floe visits and conducted ARIEL measurements.

Date	Floe	Local Measurements	Transect Measurements	Comment
2025-07-10 - 2025-07-12	Station 1a (PS149_13-1- ARIEL)	7 (different surfaces)	200 m transect (every 20 m), 2 visits	Hot and cold load of instrument were not working properly. Data quality might be impacted.
2025-07-20 - 2025-07-21	Station 3a (PS149_18-1- ARIEL)	7 (RS site, SSL site, different surfaces)	100 m outer/main transect (every 10 m), 2 visits	
2025-07-26 - 2025-07-27	Station 1b (PS149_21-1- ARIEL)	10 (RS site, different surfaces, changing incidence angles)	183.3 m transect (every 10 m)	Different transect due to floe melting
2025-07-30 - 2025-08-01	Station 2b (PS149_25-1- ARIEL)	2 (RS site, different surfaces)	200 m transect (every 10 m)	

Date	Floe	Local Measurements	Transect Measurements	Comment
2025-08-04 - 2025-08-06	Station 3b (PS149_30-1- ARIEL)	8 (RS site, SSL site, different surfaces)	100 m outer/main transect (every 10 m), 100 m optical/inner transect (every 10 m), 2 visits for both	
2025-08-10	Station 1c (PS149_32-1- ARIEL)	1 (RS site)	100 m main transect (every 10 m), 100 m ROV transect (every 10 m), 20 m snow transect (every 5 m)	Different floe to station 1a and station 1b
2025-08-12 - 2025-08-14	Station 2c (PS149_36-1- ARIEL)	11 (different surface, RS site, SSL site, snow and albedo team cooperate)	90 m transect (every 10 m), 100 m Tline transect (every 10 m)	200 m transect only left 90 m in the north part due to melting
2025-08-16 - 2025-08-18	Station 3c (PS149_41-1- ARIEL)	17 (different surface, RS site, SSL site, snow and albedo team cooperate)	100 m outer transect (every 10 m), 100 m optical transect (every 10 m)	
2025-08-23 - 2025-08-24	Station 2d (PS149_46-1- ARIEL)	23 (different surface, RS site, SSL site, snow and albedo team cooperate)	25 m snow transect (every 5 m), 90 m transect (every 10 m), 100 m Tline transect (every 10 m)	200 m transect only left 90 m in the north part due to melting, measurement started at 15 m
2025-08-26	Station 3d (PS149_47-1- ARIEL)	10 (different surface, RS site, SSL site)	100 m outer transect (every 10 m), 100 m optical transect (every 10 m)	

Preliminary results

The L-band microwave signal is sensitive to surface properties such as moisture and salinity, and therefore responds differently to various sea ice surface types and stages of snow and ice melting. Preliminary results based on a subset of the data (approximately 50 samples) show that the measurements can be manually classified into five surface types: homogeneous ice surface, ice ridge, melting surface, mixed surface, and pond (see Fig. 2.6.2). Differences in brightness temperature (TB) can be observed among the different sea ice surface types. For homogeneous ice surfaces and ice ridges, the brightness temperatures are relatively high, with mean TB_v values (black cross in the boxplot) of 232.04 K and 235.12 K, respectively. Ridges, in addition show the lowest polarization difference (mean of 13.66 K). In contrast, ponds show much lower TB values, with a mean TB_v of 129.42 K and a high polarization difference (mean of 58.47 K) as it can be expected for water surfaces. The melting and mixed surfaces fall in between and are similar to each other. Given the limited number of samples, these results should be considered only as a preliminary qualitative observation.

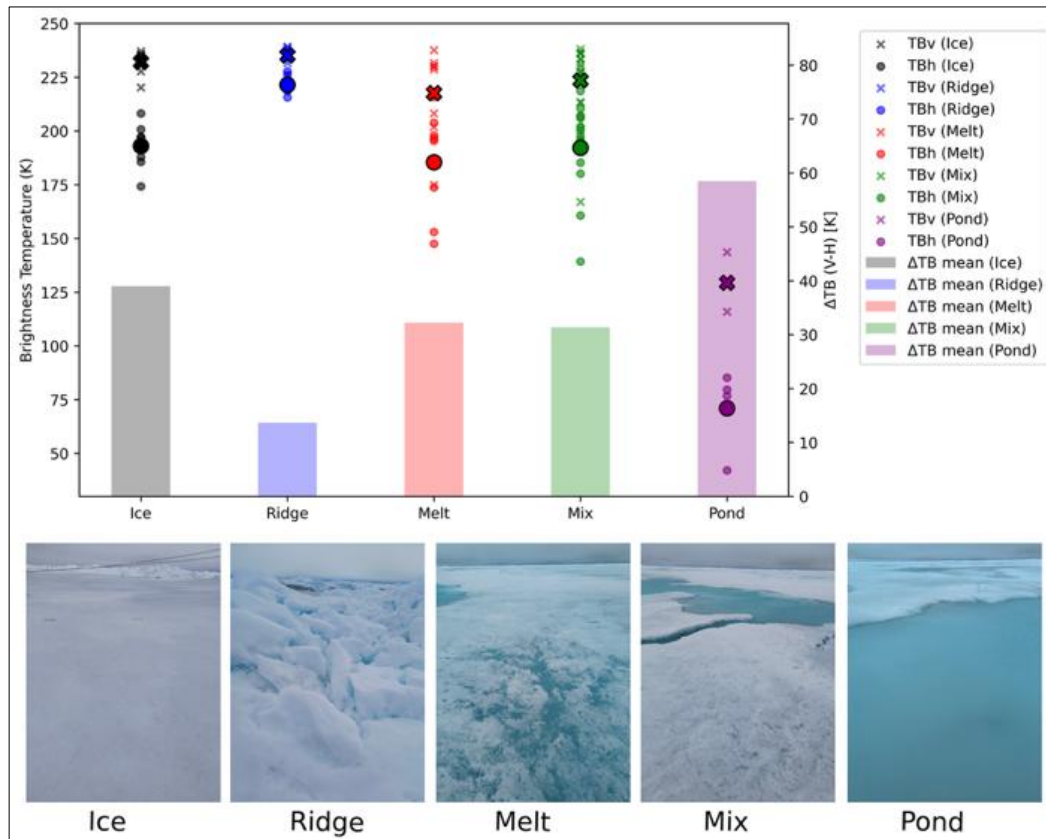


Fig. 2.6.2: Microwave L-band brightness temperatures for different surface types (homogeneous ice surface, ice ridge, melting surface, mixed surface, and pond). Crosses and circles represent vertical and horizontal polarizations (TBv and TBh), respectively, and black outlines indicate the corresponding mean values. The shaded bars show the mean polarization difference ($\Delta TB = TBv - TBh$) of each surface type.

Figure 2.6.3 presents example results from the transect measurements. As an example, measurements during three visits to floe 3 are presented. During the second visit (3b) the transect line was measured twice, which results in four datasets for the comparison (data from the floe 3d visit are not processed yet). During the four repetitions the brightness temperature results remained relatively consistent (similar TB development along the transect line). During the first visit, a lower brightness temperature was observed at 0 m over a melt pond, increasing at 10 m over a mixed surface, and showing higher values at 50 m over a homogeneous ice surface. This pattern is consistent with the characteristic brightness temperatures of different surface types. In the second visit (station 3b-1), the overall brightness temperatures increased. This is to first order consistent with the increase of physical surface temperature measured by the IR diode (compare black and blue dotted lines). Photographs (see Fig. 2.6.3) taken at that time indicate that the surface at 10 m had become more uniform, which corresponded to the higher brightness temperature compared to the first visit, and showed little change in subsequent visits. During the third visit to floe 3 (station 3c), no significant change was observed at 0 m and 10 m, but at 50 m pronounced melting occurred, leading to a reduction in brightness temperature and an increase in the polarization difference. During the second visit of floe 3 (station 3b) a rainfall event happened. Measurements before (station 3b-1) and after (station 3b-2) the rainfall event show a general decrease in brightness temperatures after the rainfall at most stops, with only a few exceptions. This is consistent with a higher dampening due to the higher liquid water content close to the surface.

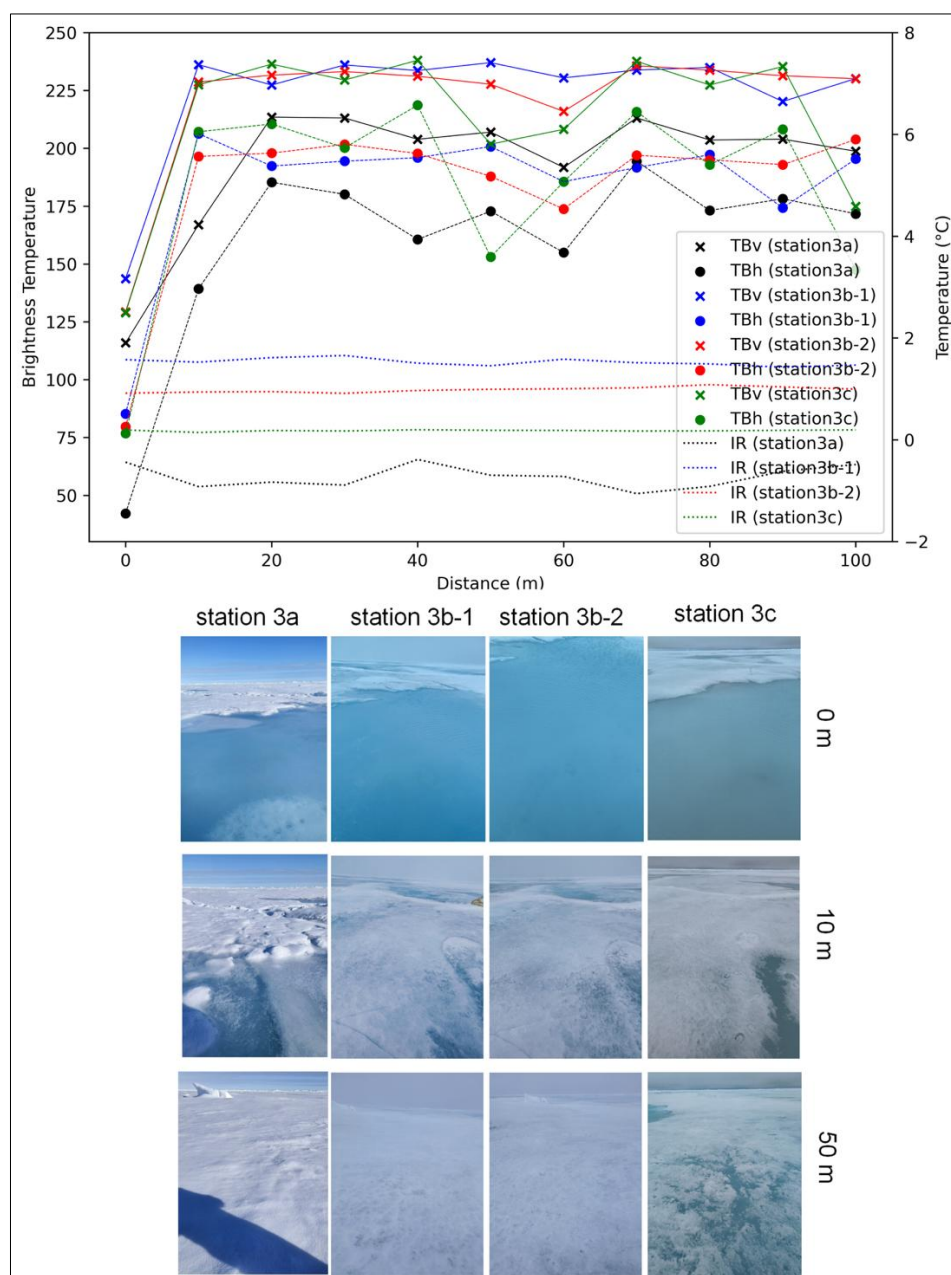


Fig 2.6.3: Brightness temperature (TB) and infrared surface temperature (IR) along transects at floe 3 during four repeated measurements (stations 3a, 3b-1, 3b-2, and 3c). The upper panel shows the brightness temperature (TBv, TBh) and infrared temperature. The lower panels display photographs of the surface conditions at 0 m, 10 m, and 50 m along the transects during each visit.

In addition, measurements of four surface scattering layer (SSL) experiments were conducted and processed (Fig. 2.6.4). The SSL, which forms as a thin, highly scattering layer at the sea ice surface during summer, can influence the microwave emission signal. To investigate its impact, we compared measurements over surfaces where the SSL was removed with those where it was left intact. Overall, the results show that removing the SSL generally led to lower brightness temperatures and increased polarization differences. At station 2c, the first set of measurements (2c-1) was taken immediately after the SSL had been removed, while the second set (2c-2) was conducted one day later. Already after one night, the brightness temperature of the surface increased again to the same values as for the undisturbed SSL site (green lines). This indicates rapid SSL recovery condition during Arctic summer, for cases when the SSL would have been destroyed like, e.g., after heavy rain. As a consequence, at least for L-band, these results indicate that one should basically always assume an SSL to be present if modeling the sea ice surface emission.

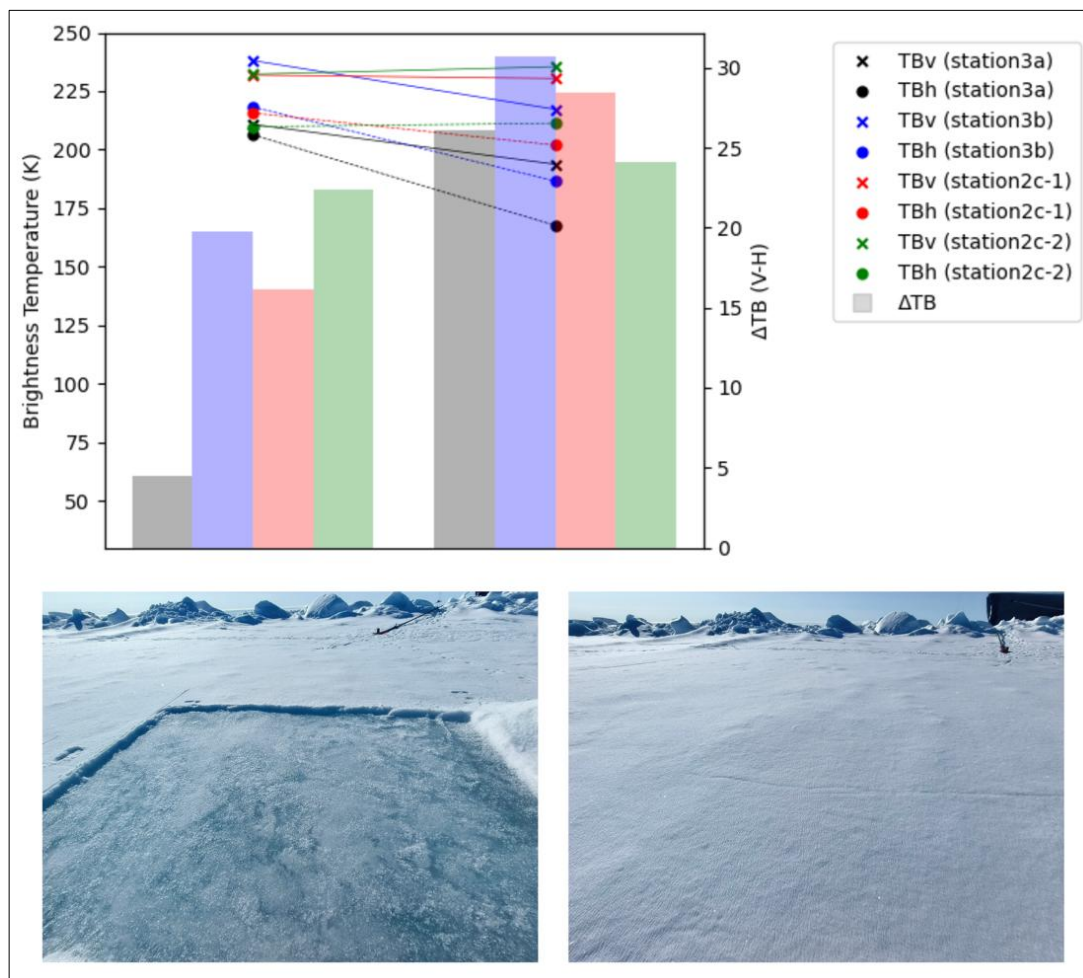


Fig. 2.6.4. Brightness temperature and polarization difference ($\Delta TB = TB_v - TB_h$) during surface scattering layer (SSL) experiments. Left site for measurements with SSL removed and right site with SSL. The upper panel shows TBv and TBh for each SSL site (different colors), with bar plots representing the polarization difference (ΔTB). The lower photographs illustrate the example SSL site surface conditions: SSL removal (left) and SSL undisturbed (right).

2.7 In-situ melt pond depths

Work at sea

During the CONTRASTS campaign, repeated in-situ cross-sections of melt pond depth were conducted within a specific pond on each floe using the MagnaProbe, a folding meter (point measurements), and the GEM (line measurements). The MagnaProbe was additionally employed to measure depths in a grid at approximately 1 m spacing. From station 2c onwards, supplementary Snow Probe measurements along the cross-sections were carried out. At station 3c, these measurements were further refined through the use of a wooden plate with a thickness of 1 cm attached to the probe tip, as shown in Figure 2.7.1, in order to determine pond depth independent of small-scale bottom irregularities. To ensure consistent positioning of all instruments along the cross-sections and during repeated visits, a rope was installed along the intended measurement transects. Although the rope experienced a considerable loss of tension over time, the attachment points at either side of the pond remained intact throughout the campaign. Table 2.7.1 provides an overview of the measurements conducted, while the respective floe locations are illustrated in Figure 2.7.2. Due to instrument malfunctions of the MagnaProbe, no MagnaProbe cross-section was conducted at station 3b, and no measurements were obtained at station 1c. Additionally, no measurements were conducted on stations 2d and 3d as the melt ponds were overfrozen.



Fig. 2.7.1: Image of the Snow Probe. A wooden plate is attached to minimize pond bottom penetration. The primary objective was the validation of bathymetry measurements from airborne sensors and the assessment of temporal changes in melt pond depth. For a consistent comparison of the measurements, cross-sections obtained with the folding meter, MagnaProbe, and Snow

Probe were referenced to a local coordinate system using a tachymeter. The origin point and local north of this system were defined by black–white ground targets, which were visible from all airborne platforms employed. Measurements with the MagnaProbe and GEM were additionally referenced through built-in GPS positioning.

Measurement accuracies were affected by a range of system-specific factors. For snow penetration, both the MagnaProbe and the Snow Probe were equipped with a metal spike, which caused penetration into the lower layers of the pond. In cases of thicker slush layers, this penetration resulted in discrepancies of several centimeters. To address this issue, additional cross-sections were acquired using the Snow Probe with a wooden board attached to its tip. For the folding meter, ground penetration was less critical; however, bending of the meter stick, particularly under strong wind conditions, introduced inaccuracies at the centimeter scale. Furthermore, surface waves on the pond complicated precise readings. Both instruments were also subject to errors caused by insufficient levelling. In the case of the GEM, major errors occurred when false bottoms with freshwater pockets were present beneath the pond, leading to depth measurements that referred to the false bottom rather than the actual visible pond floor.

Tab. 2.7.1: Overview of in-situ melt pond depth surveys during CONTRAST.

Event Label	Location	Instrument	Surveying activity	Reference
PS149_13-1-magnaprobe-marcel-02	1a	MagnaProbe	Cross Section	Local + GPS
- (after MagnaProbe)	1a	Folding Meter	Cross Section	Local
PS149_13-1-GEM-730-iup-04	1a	GEM	Cross Section	GPS
PS149_13-1-magnaprobe-marcel-03	1a	MagnaProbe	Grid	GPS
PS149_16-1-magnaprobe-marcel-01	2a	MagnaProbe	Cross Section	Local + GPS
- (after MagnaProbe)	2a	Folding Meter	Cross Section	Local
PS149_16-1-GEM-730-iup-05	2a	GEM	Cross Section	GPS
PS149_16-1-magnaprobe-marcel-02	2a	MagnaProbe	Grid	GPS
PS149_18-1-magnaprobe-marcel-01	3a	MagnaProbe	Cross Section	Local + GPS
- (after MagnaProbe)	3a	Folding Meter	Cross Section	Local
PS149_18-1-GEM-730-iup-04	3a	GEM	Cross Section	GPS
PS149_18-1-magnaprobe-marcel-02	3a	MagnaProbe	Grid	GPS
PS149_21-1-magnaprobe-marcel-01	1b	MagnaProbe	Cross Section	Local + GPS
- (after MagnaProbe)	1b	Folding Meter	Cross Section	Local
PS149_21-1-GEM-730-iup-02	1b	GEM	Cross Section	GPS
PS149_21-1-magnaprobe-marcel-02	1b	MagnaProbe	Grid	GPS
PS149_25-1-magnaprobe-marcel-01	2b	MagnaProbe	Cross Section	Local + GPS
- (after MagnaProbe)	2b	Folding Meter	Cross Section	Local
PS149_25-1-GEM-730-iup-04	2b	GEM	Cross Section	GPS
PS149_25-1-magnaprobe-marcel-02	2b	MagnaProbe	Grid	GPS
PS149_30-1-magnaprobe-anja-02	3b	MagnaProbe	Grid	GPS
- (05.08.2025, 10:55:00)	3b	Folding Meter	Cross Section	Local
PS149_30-1-GEM-730-iup-03	3b	GEM	Cross Section	GPS
- (10.08.2025, 10:45:00)	1c	Folding Meter	Cross Section	Local
- (10.08.2025, 10:58:00)	1c	Folding Meter	Grid	Local
PS149_32-1-GEM-730-iup-05	1c	GEM	Cross Section	GPS
PS149_36-1-magnaprobe-anja-01	2c	MagnaProbe	Cross Section	Local + GPS
PS149_36-1-magnaprobe-anja-02	2c	MagnaProbe	Grid	Local + GPS

Event Label	Location	Instrument	Surveying activity	Reference
- (after MagnaProbe)	2c	Folding Meter	Cross Section	Local
- (after Folding Meter)	2c	Snow Probe	Cross Section	Local
PS149_36-1-magnaprobe-anja-01	3c	MagnaProbe	Cross Section	Local + GPS
PS149_36-1-magnaprobe-anja-02	3c	MagnaProbe	Grid	Local + GPS
- (after MagnaProbe)	3c	Folding Meter	Cross Section	Local
- (after Folding Meter)	3c	Snow Probe	Cross Section	Local
- (after Snow Probe)	3c	Snow Probe + Wood	Cross Section	Local
- (after Snow Probe)	3c	Snow Probe	Polar 6 Transect	Transect

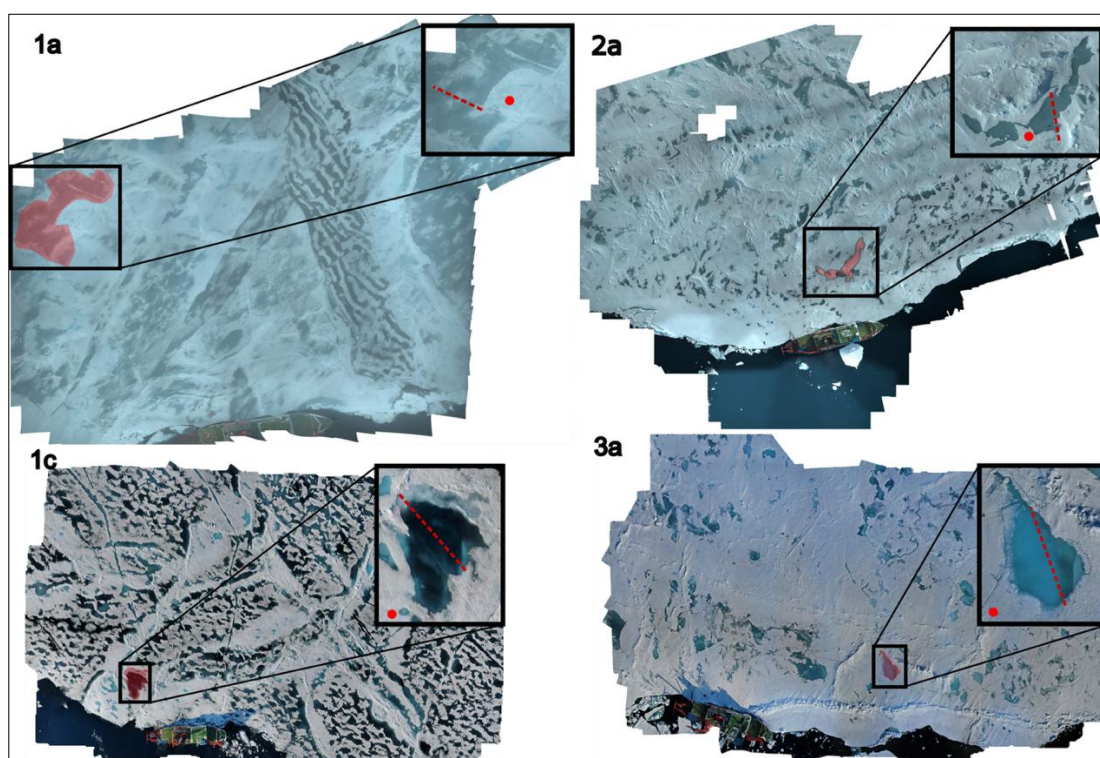


Fig. 2.7.2: Pond locations on floes 1a, 2a, 3a, and 1c during the respective first visits (red). Note that floe 1 was replaced between stations b and c. Origin points of the local coordinate systems are marked with a red dot. Cross-sections are indicated by dotted red lines and remained at close-to-similar positions despite topographic changes over time.

At station 3c, additional pond depth measurements were carried out with the Snow Probe along a transect, as shown in Figure 2.7.3. These measurements provide supplementary ground-truth data for the overflight of the *Polar 6* research aircraft on Monday, 18 August, and will be presented in a forthcoming publication.

Preliminary results

Figure 2.7.2a illustrates pronounced melt of the pond bottom between stations 2a and 2b. Two exceptions at 11 and 13 m resulted from a small patch of snow that remained stable in both size and position throughout all three stations. In addition, an increase in the horizontal extent of the pond was observed, as shown in Figure 2.7.2c. In contrast, the measurements indicated a decrease in pond depth between stations 2b and 2c (Fig. 2.7.2b). This reduction may have been partly influenced by the relocation of the rope, which became necessary after the original cross-section had melted through in larger sections. However, the main driver of the observed changes was attributed to an uplift of the pond bottom, with the most pronounced rise occurring around the 20 m mark. During station 2c, this process was observed in real time, and the respective area was seen to protrude above the pond surface one day after the in-situ surveys. These observations are consistent with the results of the thickness and snow depth transects presented in Chapter 2.4.

The presented evaluation will be carried out for each in-situ measurement throughout the campaign and will, among other purposes, serve as ground truth for the airborne measurements presented in Chapters 2.8 and 2.10.



Fig. 2.7.3: Map of Station 3c. The transect is shown in red and extends between two airborne targets, indicated by black dots.

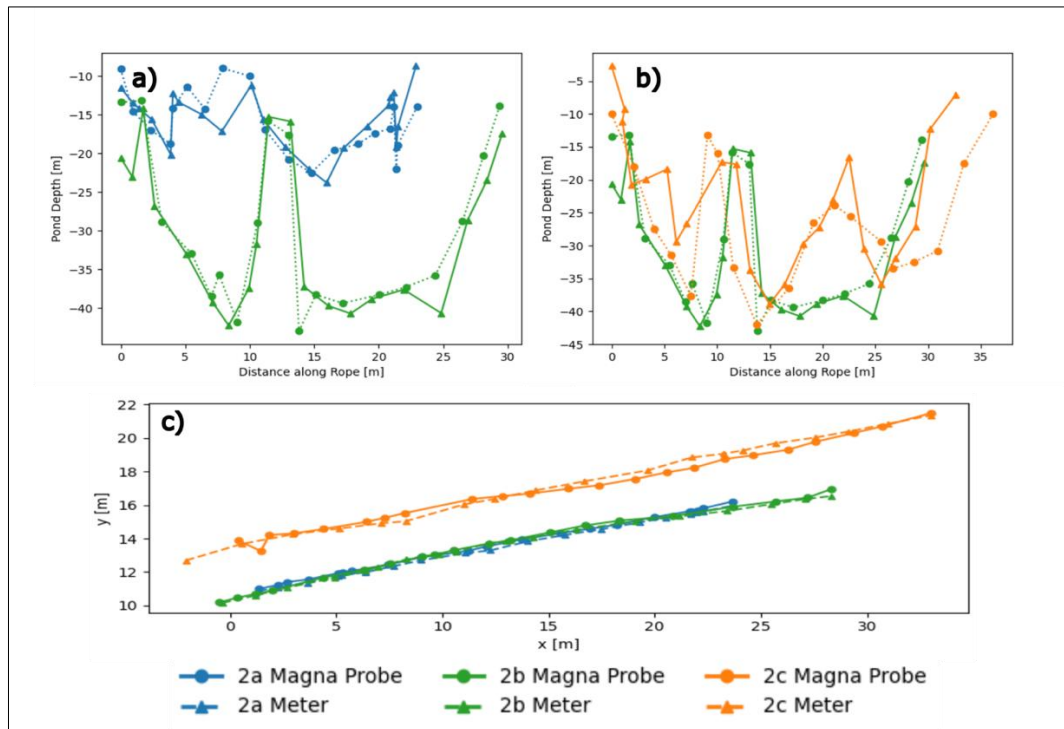


Fig. 2.7.4: In-situ cross-sections of Torben's Pond obtained with the folding meter and MagnaProbe. a) Stations 2a and 2b, b) Stations 2b and 2c, and c) combined cross-sections from Stations 2a, 2b, and 2c within an identical local coordinate system.

Airborne Measurements

2.8 Drone surveys

DJI Mavic 3, DJI Matrice 350 RTK

Work at sea

During the CONTRASTS campaign, drone surveys of the ice work area in front of *Polarstern* were conducted whenever conditions permitted. During extended periods of favorable flying weather, additional areas of the floe were surveyed. An overview of all flight events is provided in Table 2.8.1. The drones employed were the DJI Mavic 3 and the DJI Matrice 350 RTK. While both systems are equipped with optical cameras, the Matrice additionally provides improved image stabilization and an infrared sensor. It is also capable of operating at higher wind speeds and features an automated survey mode with consistent along- and cross-track image overlap. Although the Matrice generally enabled simultaneous acquisition of optical and infrared imagery, this substantially reduced flight speed and posed challenges under conditions of strong floe drift. For this reason, in most cases only one channel was operated at a time. In contrast, imagery with the Mavic 3 was acquired manually.

Two primary objectives guided the campaign. The first was the mapping of melt pond fraction, bathymetry, and surface topography across multiple ice regimes, including the generation of digital elevation models (DEMs) with high vertical accuracy. The second was the evaluation of drones as a complementary tool or potential alternative to helicopters for large-scale melt pond observations under varying weather conditions. In addition, an orthophoto of the full area of interest (Aoi) for ice work was produced on each new floe to support the planning of on-ice activities.

With few exceptions, surveys were conducted in two distinct patterns, depending on weather conditions and objectives. In general, flights followed a grid pattern with 80% along-track and 40–60% cross-track image overlap, adjusted according to ice drift. Flight altitudes ranged between 40 and 120 m, depending on cloud ceiling and survey area size. While this configuration was sufficient for orthophoto generation, DEM production required an additional grid flown perpendicular to the first, with flight height increased or decreased by approximately 20%. This “chessboard pattern” was applied to minimize doming effects. Although a complete chessboard survey was the intended standard, sudden changes in local weather conditions occasionally required termination of the survey after completion of only a single grid.

On all floes, black-and-white targets equipped with GPS stations were deployed to serve as check and control points. Each target measured one square meter and was visible from all platforms used during the campaign, including drones, the helicopter, and the *Polar 6* aircraft. To maximize the likelihood of *Polar 6* overflights with active ground control points, three targets and two GPS stations were left on floe 3 for the duration of the cruise. In addition, two targets were maintained on the other floes to act as fixed points for local coordinate systems. Respective target’s GPS station numbers can be found in Chapter 2.14. These targets were surveyed with a tachymeter during each visit to the respective floes.

Tab. 2.8.1: Overview of drone surveys and target areas conducted with the DJI Mavic 3 and DJI Matrice 350 RTK. Rows highlighted in blue indicate multiple flight events that together form a chessboard pattern, while rows highlighted in green represent extended chessboard patterns involving more than two flight heights.

Event Label	Station/ Area	Shadows?	Grid	Camera
PS149_13-1-Mavic3-01	1a/full AoI	No	Single	Optics
PS149_13-1-Mavic3-02	1a/full AoI	No	Single	Optics
PS149_13-1-Mavic3-03	1a/ Pond Survey Torben	No	Chessboard	Optics
PS149_13-1-Mavic3-04	1a/Turbulence	No	Single	Optics
PS149_13-1-Matrice_350_RTK-01	1a/full AoI + Additional Floe	No	Single	Optics + IR
PS149_16-1-Mavic3-01	2a/full AoI	Yes	Single	Optics
PS149_16-1-Mavic3-02	2a/Pond Survey Turbulence	No	Single	Optics
PS149_16-1-Mavic3-03	2a/Pond Survey Torben	No	Chessboard	Optics
PS149_16-1-Mavic3-04	2a/ <i>Polarstern</i> mapping	No	Rotation	Optics
PS149_16-1-Mavic3-05	2a/ Cinematics (Videos)	No	-	Optics
PS149_16-1-Matrice_350_RTK-01	2a/Full AoI	Yes	Single	Optics
PS149_16-1-Matrice_350_RTK-02	2a/Full AoI	Yes	Chessboard	IR
PS149_16-1-Matrice_350_RTK-03	2a/Pond Survey Torben	Yes	Chessboard	IR
PS149_18-1-Mavic3-01	3a/Full AoI	No	Single	Optics
PS149_18-1-Mavic3-02	3a/Full AoI	Yes	Chessboard	Optics
PS149_18-1-Mavic3-03	3a/Pond Survey Torben	Yes	Chessboard	Optics
PS149_18-1-Mavic3-04	3a/Pond Survey Torben	Yes	Chessboard	Optics
PS149_18-1-Matrice_350_RTK-01	3a/full AoI	Yes	Single	Optics
PS149_18-1-Matrice_350_RTK-02	3a/Pond Survey Torben	Yes	Single	Optics
PS149_18-1-Matrice_350_RTK-03	3a/Turbulence sight	Yes	Single	IR
PS149_18-1-Matrice_350_RTK-04	3a/fullAoI	Yes	Single	Optics
PS149_21-1-Mavic3-01	1b/Pond Survey Torben	No	Chessboard	Optics
PS149_21-1-Mavic3-02	1b/Pond Survey Torben	No	Chessboard	Optics
PS149_21-1-Mavic3-03	1b/Full AoI	No	Chessboard	Optics
PS149_21-1-Matrice_350_RTK-01	1b/Full AoI	No	Chessboard	Optics
PS149_21-1-Matrice_350_RTK-02	1b/Full AoI	No	Chessboard	Optics
PS149_21-1-Matrice_350_RTK-03	1b/Pond Survey Torben	No	Chessboard	Optics
PS149_21-1-Matrice_350_RTK-04	1b/Pond Survey Torben	No	Chessboard	Optics
PS149_21-1-Matrice_350_RTK-05	1b/Thermal Cinematics	No	-	IR

Event Label	Station/ Area	Shadows?	Grid	Camera
PS149_25-1-Mavic3-01	2b/Full AoI	No	Chessboard	Optics
PS149_25-1-Mavic3-02	2b/Pond Survey Torben	Yes	Chessboard	Optics
PS149_25-1-Matrice_350_RTK-01 PS149_25-1-Matrice_350_RTK-02	2b/Full AoI	Yes	Chessboard	Optics
PS149_30-1-Mavic3-01	3b/Rubblefield next to Floe	Yes	Chessboard	Optics
PS149_30-1-Mavic3-02	3b/Videos above Clouds	Yes	-	Optics
PS149_30-1-Mavic3-03	3b/Images over Clouds	Yes	-	Optics
PS149_30-1-Mavic3-04	3b/Half of full Floe	Yes	Single	Optics
PS149_30-1-Matrice_350_RTK-01 PS149_30-1-Matrice_350_RTK-02 PS149_30-1-Matrice_350_RTK-03	3b/Full AoI	No	Chessboard	Optics
PS149_30-1-Matrice_350_RTK-03 PS149_30-1-Matrice_350_RTK-03	3b/Pond Survey Torben	No	Chessboard	Optics
PS149_32-1-Mavic3-01	1c/Pond Survey Torben	No	Chessboard	Optics
PS149_32-1-Mavic3-02	1c/Images of Floe	No	-	Optics
PS149_32-1-Matrice_350_RTK-01	1c/Full AoI	Yes	Chessboard	Optics
PS149_32-1-Matrice_350_RTK-01	1c/Pond Survey Torben	Yes	Chessboard	Optics
PS149_32-1-Matrice_350_RTK-01	1c/Full AoI	Yes	Chessboard	IR+Optics
PS149_36-1-Mavic3-01	2c/Images of long transit group	No	-	Optics
PS149_36-1-Mavic3-02	2c/Full AoI and Torbens Pond by Marcel	No	Single	Optics
PS149_36-1-Mavic3-03	2c/Torbens Pond	No	Chessboard	Optics
PS149_36-1-Mavic3-04	2c/Torbens Pond	No	Chessboard	Optics
PS149_36-1-Matrice_350_RTK-01 PS149_36-1-Matrice_350_RTK-02 PS149_36-1-Matrice_350_RTK-02	2c/Full AoI	No	Chessboard	Optics
PS149_39-1-Mavic3-01	3c/Polar 6 transit Scouting	No	-	Optics
PS149_39-1-Matrice_350_RTK-01 PS149_39-1-Matrice_350_RTK-02	3c/full AoI	Yes	Chessboard	Optics
PS149_39-1-Matrice_350_RTK-03 PS149_39-1-Matrice_350_RTK-04	3c/Torbens Pond	Yes	Chessboard	Optics
PS149_46-1-Mavic3-01 PS149_46-1-Mavic3-02 PS149_46-1-Mavic3-03	2d/full AoI	No	Chessboard	Optics
PS149_47-1-Mavic3-01 PS149_47-1-Mavic3-02	3d/Torbens Pond	Yes	Chessboard	Optics
PS149_47-1-Mavic3-03 PS149_47-1-Mavic3-04	3d/full AoI	Yes	Chessboard	Optics

Event Label	Station/ Area	Shadows?	Grid	Camera
PS149_47-1-Mavic3-05 PS149_47-1-Mavic3-06	3d/full Aol drift corrected	Yes	Chessboard	Optics
PS149_47-1-Mavic3-07	3d/full Aol drift corrected	Yes	Single	Optics
PS149_47-1-Matrice_350_RTK-01	3d/full Aol	No	Single	Optics
PS149_47-1-Matrice_350_RTK-02 PS149_47-1-Matrice_350_RTK-03	3d/ full Aol	Yes	Chessboard	Optics
PS149_47-1-Matrice_350_RTK-04 PS149_47-1-Matrice_350_RTK-05	3d/ Torbens Pond and surroundings	Yes	Chessboard	IR+Optics

Preliminary results

Figure 2.8.1 presents the maps of all three floes. Distinct changes in surface topography and melt pond distribution are clearly visible. In addition, DEMs were generated for each floe and will be included in forthcoming publications. Differential DEMs will also be processed to illustrate variations in floe topography between the different stations.

Further, important observations were made regarding drone flightability, resulting image stability, and operational limits compared to the helicopter. The DJI Mavic 3 could fly up to 12 m/s while producing blur-free images. In higher wind speeds and in the case of stronger gusts, the drone's wind resistance was in some cases not sufficient anymore requiring manual thrust. In these cases, images got blurred. Additionally, the Mavic 3 lacks wind speed measurement and required visual judgment of stability. The DJI Matrice 350 RTK handled up to 16 m/s without manual thrust, however slight blurring was observed in some images in wind speeds above 14 m/s. No visual judgment of stability was required, as the Matrice 350 RTK is equipped with a wind speed sensor. The helicopter was largely unaffected by wind but suffered image rotation in strong winds due to a fixed camera mount that only stabilized against vibrations. Large restrictions inflicted on its flyability were caused by temperature and moisture. The helicopter could not operate in fog, beginning icing risk or incoming fog. Additionally, a ceiling beneath 500–600 ft restricted photogrammetric surveys due to an insufficient imaging rate or helicopter capability to reduce the travel speed respectively. In contrast, drones were capable of launching in basically any ceiling level including light ground fog, as long as temperatures remained above the freezing point. Around 0 degrees Celsius, icing checks were performed using the Mavic 3 as long as no icing was visible on the mast of *Polarstern*. These included lift off, altitude increase till the foggy layer was reached and flight activities right beneath that layer for 2–4 minutes. Light icing was manageable with regular removal from the rotors. In cases of severe icing, manoeuvrability was decreased over time and the drone eventually emitted a warning. In this case, immediate landing was performed without complications and no further flights were performed. The Matrice 350 RTK was not used in cases of any icing due to its size and the respectively reduced manoeuvrability, which limited landing manoeuvres with increased speeds. Finally, flight height was a significantly limiting factor for the drones. Despite their maximum activation for up to 500 m, wind and temperature usually restricted them to 40–80 m. On these heights, battery life and ice drift limited the survey area significantly, making large scale mapping of the floe, apart from our full Aol, impractical. In contrast, the helicopter could cover large areas at higher altitudes with less constraints, completing various surveys of the full floe in 1.5–2 h while collecting IMU data for drift correction.

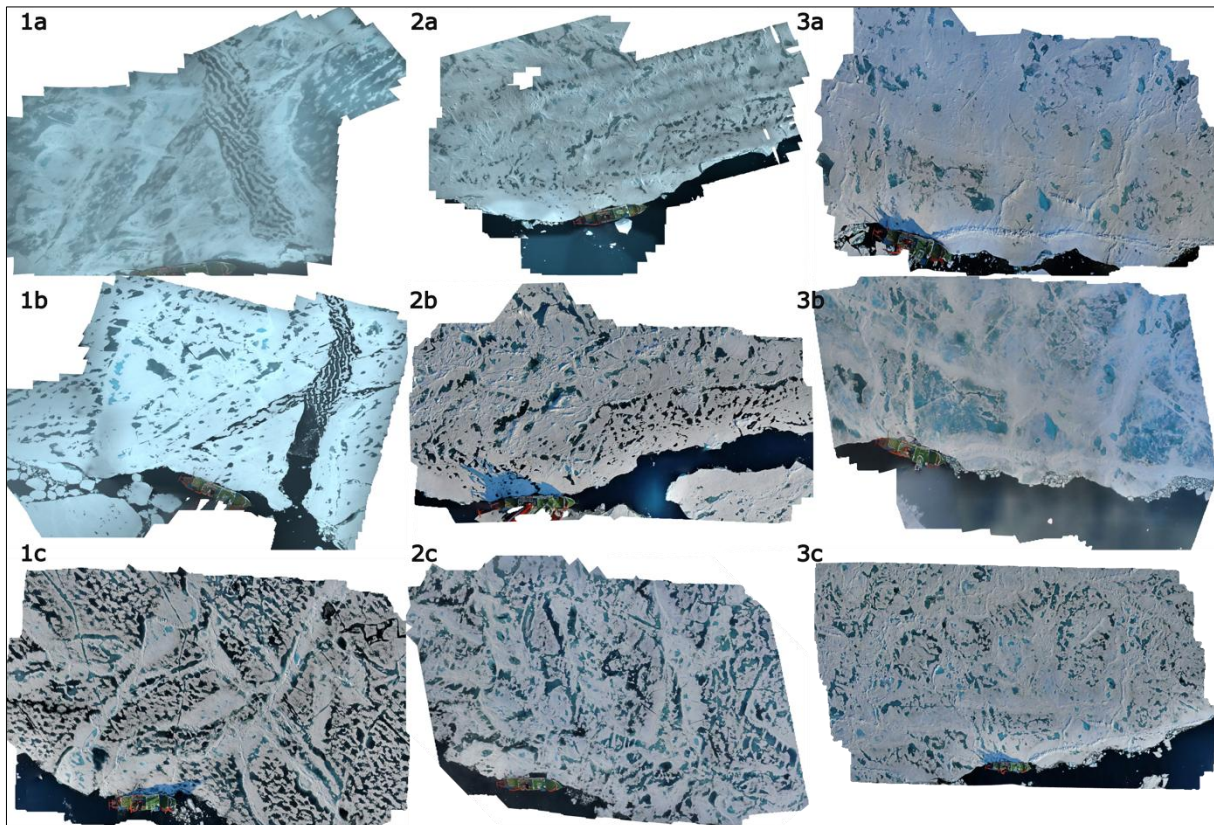


Fig. 2.8.1: Orthophotos from repeated visits on all three floes. For station 1c, a new floe was selected as the original one had become inaccessible.

SPECTRA albedo drone (FMI)

Work at sea

Aerial albedo measurements are needed to characterize the effect of the various surface types on the areal-averaged albedo over different horizontal scales. These measurements will also enable the derivation of relationships between the albedo measured from ground-based platforms, which typically have metre-to-tens-of-meters footprint, and satellite observations or large-grid model outputs.

We operated the custom-built drone SPECTRA, equipped with paired Kipp and Zonen CM4 pyranometers measuring broadband albedo and paired Ocean Optics STS VIS (350 – 800 nm) and NIR (650-1100 nm) micro-radiometers measuring visible and near-infrared spectral albedo. Before taking off, we calibrated the compass and the accelerometer at every station. The SPECTRA drone was operated for up to three consecutive flights, each of them lasting approximately 20-25 minutes. During the flights, we performed two types of surveys: (1) Horizontal serpentine mapping over a ~200x200 m² area, with a point distance of ~30 m distance between waypoints, at a flight height of 5m and (2) vertical profiles with height increments of 5 m close to the surface and 10 m higher up. In both surveys we hovered for 25s at each point due to the sensor's integration time of about 10-15 s. We flew the grid surveys mostly over the ROV non-walking area and coordinated with Florian Zimmer (ROV) for collocation of the ROV transmittance depth profile and a SPECTRA albedo vertical profile. Since the on-board VIS camera did not work, we mounted 3D camera on the drone for a view of the measured area. More detailed flight description and pictures can be found in the AWI logbook for each individual flight. Furthermore, locations are marked on the station maps.



Fig. 2.8.2: Flying the albedo drone on station 1b

Preliminary (expected) results

A first look into the time series of the broadband albedo measured during the serpentine mapping flight made at 5m altitude above the sea ice on 21 July at station 3a (Fig. 2.8.3) shows that albedo varied between 0.3 and 0.8. There were three time-intervals with albedo continuously lower than 0.5, with melt pond area dominating the field of view of the downward looking pyranometer. These intervals were much shorter than the two time-intervals with albedo continuously around 0.8, evidently dominated by snow covered ice (c.f. snow pits) covering larger areas than melt ponds.

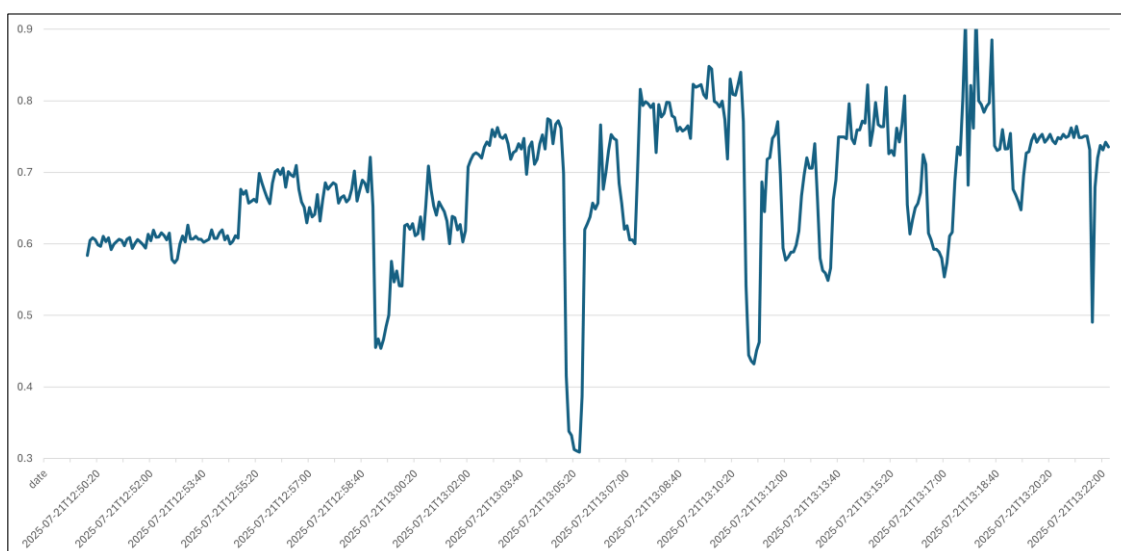


Fig. 2.8.3: Time series of broadband albedo measured along a serpentine flight made at 5m above the sea ice on 21 July 2025 (station 3a), covering an area of approximately 200x200 m.

Tab. 2.8.2: Overview of the flights with the drone SPECTRA

Station	date	Surveys
3a	21.07.	Grid over ROV non-walking, 2 vertical profiles
1b	27.07.	Vertical profile between MetCity and Coralie's ROV toilet (upwards), vertical profile descending over landing spot eastish of highway towards OCEAN
3b	06.08. 09:20	Grid over ROV non-walking area, vertical profile up to 30m in middle of ROV domain
3b	06.08. 17:30ish	Same grid as in the morning (now clearish vs. cloudy in the morning), vertical profile at roughly same location as in the morning, descending profile between radiation station and ship, new flight with vertical profile at ROV transmittance location
1c	10.08.	Grid over ROV non-walking area (as far as visibility allowed)
2c	13.08.	Upward profile at ROV transmittance depth profile location (tilted red flag), 200-300 m at ship's 11 o'clock descending profile; grid over ROV non-walking area extended over lead and ocean (had to quit, since battery was almost empty; grid again, little transect from ice to ocean, camera flight over the ship and the floe
3c	17.08.	Upwards profile at ROV transmittance depth profile location (ROV did depth profile at same time), downward profile over kind of middle of the ROV no-walking area, upwards profile to 40 m in between the two; grid over ROV non-walking area, upward profile over blueish area towards Torben's pond, small upward profile over Torben's pond
2d	24.08.	Grid over ROV non-walking area, vertical profiles, transect over ice, thin new ice on lead, lead
3d	27.8.	Profile at ROV transmittance; grid ROV non-walking, profile at former blueish pond (now flat with new snow)

2.9 Helicopter-borne sea ice thickness and surface roughness

Work at sea

During the CONTRASTS campaign, helicopter-borne sea ice thickness surveys were conducted using the Electromagnetic (EM) Bird, a towed sensor system flown at an altitude of 12 to 20 meters above the ice surface. The system measures sea ice thickness by calculating the difference between the EM-derived distance to the ice–water interface and the distance to the snow and ice surface obtained from a single-beam laser altimeter.

The primary objective was to determine the ice thickness distribution of floes R1–R3 and, in particular, to document how this distribution evolved over the course of the melt season. An additional goal was to characterize the ice thickness distribution in the broader surroundings of the floes and to identify potential gradients in ice properties that might indicate a regime shift. Due to the strong dependence of helicopter flights on weather conditions, it was not possible to survey all floes multiple times. Table 2.3.1 provides an overview of the flights that were conducted.

Ice thickness measurement accuracy is within 0.1 m to drill-hole measurements over level sea ice, while water inclusions within pressure ridges lead to a general underestimation of ridges by as much as 40 % to 50 % (Pfaffling et al., 2007; Haas et al., 2009). Pressure ridges along flight tracks were detected using range readings from the single beam laser altimeter. For this we applied filter technique developed by Hibler et al. (1975) that detects local maxima based on a predefined minimum height threshold (0.6 m). A local maximum is classified as a pressure ridge sail if it meets the Rayleigh criterion, which requires that the troughs descend to a height at least half that of the local maximum (see Krumpen et al., 2025). The highest point of a ridge is defined as the ridge sail height. The ridge sail spacing provides the peak-to-peak distance between consecutive sail maxima. Ridge density is defined as the number of ridges (n) per km.

For further data analysis and the construction of the time series, the profiles were divided into sections of 5, 10, and 15 km each, and the means, medians, and modes were computed for various parameters (ice thickness, pressure ridge density, sail spacing, etc.). The selected segment length of 10 km corresponds to the resolution of commonly used satellite-based sea ice products. Each segment was then backtracked using IceTrack (see chapter: Sea Ice Age, Drift Trajectories, and Origins) and assigned a corresponding ice age and ice origin. In addition, various other satellite and model data were extracted along the track and archived.

Tab. 2.3.1: Overview of EM Bird surveys during CONTRASTS.

Event label	Date/time	Surveying activity
PS149_heli-EMBIRD-01	2025-07-06T15:14:00	Flight from ice edge straight north and back
PS149_heli-EMBIRD-02	2025-07-14T12:25:00	Flight across R2 and from R2 (SYI) towards east into FYI zone
PS149_heli-EMBIRD-03	2025-07-20T13:56:00	Flight across R3 and surrounding (limited to 5 min)
PS149_heli-EMBIRD-04	2025-07-21T14:19:00	Flight from R3 over MYI towards SYI and back
PS149_heli-EMBIRD-05	2025-07-23T12:42:00	Flight on transit in SYI area between R3 and R1
PS149_heli-EMBIRD-06	2025-07-30T18:56:00	Flight across R2 and from R2 (SYI) towards east into FYI zone
PS149_heli-EMBIRD-07	2025-08-07T14:47:00	Flight on transit in SYI area between R3 and R1

Event label	Date/time	Surveying activity
PS149_heli-EMBird-08	2025-08-09T13:50:00	Flight across R1 (alternative floe) and towards the ice edge and east of R1
PS149_heli-EMBird-09	2025-08-18T09:20:00	Flight across R3
PS149_heli-EMBird-10	2025-08-18T10:45:00	Flight over sea ice east of R3
PS149_heli-EMBird-11	2025-08-18T17:00:00	Flight over sea ice northwest of R3 and towards Greenland
PS149_heli-EMBird-12	2025-08-21T09:42:00	Flight across R1 and surroundings during recovery
PS149_heli-EMBird-13	2025-08-22T11:42:00	Transit between R1 and R2
PS149_heli-EMBird-14	2025-08-26T12:17:00	Flight across R3 and eastern surrounding
PS149_heli-EMBird-15	2025-08-27T09:30:00	Flight across R3 and western surrounding
PS149_heli-EMBird-16	2025-08-27T18:10:00	Testing flight

Preliminary (expected) results

Flight activity and spatial/temporal coverage

The CONTRASTS campaign benefited from generally favorable flying weather, enabling 16 EM Bird helicopter surveys over stations and during transits. In total, these flights yielded more than 1,200 km of sea ice thickness data. The *Polar 6* aircraft (IceBird Summer 2025) conducted complementary surveys totaling ~2,500 km, expanding the spatial footprint and providing context for the ship based measurements.

Figure 2.9.1 (bottom panel) maps the helicopter flight tracks (yellow) alongside *Polar 6* tracks (red) across the study area obtained in July and August 2025. All stations, their immediate surroundings, and the ice between stations were surveyed, some repeatedly, so the dataset resolves both spatial gradients and changes over time through the melt season.

Evolution of thickness by regime

For interpretation, we distinguish three regimes: Regime 3 (west, thicker/deformed ice), Regime 2 (central Fram Strait), and Regime 1 (marginal ice zone, MIZ). Here, regime refers to the extended environment of the floes (approximately 10–20 minutes of flight time), not solely to the thickness distribution of an individual floe.

Across the campaign, Regime 2 and Regime 1 show pronounced thinning, reflected in decreases of both modal and mean thickness. In contrast, Regime 3, characterized by thicker, more deformed ice, shows weaker thinning, with evidence that basal and surface melt became more significant during second half of the expedition upon entry into Fram Strait. These assessments are illustrated in Figure 2.9.1, which present thickness histograms for the three regimes at multiple survey dates. At this stage, the histograms represent manually selected subsections of flight lines. As analysis proceeds, we will aggregate segments more systematically and stratify by region and ice age. The panels in Figure 2.9.1 should therefore be regarded as preliminary, intended to orient the reader to the order of magnitude and direction of observed melt.

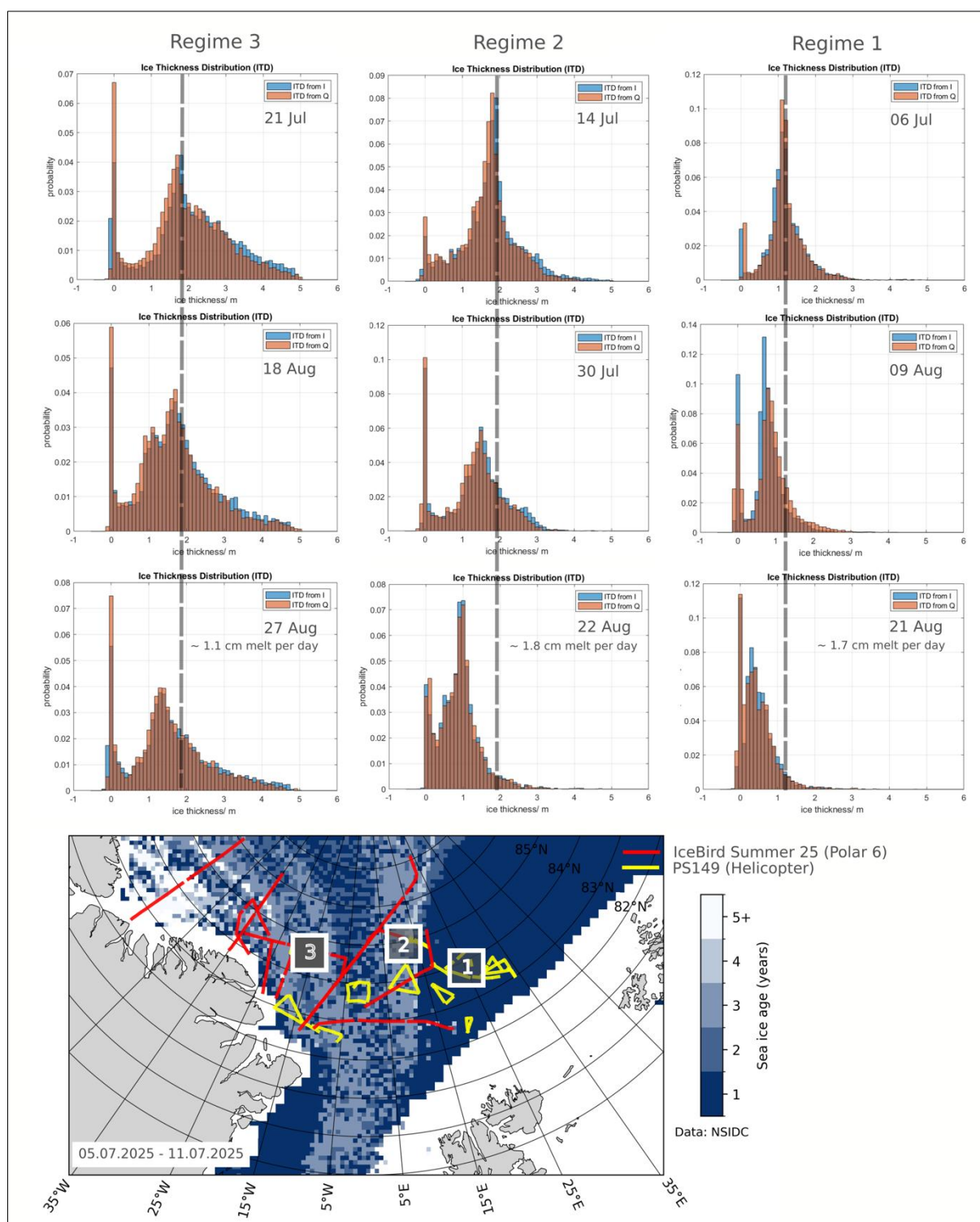


Fig. 2.9.1: Ice thickness distributions in the individual regimes (1–3) on different days / times of the expedition. The differences provide information on melt rates, which were significantly more pronounced at the stations located in the east and central regions compared to those in the west. The map below shows the sea ice age distribution (NSIDC data) at the beginning of the expedition together with the ice thickness survey flights carried out during PS149 (yellow) and the IceBird Summer campaign (red).

Campaign wide thickness distribution

Figure 2.9.2 compiles the thickness distribution for all EM Bird surveys conducted during CONTRASTS. To characterize the sea ice component, we exclude open water (the 0 m mode) when computing the mean and mode. The open water fraction along the flight tracks was ~15%, which likely enhanced lateral melt. This relatively low ice concentration is also evident in satellite products during July, consistent with divergent ice motion.

Across the campaign, the mode and mean thicknesses are close, and the histogram exhibits a weak positive tail, both of which suggest that the ice, despite being partly older, was less strongly deformed overall during the observation period.

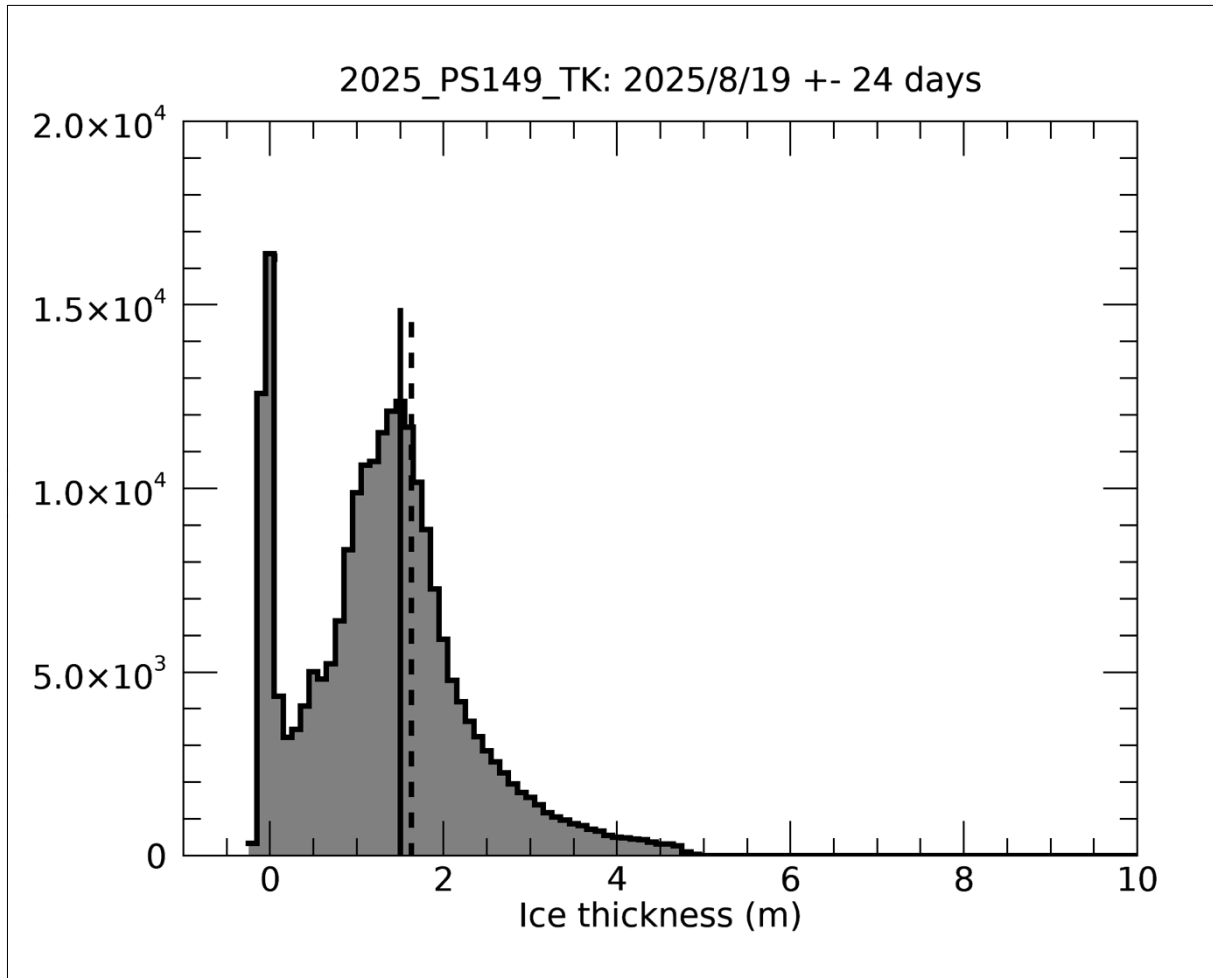


Fig. 2.9.2: Ice thickness histogram from all EM Bird surveys carried out during CONTRASTS. The distribution shows relatively undeformed ice cover with a modal thickness of approximately 1.5 m and a mean thickness of 1.65 m.

Context relative to previous years

Figure 2.9.3 compares CONTRASTS modal (blue) and mean (orange) thickness to measurements from previous years, using Fram Strait region filter as in Krumpfen et al. (2025). The modal thickness during CONTRASTS does not deviate strongly from past years, implying that seasonal melt in 2025 is broadly comparable to prior campaigns in this region. In contrast, the mean being close to the mode indicates the ice pack was more homogeneous than in many previous seasons.

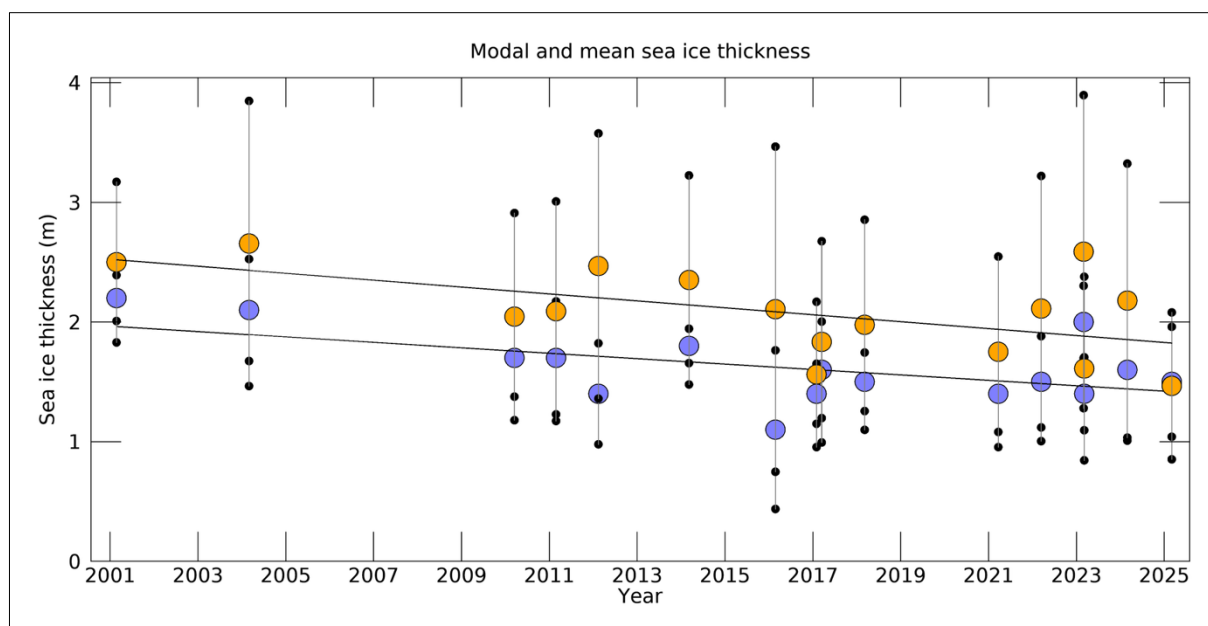


Fig. 2.9.3: Preliminary time series (mean $\pm$ S.D. in orange and mode in blue) of sea ice thickness in the study area (cf. Krumpen et al. 2025) across different campaigns. A trendline is plotted on top.

Figure 2.9.4 examines pressure ridge frequency, defined here as ridges per flight kilometer detected from the EM Bird single beam laser, and compares CONTRASTS values to previous campaigns conducted in the same Fram Strait region (again following Krumpen et al., 2025 for spatial filtering). Relative to much of the last ~ 30 years, the 2025 surveys show notably lower ridge density, implying an unusually smooth ice surface with infrequent ridge sails.

Understanding the causes of this reduced roughness will require additional analysis, for example using satellite derived deformation fields to reconstruct the dynamic forcing and thermodynamic history of the sampled ice. Going forward, an important question is how surface roughness modulates the distribution of melt ponds (and thereby albedo and melt rates).

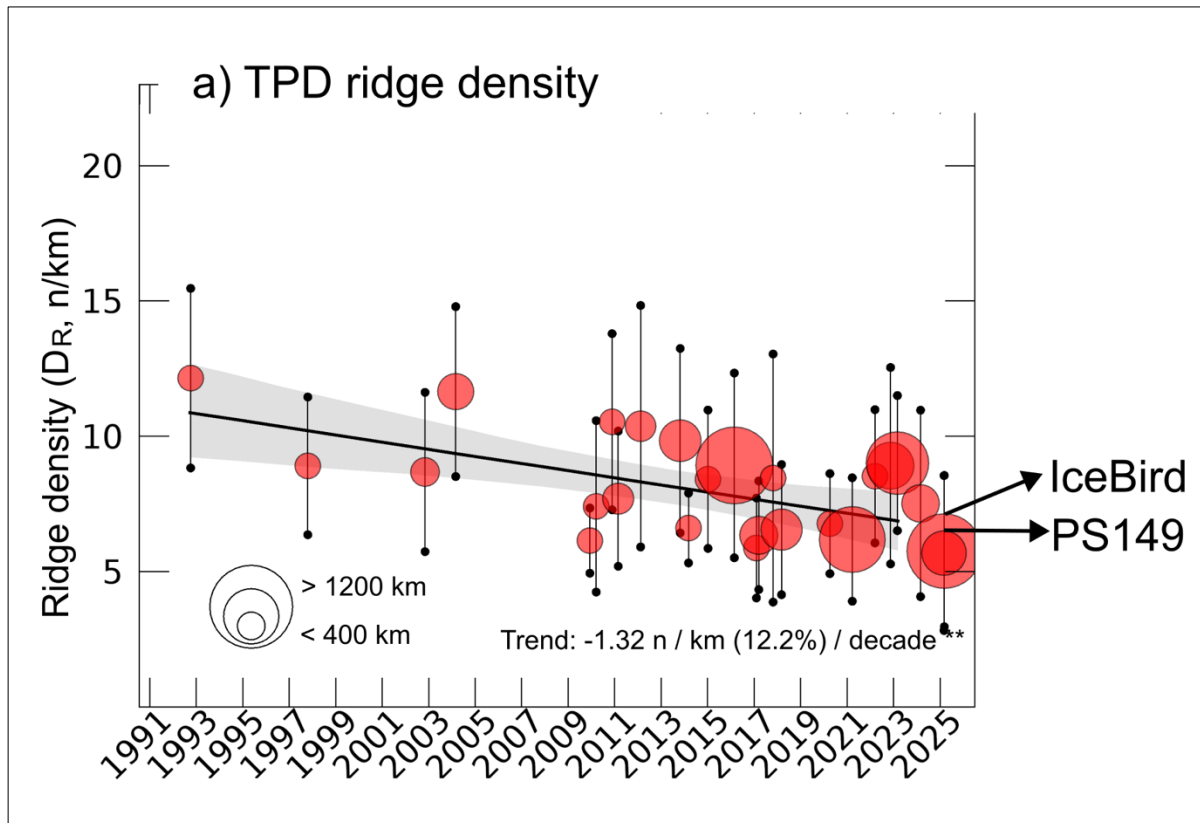


Fig. 2.9.4: Time series (mean $\pm$ S.D.) of pressure ridge densities for sails higher than 0.6 m in the study area (cf. Krumpen et al. 2025) across different campaigns. The symbol size reflects the survey distance covered during each campaign. Trends (black lines) with 95% confidence intervals (grey shading) are shown in the background. This Fig. represents an update of Figure 2 in Krumpen et al. (2025).

2.10 Helicopter-borne visible and thermal infrared imaging and laser scanner surface topography

Work at sea

The helicopter sea ice surveys with optical and infrared (IR) cameras, and laser scanner extend the spatial coverage of comparable in-situ observation and measure geophysical parameters accessible only to airborne sensors. In addition, the helicopter observations are providing ground-truth at a higher spatial resolution than achieved by satellite remote sensing to assess the impact of sub-footprint scale variability of the ice surface on the satellite retrievals. The main geophysical parameters observed from the helicopter are (i) melt pond fraction, depth, and size distribution, (ii) ice surface topography including freeboard, (iii) surface temperature of different ice types and the ocean. These parameters are needed to assess albedo changes, the surface energy budget, freshwater storage, and momentum transfer in the atmosphere-ice-ocean system and are relevant for corresponding process studies. Improved melt pond, lead and ridge distributions as well as ice type information can be retrieved by combining measurements from different sensors.

Camera and laser scanner sea ice surveys were performed with a fixed sensor installation in one of the two helicopters onboard *Polarstern*, namely the D-HARK helicopter. The installation (Table 2.10.1) consisted of two (14 mm and fisheye) downward-looking visual Nikon cameras, a nadir KT19 infrared radiometer, a downward-looking pyranometer located in the belly of the helicopter, and an airborne laser scanner (ALS) with Inertial Navigation System (INS), a downward-looking infrared camera, distribution of power and network, and the main data acquisition systems located in the rear baggage compartment (Fig. 2.10.1), as well as an upward-looking pyranometer on the tail fin. The Applanix INS contains a gyro compass coupled with two GPS receivers installed on the helicopter hull. The INS roll, pitch, speed, heading, and position data is used by all cameras and the ALS to map the sensor acquisitions on the Earth surface. All sensors were operated from the backseat in the helicopter cabin with a single display and keyboard/mouse that could connect to different industrial (ebox) PCs in the baggage compartment. An overview of the sensors is provided in Table 2.10.1. All sensors were controlled by two operators during flight. Two different flight patterns were performed: (1) long (>30 nm) flights along transect lines (e.g., in a triangle pattern) and (2) floe-grid patterns over all sea ice station floes (see Table 2.10.2 for a table of which floe visits were covered). In total 23 science flights were conducted with this setup. Two of these flights (8 and 17) had to be aborted early due to bad weather and contain little usable data. A list of all flights is summarized in Table 2.10.3. Figure 2.10.2 shows an overview map of all flights for the CONTRASTS region. The Nikon fisheye camera rarely worked. During flights 1 and 2 some data was recorded. Thereafter the camera stopped working for unknown reasons. The downward-looking pyranometer was broken on the ground after flight 7 when handling the helicopter. Therefore, from flight 8 onwards both pyranometers were not operated anymore.

Helicopter-borne thermal infrared surface imaging

A nadir looking thermal infrared camera (Infratec VarioCAM HD head 680) was operated as part of the camera helicopter suite to measure surface temperature variability of ice, ocean and melt ponds. During summer the temperature difference between ocean, sea ice, and melt pond surface gets reduced to mostly below 5 K (example image in Figure 2.10.3). To calibrate the infrared brightness temperatures to physical surface temperatures, calibration targets (see Chapter 3.5) with a known temperature and emissivity of 1 were installed at different locations on the ice floes (see Chapter 3.5). Depending on region and atmospheric conditions also the relative amplitudes of the surfaces can change, e.g., the ice surface can be warmer than the ocean. In the ocean, small-scale turbulence in the wake of drifting ice floes can cause strong gradients in ocean surface temperature signature. Melt ponds usually have a surface

temperature that differs from both ocean and sea ice. The thermal infrared imaging obtained from helicopter will be used to explore the summer surface temperature variability and in particular to derive melt pond fraction from thermal infrared imaging.

Helicopter-borne airborne laser scanning

A nadir looking laser scanner (Riegl VQ-580) was operated as part of the camera helicopter suite to measure surface topography features. It is equipped with a laser range finder and a one-axis scan mechanism to scan in a 2D fan like pattern. It uses a wavelength of 1064 nm in the near infrared spectrum, which makes it particularly suitable for detecting snow and ice surfaces with high reflectivity. The scanner provides dense point cloud data with high spatial resolution, enabling the characterization of small-scale surface roughness as well as larger morphological features. However, varying illumination and flight dynamics can affect the stability of the measurements. While the latter is compensated through the Applanix INS, varying illumination due to fast travelling clouds within one flight remains a challenge.

Helicopter-borne Nikon camera system

Two downward-looking Nikon cameras (Nikon D5) were operated as part of the camera helicopter suite to provide optical images. These will be used to derive digital elevation models and provide visual information as an addition to the ALS data. Due to an unresolved system error, the fish eye camera was not functioning after the third flight. As a consequence, the overall imaging capacity of the system was reduced. The lack of fisheye coverage constrained the documentation of environmental conditions and limited the redundancy of the optical dataset, which had been designed to complement the ALS measurements under varying flight dynamics. This reduced the potential to capture panoramic context that would allow a more comprehensive interpretation of the optical and laser data.

Tab. 2.10.1: Overview of sensors used for the helicopter camera and ALS sea ice surveys

Sensor	Description	Device ID (O2A Registry)	Geophysical Parameter
14 mm-Cam	Wide-angle nadir camera (Nikon D5, 14 mm lens)	6864	Melt pond parameters, surface albedo
Fisheye-Cam	Wide-angle nadir camera (Nikon D5, fisheye lens)	6865	Melt pond parameters, surface albedo; not working on most of the flights
ALS	Airborne Laser Scanner (Riegl VQ580)	6350	Surface elevation, freeboard and roughness
IR-Camera	Nadir Infrared-Camera (Infratec VarioCAM HD head 680)	4192	Melt pond parameters, surface temperature distribution
INS	Applanix Inertial Navigation System (AP60-Air)	5061	Position, speed, heading, roll and pitch of helicopter
KT19	Radiation thermometer (HEITRONICS KT19.85 II)	4537	Surface temperature
Pyranometer upward-looking	Pyranometer upward-looking with spectral range 200 to 3600 nm (Kipp and Zonen CMP22)	4458	Incoming solar radiation; was not operated anymore after the 2nd pyranometer broke
Pyranometer downward-looking	Pyranometer downward-looking with spectral range	4459	Outgoing reflected solar radiation; broke → not

Sensor	Description	Device ID (O2A Registry)	Geophysical Parameter
	200 to 3600 nm (Kipp and Zonen CMP22)		working from flight 8 onwards

Tab. 2.10.2: Overview of which floe visits were covered by helicopter survey grid flies

Visit	Floe 1	Floe 2	Floe 3
a	2025-07-10	2025-07-16	2025-07-20 2025-07-22
b	2025-07-25 aborted	2025-07-30	2025-08-03
c	2025-08-09 different floe		2025-08-18
d	2025-08-21 no grid; just overflight of floe 1 remains	2025-08-21	

Tab. 2.10.3: List of all flights performed with the cameras and ALS setup

No.	Date	Type	Start Time	End Time	Sensors	Weather & comment
1	2025-07-10	Floe 1a, 350–400 ft, 50 kn	09:50	11:41	Fisheye, 14 mm, ALS, INS, IR-Cam, KT19, Pyran.	Ceiling at appr. 500 ft, cloud fraction 7/8, no shadows
2	2025-07-14	Transect, 1,000 ft, 90 kn	13:06	15:05	Fisheye, 14 mm, ALS, INS, IR-Cam, KT19, Pyran.	Cloud fraction 6/8, some spots of sun visible
3	2025-07-16	Floe 2a, 1,000 ft, 90 kn & 800 ft, 82 kn	16:44	18:15	14 mm, ALS, INS, IR-Cam, KT19, Pyran.	Cloud fraction 3/8, sun visible, shadows visible, appr. 17:40 clouds over floe
4	2025-07-20	Floe 3a, 1,000 ft, 90 kn & 800 ft, 82 kn	09:51	11:13	14 mm, ALS, INS, IR-Cam, KT19, Pyran.	Lost IR GPS at ~10:00, cloud fraction 8/8, no sun visible, ceiling appr. 7000ft, clear visibility in nadir
5	2025-07-21	Transect, 1,000 ft, 90 kn	14:26	15:56	14 mm, ALS, INS, IR-Cam, KT19, Pyran.	Cloud fraction 5/8, sun partly visible, varying cloud layers
6	2025-07-22	Floe 3a, 1,000 ft, 90 kn & 800 ft, 82 kn	12:42	13:40	14 mm, ALS, INS, IR-Cam, KT19, Pyran.	Cloud fraction 3/8, no clouds over floe, shadows visible
7	2025-07-23	Transect, 1,000 ft, 90 kn	09:46	11:31	14 mm, ALS, INS, IR-Cam, KT19, Pyran.	

No.	Date	Type	Start Time	End Time	Sensors	Weather & comment
8	2025-07-25	Floe 1b, aborted	12:36	12:50	14 mm, ALS, INS, IR-Cam, KT19	Ceiling too low (<200ft) -> flight aborted shortly after start; has two overflights of the floe at 170ft height
9	2025-07-30	Floe 2b, 1,000 ft, 90 kn & 800 ft, 82 kn	20:41	22:43	14 mm, ALS, INS, IR-Cam, KT19	Cloud fraction 2/8, no clouds over floe apart from 21:02 - 21:52
10	2025-08-03	Transect + Floe 3b, 1,000 ft, 90 kn & 800 ft, 82 kn	13:16	15:03	14 mm, ALS, INS, IR-Cam, KT19	Transect to floe 3 & survey grid over floe; lost IR GPS, recovered at 13:25, cloud fraction 4/8, sun visible, high cloud coverage starting 13:46
11	2025-08-03	Transect, 1,000 ft, 90 kn	15:52	17:40	14 mm, ALS, INS, IR-Cam, KT19	Transect triangle flight to Calib buoy deployed in spring by Polar-5, cloud fraction 6/8, high thin clouds, light shadows visible, appr. 16:40 cloud fraction 8/8, no sun visible
12	2025-08-07	Transect, 1,000 ft, 90 kn	17:21	19:08	14 mm, ALS, INS, IR-Cam, KT19	Cloud fraction 2/8, sun visible, 17:45 cloud fraction 8/8, 18:15 – 18:20 light rain
13	2025-08-09	Transect, 1,000 ft, 90 kn	16:20	18:02	14 mm, ALS, INS, IR-Cam, KT19	Cloud fraction 1/8, sun and shadows visible
14	2025-08-09	Floe 1c, 1,000 ft, 90 kn & 800 ft, 82 kn	18:41	20:45	14 mm, ALS, INS, IR-Cam, KT19	Cloud fraction 1/8, sun and shadows visible
15	2025-08-18	Floe 3c, 1,000 ft, 90 kn & 800 ft, 82 kn	12:51	13:50	14 mm, ALS, INS, IR-Cam, KT19	At the end, overflight in 500ft of transect laid out for Polar 6, cloud fraction 2/8, no clouds over floe, sun and shadows visible
16	2025-08-18	Transect, 1,000 ft, 90 kn	14:17	16:21	14 mm, ALS, INS, IR-Cam, KT19	cloud fraction 2/8, no clouds over floe, sun and shadows visible
17	2025-08-20	Aborted	09:28	09:44	14 mm, ALS, INS, IR-Cam, KT19	bad weather; measurements affected by fog/cloud
18	2025-08-21	Transect & Floe 1d, 1,000 ft, 90 kn	12:08	13:35	14 mm, ALS, INS, IR-Cam, KT19	Transect flight and overflight of floe 1 remains, cloud fraction 6/8, sun visible
19	2025-08-22	Transect & Floe 2d, 1,000 ft, 90 kn	12:59	15:04	14 mm, ALS, INS, IR-Cam, KT19	transect to floe 2 & survey grid over floe, cloud fraction 2/8, sun and shadows visible, 13:15-13:26: cloud fraction 6/8, sun not visible, 13:26: cloud fraction 1/8, sun and shadows visible

No.	Date	Type	Start Time	End Time	Sensors	Weather & comment
20	2025-08-26	Floe 3d, 1,000 ft, 90 kn & 800 ft, 82 kn	09:21	11:36	14 mm, ALS, INS, IR-Cam, KT19	Cloud fraction 6/8, fod patches visible, sun patches visible, 09:29- 09:35 floe covered with light fog, 09:35-10:15 clear skies over floe, sun and shadows visible, 10:15-11:02: floe covered with light fog, 11:02: fog vanishes, shadows reappear
21	2025-08-26	Transect, 1,000 ft, 90 kn	16:38	18:26	14 mm, ALS, INS, IR-Cam, KT19	Cloud fraction 4/8, varying fog thickness during flight starting 17:03, 17:45 fog vanishes and sun visible
22	2025-08-27	Floe 3d, 1,000 ft, 90 kn & 800 ft, 82 kn	11:44	12:31	14 mm, ALS, INS, IR-Cam, KT19	Cloud Fraction 2/8, sun and shadows visible
23	2025-08-27	Transect, 1,000 ft, 90 kn	12:53	14:25	14 mm, ALS, INS, IR-Cam, KT19	Cloud Fraction 2/8, sun and shadows visible

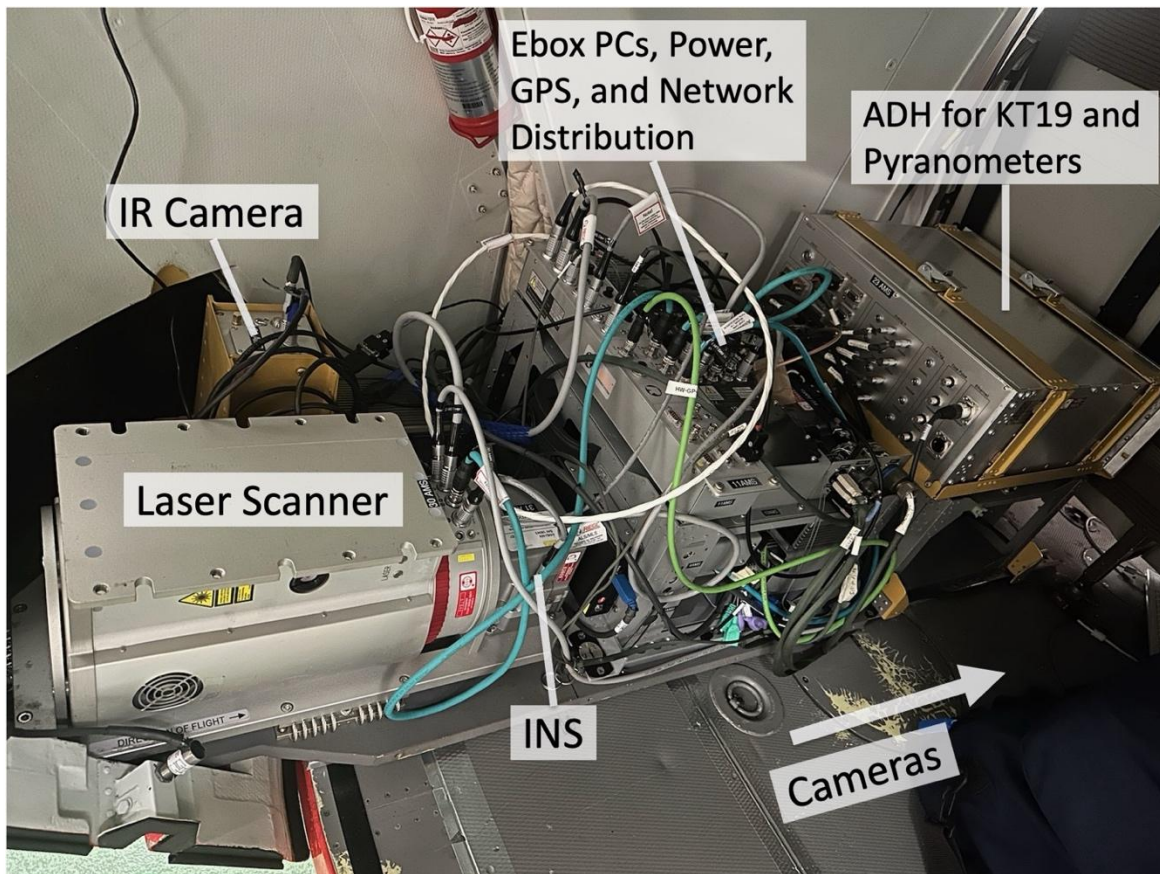


Fig. 2.10.1: Helicopter sensor installation in the rear baggage compartment of the helicopter (D-HARK). The ALS and IR camera look nadir downwards through openings in the left back door. Not on the photo are the two Canon cameras, KT19 IR radiometer, and pyranometer mounted in the belly panel at the front of the helicopter.

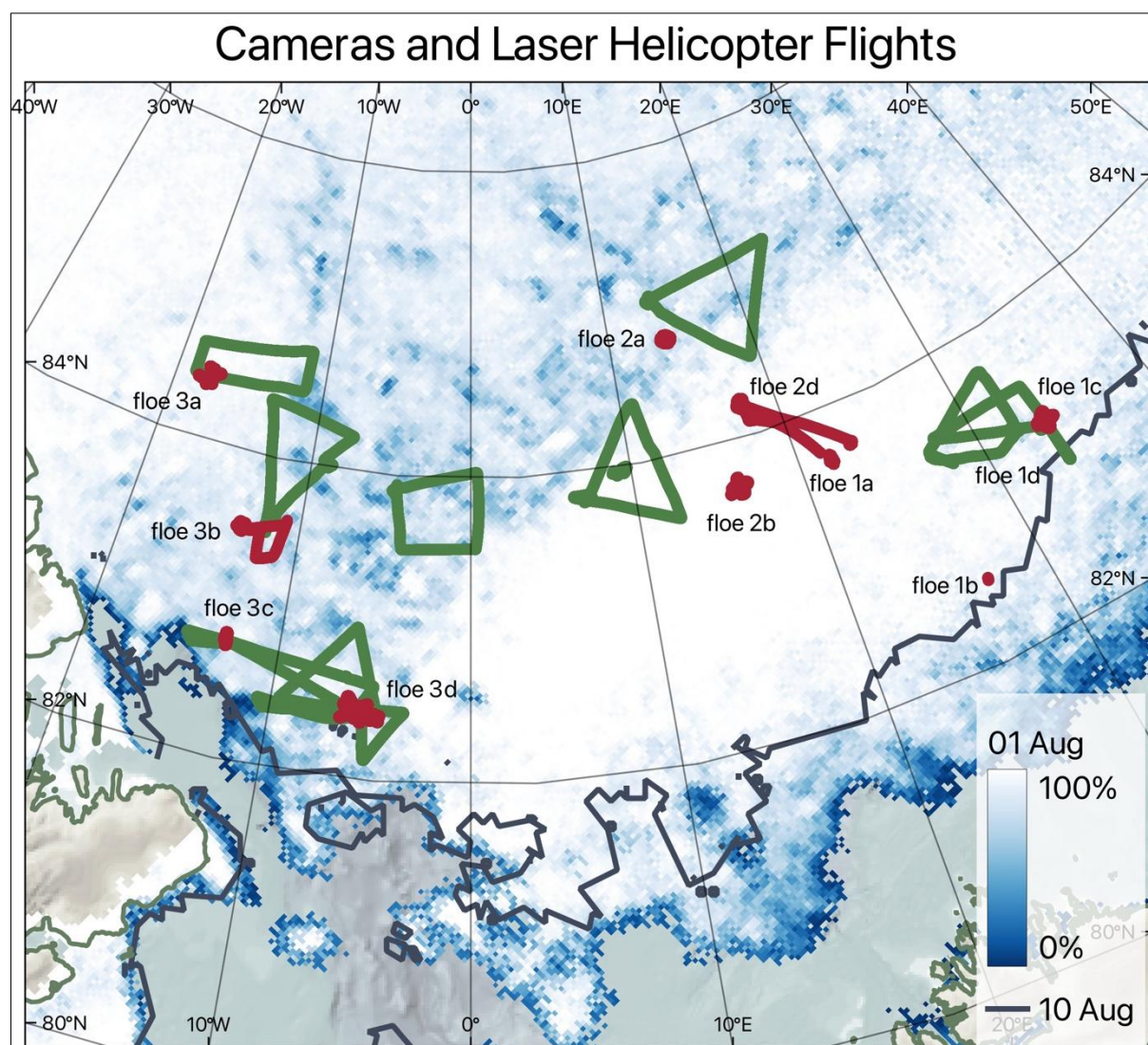


Fig. 2.10.2: Overview map of all helicopter flights with the camera and ALS setup

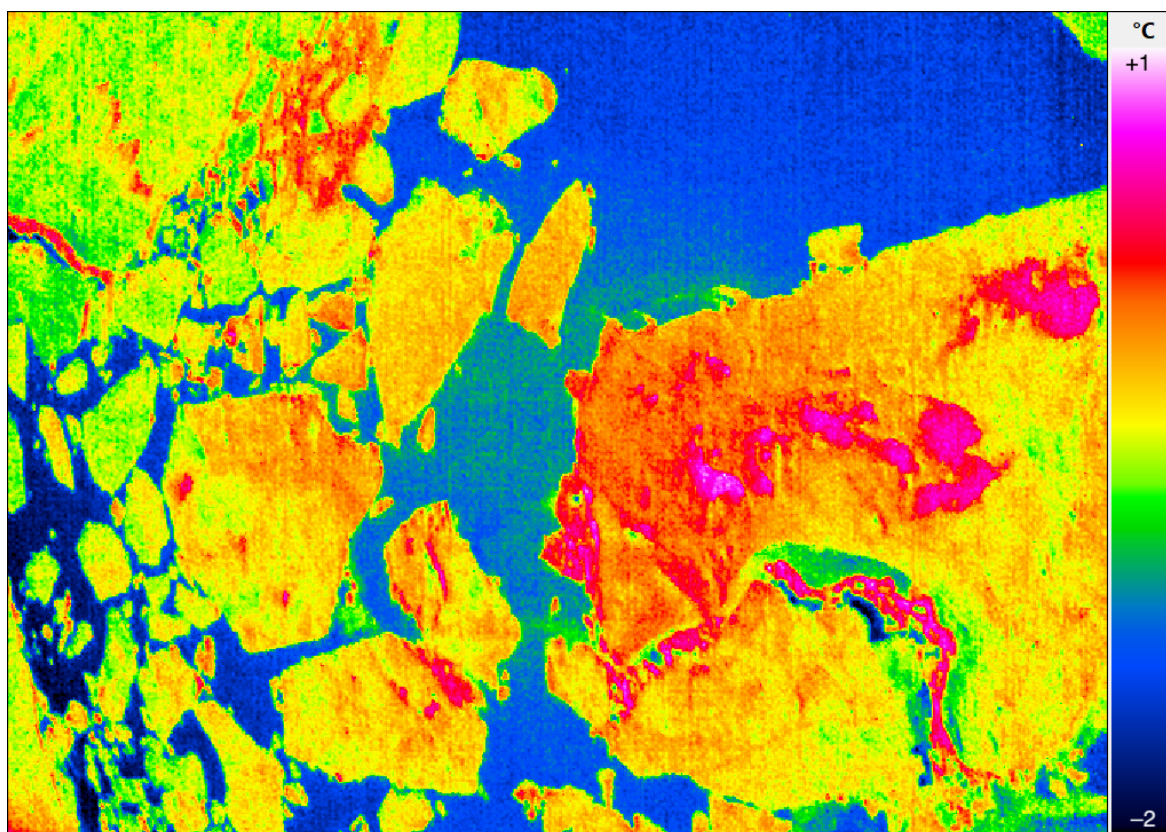


Fig. 2.10.3: Example image from the VarioCAM thermal infrared camera from 2025-07-16. The ocean shows lowest temperature (blue), sea ice is in the middle (green to orange), and the melt ponds are warmest (purple).

Preliminary (expected) results

Helicopter-borne thermal infrared surface imaging

The thermal infrared brightness temperatures maps from the helicopter IR camera (Fig. 2.10.3) will be used to classify the surface in open ocean, sea ice, and melt pond classes using a machine learning based method (Reil et al., 2024). Surface temperature estimates from the IR camera will be analysed jointly with the coincident visible camera data (Nikon 14 mm). The floe grid flies allow to get continuous 2-D temperature maps of the three CONTRASTS ice floes and monitor their temperature evolution. To first order the surface temperature magnitude follows the atmosphere 2-m temperature as can be obtained from the meteorological towers on all ice floes (Chapter 3). However, relative temperature differences between melt ponds and ice allow to monitor the melt pond size distribution. There is also some indication that melted through ponds have a lower surface temperature than the still intact ponds, which offers the potential to discriminate the two cases. The long transect flights are especially useful for comparison to satellite data as several satellite footprints are covered. Regional statistics of IR surface properties can be obtained, which can be compared to the large scale satellite measurements and thereby allows upscaling of the CONTRASTS data to a regional and pan-Arctic scale.

2.11 Physical properties of sea ice from ice coring

Work at sea

Ice core work involved the acquisition of a large set of cores at representative locations of the floes (see floe maps in the appendix). The same coring site was shared between Sea Ice physics, BGC (Section 2.12) and ECO (Section 5.) groups. Surface measurements were made by the Snow (Chapter 2.3) and albedo (Chapter 2.1) teams, and underwater measurements were made by the ROV and light transmittance teams (Chapter 2.13). Typically, all cores would be recovered from the area of about 10 m on the same type of level ice representative for the area. The sites were selected to be spacious enough to accommodate all planned research activities over the three scheduled visits. On successive visits of the same floe, coring would be done on the undisturbed part of the area as close as possible to the previous coring location.

Coring for physical properties of sea ice was conducted using Kovacs Mark II coring system. On each coring site, depending on conditions some 2-4 cores were recovered. Processing of the cores and data logging followed MOSAIC protocols and standards. A handheld GPS tracker was turned on during the coring and placed next on the coring site. Pictures of the site were taken prior to the coring procedures.

Coring for ice physics was conducted on two sites with different types of ice on floes of Regime 1 (Floe 1) and Regime 2 (Floe 2) and on one site of Regime 3 (Floe 3). A brief overview of the sites is presented below. The corings sites were selected during the first surveys of the floes based on the assessment of ice thickness from direct drillings and features of surface morphology.

Regime1 / Floe 1 (Stations 1a, 1b, 1c)

There were two coring locations for ice physics on Floe 1; see ice station maps for details. The first location represented level ice of the refrozen lead that was some 0.8 m thick during the first visit of Floe 1 (Station 1a and b, sites “1a/lead” and “1b/lead”, see Tab. 2.11.1). This location was considered to be representative of the area and chosen as a main coring location for multidisciplinary coring. However, additional thickness drillings and GEM/MP transect floe surveys revealed later that the modal ice thickness of Floe 1 is higher being of the order of 1.3 m. The second coring location, some 10 m away of the first site with a thicker FYI was therefore found to be more representative of the area. These sites are referred to as “1a/repr FYI” and “1b/repr FYI”.

Note that due to ice melting between the first and the second visit of Floe 1, the initial coring spots became difficult to access. The coring on Station 1b had to be moved to a representative level ice area outside the meteorological site, referred as “1b/repr FYI”. The remaining refrozen lead ice some 10 m away from this site was also cored again to capture melt processes in a thinner FYI (site 1b/lead).

Due to eastward drift and ice floe breakup another ice floe had to be chosen for Station 1c. The floe that was picked was very representative for the area and clearly associated with Regime 1, with ice thickness and melt-driven state of the surface similar to what would be expected to be on the original Floe 1. The coring site was organized on level ice away of melt ponds, but effects of bottom melt were clearly manifested in variable ice thickness and slanted core bottoms.

Regime 2/ Floe 2 (Stations 2a, 2b, 2c, 2d)

There were two main coring locations for ice physics on Floe 2. The main site is on level FYI part of the floe with ice thickness of about 1.5 m registered on the first visit, also representative for the area of Floe 2 ice camp. This site was visited and cored on visits one, two, three and four (2a/FYI site, 2b/FYI site, 2c/FYI site, 2d/FYI site). Despite the melt progression the coring location remained intact, though on visits 3-4 it was already only 20 m away of the floe edge. On visit 4 a higher variability in ice thickness on the coring site was found indicative of intensification of the bottom melt. Another coring location was established on a sediment-laden SYI/MYI in the older part of Floe 2 some 1 km away of the main ice camp. The site was visited on Station 2a and cored on Station 2b (2b/SYI(MYI) site). Due to surface melt progression and low visibility this site was not visited again.

Regime 3/ Floe 3 (Stations 3a, 3b, 3c)

There was one coring location on Floe 3, visited on Station 3a, 3b and (3a/coring site, 3b/coring site, 3c/coring site). The ice camp of Floe 3 was established on SYI some 1.7-1.8 m thick at the coring site during the first visit. Based on electromagnetic helicopter-borne EM Bird and onice GEM/MP surveys this ice thickness was also representative of the area. During the three visits the area has undergone substantial surface changes. While deeper ponds were already present formed in depressions from the previous summer(s), additional shallow melt pond expansion occurred around the timing of the second visit to the site (Station 3b, 04-06 August). By the timing of the third visit (Station 3c, 16-18 August) the shallow ponds have drained, and the surface was dry again except for the areas with the older melt ponds. The coring location was, however, not affected by this melt pond expansion. On the fourth visit (Station 3d, 26-27 August) the site was covered with some 2-4 cm thick snow cover that deposited within a few days before arrival to the floe.

Types of ice cores recovered during the cruise

The following ice cores were included in the general ice coring program for physics:

- SALO18: Salinity/Stable water isotopes core. The cores were cut onsite in 5 cm sections. Onboard, bulk salinity of melted sections were measured using a conductivity meter Cond 3110 (S/N 11440477). Salinity is reported on the practical salinity scale (dimensionless). Oxygen isotope ratio samples were collected from the same cores; vials sealed tight and stored at +4°C.
- T: Temperature core, processed on the ice. Temperature of the ice was measured in drill holes inside the core at 0.1 m intervals from the top to bottom within 5 minutes after the core recovery. The same temperature probe Testo 720 was used to measure all temperatures on all ice stations. The T-core was then sealed in plastic sleeves to be stored at -20 °C as an archive core (REP-core).
- RHO: The core for sea ice density was typically recovered last and brought onboard to the freezer lab within some 20-30 minutes after recovery. Pictures of the cores were taken both onsite and in the freezer lab. To minimize the brine loss, the cores were cut in 5-cm sections in the freezer lab within some 2 hours after recovery. Density of the ice was measured at -20°C the same day or day after using hydrostatic weighing in paraffin with Shimadzu 4200UX balance equipped with SMK-101 specific gravity kit. Density of the immersion fluid was controlled after each measurement series using a hydrometer with a suitable density range and the accuracy better than 0.001 g/cm³. Salinity of the ice was then measured on the melted samples with a conductivity probe Cond 3110 from NPI. The readings of the two salinity probes used were cross-checked on 5 samples for a range of salinities typical for sea ice to find the agreement between the two probes to be within 0-0.1. Due to effects of rolling on the high precision balance measurements, hydrostatic weighing of the ice for densimetry could be conducted only

during ice station work when the ship was stable. One should also note that vibrations from the vessel's main engines/shafts often hinder balance stabilization, hence representing a consistent problem for accurate weight measurements. The accuracy for the measured weights both in paraffin and in the air was conservatively estimated to be within 0.5 g for a substantial fraction of measurements.

A series of ice cores was also recovered from melt ponds. This work was done as a part of the program on melt pond studies and was aimed at improving the knowledge of the relationships between the physical and optical properties of melt ponds (Section 2.1). Whenever possible, the same melt ponds were sampled on repeat visits. Spectral albedo and transmittance were measured at each melt pond coring site. Same as cores for densimetry, they were transported onboard and processed right after recovery to minimize the effects of brine escape on the inferred physical properties of the ice. The melt pond cores were analyzed for salinity and density. The inner portion of the ice column was also used for preparing thick and thin sections for subsequent texture analysis in order to study the linkages between the light transmission through melt ponds and ice stratigraphy.

Melt pond coring locations were selected in an attempt to survey a variety of pond types. The factors considered were qualitative pond color ('light' vs. 'dark' ponds), ice age, and deformation. These factors are summarized in Table 2.11.2. Additionally, ponds needed to be large and uniform enough for the core to be considered representative of the entire footprint of the albedo and transmittance measurements. Finally, there were various logistical considerations, including avoiding draining sensitive measurement sites and accessibility by the ROV.

Ice core data logging and data structure

The data from sea ice physics ice cores were logged in Excel workbooks of MOSAiC standard, one workbook for each ice core. The core type -relevant data would be registered in respective spreadsheets. The naming convention for the workbooks has the following standard: YYYYMMDD-PS149_EVENT(STATION)-ID-action number-Ice Type-Core Type. Site names and core types follow the system presented above. Device action numbers for sea ice physics cores was agreed to start from 15 and onwards, with positions 1-14 pre-allocated for sea ice cores of the ECO team.

For melt pond cores, descriptive names were given, typically related to nearby features. For example, 'T3pond' was next to the 'Target 3' for the aerial floe surveys. All melt pond sites include 'pond' in the name.

Ice cores workbook files are grouped on a station basis and stored in one folder together with accompanying data such as GPS position data and photos of the core site and ice cores.

Table 2.11.1 summarizes the list of cores collected during the common coring program as function of the site. All T-, SALO18- and -RHO cores as well as melt pond cores were processed on-site/onboard, while all REP were kept frozen for archiving.

Tab. 2.11.1: List of sea ice cores for the physical properties of sea ice recovered during the expedition. Note that “ID” in the “Name” category substitutes “SI_corer_9cm” instrument short name from O2A registry used in the actual core name/file name. This is to reduce the overall length of the table and hence the size of the presentation. “H_{ice}” and “H_d” stands for ice thickness and ice draft (ice thickness below water level), respectively, as was measured by ice thickness gauge on site. “H_s” stands for snow or scatter layer depth averaged over 5-7 thickness measurements at the coring spot. For ponded ice, this column refers to the pond depth “H_p”. When the corehole parameters were not measured, a “not available” (“na”) flag is used. The cores from melt ponds are listed in the end of the table.

Name	Station/ site	H _{ice} , m	H _d , m	H _s or H _p , m
20250710-PS149_13-1-ID-016-FYI-REP	1a/lead	0.68	0.64	0.05
20250710-PS149_13-1-ID-017-FYI-RHO	1a/lead	0.67	0.65	0.05
20250710-PS149_13-1-ID-018-FYI-SALO18	1a/lead	0.68	0.64	0.05
20250710-PS149_13-1-ID-019-FYI-T	1a/lead	0.68	0.64	0.05
20250710-PS149_13-1-ID-020-FYI-TEX	1a/lead	0.70	0.65	0.05
20250711-PS149_13-1-ID-21-FYI-T	1a/repr FYI	1.36	1.21	0.03
20250711-PS149_13-1-ID-22-FYI-SALO18	1a/repr FYI	1.36	1.21	0.03
20250711-PS149_13-1-ID-23-FYI-RHO	1a/repr FYI	1.43	1.29	0.03
20250726-PS149_21-1-ID-020-FYI-lead-T	1b/lead	0.32	0.32	0.05
20250726-PS149_21-1-ID-021-FYI-lead-SALO18	1b/lead	0.32	0.32	0.05
20250726-PS149_21-1-ID-022-FYI-lead-RHO	1b/lead	0.35	0.35	0.05
20250726-PS149_21-1-ID-016-FYI-T	1b/repr FYI	1.18	1.11	0.07
20250726-PS149_21-1-ID-017-FYI-REP	1b/repr FYI	1.18	1.11	0.07
20250726-PS149_21-1-ID-018-FYI-SALO18	1b/repr FYI	1.12	1.06	0.07
20250726-PS149_21-1-ID-019-FYI-RHO	1b/repr FYI	1.27	1.18	0.07
20250715-PS149_16-1-ID-016-FYI-SALO18	2a/FYI site	1.4	1.33	0.05
20250715-PS149_16-1-ID-017-FYI-T	2a/ FYI site	1.43	1.33	0.05
20250715-PS149_16-1-ID-018-FYI-REP	2a/ FYI site	1.43	1.33	0.05
20250715-PS149_16-1-ID-019-FYI-RHO	2a/ FYI site	1.44	1.33	0.05
20250730-PS149_25-1-ID-016-FYI-SALO18	2b/ FYI site	1.21	1.13	0.06
20250730-PS149_25-1-ID-017-FYI-T	2b/ FYI site	1.23	1.13	0.06
20250730-PS149_25-1-ID-018-FYI-REP	2b/ FYI site	1.23	1.13	0.06
20250730-PS149_25-1-ID-019-FYI-RHO	2b/ FYI site	1.23	1.14	0.06
20250730-PS149_25-1-ID-020-SMYI-T	2b/SYI(MYI) site	na	na	0.08
20250730-PS149_25-1-ID-021-SMYI-RHO	2b/SYI(MYI) site	na	na	0.08
20250730-PS149_25-1-ID-022-SMYI-REP	2b/SYI(MYI) site	1.62	1.52	0.08
20250720-PS149_18-1-ID-016-SYI-SALO18	3a/SYI site	1.76	1.62	0.08
20250720-PS149_18-1-ID-017-SYI-T	3a/SYI site	1.76	1.61	0.08
20250720-PS149_18-1-ID-018-SYI-REP	3a/SYI site	1.76	1.61	0.08
20250720-PS149_18-1-ID-019-SYI-RHO	3a/SYI site	1.77	1.63	0.08
20250804-PS149_30-1-ID-016-SYI-SALO18	3b/SYI site	1.72	1.57	0.0
20250804-PS149_30-1-ID-017-SYI-T	3b/SYI site	1.70	1.575	0.0
20250804-PS149_30-1-ID-018-SYI-REP	3b/SYI site	1.70	1.575	0.0
20250804-PS149_30-1-ID-019-SYI-RHO	3b/SYI site	1.72	1.56	0.0
20250809-PS149_32-1-ID-016-FYI-SALO18	1c/repr FYI	0.66	0.6	0.015
20250809-PS149_32-1-ID-017-FYI-T	1c/repr FYI	0.69	0.64	0.015

Name	Station/ site	H _{ice} , m	H _d , m	H _{50r} H _p , m
20250809-PS149_32-1-ID-018-FYI-REP	1c/repr FYI	0.69	0.64	0.015
20250809-PS149_32-1-ID-019-FYI-RHO	1c/repr FYI	0.67	0.62	0.015
20250812-PS149_36-1-ID-016-FYI-SALO18	2c/ FYI site	1.03	0.9	0.03
20250812-PS149_36-1-ID-017-FYI-T	2c/ FYI site	1.03	0.9	0.03
20250812-PS149_36-1-ID-018-FYI-REP	2c/ FYI site	1.03	0.9	0.03
20250812-PS149_36-1-ID-019-FYI-RHO	2c/ FYI site	1.01	0.89	0.03
20250817-PS149_41-1-ID-016-SYI-SALO18	3c/SYI site	1.57	1.4	0.025
20250817-PS149_41-1-ID-017-SYI-T	3c/SYI site	1.58	1.4	0.025
20250817-PS149_41-1-ID-018-SYI-REP	3c/SYI site	1.58	1.4	0.025
20250817-PS149_41-1-ID-019-SYI-RHO	3c/SYI site	1.54	1.39	0.025
20250823-PS149_46-1-ID-016-FYI-SALO18	2d/ FYI site	0.68	0.54	0.05
20250823-PS149_46-1-ID-017-FYI-T	2d/ FYI site	0.71	0.57	0.05
20250823-PS149_46-1-ID-018-FYI-REP	2d/ FYI site	0.71	0.57	0.05
20250823-PS149_46-1-ID-019-FYI-RHO	2d/ FYI site	0.68	0.54	0.05
20250826-PS149_47-1-ID-016-SYI-SALO18	3d/SYI site	1.53	1.36	0.03
20250826-PS149_47-1-ID-017-SYI-T	3d/SYI site	1.52	1.35	0.03
20250826-PS149_47-1-ID-018-SYI-REP	3d/SYI site	1.52	1.35	0.03
20250826-PS149_47-1-ID-019-SYI-RHO	3d/SYI site	1.54	1.36	0.03
20250727-PS149_21-1-ID-023-FYI-melt_pond-RHO	1b/sharedpond	0.8	1.05	0.25
20250810-PS149_32-1-ID-020-FYI-melt_pond-RHO-TXT	1c/ROVPOND10	0.62	0.72	0.10
20250731-PS149_25-1-ID-023-FYI-S-melt_pond-RHO-TXT	2b/Spond	0.32	0.55	0.23
20250731-PS149_25-1-ID-024-FYI-NE-melt_pond-RHO-TXT	2b/NEpond	0.4	0.69	0.29
20250813-PS149_36-1-ID-020-FYI-T3-melt_pond-RHO-TXT	2c/T3pond	0.69	1.045	0.355
20250805-PS149_30-1-ID-020-SYI-melt_pond-RHO-TXT	3b/SSLpond	1.32	1.46	0.14
20250817-PS149_41-1-ID-020-SYI-SSL_melt_pond-RHO-TXT	3c/SSLpond	1.38	1.44	0.06
20250823-PS149_46-1-ID-020-FYI-T3-melt_pond-RHO-TXT	2d/T3pond	0.23	0.68	0.45

Tab. 2.11.2: List of melt pond features that guided site selection. For 2d/T3pond, the surrounding ice was probably second year ice but by the 2d visit the pond had melted so much that the remaining ice was probably congelation ice from the preceding winter.

Station/site	Color	Ice Age	Deformed
1b/sharedpond	Light	First year	Yes
1c/ROVPOND10	Dark	First year	No
2b/Spond	Dark	First year	No
2b/NEpond	Light	First year	Yes
2c/T3pond	Light	Second year	No
3b/SSLpond	Light	Second or multiyear	No
3c/SSLpond	Light	Second or multiyear	No
2d/T3pond	Dark	Second year*	No

Preliminary results

Measured profiles of salinity, temperature and density from ice cores recovered on the coring sites are shown in Figures 2.11.1-3. Table 2.11.3 summarizes the respective bulk values for all recovered ice cores together with the measured ice thickness, ice freeboard and depth of snow or surface scatter layer.

Analysis of the physical properties of sea ice cores demonstrates and quantifies the following tendencies during the summer melt progression.

1. Thinning of sea ice observed on the coring locations is in a reasonable agreement with modal ice thickness changes from EM measurements conducted on walking transects (Section 2.4). The ice core based results can therefore be considered as representative for the studied areas.
2. Analysis of recovered ice cores documents progressive warming of sea ice cover observed during the three (or four) visits of station floes. The warming was accompanied by ice slab desalination due to a gravity-driven brine drainage and sea ice density decrease (Fig. 2.11.1-2.11.3). This tendency is most pronounced in the top part of ice column and propagates downwards as summer melt progresses.
3. Thinner and more saline at the start of the observation series FYI of Regime 1 and 2 floes, despite showing bulk ice temperatures comparable with SYI/MYI of Regime 3, showed a tendency to a more rapid decrease in bulk sea ice density. Snow deposited on Floe 3 between visits 3 and 4 became a source of fresh water that infiltrated the upper layer of sea ice increasing its density and promoting snow-ice formation.
4. A detailed analysis of the acquired data corroborated by atmospheric and oceanic heat flux measurements conducted during the cruise enables accurate estimates of changing sea ice mass and energy balance for different ice types during summer melt. This also provides foundations for calculations of a downward fresh water, salt and nutrient flux into the underlying water column.
5. Different patterns of density changes during the period of summer melt may have implications for remote sensing of sea ice, e.g. sea ice thickness retrievals from measured satellite-based sea ice freeboards.

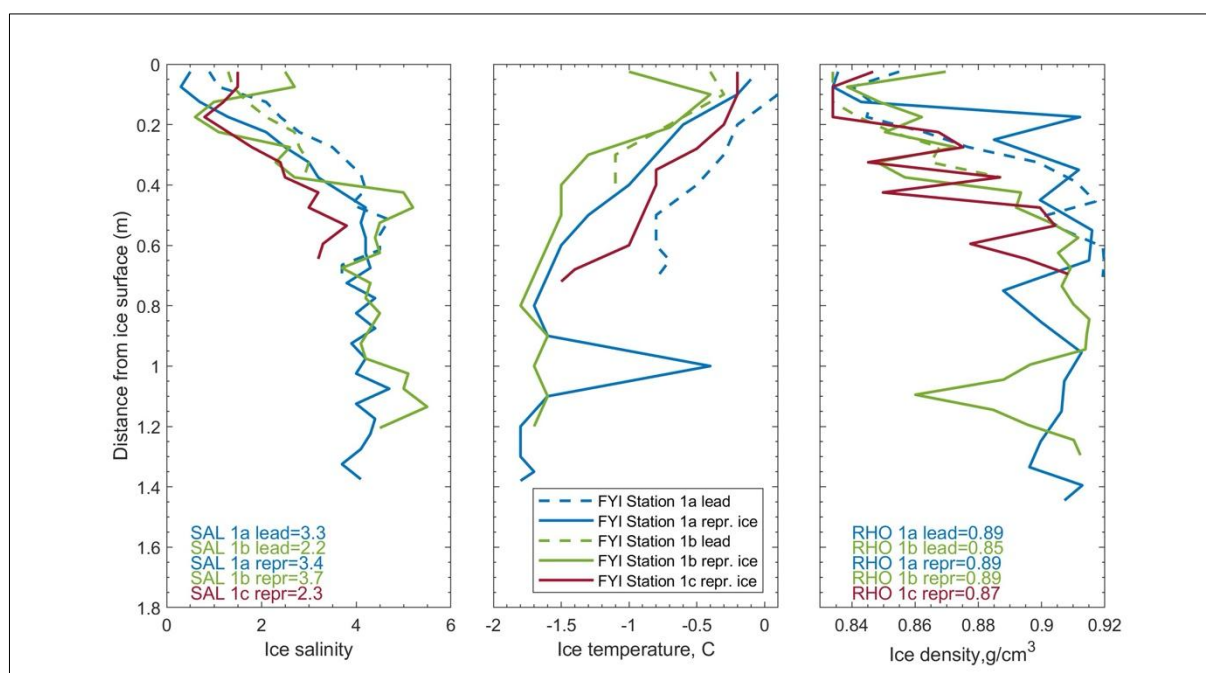


Fig. 2.11.1: Salinity, temperature and density profiles of ice cores on Regime 1 ice floe for visits 1 (Station 1a, blue), 2 (Station 1b, green) and 3 (Station 1c, red). Solid and dashed lines for visits 1 and 2 show the results for ice core recovered from the lead site and the more representative thicker FYI site, respectively. Local maximum in ice temperature at about 1 m depth on Station 1a is likely a bias due to a time delay in measuring the bottom of the recovered section of the core. Zero distance from ice surface denotes ice-snow or ice-air interface.

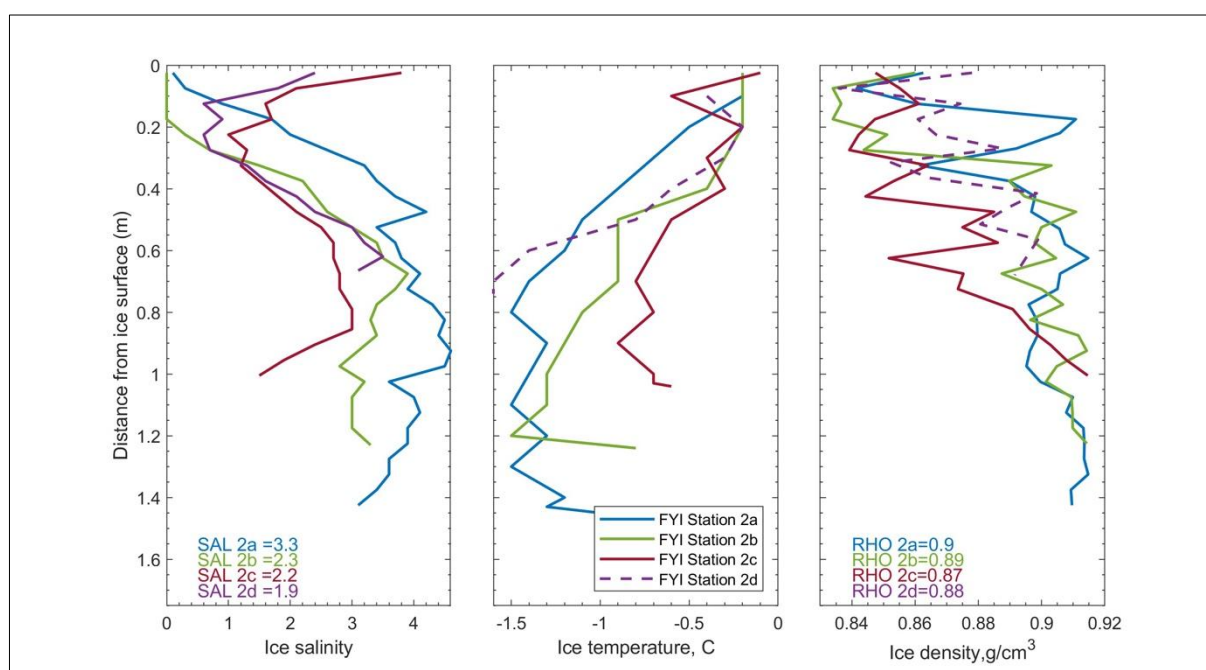


Fig. 2.11.2: Salinity, temperature and density profiles of ice cores on Regime 2 ice floe for visits 1 (Station 2a, blue), 2 (Station 2b, green), 3 (Station 2c, red) and 4 (Station 2d, purple, dashed line). Zero distance from ice surface denotes ice-snow or ice-air interface.

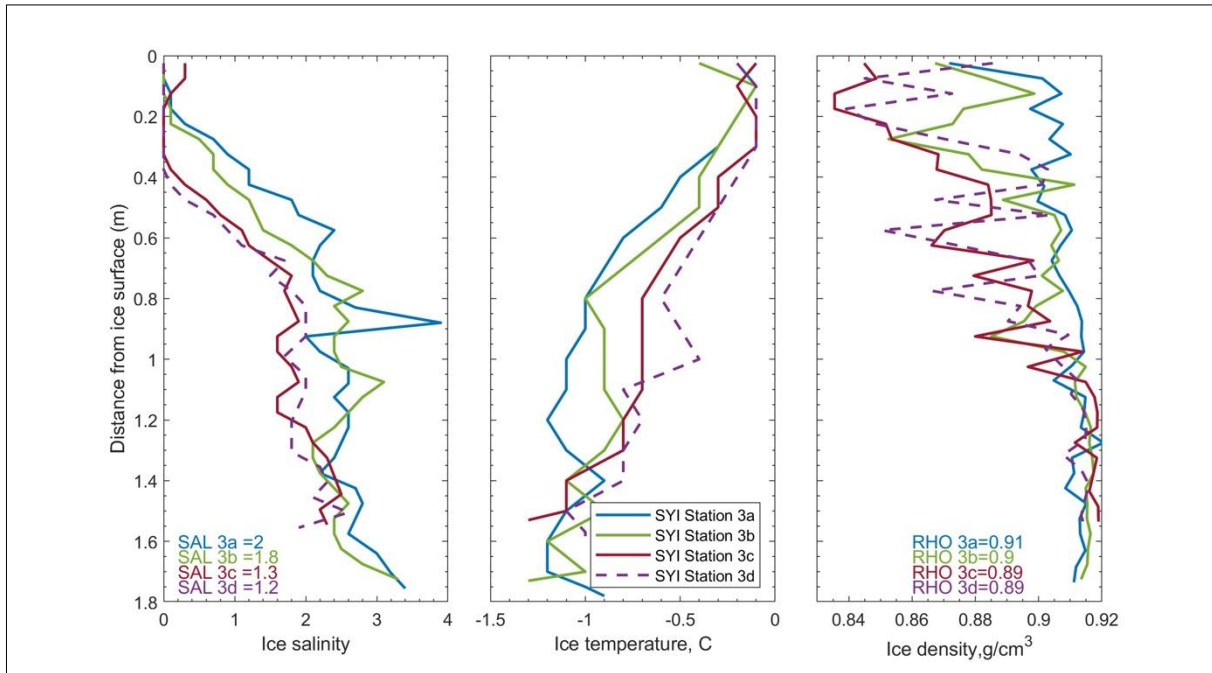
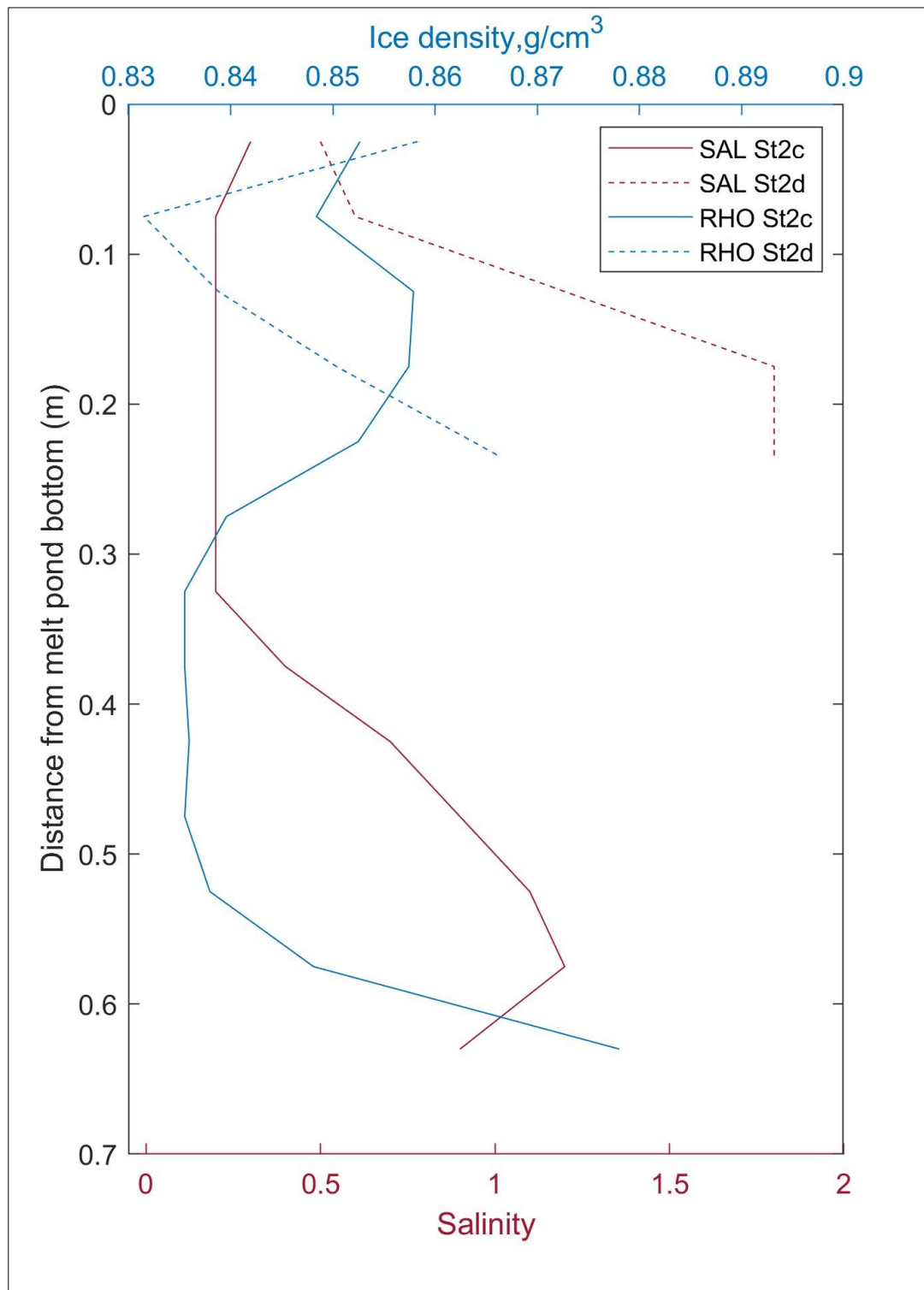
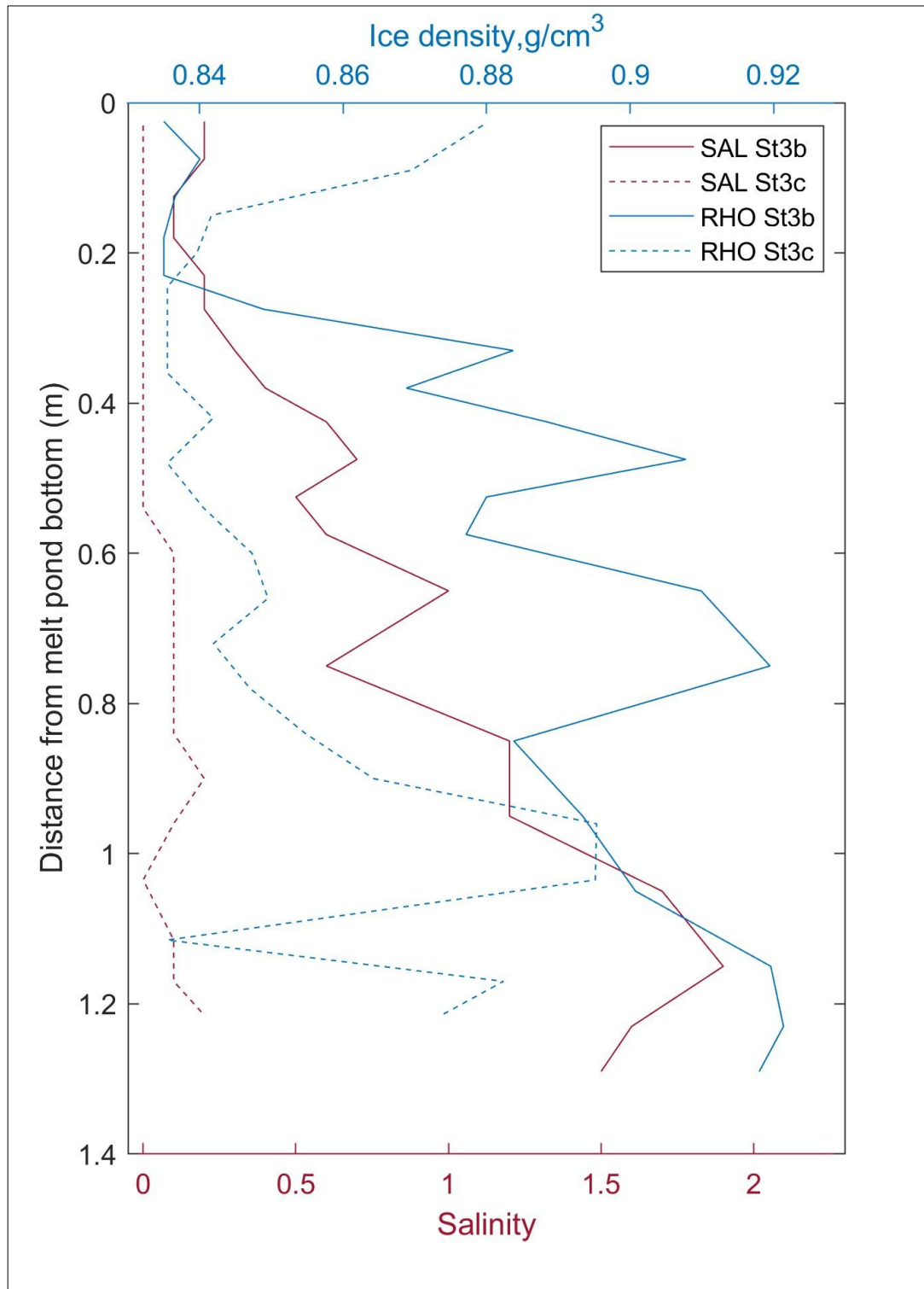


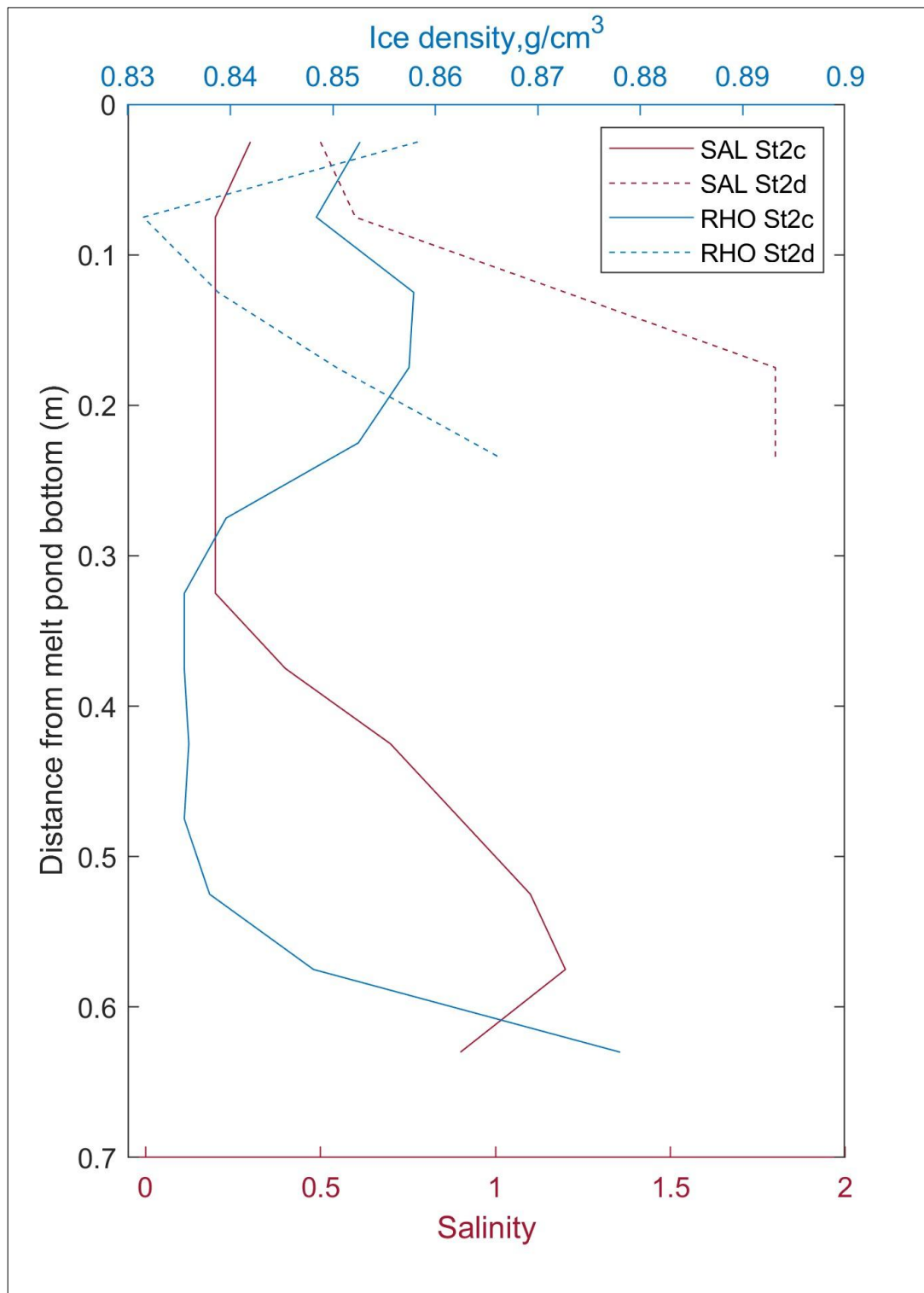
Fig. 2.11.3: Salinity, temperature and density profiles of ice cores on Regime 3 ice floe for visits 1 (Station 3a, blue), 2 (Station 3b, green) and 3 (Station 3c, red). Zero distance from ice surface denotes ice-snow or ice-air interface.

Figure 2.11.4 shows profiles of salinity and density measured on four melt pond cores recovered from melt ponds on Floe 2 (Station 2c and 2d, pond “T3”) and Floe 3 (Station 3b and 3c, pond “SSL”). Analysis of the physical properties of sea ice cores from melt ponds suggests that:

1. Desalination of the sea ice column in melt ponds occurs at a higher rate than of the ice outside melt ponds.
2. Analysis of melt ponds ice core stratigraphy demonstrate a higher porosity of sea ice associated with a higher fraction of bubbles up to a 5 mm size and melt channels inside the ice slab. The fraction of melt features increases upwards towards the ice-melt pond bottom interface.
3. From a preliminary analysis of ice texture from thin and thick sections of the recovered cores, a clear link between the initial crystal structure of the ice and the development of melt features could still not be established.
4. Sea ice from melt ponds demonstrates a considerably lower bulk density than the ice outside the ponds. However, these density profiles have to be interpreted with caution due to a brine leakage after core recovery. Followed by a potential refreezing of narrow melt channels and voids formerly filled with sea water/brine in the freezer lab, the isolation of such voids would make melt features impermeable for immersion liquid. It is therefore not unlikely that the measured densities of the most porous samples could be biased low.







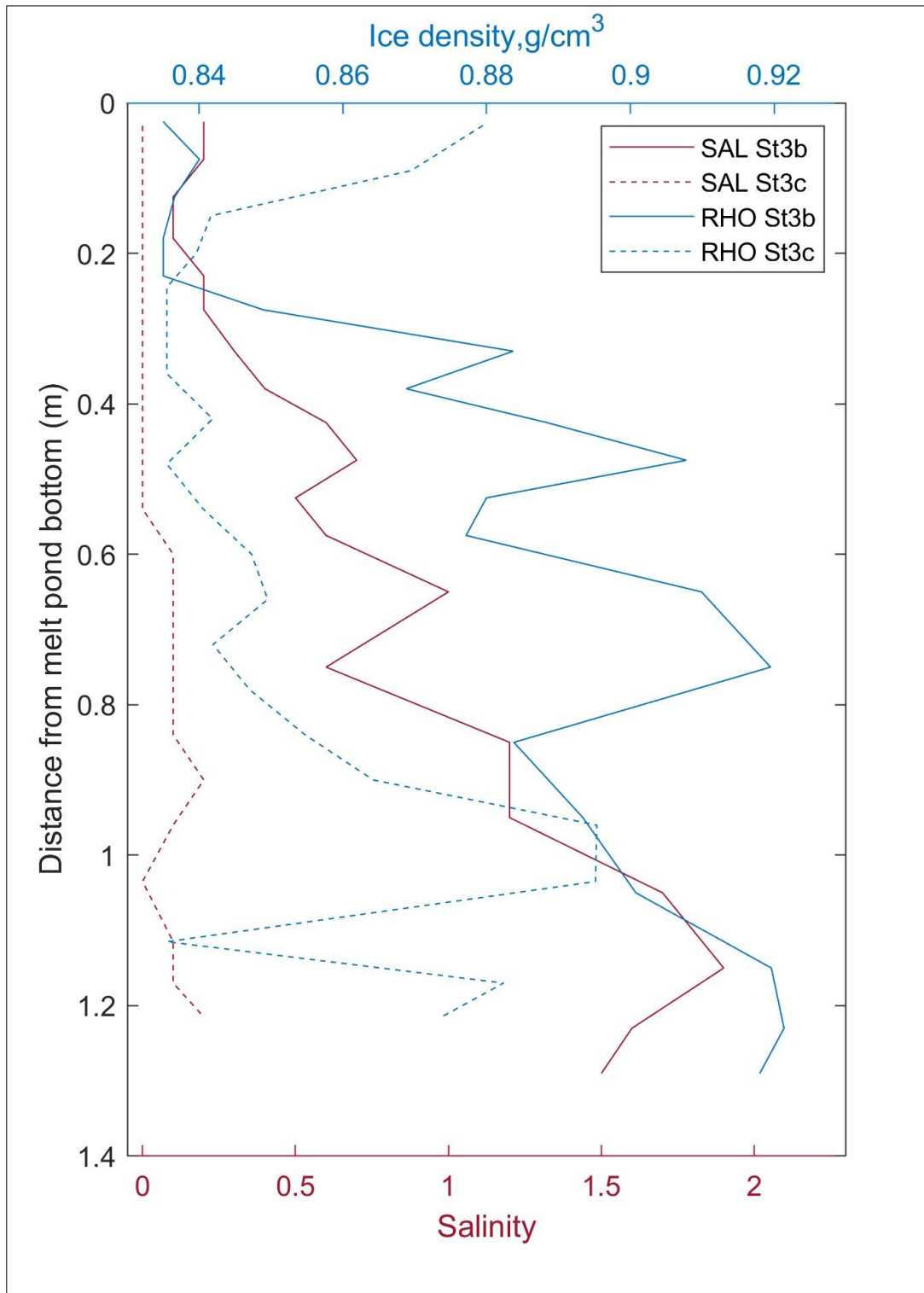


Fig. 2.11.4: Salinity (red) and density (blue) profiles of ice cores recovered from melt ponds on Floe 2 (Station 2c and 2d, left panel) and Floe 3 (Station 3b and 3c, right panel). Zero distance from ice surface denotes melt pond bottom-meltpond water interface.

Tab. 2.11.2: Major bulk parameters (S, T, sea ice density (ρ)) measured from ice cores on the three regimes and three/four floe visits.

Regime 1												
Site	SAL				T, °C				ρ, g/cm³			
	1a	1b	1c		1a	1b	1c		1a	1b	1c	
Refr. lead	3.3	2.2			-0.5	-0.7			0.89	0.85		
Repr. FYI site	3.4	3.7	2.3		-1.2	-1.4	-0.7		0.89	0.89	0.87	
Regime 2												
	2a	2b	2c	2d	2a	2b	2c	2d	2a	2b	2c	2d
Repr. FYI site	3.3	2.3	2.2	2.0	-1.0	-0.8	-0.6	-0.8	0.9	0.89	0.87	0.88
SYI/MYI site		1.8				-0.8				0.90		
Regime 3												
	3a	3b	3c	3d	3a	3b	3c	3d	3a	3b	3c	3d
Repr. SYI site	2.0	1.8	1.3	1.2	-0.8	-0.7	-0.6	-0.5	0.91	0.9	0.89	0.89

2.12 Cryomineral detection and bio-physical linkages (WISELIGHT)

Work at sea

As part of the WISELIGHT secondary-use proposal, we conducted a standardized coring sequence at least once per station at the designated coring site, with additional cores taken at local ice features of interest (e.g., sediment-laden “dirty” ice or notable floe variability). Each core was processed for imaging, texture and biogeochemical sampling sectioned into 10–20 cm (up to 40 cm) intervals from both top and bottom following the MOSAiC approach, kept dark, and transferred immediately to the freezing container. From each section, half of the section was pooled and melted for salinity, chlorophyll-a (Chl-a), turbidity, extracellular polymeric substances (EPS), and $\delta^{18}\text{O}$ analyses (see Fig. 2.12.1 a). The inner portion was reserved for thin-section preparation during transit, while the remaining half was used for vertical and horizontal slicing for hyperspectral imaging, melting, filtering and microphotography. The 14 cm diameter Kovacs Mark V corer reduced the total number of cores needed for the required samples. Melted subsamples were analysed for cryogenic mineral content following Wollenburg et al. (2020) method.

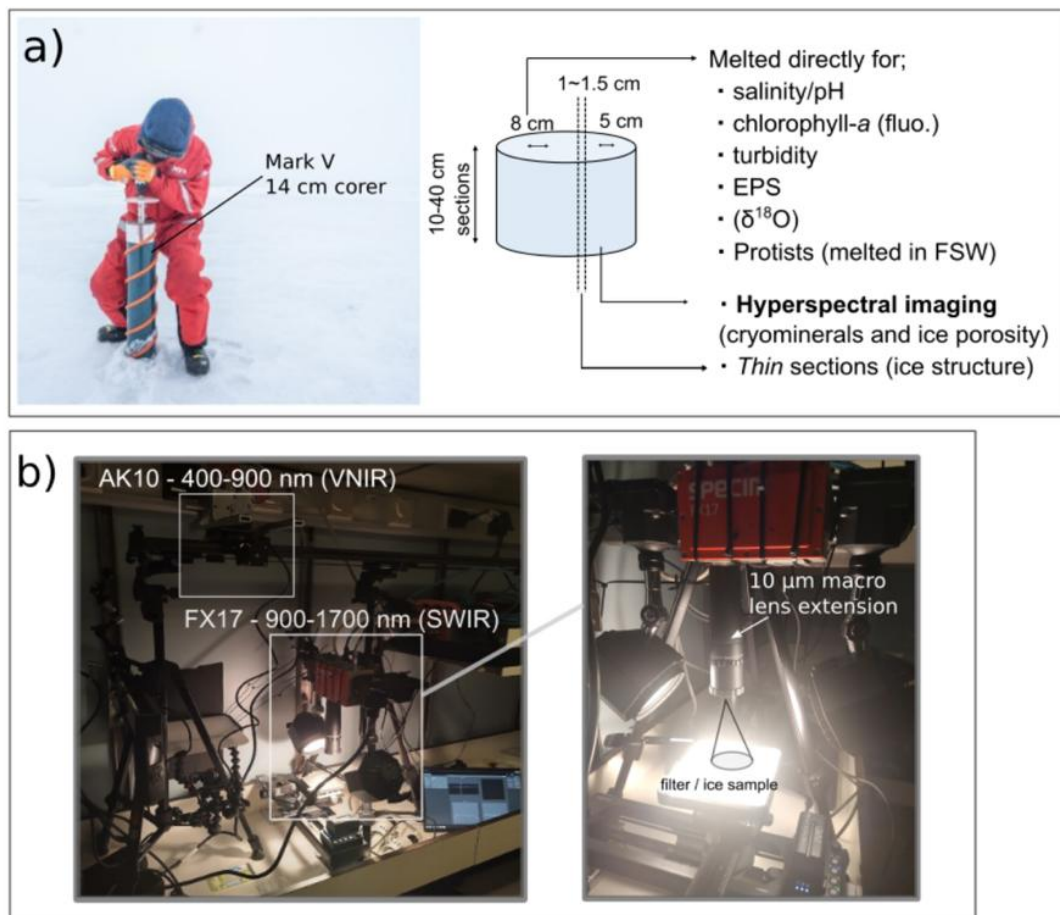


Fig. 2.12.1: Panel a) displays an overview of the ice core sectioning and sampling procedure conducted for each BGC core while panel b) illustrates the VNIR and SWIR hyperspectral pushbroom imaging set-up on board utilised to image the ice core sections and the filtered samples.

To trial new ice-core scanning methods, we tested two approaches: (1) scanning intact sections, and (2) scanning residual material after melting and filtering through a 10 µm mesh. Two hyperspectral systems were used: the Asia Kestrel 10 (400–900 nm, VNIR, transmitted light, ~14 × 10 cm sections) and the FX17 (900–1700 nm, SWIR, macro extension tube, ~10 µm pixel size, transmitted and reflected light on ~2 cm wide sections) (see Fig. 2.12.1 b).

In addition, at most of the coring sites, up to three Knauer traps and gel-enclosed sediment traps (~50 mm diameter) were deployed through existing core holes for 24 h. Knauer trap samples were pooled and subsampled for chlorophyll-a, EPS, algal composition, and gypsum analyses. Seawater was also collected just beneath the ice and at +3 m depth to estimate particle loss rates (flux vs. standing stock) from chlorophyll-a, cell counts, and EPS.

Tab. 2.12.1: List of cores that were acquired during the expedition and sections processed and measurements acquired for each core as part of the WISELIGHT secondary use proposal. Length refers from top to bottom.

Event name	Total core length extracted	Number of sections processed	Site	Traps deployed/ Event	Comment
PS149_13-1-si_corer_14cm-001	80	5	Coring site	PS149_13-1-under-ice_traps_001	Includes temperature profile.
PS149_13-1-si_corer_14cm-002	182	8	SSL experiment site		Includes temperature profile and L-Arm), no thin sections.
PS149_16-1-si_corer_14cm-001	150	6	Coring site	PS149_16-1-under-ice_trap_001	
PS149_16-1-si_corer_14cm-002	193	10	Sediment-laden ice	NA	Clean side of ridge.
PS149_16-1-si_corer_14cm-003	76	7	Sediment-laden ice	NA	Dirty side of ridge. Only top half taken includes snow samples.
PS149_18-1-si_corer_14cm-001	173	6	Coring site	NA	
PS149_18-1-si_corer_14cm-002	9	3	Coring site	NA	Chl-a and only bottom taken.
PS149_18-1-si_corer_14cm-003	27	2	Ocean site	PS149_18-1-under-ice_trap_001	Away from ship thrusters and only bottom taken (10+17 cm)
PS149_21-1-si_corer_14cm-001	112	5	Coring site (new)	PS149_21-1-under-ice_trap_001	
PS149_21-1-si_corer_14cm-002	9	3	Coring site (new)		Gypsum and only bottom taken.
PS149_25-1-si_corer_14cm-001	116	5	Coring site	PS149_25-1-under-ice_trap_001	
PS149_25-1-si_corer_14cm-002	9	3	Coring site		Includes L-Arm, processed for Gypsum. Only bottom taken.

Event name	Total core length extracted	Number of sections processed	Site	Traps deployed/ Event	Comment
PS149_25-1-si_corer_14cm-003	148	13	Sediment-laden ice	NA	
PS149_30-1-si_corer_14cm-001	171	6	Coring site	NA	
PS149_30-1-si_corer_14cm-002	10	1	Ocean site	PS149_30-1-under-ice_trap_001	Gypsum and only bottom taken.
PS149_32-1-si_corer_14cm-001	62	4	Coring site	PS149_32-1-under-ice_trap_001	
PS149_32-1-si_corer_14cm-002	10	1	Coring site	PS149_32-1-under-ice_trap_001	Gypsum and only bottom taken.
PS149_36-1-si_corer_14cm-001	97	5	Coring site	NA	
PS149_36-1-si_corer_14cm-002	20	2	Ocean site	PS149_36-1-under-ice_trap_001	Away from ROV grid. Only bottom taken.
PS149_41-1-si_corer_14cm-001	156	6	Coring site	NA	
PS149_41-1-si_corer_14cm-002	30	3	Ocean site	PS149_40-1-under-ice_trap_001	Away from ROV grid. Only bottom taken.
PS149_41-1-si_corer_14cm-003	141	11	Sediment-laden ice	NA	Includes temperature and snow samples
PS149_41-1-si_corer_14cm-004	119	7	Sediment-laden ice (pond)	NA	BGC with temperature (pond), snow and pond water

Preliminary (expected) results

An overview of the number of samples acquired in relationship each event number can be seen in Table 2.12.1. Transmittance VNIR imagery is expected to assess the presence and distribution of algal biomass within brine channels and allow to investigate other physical properties such as porosity proxies, while SWIR imagery was explored for the detection of cryogenic mineral crystals (e.g., gypsum) within filtered samples and potentially directly in thin sections. From the preliminary analysis we observed spectral signatures highly likely to be associated with cryomineral presence which such as detectability optically based on its 1450 nm absorption peak (Fig. 2.12.2). Estimates of gypsum obtained with this optical method will be compared with samples acquired in collaboration with ECO team which will be measured through traditional microscopy approaches.

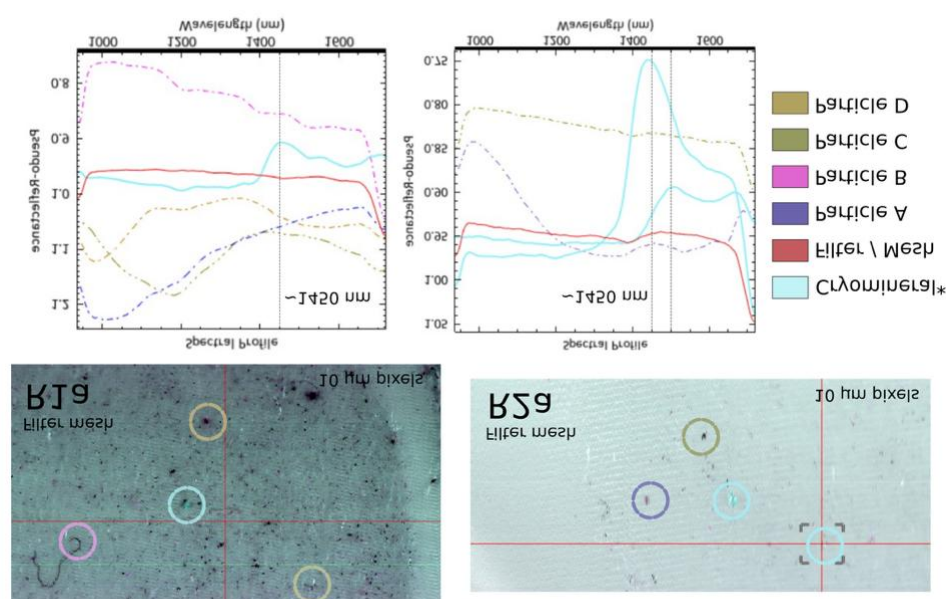


Fig. 2.12.2: Preliminary results of two exemplar filtered ice core sections and hyperspectral imaging data illustrating advancement in optical cryomineral detection. 1450 nm refers to the absorption features of cryogenic gypsum that are remarkably visible in the SWIR imagery.

Cryomineral counts for each ice section from this method will be combined with other retrieved biological and physical sea ice properties from the cores to identify potential drivers of cryogenic gypsum precipitation. Figure 2.12.3a showcase an example dataset from two contrasting bottom ice core sections. Figure 2.12.3b provides a holistic view of all the cores taken and section analysed across the entire expedition. By combining all this data from the three contrasting regimes over the course of the melt season the expected results for this secondary proposal are the following:

1. Delivery of a new optical method to detect cryogenic minerals – We will develop an automated algorithm to detect and count cryominerals in filtered samples based on the spectral signatures of the filtered samples (see Fig. 2.12.2 as an example). This will enable high-throughput quantification of gypsum and potentially other cryominerals in sea ice.
2. Advancing understanding of any cryomineral biophysical drivers – By combining automated cryomineral counts from melted ice cores with biophysical properties for each core section (e.g., Chl-a, turbidity, thin sections, and porosity etc.), we expect to deliver new insights on the environmental conditions driving gypsum formation across different ice regimes and types.
3. Report on state of EPS and other biogeochemical properties for different ice regimes and the under-ice sediment traps in across the melt season in comparison different seasons and years and to be linked to sea ice density profiles to support porosity and mass-balance assessments.

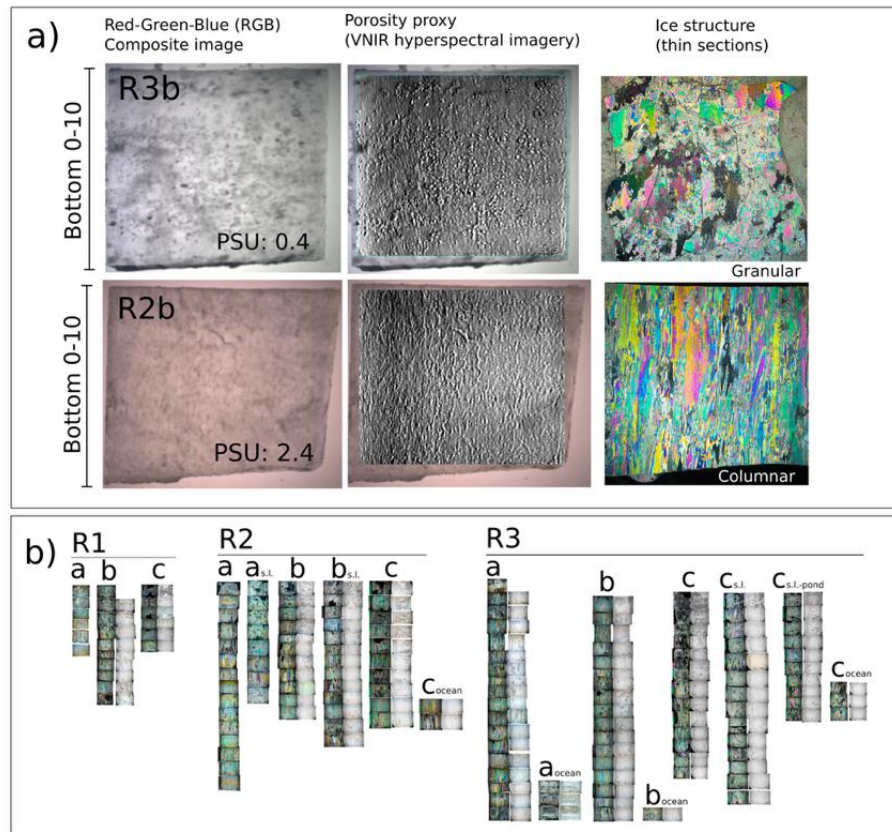


Fig. 2.12.3: In panel a) preliminary results of cores analyses and examples of data outputs for two selected contrasting bottom sections in regimes 2 and 3. b) is an overview of all thin section produced across all ice stations and related to Table 2.12.1 (pending textural classification). s.l. refers to sediment-laden ice. Ocean refers that core was taken at the Ocean site as reflected in Table 2.12.1.

2.13 Remotely Operated Vehicle (ROV) operations

Work at sea

During the expedition, the ROV system “Beast” (Kattlein et al., 2017) was deployed on all investigated ice floes. Table 2.4.1 gives an overview over all performed dives. In total, 11 optical dives were performed, along with 10 multibeam surveys and 7 biological dives, each consisting of three nets. Additionally, 9 depth profiles were taken, as well as 6 co-located measurements with an L-arm, and coring or pond measurements. Finally, an extensive test of the Nortek Nucleus DVL was performed.

The interdisciplinary sensor suite comprised:

- Radiance sensors (7° opening angle, RAMSES) and irradiance sensors (cosine collector, RAMSES) for under-ice light field mapping and vertical profiling.
- Altimeter for sea ice draft determination.
- Multibeam sonar for high-resolution mapping of under-ice topography.
- Underwater Hyperspectral Imager (UHI, Ecotone UHI model 4) for mapping microscale biophysical features.
- Integrated INS/DVL navigation system for precise vehicle localization.
- Upward- and forward-looking cameras for visual documentation and assessment of the ice underside.
- ROV-mounted zooplankton and gypsum net towing system for targeted biological sampling.

CTD and SUNA were not operational during the expedition. On several surveys the incoming irradiance data at the ROV hut was incorrect due to shadow from *Polarstern* and was substituted by the data from *Polarstern* crow'snest.

Deployment, setup and operations

For all deployments, the ROV was operated in a split-setup configuration, with the control container positioned on the floe adjacent to the vessel. As the ship was moored alongside during station work, this arrangement avoided the need to transport the container across the ice and enabled the control container to be powered directly from the ship, eliminating the requirement for an additional generator. The ROV control container and the vehicle were connected via a 300 m fiber-optic tether. Depending on dive duration and power demand, the ROV was operated either from onboard batteries or via two portable generators.

The vehicle was launched through a pre-cut hole in the ice via a tripod deployment frame, allowing access to an operational radius of approximately 300 m per station.

Survey sites were selected to be representative of the respective floe. Within the operational radius, missions followed a lawnmower-pattern survey design, typically covering areas up to 200 m x 150 m depending on ice conditions and available time. Line spacing was 10 m for optical surveys and 20 m for multibeam mapping, ensuring representative spatial coverage and resolution suitable for quantitative analyses.

During subsequent visits by the regime, ROV investigations are always carried out in the same area of the ice floe whenever possible.

Ice conditions at ROV sites

The ROV access holes were located near the origin (0, 0) of the main station grids. Measured ice thicknesses at the deployment hole were:

- Floe 1a: 0.53 m, 0.05 m snow
- Floe 2a: 0.74 m, 0.05 m snow
- Floe 3a: 1.72 m, thick snow cover
- Floe 1b: 1.10 m, thin snow cover, 0.08 m snow (new hole)
- Floe 2b: 0.67 m, 0.09 m snow
- Floe 3b: 1.79 m, 0.03 m snow
- Floe 1c: 0.77 m, 0.05 m snow (new hole)
- Floe 2c: 0.89 m, 0.05 m snow (new hole)
- Floe 3c: 1.73 m, 0.04 m snow
- Floe 2d: 0.57 m, 0.02 m snow
- Floe 3d: 1.70 m, 0.05 m snow

Tab. 2.4.1: List of surveys

Station	Event label	Survey name	Date	Dive mission
1a	13-1-BEAST-2	20250711_3	11.07	Optics
	13-1-BEAST-3	20250712_1	11.07	Multibeam, Depth profile
	13-1-BEAST-4	20250712_1	12.07	Optics
2a	16-1-BEAST-2	20250716_1	16.07	Optics, Depth profile, optics along albedo line
	16-1-BEAST-3	20250716_1	16.07	Multibeam
	16-1-BEAST-4	20250717_1	17.07	Nets 1
	16-1-BEAST-5	20250717_1	17.07	Nets 2
	16-1-BEAST-7	20250717_1	17.07	Nets 3
3a	18-1-BEAST-2	20250721_1	21.07	Multibeam
	18-1-BEAST-3	20250721_3	21.07	Optics
	18-1-BEAST-4	20250721_3	21.07	Nets 1
	18-1-BEAST-5	20250721_3	21.07	Nets 2
	18-1-BEAST-6	20250721_3	21.07	Nets 3
	18-1-BEAST-8	20250722_2	22.07	Optics
	18-1-BEAST-9	20250722_2	22.07	Depth
1b	21-1-BEAST-3	20250727_1	27.07	Optics, multibeam

Station	Event label	Survey name	Date	Dive mission
	21-1-BEAST-4	20250727_1	27.07	Nets 1
	21-1-BEAST-5	20250727_1	27.07	Nets 2
	21-1-BEAST-6	20250727_1	27.07	Nets 3
	21-1-BEAST-7	20250728_1	28.07	Depth profile
	21-1-BEAST-8	20250728_3	28.07	UHI
	21-1-BEAST-9	20250728_3	28.07	L-Arm
2b	25-1-BEAST-2	20250731_1	31.07	Optics
	25-1-BEAST-3	20250731_1	31.07	Depth profile
	25-1-BEAST-4	20250801_1	01.08	Multibeam
	25-1-BEAST-5	20250801_1	01.08	UHI
	25-1-BEAST-6	20250801_1	01.08	L-Arm
3b	30-1-BEAST-2	20250804_1	04.08	Optics
	30-1-BEAST-4	20250805_1	05.08	Nets 1
	30-1-BEAST-5	20250805_1	05.08	Nets 2
	30-1-BEAST-6	20250805_1	05.08	Nets 3
	30-1-BEAST-7	20250805_1	05.08	Multibeam
	30-1-BEAST-8	20250805_1	05.08	Depth
	30-1-BEAST-9	20250805_1	05.08	UHI
	30-1-BEAST-10	20250805_1	05.08	L-ARM and 360° media dive
	30-1-BEAST-11	20250805_1	05.08	Optics
1c	32-1-BEAST-2	20250809_1	09.08	Optics
	32-1-BEAST-3	20250810_1	10.08	Optics
	32-1-BEAST-4	20250810_1	10.08	Depth profile
	32-1-BEAST-5	20250810_1	10.08	L-ARM
	32-1-BEAST-6	20250810_1	10.08	Multibeam

Station	Event label	Survey name	Date	Dive mission
	32-1-BEAST-7	20250810_1	10.08	Nets 1
	32-1-BEAST-8	20250810_1	10.08	Nets 2
	32-1-BEAST-9	20250810_1	10.08	Nets 3
	32-1-BEAST-10	20250810_1	10.08	UHI
2c	36-1-BEAST-2	20250812_1	12.08	Optics
	36-1-BEAST-3	20250813_1	13.08	Multibeam
	36-1-BEAST-4	20250813_1	13.08	Nets 1
	36-1-BEAST-5	20250813_1	13.08	Nets 2
	36-1-BEAST-6	20250813_1	13.08	Nets 3
	36-1-BEAST-7	20250814_1	14.08	UHI
	36-1-BEAST-8	20250814_1	14.08	L-Arm colocation
	36-1-BEAST-9	20250814_1	14.08	Depth profile
	36-1-BEAST-10	20250814_1	14.08	Multibeam along floe edge
	36-1-BEAST-11	20250814_1	14.08	DVL navigation trials
3c	41-1-BEAST-2	20250817_1	17.08	Optics
	41-1-BEAST-3	20250817_1	17.08	Depth profile
	41-1-BEAST-4	20250817_1	17.08	Multibeam
	41-1-BEAST-5	20250818_1	18.08	Nets 1
	41-1-BEAST-6	20250818_1	18.08	Nets 2
	41-1-BEAST-7	20250818_1	18.08	Nets 3
	41-1-BEAST-8	20250818_1	18.08	UHI
	41-1-BEAST-9	20250818_1	18.08	360° media dive
	41-1-BEAST-10	20250818_1	18.08	L-arm colocation
2d	46-1-BEAST-2	20250823_1	23.08	Optics
	46-1-BEAST-3	20250823_1	23.08	Multibeam

Station	Event label	Survey name	Date	Dive mission
	46-1-BEAST-4	20250823_1	23.08	Depth profile
	46-1-BEAST-5	20250824_1	24.08	Nets 1
	46-1-BEAST-6	20250824_1	24.08	Nets 2
	46-1-BEAST-7	20250824_1	24.08	UHI
	46-1-BEAST-8	20250824_1	24.08	L-arm colocation
3d	47-1-BEAST-2	20250826_1	26.08	Optics
	47-1-BEAST-3	20250826_1	26.08	Multibeam
	47-1-BEAST-4	20250826_1	26.08	Depth profile
	47-1-BEAST-5	20250827_1	27.08	Nets 1
	47-1-BEAST-6	20250827_1	27.08	Nets 2
	47-1-BEAST-7	20250827_1	27.08	L-arm colocation
	47-1-BEAST-8	20250827_1	27.08	UHI
	47-1-BEAST-9	20250827_1	27.08	360° media dive

Preliminary (expected) results

For the different regimes, very distinct signatures of draft distribution and light availability are expected. First analysis of the ROV data support this assumption.

Figure 2.13.1 shows the histogram of the draft measurements from single sonar measurements. All 3 stations show considerable melt, while for the first station the thicker ice classes completely disappear, for station 2 and 3 thick ice remains during the melt season. Figure 2.13.2 shows the spatial distribution of ice draft for the 3 regimes on the first three visits.

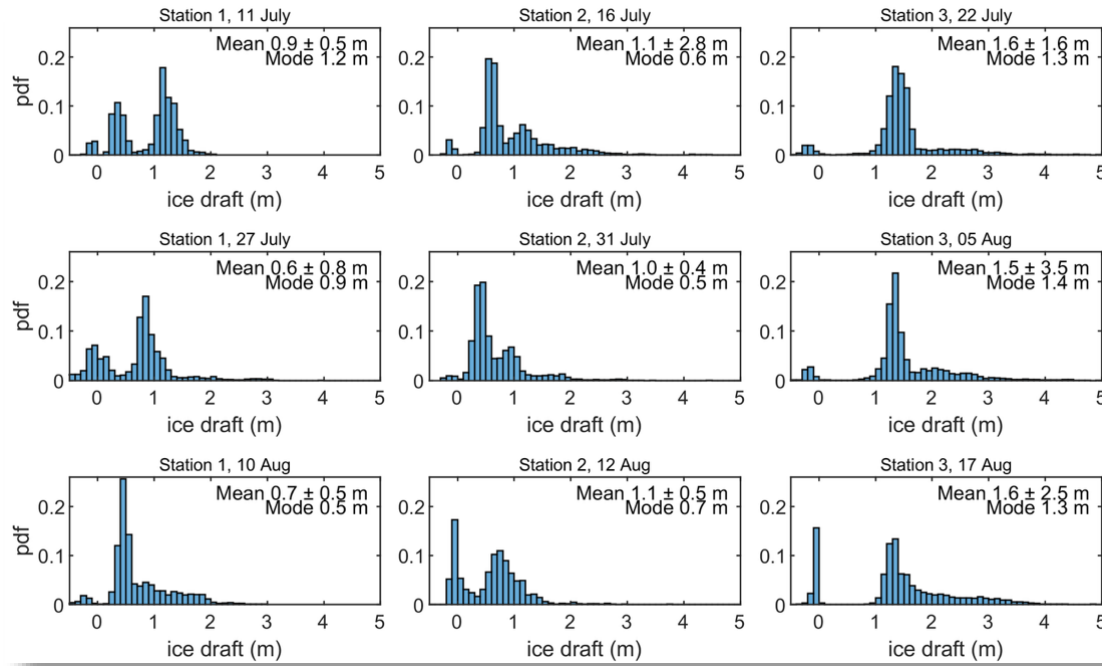


Fig. 2.13.1: Ice draft distribution for optical surveys for each ice station measured by single-beam sonar altimeter.

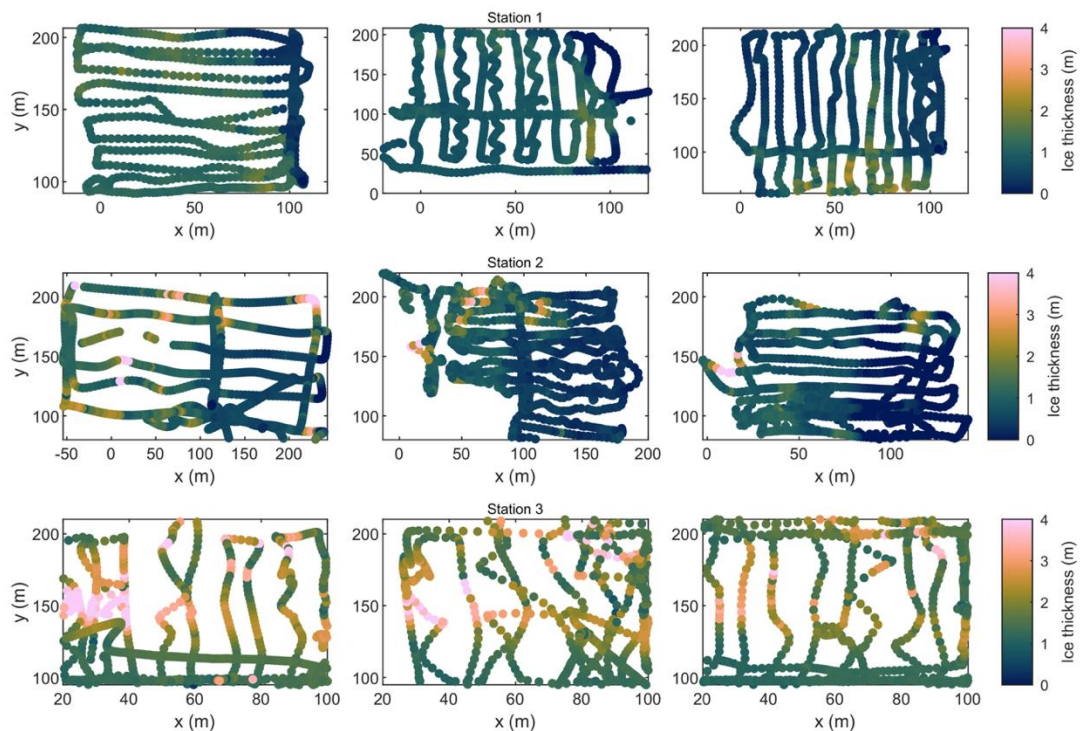


Fig. 2.13.2: Spatial distribution of ice draft for all three regimes for the first three visits

Figure 2.13.3 shows the spatial distribution of transfectance for the 3 regimes on the first three visits. Transfectance is defined as the ratio of under-ice radiance to surface irradiance. Transfectance data is not yet corrected for depth, as under-ice radiance decreases with increasing depth. Station 1 exhibits a patchy distribution of transfectance due to melt ponds. Station 2 shows the most pronounced melt ponds at the second visit, while for station 3, the influence of melt ponds seems mainly limited to the second and the third visit and only along the y-axis of the survey. It needs to be noted that station 1b and 2c are heavily influenced by open water.

Figure 2.13.4 shows the mean transfectance and the adjacent standard deviation for the three regimes on the first three visits. At the first visit, station 2 transmits only half of the light, compared to station 1, while station 3 transmits only 30% of the radiative energy compared to station 1. The high standard deviation for Station 1 correlates with the occurrence of many open melt ponds and the patchy spatial distribution described above. Station 1 and 3 seem to undergo similar seasonal evolution with an increase during the second visit and a subsequent decrease on the third visit. Station 2 follows the increase on the second visit but shows further increase in light transfectance on the third visit. This might be due to the open water or very thin and rotten ice which was measured on this visit and may not be related to the ice properties itself. If this ice were not taken into account in the analysis, it can be assumed that a similar behavior to that at stations 1 and 3 would occur.

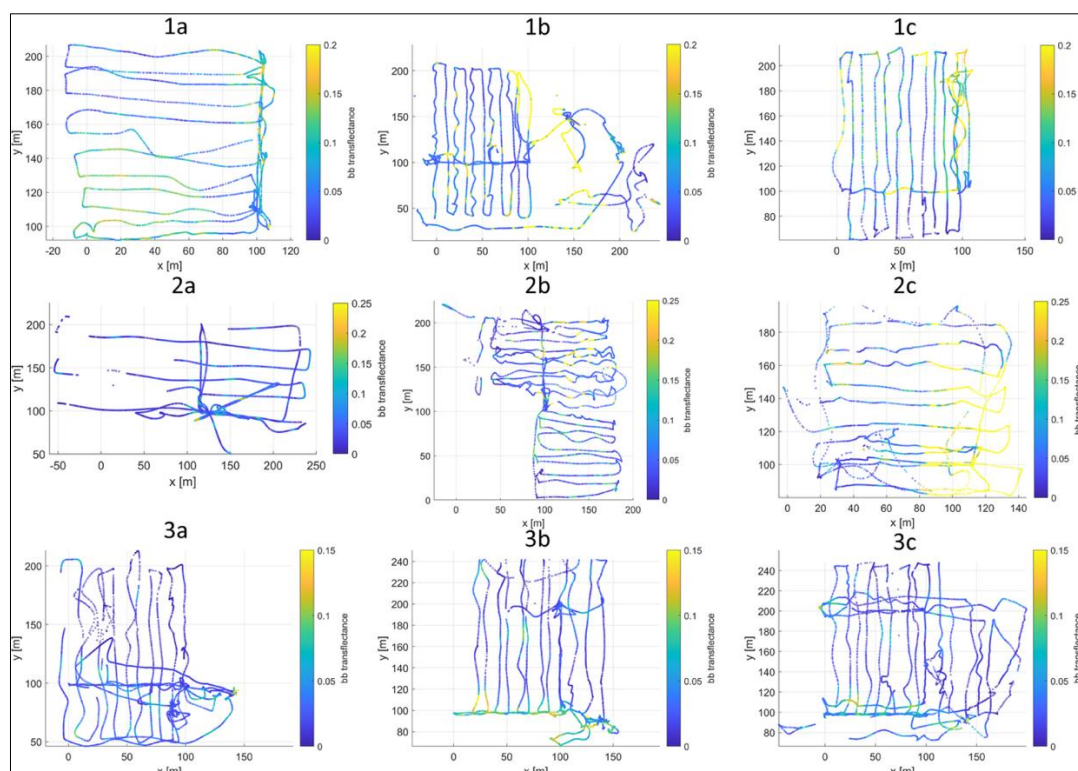


Fig. 2.13.3: Spatial distribution of transfectance for all three regimes for the first three visits

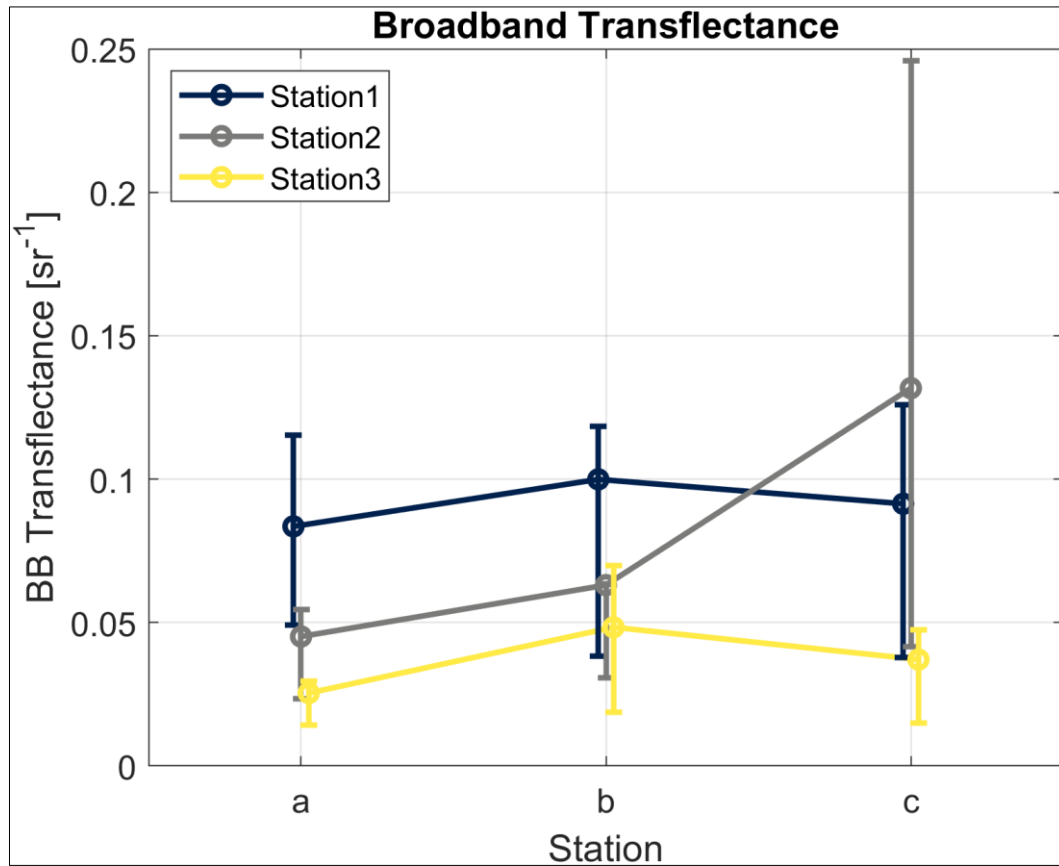


Fig. 2.13.4: Evolution of mean transflectance and 25 and 75 percentiles for all three regimes during the first three visits

The UHI sensor is expected to capture fine- to medium-scale patterns of sea ice biophysical properties such as algal biomass and photophysiology proxies through transmitted radiance in the 400–720 nm range. The resulting datasets are intended to be correlated with biogeochemical and ecological measurements collected by other groups (e.g., sediment traps, biogeochemistry) to investigate spatial drivers and relationships with sea ice physical properties such as floe history, ice thickness, and snow depth.

2.14 Autonomous measurements and seasonal installations

Work at sea

On the transit from Tromsø to the first ice station, we deployed 4 Surface Velocity Profilers (SVP) with barometric pressure sensor. Two of the buoys were deployed directly into the open ocean and the other two on sea ice. All other buoys were deployed during the ice station work with additional deployments described in Section 4.9.

During first visit of each ice regime (Stations 1a, 2a, 3a), we deployed one Snow Buoy, one camera buoy, and one spectral radiation station in level ice close to each other. The installations were arranged in a way that the camera buoy has at least these buoys in the field of view. In addition, one Snow and Ice Mass Balance Array (SIMBA, SAMS) buoy was deployed in ridged ice at each ice floe. We also deployed autonomous Remotely Operated Vehicle (ROV buoys) on floes 2 and 3 and oceanic buoy RI2P on floe 2. During Stations 2b and 3b, we deployed each one SIMBA in level ice. During Station 3c, we deployed one Seasonal Ice Mass Balance Buoy 3 (SIMB3, Cryosphere Innovation) and Snow Depth Network (SnoTATOS) on level ice. The overview of all deployed units is given in Table 2.14.1 and pictures of different buoys are shown in Figure 2.14.1.

Tab. 2.14.1: List of buoys that were deployed during the expedition. Values in brackets are for station revisit or after buoy relocation. Photos of the buoys are shown in Figure 2.14.1.

Type	Floe	Name	Deployment/ revisit date	Ice thickness	Ice freeboard	Snow depth	Comment
Radiation station	1	2025R29	10.07.2025	0.85	0.06	0.03	Level ice
			(26.07.2025)	(0.25)	(0.04)	(0.06)	(Revisit)
			(28.07.2025)	(1.23)	(0.12)	(0.04)	(Reloc.)
			(05.08.2025)	-	-	-	(End)
	2	2025R30	16.07.2025	1.36	0.06	0.06	Level ice
			(31.07.2025)	(1.25)	(0.14)	(0.05)	(Revisit)
			(12.08.2025)	(0.95)	(0.11)	(0.05)	(Revisit)
			(23.08.2025)	(0.60)	(0.07)	(0.02)	(Revisit)
			(24.08.2025)	(0.64)	(0.04)	(0.02)	(Recovery)
	3	2025R31	21.07.2025	1.89	0.12	0.07	Level ice
			(04.08.2025)	(1.74)	(0.19)	(0.00)	(Revisit)
			(18.08.2025)	(1.62)	(0.18)	(0.04)	(Revisit)
Snow Buoy	1	2025S145	11.07.2025	0.85	0.06	0.04	Level ice
			(19.08.2025)	-	-	-	(End)
	2	2025S146	15.07.2025	1.36	0.06	0.06	Level ice
			(14.07.2025)	(2.70)	-	(0.03)	(Reloc.)
	3	2025S133	(23.08.2025)	-	-	(0.01)	(Revisit)
			20.07.2025	1.89	0.14	0.06	Level ice
Camera buoy	1	2025K5	(26.08.2025)	-	-	0.05	(Revisit)
			12.07.2025	0.85	0.06	0.03	Level ice
	2	2025K4	(05.08.2025)	-	-	-	(End)
			(21.08.2025)	-	-	-	(Recovery)
	2	2025K4	15.07.2025	1.36	0.06	0.06	Level ice
			(24.08.2025)	-	-	-	(Recovery)

Type	Floe	Name	Deployment/ revisit date	Ice thickness	Ice freeboard	Snow depth	Comment
	3	2025K3	22.07.2025	1.89	0.12	0.07	Level ice
SIMBA	1	2025T143	12.07.2025 (21.08.2025) (23.08.2025)	2.85 - -	0.85 - -	0.01 - -	Ridge (End) (Recovery)
	2	2025T144	16.07.2025 (17.08.2025)	3.40 -	0.80 -	0.04 -	Ridge (End)
	3	2025T145	21.07.2025	3.23	0.82	0.12	Ridge
	2	2025T135	31.07.2025 (12.08.2025) (23.08.2025)	1.97 (1.59) (1.21)	0.17 (0.16) (0.11)	0.065 (0.05) (0.02)	Level ice (Revisit) (Revisit)
	3	2025T136	04.08.2025 (17.08.2025) (26.08.2025)	2.09 (1.82) (1.81)	0.34 (0.26) (0.25)	0.035 (0.04) (0.07)	Level ice (Revisit) (Revisit)
SIMB3	3	2025I19	18.08.2025	1.62	0.17	0.00	Level ice
RI2P	2	Oceanb_ri2p	17.07.2025	1.80	-	0.04	Level ice
Snow depth network	3	snowdepth (SnoTATOS)	18.08.2025	-	-	-	-
ROV buoy	2	AROV_2	17.07.2025	1.40	-	0.05	Level ice
	3	AROV_3	22.07.2025	1.72	0.22	0.05	Level ice
	3	AROV_2	18.08.2025	1.73	0.23	0.04	Level ice
SVP	Un- der- way	2025P343	06.07.2025	-	-	-	
		2025P344	04.07.2025	Open water			
		2025P346	05.07.2025	Open water			
		2025P348	11.07.2025	1.40	-	-	

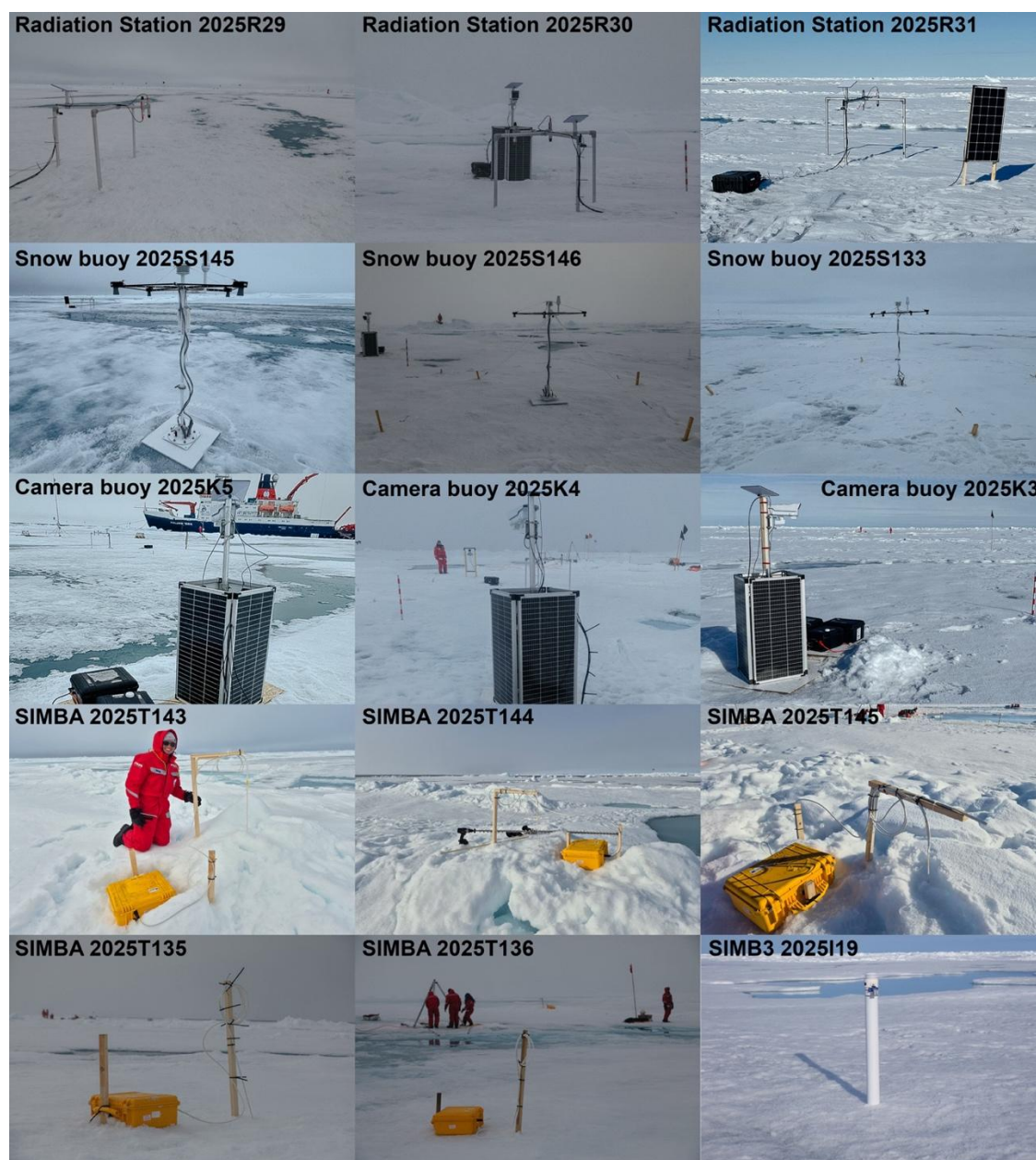


Fig. 2.14.1: Photos of deployed buoys.

Spectral radiation stations

The spectral radiation stations consist of three Trios Ramses spectral radiometers (320-950 nm) measuring incoming, reflected and transmitted irradiance. The stations measured in 10min intervals and transmitted their data based on power availability several times per day via their own Starlink antenna. The stations were equipped with an additional solar panel to support power supply (Fig. 2.14.1). The stations were deployed in level ice with ice thickness of 0.9, 1.4, and 1.9 m, respectively, during the first visit of each station (Tab. 2.14.1). Station 2025R31 had issues with the incoming radiation sensor. Station 2025R29 was relocated to thicker ice (1.2 m) after dynamic on 28 July event following ice thickness reaching 0.25 m on 26 July, and stopped sending data on 5 August. Station 2025R30 was recovered on 24 August, located 5

m from the floe edge. Station 2025R29 on floe 3 continued its observation beyond the CONTRASTS expedition and is planned to be recovered during the following EGC-Sources (PS150) expedition.

Snow Buoys

Snow Buoys measure surface elevation changes with 4 ultrasonic sensors, mostly representing surface ablation during this time of the year (Fig. 2.14.1). In addition, 1.5-m air temperature and atmospheric pressure are measured. All data were measured and transmitted hourly. The initial surface scattering layer (SSL) depth was 0.04–0.06 m. The Snow Buoy at floe 1 stopped sending data on 19 August. Snow Buoy at floe 2 was repositioned to enable a possible life time through winter on 14 August. The former site was expected to decay soon after relocation. Snow Buoys on floes 2 and 3 continue their observations beyond CONTRASTS into the coming winter.

Camera buoys

The camera buoys consist of two cameras each, one over and one under sea ice (Fig. 2.14.1). The systems were specifically developed for this kind of seasonal deployments on sea ice (type Panomax, see also Section 2.15). Both cameras have an opening angle of 120° and individual pictures consist of 2,688 x 1,512 pixels. Standard picture interval was 10 min for most of the time. These photos were transferred to a web server on land via Starlink data link. As the cameras also have a motion detection option, this was enabled towards the end of the observation period. These photos and videos were stored on the SD-cards in the cameras and were only read out after recovery. This resulted in much higher picture frequencies, in particular for the under-ice cameras, observing motions by organisms and particles in the water (see below). Table 2.14. gives an overview of the operation times and the number of photos and videos per camera. Depending on power availability they transmitted the pictures hourly through an own Starlink antenna. The pictures were made available immediately after transmission on the project web page (www.meereisportal.de, see Section 6.2, and awi.panomax.com). The cameras have a live-stream video option, which was only used for some short-term tests in order to not compromise the main time series of the pictures. These videos streams were not recorded.

The cameras were typically deployed in representative sea ice in close vicinity of the spectral radiation station, the Snow Buoy, and ROV buoy. Ablation stakes were deployed in front of the underwater and the surface cameras to track ice surface and bottom interface evolution. Buoy 2025K5 deployed on Floe 1 stopped sending data on 5 August and was recovered from floating in open ocean on 21 August. Buoy 2025K4 deployed at Floe 2 was recovered during the last visit on 24 August (Station 2d). Buoy 2025K3 on Floe 3 continued its observation beyond the CONTRASTS expedition and was recovered during the following EGC-Sources (PS150) expedition on 8 September.

Tab. 2.14.2: Overview of the camera buoys and panorama cameras on *Polarstern*. Dates and times give the first and last photo of the respective camera. The number of photos and videos differs depending on operation times and modes.

Camera	First	Last	Pictures Web	Pictures SD-card	Videos
Polarstern 180	02.07. 00:58	24.10. 08:50	2719	-	-
Polarstern 360	02.07. 01:00	24.10. 18:00	2282	-	-
Regime 1 surface	12.07. 18:55	05.08. 15:29	3318	3635	-
Regime 1 water	12.07. 18:55	05.08. 15:29	3907	6894	-
Regime 2 surface	17.07. 16:50	24.08. 09:37	5454	tbd	tbd
Regime 2 water	17.07. 16:46	24.08. 09:35	14530	tbd	1080
Regime 3 surface	22.07. 11:47	08.09. 18:02	7550	7106	516
Regime 3 water	22.07. 11:47	08.09. 18:02	12821	7105	516

Snow and Ice Mass Balance Arrays (SIMBAs)

SIMBA buoys are thermistor string buoys that measure temperature and heating cycle data to obtain sea ice thickness and temperatures (Fig. 2.14.1). The CONTRASTS deployments contribute to long-term observations with this kind of sea ice mass balance buoys.

On floe 1, SIMBA was deployed in 2.9 m thick ridge surrounded by 1.0–1.2 m thick level ice. On floe 2, one SIMBAs was deployed in 3.4 m thick ridge surrounded by 1.4 m thick level ice, and another SIMBA was deployed in 2.0 m thick level ice. On floe 3, one SIMBA was deployed in 3.2 m thick ridge surrounded by 1.8 m thick level ice and another SIMBA was deployed in 2.1 m thick level ice. SIMBA 2025T144 at the ridge at floe 2 eventually reached the floe edge and stopped recording reasonable data since 17 August. SIMBA 2025T143 at floe 1 stopped recording reasonable data since 21 August and was recovered from open water on 23 August. SIMBA 2025T135 was damaged by ROV Beast during Station 2d, with only sensors above ice-water interface (sensor number 100) still working.

Seasonal Ice Mass Balance buoy (SIMB-3)

Seasonal Ice Mass Balance buoys of the third generation measure sea ice thickness and snow depth with ultrasonic sensors and in addition sea ice temperature. Different to the SIMBA buoys, they are able to float in open water when melting out of the ice. The deployment continues a long-term measurement program of sea ice mass balance. We deployed one SIMB3 buoy (Fig. 2.14.1) during Station 3d in 1.6 m thick level ice next to the main transect. This buoy continues measuring beyond the CONTRASTS expedition.

Autonomous ROV buoys

Two autonomous mini-Remotely Operated Vehicle (ROV) stations were deployed for remote under-ice monitoring. Each station consisted of a solar-powered surface platform, a tethered mini ROV, and a satellite communication link (Starlink) enabling real-time operation from shore. The goal was to achieve sustained, fixed-point visual and radiometric observations beneath the sea ice without requiring on-site personnel after deployment. The ROVs are remotely operated from Bremerhaven and carried out short-duration under-ice surveys, capturing video footage and measuring Photosynthetically Active Radiation (PAR).

Based on the issues encountered during the first deployments at Stations 2a and 3a, the remaining unused vehicle (originally planned for Station 1a, ROV 1) was upgraded, with particular focus on sealing improvements and other critical points identified during the initial operations. ROV 1 was then installed on Station 3d and successfully redeployed for continued autonomous under-ice monitoring. The system is once again operated remotely via satellite,

with the goal of maintaining functionality until its planned recovery at the end of the following expedition, PS150.

Snow Depth Network (SnoTATOS)

The SnoTATOS are a network of snow depth sensors, which are installed as 15 individual units and communicating with one central node, which also transmits the data to land. The individual deployments are meant to cover a wide range of surface and snow conditions in order to get towards distribution functions of snow depth on sea ice, acknowledging the large heterogeneity of the surface. We deployed one network of 15 SnoTATOS nodes on a variety of surfaces including melt pond, level ice, behind ridges, and the main server on top of a ridge beyond the Ocean City at Station 3c on 18 August.

GPS stations

On all Floes, 6 GPS stations in combination with black and white targets were layed out to serve as check- and control points for airborne surveys as well as reference points for the stations and local coordinate systems. Targets marking the latter were not removed between stations. While 4 stations were deployed solely during station times and picked up before departure, 2 remained on floe 3 throughout the whole cruise to serve as reference for potential *Polar 6* flyovers. Due to various issues, data from these stations was only recorded for 5–7 days past the respective station ends. Table 2.14.3 shows an overview over the station deployments and key points of the local coordinate systems.

Tab. 2.14.3: Overview over GPS station deployments on floes 1a through 3c as well as origin points (O) and local north (L) for the local coordinate systems. Cells marked in blue indicate stations that stayed on floe 3 beyond the designated station times. * GPS 2 did not record data during 3b. ** No GPS Station was deployed at the local north target. *** Local north was changed along the old axis at the end of the station due to floe deformation.

	1a	2a	3a	1b	2b**	3b	1c**	2c	3c	2d	3d
GPS 1	X	X (L)	X (L)			X (L)			X (L)		X (L)
GPS 2		X	X (O)			X* (O)	X	X	X	X (O)	
GPS 3	X (L)	X		X	X (O)		X	X (L)***	X	X	
GPS 4	X (O)	X	X	X	X		X (O)	X (O)		X(L)	
GPS 5	X	X	X	X (L)	X	X	X	X			X
GPS 6		X (O)	X	X (O)	X	X			X (O)		X (O)

Preliminary (expected) results

Spectral radiation stations

Radiation station at floe 1 showed a wide range of broadband albedo of 0.2–0.9. Albedo for Regime 2 was close to 0.5–0.7, while Regime 3 albedo was 0.4–0.9. Floe 1 experienced a strong reduction of light transmittance from 0.2 to 0.1 right after deployment followed by a stable period in the range of 0.05–0.10 right before rapidly increasing back to 0.2 upon ice thickness reaching 0.25 m thickness. After relocation to thicker ice, transmittance of ice at Regime 1 returned back to 0.04–0.06, and later increased to 0.10 and to 0.20 right before the end of measurements at floe 1. Ice at Regime 2 had light transmittance of 0.03–0.15, while ice at Regime 3 had light transmittance of 0.05–0.20. There were snow events on 14 and 24 July followed by the rapid increase of albedo at the Station 1. Similarly, snow events led to a minor decrease of light transmittance. Snow event on 27 July led to a similar albedo increase in Regime 3. Around 1 August there was a rapid decrease of albedo and increase of transmittance at all 3 floes. After that, higher values of transmittance around 0.10–0.15 remained unchanged for several weeks at Regimes 2 and 3. There was a rapid increase of albedo and decrease of transmittance around 15 August at Regime 3. Generally, Regime 1 had the highest albedo almost until its breakage, while Regime 2 had the lowest light transmittance in July and August.

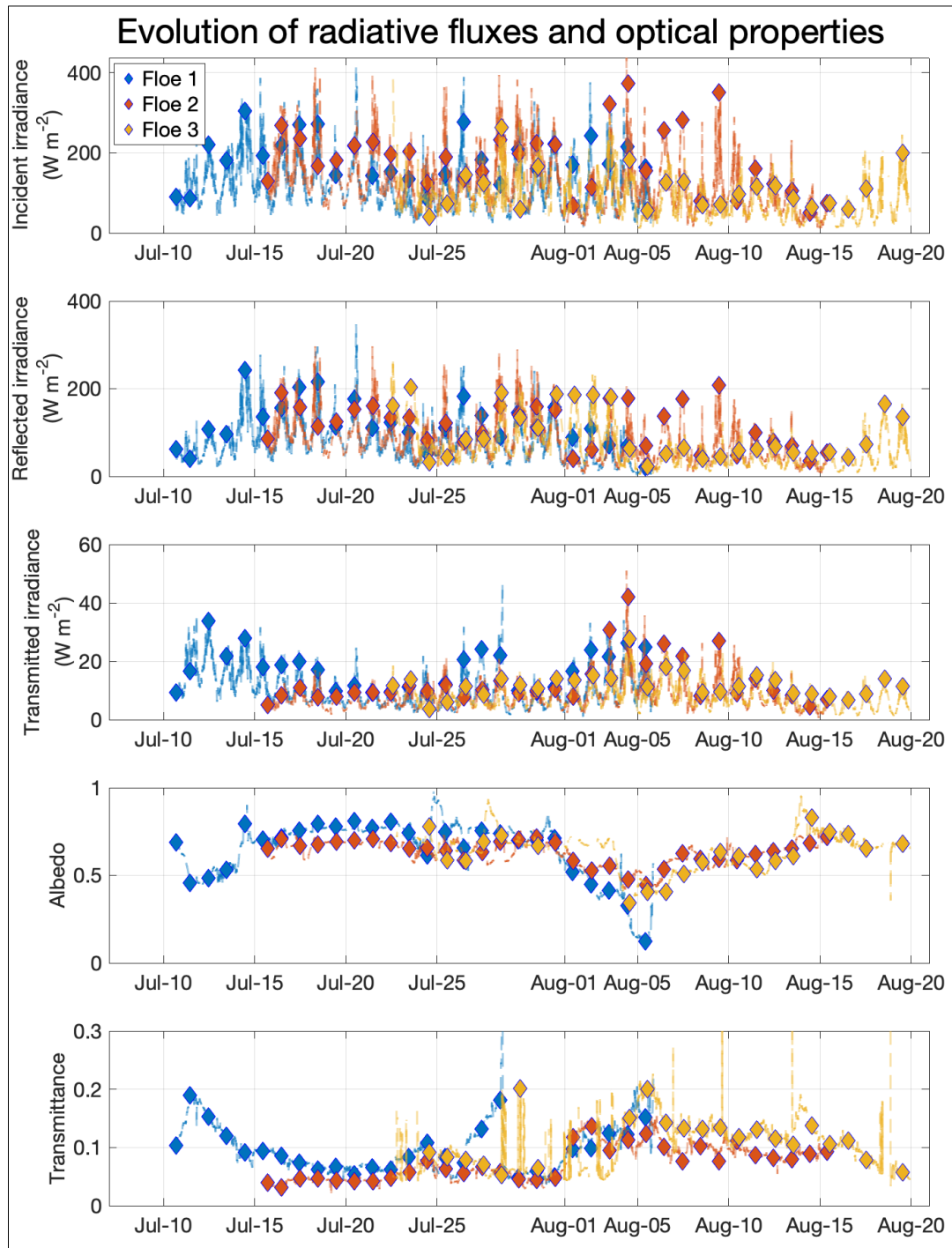


Fig. 2.14.2: Incoming, reflected, and transmitted radiation measured by radiation stations at ice floes 1–3, and calculated values of broadband albedo and light transmittance.

Snow Buoys

Surface at floe 1 experienced a faster decrease after 26 July, floe 2—on 22 July, floe 3—on 24 July. The largest surface ablation of around 0.18 m was recorded at floe 2, while the lowest surface ablation of around 0.08 m was recorded at floe 3. The absolute values of surface ablation at floe 1, which were only slightly larger than for floe 3, might be biased by a downward movement of the buoy relative to the initial position.

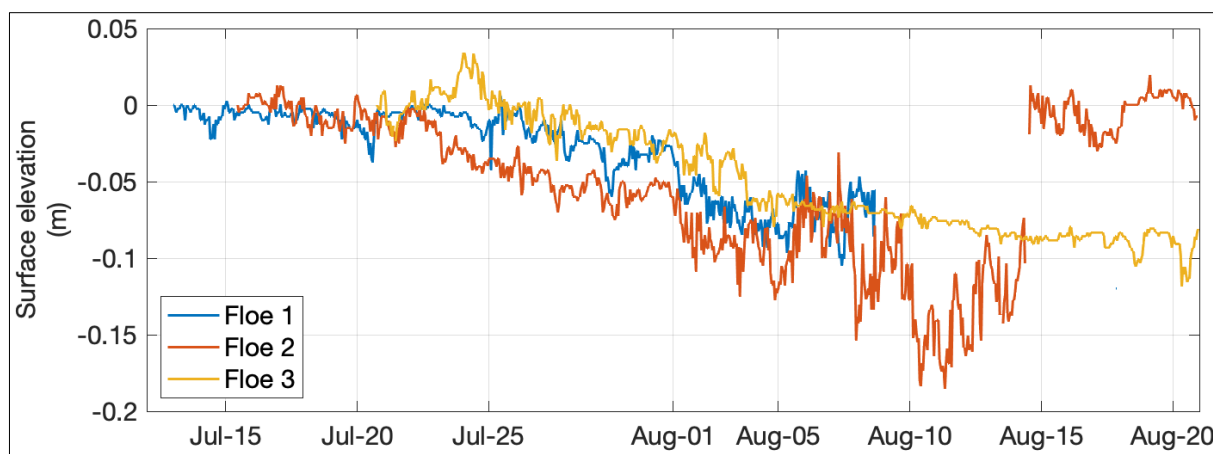


Fig. 2.14.3: Evolution of surface elevation from snow buoy data for floe 1 (blue), 2 (red), and 3 (yellow).

Camera buoys

The camera buoys turned out to be excellent instruments to document seasonal changes in each regime and differences and similarities between the regimes. The pictures describe the conditions of atmosphere, surface, sea ice, and ocean in a very systematic and objective way. The ability to observe surface and under-ice changes at the same time is new and a major advance in such studies. Figure 1.0.6 summarizes the main evolution of the regimes over the observation period based on the pictures of the three camera buoys, one in each regime. The camera buoys enable a better understanding of changes and will help to interpret the many (sensor) measurements, in particular during the time when the teams were away from the stations. In general the pictures show the melt pond and surface evolution. Here the comparison of the 3 regimes at the same time is striking, while more similar features may be found when allowing time shifts between the stations. Time laps animations of the entire picture set show how non-linear the changes are at the surface and under the ice. Some of these features would have been missed without these visual documents. Under the ice the change in color shades and visibility will support the analyses of changing particles and organisms and their abundance in the water. Zooming into the pictures allows even the identification of those particles and organisms. Figure 2.14.2 shows a few selected highlights from these autonomous observations. The surface pictures give additional information of the atmospheric conditions, incl. snow and rain events. Reading the ablation stakes allows quantification of bottom melt (and surface ablation) in addition to measurements from the different sea ice mass balance buoys.

More specific results, based on the time series in Figure 1.0.6 are:

- Regime 1: The decay of the floe unit its final failure on 5 August, which happened after the visit during Station 1b.
- Regime 2: The shift of under-ice color and visibility
- Regime 2: Lateral ablation of the floe edge
- Regime 2: Temporary fresh-water freezing (false bottom formation) for a few days interrupting the ongoing bottom melt
- Regimes 2 and 3: The surface pond evolution, including major drainage events.
- Regimes 2 and 3: Break-up events
- Regime 3: Rather stable bottom conditions

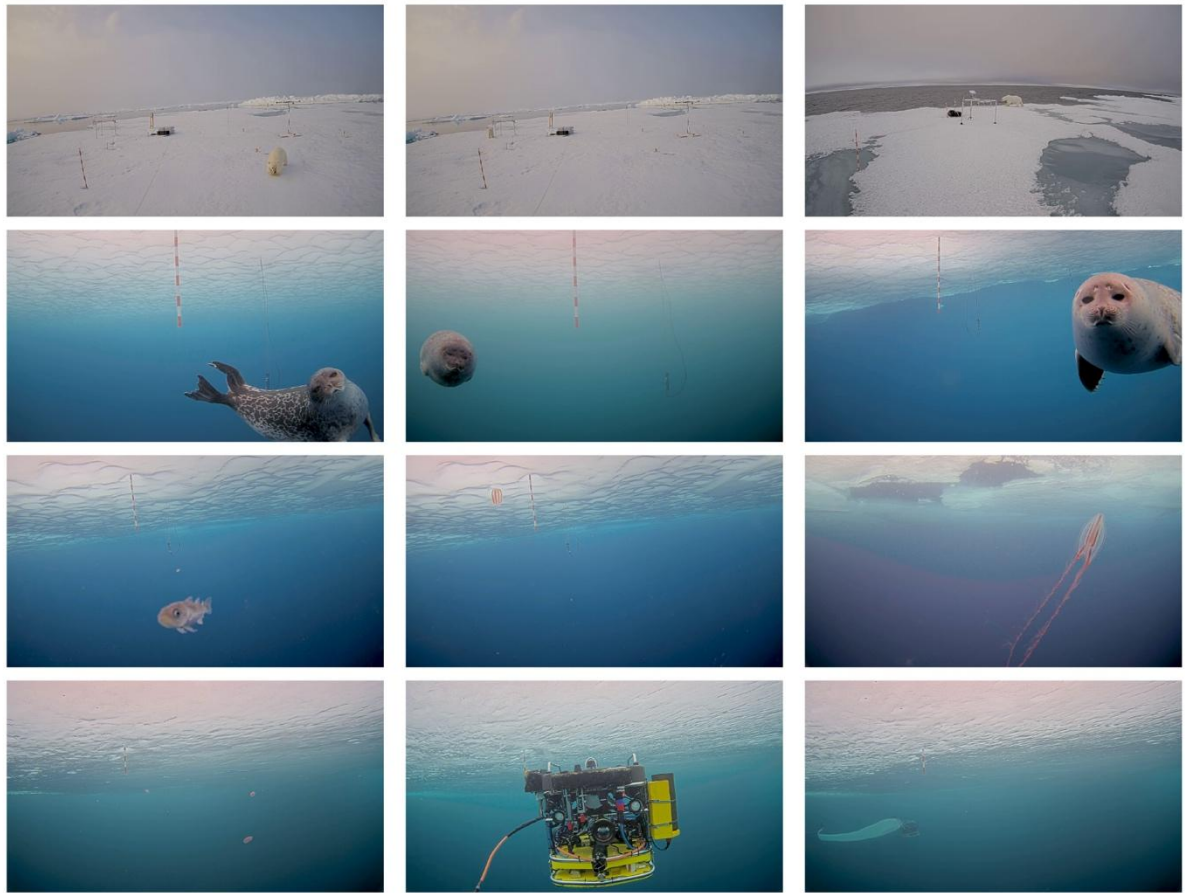


Fig. 2.14.4: Selected pictures from the autonomous camera buoys. The selection focusses on the marine life, which was observed mostly using the motion detection function of the camera. The bottom row also shows the operation of the ROV Beast, including a net tow of the ROV.

Snow and Ice Mass Balance Arrays (SIMBAs)

SIMBA buoys deployed in three small ridges showed different regimes in ice melt (Fig. 2.14.5). The ridge at floe 1 showed a small surface melt of 0.3 m and a large bottom melt of 1.3 m. Ridge at floe 2 showed a moderate surface melt of 0.7 m and moderate bottom melt of 0.8 m. Ridge at floe 3 showed a minor surface melt of 0.3 m and bottom melt around 0.2 m. The total ridged ice melt was 1.5 m for floe 1, 1.4 m for floe 2, and 0.5 m for floe 3. SIMBA deployed in level ice at floe 2 showed 0.1 m of surface melt and 0.7 m of bottom melt. SIMBA deployed in level ice at floe 3 showed 0.1 m of surface melt and 0.2 m of bottom melt.

The largest surface melt was observed at ridged ice at floe 2. Both level ice and ridged ice experienced the smallest surface melt at floe 3. The largest bottom melt was observed at ridged and level ice at stations 1 and 2. The small bottom melt was observed at level ice and ridged ice at station 3. Similarly, the total melt was larger for floes 1 and 3 for both level ice ridges ice, with equivalent heat fluxes reaching 100–180 W/m². The total melt was substantially smaller for floe.

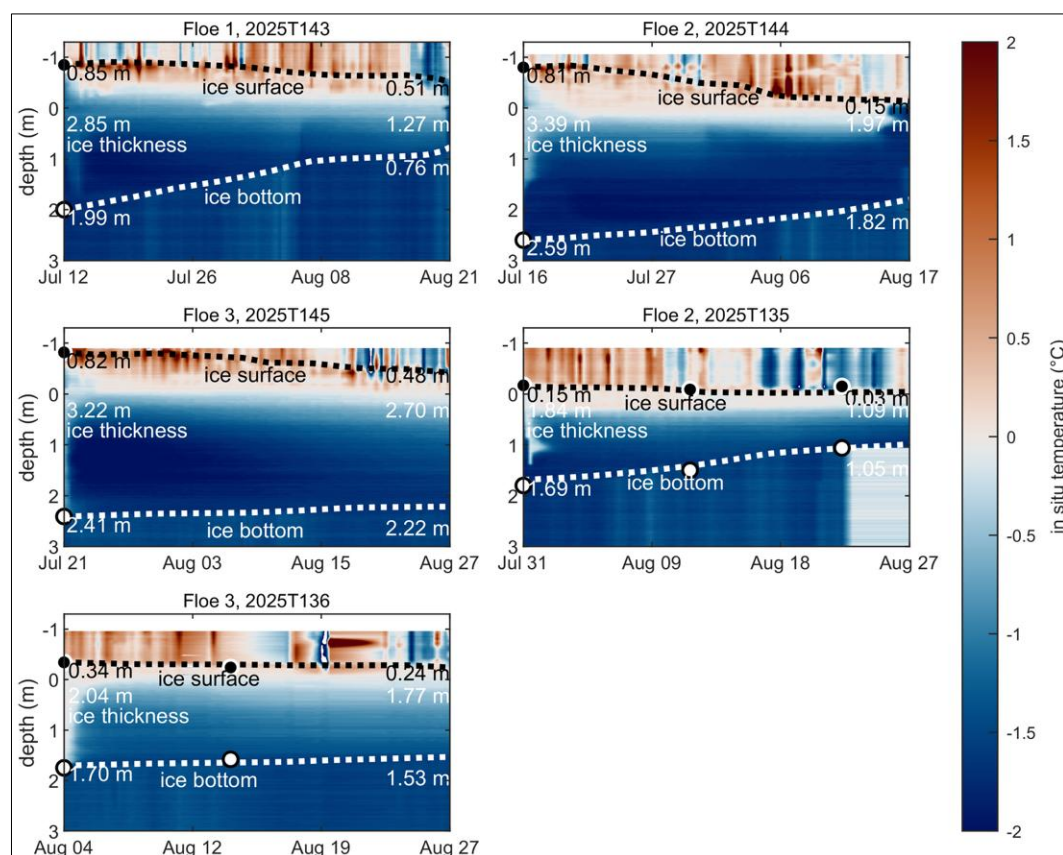


Fig. 2.14.5: Contour plots of in situ temperature from SIMBA buoys. Black and white dotted lines represent surface and bottom ice interfaces manually identified from temperature and heating data, with values of surface, bottom elevation at the start and end of measurements.

Seasonal Ice Mass Balance buoy (SIMB3)

2025I19 buoy deployed in level ice at floe 3 experiences several rapid increases of bottom ice depth from acoustic sounder. This may be related to the formation of false bottoms. Due to the substantial size of the instrument in comparison to SIMBAs, the temperature profile within ice was only slowly adjusting from temperatures around 0°C during August. By 28 August, the buoy measured no surface melt, 0.1 m bottom melt, and 0.02 m snow accumulation.

Autonomous ROV buoys

Despite initial failures, the deployment successfully demonstrated the feasibility of operating an under-ice observation system remotely via satellite. Core functionalities—including remote piloting, real-time video transmission, and autonomous surface station control—were validated under Arctic field conditions. The missions provided valuable insights into environmental constraints, technical vulnerabilities (particularly pressure sealing and waterproofing), and the overall robustness of the system.

The remotely operated vehicles (ROVs) delivered usable visual and light field datasets that enhance our understanding of spatial variability in under-ice light conditions and the structure of the ice–ocean interface. These short trials confirmed the reliable performance of key components such as power management, satellite communications, and deployment procedures, thereby establishing a solid foundation for further technological development.

The second / repeated deployment of an ROV on Station 3 will test the design improvements under real Arctic conditions and is expected to further increase system reliability, paving the way for long-term autonomous operations.

2.15 Panorama cameras

Work at sea

Two autonomous panorama cameras were operated continuously over the entire expedition, resulting in each approx. 1,500 pictures. Both provide hourly time laps pictures of the surrounding of the vessel in order to document ice, snow and weather conditions over the melt season across along the route. The cameras were both mounted above the crow's nest and worked without interruption. Both cameras complement each other in terms of image information. The hourly pictures were transferred to a server on land after recording, through an own Starlink satellite antenna. A small PC-server was installed in the crow's nest controlling the cameras and data transmission.

- The 'Panorama 360°' camera (device short name: Panomax) was operated on different expeditions since MOSAiC in 2019. The camera is based on a rotating line scan camera (type Panomax Roundshot 360°) and each picture consists of 15,680 x 2,048 pixels. This camera has a slightly higher resolution and a complete round view. While moving, the moving ship causes distortions / waves in the resulting image, because the recording of a single round shot takes several minutes, depending on light conditions.
- The 'Panorama 180°' camera (device short name: Panomax180) was operated for the first time during CONTRASTS. The camera consists of four individual cameras, which are automatically and directly stitched into one picture. Then each picture consists of 8,192 x 1,728 pixels. The camera also allows the recording and streaming of 4k video streams. Therefore, the 180° camera was also used to live-stream the departure from Tromsø for several hours. These video streams data were used for communication purposes and not recorded. In addition to the hourly photos, the camera records internally 20-second interval pictures, which were only used to create daily time-laps video. The individual high-frequency pictures were not stored or transmitted to land.

Preliminary (expected) results

Using the panorama cameras, we documented the sea ice, snow and weather conditions through the observation period. Figure 2.15.1 gives examples for each regime, when *Polarstern* was at the stations. These pictures are selected as representative views of the different regimes, illustrating the melt season at the sites. The cameras turned out to be a most valuable tool to document the changes over time and space of the expedition. They will be used in connection with the bridge observations (Section 2.16) and in general to document sea ice and weather conditions. Together with the autonomous camera buoys (Section 2.14, also Panomax products) they build the basis of the CONTRASTS project homepage (Section 6.2), as they greatly illustrate the expedition, the conditions, and the work at sea.

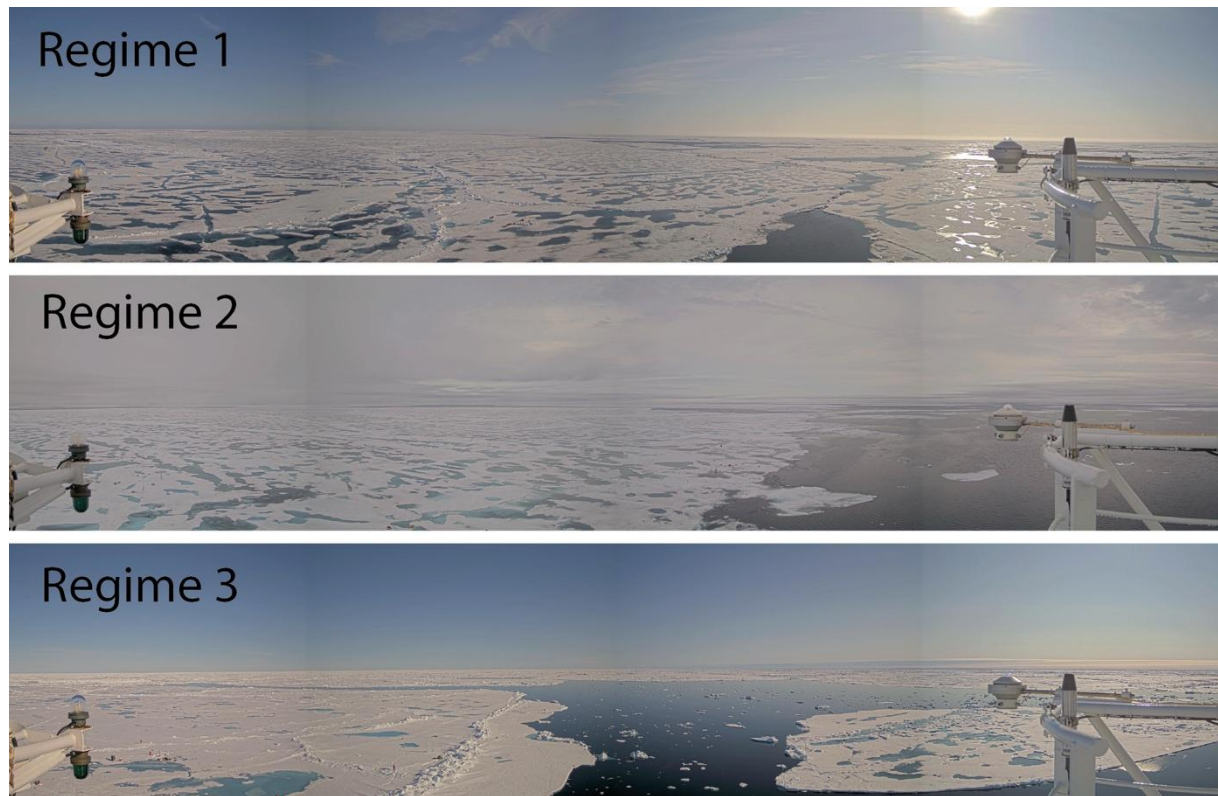


Fig. 2.15.1: Photographs of the 180° panorama camera on the crow's nest of Polarstern. The photos represent the conditions for each regime. The photos were taken during the ice stations (Regime 1 on 10 August 09:11, Regime 2 on 13 August 13:40, Regime 3 on 21 July 15:13). The station floes are on the left hand side.

2.16 Ship-based sea ice observations

Work at sea

During the CONTRASTS expedition, standardized ice observations (Hutchings et al., 2018) were done hourly while the *Polarstern* was moving through ice and not on station. The aim of these observations was to describe the surrounding conditions over a ~10 minute period within a radius of 1.5 nautical miles around the vessel. The list of conditions that were recorded is comprehensive, and includes ice concentration, floe size, fraction of ridged ice, ice thickness, amount of ice algae present, melt pond coverage, and other characteristics. In addition, several parameters describing the weather conditions and present macrofauna were included. Due to the subjective nature of the observations, new observers were trained and/or initially paired with people with more experience to ensure consistency throughout the expedition. More than 300 observations were recorded in total.

Preliminary (expected) results

Visual observations of sea ice conditions by ship are an integral part of sea ice monitoring for operational and research support. These observations provide information about sea ice morphology that is not obtainable or ambiguous in remotely-sensed data (Hutchings et al., 2018). The CONTRASTS expedition covered a wide range of sea ice conditions, from brash ice to a multiyear ice cover. On average, sea ice concentrations were $61\% \pm 28\%$, with the lowest values occurring in mid-August and highest values in mid-July. Sea ice thickness was $99 \text{ cm} \pm 44 \text{ cm}$ on average, with the thickest ice located in the vicinity of R3 and the thinnest ice located near R1 (Fig. 2.16.1). Melt pond coverage was spatiotemporally variable, with a 28% mean and 13% standard deviation. The highest pond coverage was observed in the vicinity of R1, whereas the region of R3 exhibited markedly lower melt pond fractions.

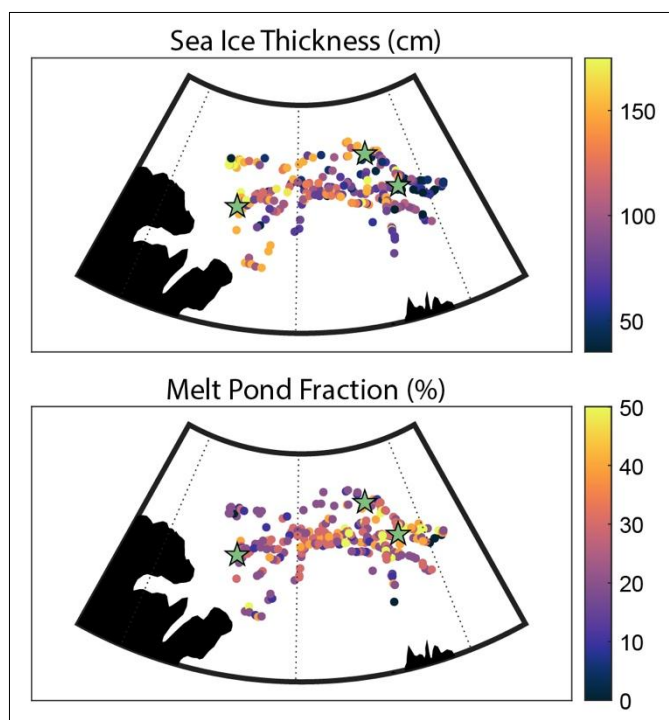


Fig. 2.16.1: By conducting standardized sea ice observations, the CONTRASTS expedition captured an east-west gradient ice sea ice thickness (top panel) and melt pond fraction (bottom panel) during the 2025 melt season. The three green stars mark locations of the three CONTRASTS ice stations.

2.17 Ship-based L-band microwave radiometer

Work at sea

During transits between the ice stations the ARIEL L-band microwave radiometer described in Chapter 2.6 was mounted on the highest deck of *Polarstern* (Peildeck) looking to port side (Fig. 2.17.1 left). It thus provides long-term observations of the ocean and sea ice microwave emission at an incidence angle of around 50° (comparable to SMOS, SMAP and future CIMR satellite observations between 40° and 52°). Beginning on 7 July, the instrument was relocated from the lower Peildeck to the upper Peildeck due to strong Radio Frequency Interference (RFI; likely caused by the close-by GoPro camera). Owing to connection problems with the RF front-end components (probably caused by ship motion), regular data acquisition started on 18 July. In addition, during periods of unsuitable weather conditions (e.g., rainfall, snowfall, possible condensation on the antenna window, or high humidity), measurements were temporarily suspended to ensure good data quality.

Preliminary results

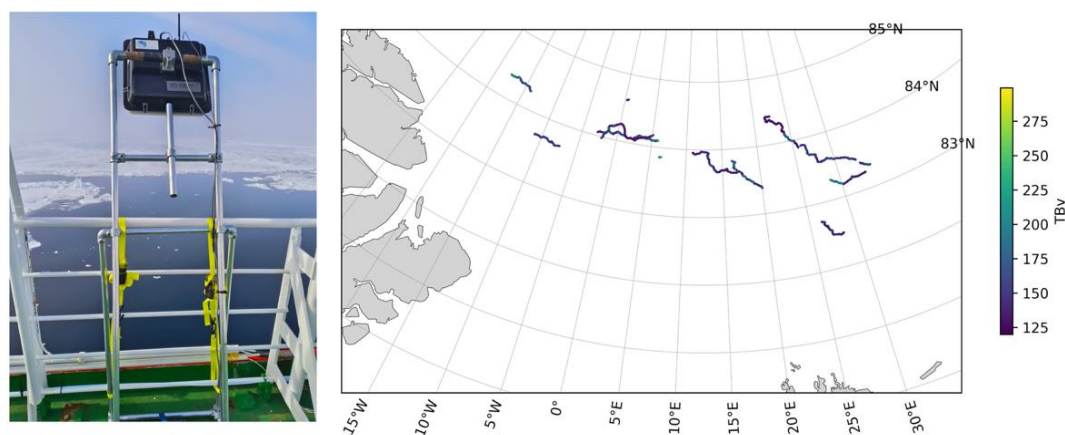


Fig.2.17.1: Left: ARIEL installed on the Peildeck; Right: spatial coverage of ARIEL measurements (TBs) on Peildeck from 18 July to 21 August 2025.

Through measurements along the *Polarstern* ship track, brightness temperatures of different surfaces were obtained. Figure 2.17.1 illustrates the spatial coverage from 18 July to 21 August. Measurements cover a range of latitudes between $\sim 83^\circ\text{N}$ and 85°N , and longitudes from $\sim 15^\circ\text{W}$ to 30°E in the north of Fram Strait. More measurements were acquired until the end of the expedition but are not processed yet.

2.18 Ship-based electromagnetic sea ice thickness monitoring system

Work at sea

We carried out ship-based ice thickness observations using the onboard Sea Ice Monitoring System (SIMS) to measure the sea ice thickness along the track of *Polarstern*. The SIMS consists of two major instruments: a sonar measuring the distance to the air/snow interface and an EM31 recording the distance to the ice/ocean interface.

The SIMS is located in front of the ship's bow mast. The bow mast was installed on 7 July at the first station work (no station number). The SIMS was installed alongside with (1) a downward-looking Trios RAMSES, measuring the reflected irradiance with a wavelength of 320 to 950 nm. Together with the upward-looking Trios RAMSES installation on the Crows' Nest, broadband and spectral albedo can be observed as an addition to the ice thickness observations. (2) a Reolink Time-Lapse Camera provides a visual inspection looking downward to the SIMS sensor and the sea ice surface.

The SIMS measures sea ice thickness at 1 1-second interval and sends the data to a computer located at the bridge. The time series was saved every 12 hours. The SIMS records primarily the along-track sea ice thickness, and was turned off during ice station work. From the data records, we computed 10 collective long-term datasets.

Tab. 2.18.1: List of transit datasets collected by the SIMS (Sea ice monitoring system). Note that the times of first and last data only marked those of the collective long-term SIMS dataset, but not the start and the end of the transit.

Transit	Start date	End date
First station to Floe 1	2025-07-05	2025-07-09
Floe 1 to 2	2025-07-10	2025-07-14
Floe 2 to 3	2025-07-17	2025-07-19
Floe 3 to 1 (round 2)	2025-07-22	2025-07-26
Floe 1 to 2	2025-07-27	2025-07-31
Floe 2 to 3	2025-08-01	2025-08-04
Floe 3 to 1 (round 3)	2025-08-06	2025-08-10
Floe 1 to 2	2025-08-11	2025-08-13
Floe 2 to 3	2025-08-14	2025-08-17
Floe 3 to 1 (recovery) to 2 (round 4)	2025-08-18	2025-08-20
Floe 2 to 3	Tbd	Tbd
Final transit	Tbd	Tbd

Calibrations were carried out while the vessel was stationary over open water, typically near the ice edge. Under these conditions the true ice thickness is zero, and the system uncertainty is no more than ± 0.02 m. The calibration relies on fitting the relationship between apparent conductivity and sensor height above the water surface, following the exponential function:

$$\text{Apparent Conductivity} = k_0 + k_1 e^{-k_2 \cdot \text{Height}}$$

Where k_0 , k_1 , and k_2 are the calibration coefficients. It is important that k_2 remains negative; otherwise, the fit is non-physical and the calibration must be repeated. Troubleshooting steps include checking wind effects, sensor inclination, and possible environmental noise. In some cases, spurious spikes occur in the calibration data (e.g., sonar confusion producing false heights of 0 m). Such spikes degrade the regression fit and must be removed manually or by

thresholding. After cleaning, the calibration file should be reprocessed to obtain a reliable set of coefficients. The calibrations are done over-open water at the following days:

- 2025-07-06
- 2025-07-12
- 2025-07-17
- 2025-07-23
- 2025-07-29
- 2025-08-01
- 2025-08-06
- 2025-08-14
- 2025-08-19
- 2025-08-20

Preliminary (expected) results

Figure 2.18.1 shows the overall temporal changes of sea ice thickness measured by SIMS. Typical ice thickness values cluster between 0.5–2.5 m, with occasional thicker ridged ice exceeding 4 m. Clear distinction in the ice thickness distribution are visible between transit legs and floe stations, reflecting spatial variability in ice conditions encountered during the expedition.

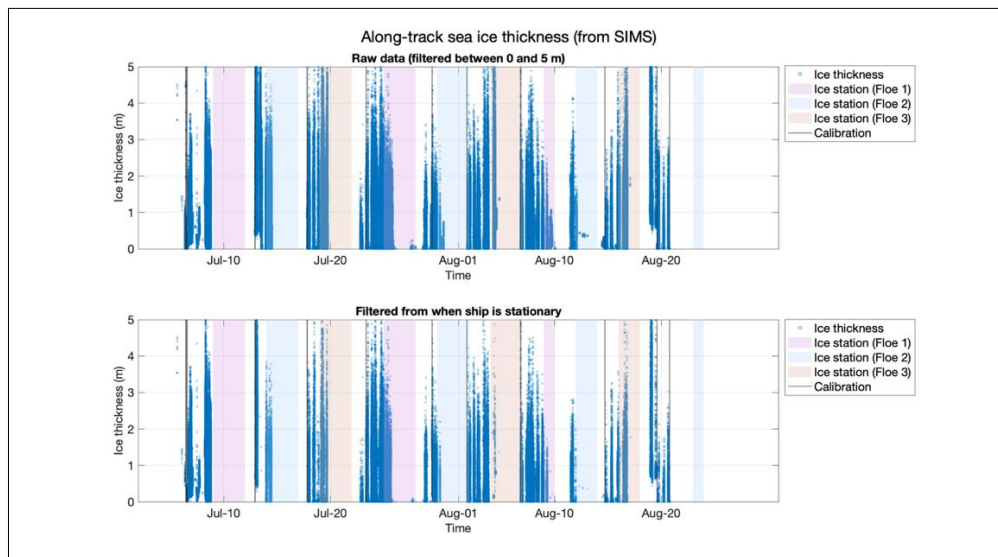


Fig. 2.18.1: Temporal evolution of sea ice thickness along-track Polarstern observed by SIMS. The pink, green, orange shaded areas mark the ice stations at Floe 1, 2, and 3 respectively. The black vertical lines mark the date of calibration.

Figure 2.18.2 shows distribution probability of ice thickness measured by SIMS during transits between floes. The transits towards Floe 1 (Fig. 2.18.2-a) shows a relatively broad thickness distribution, with modal thicknesses typically between 1–1.5 m and extended tails to 2 m, indicating the presence of thicker ice. The August 18–20 recovery transit shows a narrower distribution, dominated by thinner ice around ~1 m.

Transits from Floe 1 to Floe 2 (Fig. 2.18.2-b) shows a more clustered distributions with most thicknesses clustering around 0.7–1.5 m. The early-July transit shows a bi-modal distribution with some thicker ice around 1.5 to 3 m. Later on the same transit, the distribution of sea ice thickness shifted to a thinner mode, with the majority to be smaller than 1.5 m.

Figure 2.18.2-c shows the distribution of sea ice thickness during the transits from Floe 2 to Floe 3 (17-19 July, 1-4 and 14-17 August). These legs consistently show a distribution centered between 1–1.5 m. In the first transit (17 to 19 July), the distribution of sea ice thickness centered around 1.5 m, and shifted to a thinner thickness (ca. 1 m) in August transits, with a more uniform thickness.

Overall, the SIMS distributions highlight the strong spatial variability in sea ice thickness across different floe-to-floe routes. Transits towards Floe 1 encountered the thickest and most variable ice due to ridges. The transit between Floes 1 and 2, and between Floes 2 and 3, show a increase in sea ice thickness due to different regimes, thinning with time.

The along-track SIMS thickness distributions highlights the contrasts between different ice regimes during the cruise. Such work is particularly important as it identifies the gradients in sea ice thickness, evaluates floe-scale variability, and provides the essential knowledge for targeted ice station work planning. Also, the along-track distributions provide a linkage between small-scale sea ice thickness observation and satellite grid, thus bridging our knowledge in the characteristics of different sea ice types at different regimes across various spatial scales, improve sea ice parameterisation in models.

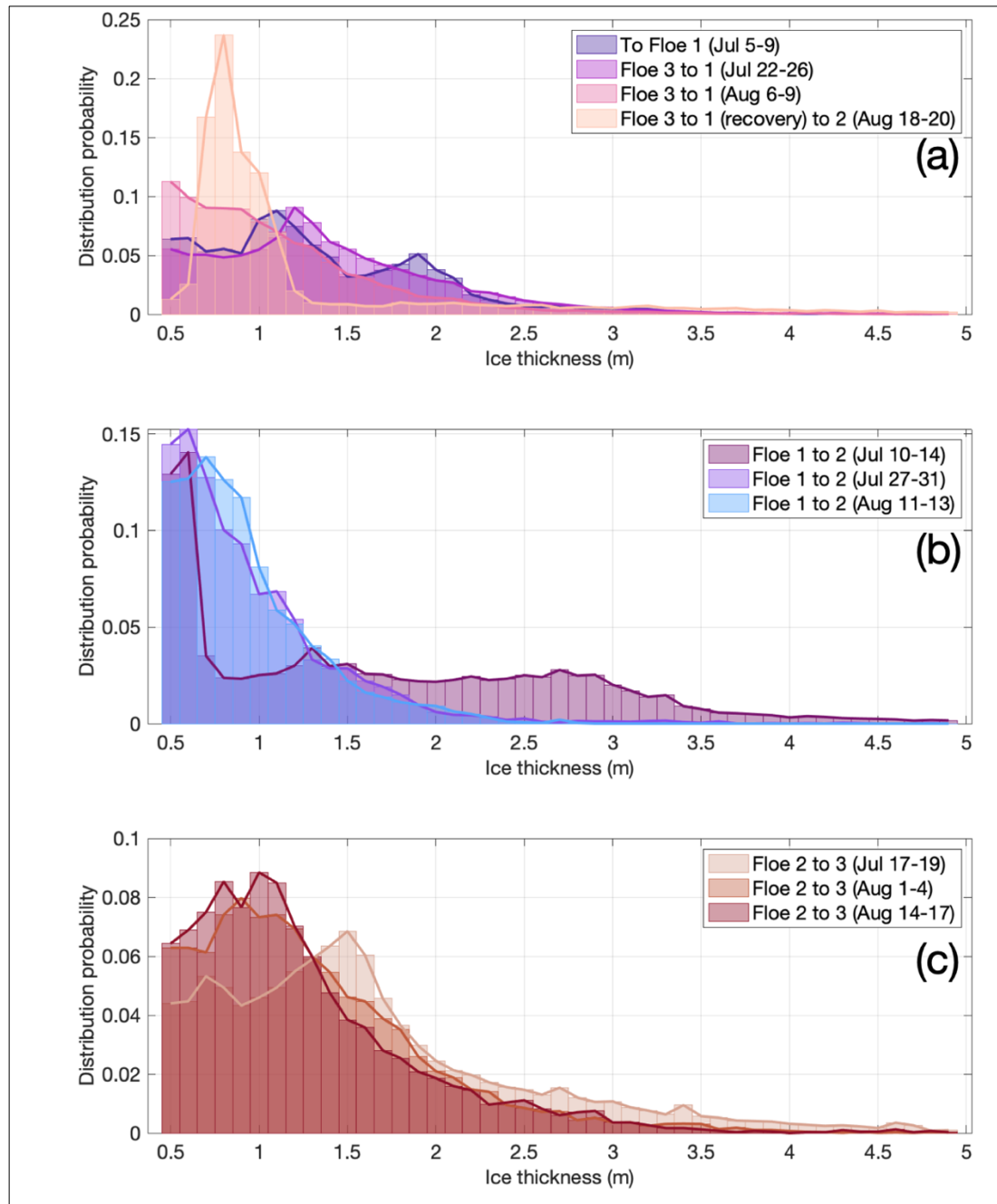


Fig. 2.18.2: Sea ice thickness distributions from the Sea Ice Monitoring System (SIMS), hanging in front of the bow. The plates give the transects to the different Floes: A) to Floe 1, B) to Floe 2, C) to Floe C.

2.19 Monitoring engine data and fuel consumption

Work at sea

During the cruise, we conducted ship experiments connected to the AWI project IceWise. The primary objective of this project is to evaluate the benefit of using satellite data for navigation in ice-covered waters. To achieve this, we collected data of transits through ice with and without satellite support using the MapViewer tool. In connection to this, we utilized the automated tool EDEN, which corrects image displacement directly on board and enhances the use of satellite imagery for real-time navigation.

Throughout the transits, we monitored the following parameters to create a comprehensive dataset:

- Engine and drive train parameters (fuel consumption, engine load, propeller shaft RPM, PTO)
- Propeller pitch angle
- Rudder angle
- Progress through ice (vessel speed, route efficiency)
- Ice radar
- Ice thickness (ship-based electromagnetic measurements, SIMs, and optical data from Panomax)
- Satellite pictures
- General navigational and environmental data (DSHIP)

In total, 27 sections of approximately 12 hours each were collected over the entire duration of the cruise. The operational area covered distinct ice regimes, all of which were systematically included in our experimental sections.

The experimental design was based on 12-hour slots, which allowed us to capture complete crew shift rotations. This approach helped eliminate potential human-related noise and excluded tidal effects, ensuring more consistent conditions.

For each section, data was collected in multiple rounds, with the navigation mode deliberately changed between with and without satellite support. This repeated switching ensured that performance could be compared under similar ice conditions.

- Without satellite support, the crew relied solely on their nautical experience and the onboard ice radar for navigation.
- With satellite support, strategic navigational decisions could be backed with drift-corrected satellite images provided through EDEN. The EDEN tool extended the timeframe in which satellite images could be used effectively by correcting for ice drift, and therefore partially mitigated the issue of image age, making older pictures more relevant and operationally useful.

By analyzing these operational metrics under the two navigation strategies, we will be able to quantify the benefits of integrating state-of-the-art satellite data (Sentinel-1, TerraSAR-X, RADARSAT) for more efficient passage through different ice types and regimes.

Preliminary (expected) results

Preliminary results from the expedition suggest that the use of satellite-supported navigation had a noticeable impact on route planning and operational decision-making under certain ice conditions. Distinct differences between satellite-supported and non-satellite-supported navigation strategies were observed, though detailed post-processing will be required to quantify the effects reliably.

At the beginning of the cruise, ice conditions were considerably more challenging, with higher ice concentrations and thicker floes. These conditions led to reduced transit speeds and increased navigational complexity. In this context, the benefit of satellite-based support became particularly evident: the imagery allowed for the identification of larger floes, leads, and open water patches, enabling the bridge team to formulate a rough strategic routing plan. This support proved especially valuable when broader situational awareness was needed to identify promising corridors or avoid particularly dense areas.

Satellite images were primarily used as a strategic planning tool—guiding overall route decisions on a larger spatial scale. They were instrumental in building an initial understanding of the ice landscape and in determining general transit directions. However, due to the limited resolution and occasional delays in image availability, tactical, real-time decisions still had to be made on the basis of direct visual observations and in-situ assessments. Exact route planning based solely on satellite data was generally not feasible.

As the expedition progressed and the ice field became more open, with lower concentrations and thinner ice, overall navigational complexity decreased. Under these lighter conditions, the relative impact of satellite support on transit performance diminished. Strategic decisions became less critical, and transit speeds increased regardless of satellite input. As a result, the time-saving effect observed earlier in the expedition became less pronounced.

While the integration of satellite imagery into navigation strategies clearly improved situational awareness and contributed to more confident decision-making, several limitations were noted. The inconsistent availability and variable quality of satellite images occasionally restricted their operational usefulness some images were outdated or too coarse in resolution by the time they were received. Furthermore, coverage gaps led to uneven support across different legs of the cruise. Finally, the dynamic and small-scale variability of the ice field often exceeded the spatial and temporal precision of the satellite products, underlining the ongoing necessity for skilled tactical decision-making in the field.

Tab. 2.19.1: Measured sections

	Start [time]	End [time]	Start [Coordinate]	End [Coordinates]	Route	Satellite Support
1	20250712;2340	20250713;1135	83.87°N/24.67°E	84.52°N/21.70°E	R1R2	x
2	20250713;2230	20250714;1000	84.65°N/20.84°E	84.92°N/14.36°E	R1R2	m
3	20250717;2135	20250718;0935	84.69°N/13.73°E	84.73°N/03.43°E	R2R3	x
4	20250718;0936	20250719;0230	84.73°N/03.43°E	84.27°N/07.29°W	R2R3	m
5	20250719;0230	20250719;1440	84.27°N/07.28°W	84.55°N/16.20°W	R2R3	m
6	20250722;1928	20250723;0730	84.34°N/17.74°W	83.91°N/05.92°W	R3R1	m
7	20250723;0922	20250723;2008	83.92°N/05.04°W	84.13°N/03.09°E	R3R1	m
8	20250723;2010	20250724;0810	84.13°N/03.09°E	83.69°N/09.83°E	R3R1	x
9	20250724;1500	20250725;0557	83.70°N/11.26°E	83.10°N/20.70°E	R3R1	x
10	20250725;0557	20250725;1615	83.10°N/20.70°E	82.69°N/27.11°E	R3R1	m
11	20250728;2010	20250729;0820	82.52°N/27.27°E	83.24°N/21.88°E	R1R2	m
12	20250729;1320	20250729;1940	83.25°N/21.92°E	83.58°N/17.85°E	R1R2	x
13	20250801;2140	20250802;0940	83.75°N/18.28°E	83.76°N/08.97°E	R2R3	x

	Start [time]	End [time]	Start [Coordinate]	End [Coordinates]	Route	Satellite Support
14	20250802;2015	20250803;0815	83.78°N/05.67°E	83.62°N/05.52°W	R2R3	m
15	20250803;0815	20250803;1455	83.63°N/05.52°W	83.61°N/10.98°W	R2R3	x
16	20250806;2005	20250807;0805	83.71°N/10.91°W	83.70°N/01.45°E	R3R1	x
17	20250807;0805	20250807;1900	83.70°N/01.45°E	83.90°N/08.71°E	R3R1	x
18	20250807;1945	20250808;0744	83.91°N/09.06°E	84.16°N/20.47°E	R3R1	m
19	20250808;0744	20250808;1947	84.16°N/20.47°E	83.62°N/29.00°E	R3R1	m
20	20250814;1820	20250815;0635	84.56°N/21.26°E	84.39°N/08.23°E	R2R3	x
21	20250815;0635	20250815;1800	84.39°N/08.23°E	84.18°N/01.40°W	R2R3	m
22	20250819;0010	20250819;1422	82.73°N/12.43°E	83.46°N/04.15°W	R3R1	m
23	20250819;1521	20250820;0300	83.48°N/04.33°W	84.08°N/03.24°E	R3R1	m
24	20250820;0300	20250820;1505	84.08°N/03.24°E	83.77°N/13.45°E	R3R1	x
25	20250820;2240	20250821;1240	83.69°N/15.53°E	83.39°N/27.76°E	R3R1	m
26	20250822;0230	20250822;2040	83.30°N/32.03°E	83.99°N/17.40°E	R1R2	m
27	20250824;2115	20250826;0840	84.10°N/15.05°E	82.43°N/06.05°W	R2R3	m

Data management

All environmental data obtained during this expedition will be archived, published, and disseminated according to international standards by the World Data Center PANGAEA (Data Publisher for Earth & Environmental Science; <https://www.pangaea.de>) within two years after the end of the expedition at the latest. Unless specified otherwise, a CC-BY license will apply. Measurements from autonomous systems, which transmit data in near real time via satellite communication, will be made immediately available through the data and information portal meereisportal.de. Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

This expedition is supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 2, Subtopic 1.

In all publications based on this expedition, the **Grant No. AWI_PS149_01** or **AWI_PS149_05** or, in case of multidisciplinary work, **AWI_PS149_00** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. <http://dx.doi.org/10.17815/jlsrf-3-163>.

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3. ATMOSPHERIC SCIENCES

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Grant-No. AWI_PS149_02 and AWI_PS149_07

Sub-Project	Project Focus
3.1	Thermodynamic structure measurements by radiosondes and drones
3.2	Remote Sensing of the atmosphere and the surface, and relation to surface properties
3.3	Autonomous measurements of surface turbulent heat fluxes and radiation components
3.4	Autonomous measurements of near surface temperature- and humidity profiles from a 10 m tower
3.5	Mobile measurements of near surface turbulent heat fluxes over different surfaces

Objectives

The atmospheric programme for CONTRASTS is focused on the direct interactions between the atmosphere and the variable surfaces in the central Arctic during the melt season. With that perspective in mind, the research is organized around three basic scientific objectives. 1) Quantify the atmosphere-surface exchanges that impact the sea ice energy and mass budgets, the upper ocean mixed-layer heat budget, and other key bio-physical processes in the ocean-ice system. To achieve this objective requires atmospheric observations that are coincident with related sea ice and ocean observations. Those atmospheric observations will quantify all components of the surface energy and momentum budgets, including the surface skin temperature and fluxes of radiation, turbulent sensible and latent heat, and momentum. As the three sea ice regimes R1-R3 are characterized by vastly different sea ice properties (e.g. ice age, thickness, roughness, pond fraction), a specific focus will be set on how those differences – and their changes during the melt – impact the atmospheric processes mentioned above. 2) Understand the drivers of variability in atmosphere-surface exchange processes and how these might be sensitive to the underlying ice and ocean properties. Variability in surface exchange processes can be driven by advection in the atmosphere, structural changes in the atmospheric boundary layer, the development and phase of clouds, precipitation in the atmosphere and reaching the surface, and the vertical structure of atmospheric winds and turbulence. To develop a process-based understanding of surface exchange requires

coordinated measurements of these processes along with the resultant surface fluxes. 3) Develop process-based model diagnostics from the observations at the three primary sites and their associated spatio-temporal variability. To support model predictive capabilities in the Arctic, and particularly of the changing sea ice and atmosphere-surface interactions, requires robust model representations of the essential processes responsible for controlling variability in surface heat and momentum. For example, the relationship between the net radiation at the surface and the sensible heat flux represents a key balance that interacts with heat conduction through the sea ice to determine the surface skin temperature (e.g., Solomon et al., 2023). To achieve the appropriate partitioning of energy in the delicate sea ice system, models must represent the balances at play. Diagnostics built from the observations in disparate sea ice conditions will be important for assessing model performance under a range of realistic and representative conditions.

3.1 Thermodynamic structure measurements by radio sondes and drones

Work at sea

As an integral part of the CONTRASTS expedition, a radiosonde program was conducted between 3 July and 1 September to characterise the vertical structure of the atmosphere above and around *Polarstern*. Radiosondes were launched regularly throughout the expedition, at least twice daily (around 11 and 23 UTC) and frequently also at 6 UTC to complement the morning weather report.

The Vaisala RS41-SGP sondes were prepared using the Vaisala MW41 sounding system. Each sonde was attached via a Vaisala RS41 unwinder to a helium-filled TOTEX meteorological balloon and subsequently released from the helicopter deck of *Polarstern*.

In total, 172 radiosondes were successfully launched during the CONTRASTS expedition (Fig. 3.1.1).

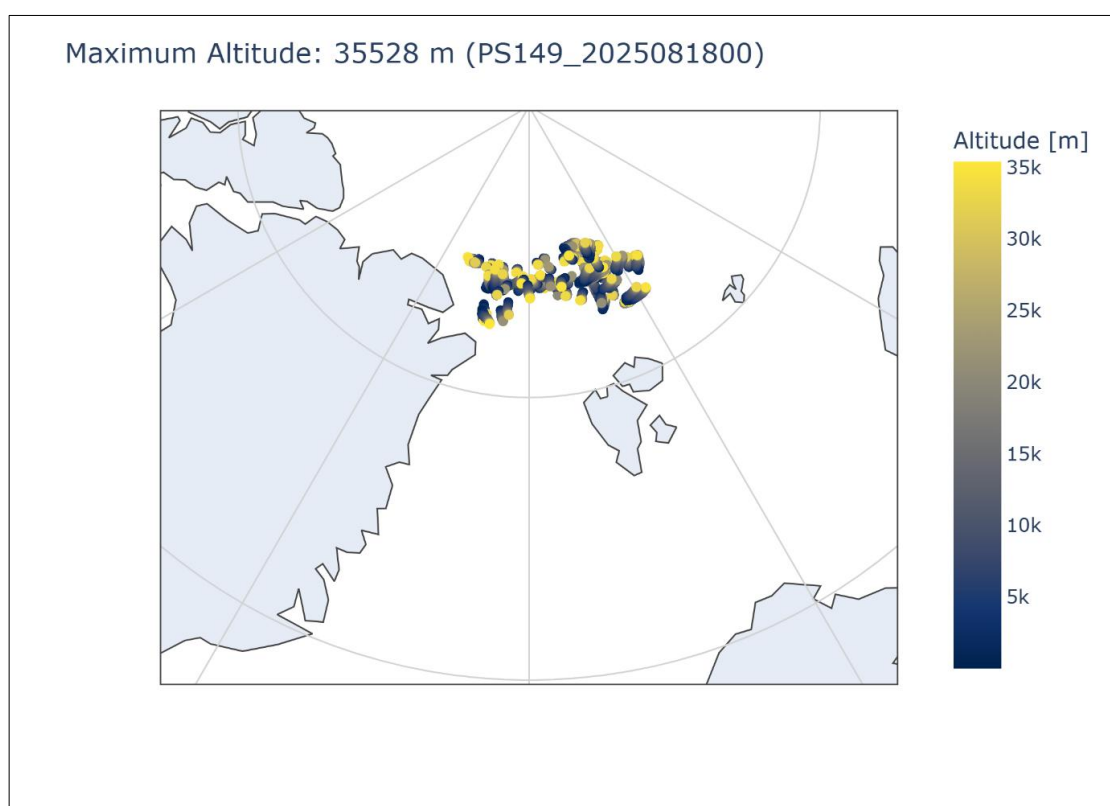


Fig. 3.1.1: Radiosonde launches and their flight routes during PS149 CONTRASTS expedition

Apart from the atmospheric profiling with radiosondes, thermodynamic profiles and lateral transects were also sampled from a DJI Mavic 3 Classic camera drone, that was equipped with a meteorological onboard backpack (Fig. 3.1.2). The backpack contains two miniature sensors for measuring atmospheric state variables (Bosch BME280 – temperature, relative humidity, air pressure, and Sensirion SHT85 – temperature, relative humidity). Additionally, the backpack contains a GPS module for position data and correct time estimate, and all the data are logged onboard with 1 Hz on a Raspberry Pi zero W minicomputer (Brus et al., 2025).

Such drone flights were generally limited to airspace clearance as well as flight weather conditions, and were undertaken both from the sea ice next to the ship, as well as from the helicopter deck.



*Fig. 3.1.2: DJI Mavic 3 Classic drone equipped with a backpack for meteorological measurements.
Photo: Sandro Dahlke/DE.AWI*

Tab. 3.1.1: List of device operations for the meteorological drone backpack

Event Label	Date/Time start	Date/Time end	Altitude [m]	Flight pattern
PS149_16-mavic_bp1_Profile_1-2a	2025-07-14T21:18:04	2025-07-14T21:26:04	100	profile
PS149_16-mavic_bp1_Transect_1-2a	2025-07-14T21:31:24	2025-07-14T21:42:37	15	transect
PS149_16-mavic_bp1_Profile_2-2a	2025-07-15T11:16:51	2025-07-15T11:31:54	500	profile
PS149_16-mavic_bp1_Profile_3-2a	2025-07-15T11:39:37	2025-07-15T11:49:20	1000	profile
PS149_18-1_mavic_bp1_Profile_4-3a	2025-07-21T22:58:13	2025-07-21T23:12:24	1000	profile
PS149_18-1_mavic_bp1_Transect_2-3a	2025-07-22T16:24:49	2025-07-22T16:36:42	10	transect
PS149_30-1_mavic_bp1_Profile_5-3b	2025-08-06T16:28:07	2025-08-06T16:48:37	1000	profile
PS149_30-1_mavic_bp1_Profile_6-3b	2025-08-06T17:00:07	2025-08-06T17:16:20	1000	profile
PS149_32-1_mavic_bp1_Profile_7-1c	2025-08-09T13:56:46	2025-08-09T14:30:10	1000	profile
PS149_32-1_mavic_bp1_Transect_3-1c	2025-08-09T14:38:34	2025-08-09T14:58:30	10	transect
PS149_32-1_mavic_bp1_Profile_8-1c	2025-08-09T23:01:54	2025-08-09T23:20:01	1000	profile
PS149_32-1_mavic_bp1_Profile_9-1c	2025-08-10T12:41:25	2025-08-10T12:58:31	1000	profile
PS149_41-1_mavic_bp1_Profile_10-3c	2025-08-18T17:10:30	2025-08-18T17:32:14	1000	profile
PS149_41-1_mavic_bp1_Transect_4-3c	2025-08-20T18:54:29	2025-08-20T19:13:07	10	transect
PS149_47-1_mavic_bp1_Transect_5-3d	2025-08-26T16:10:27	2025-08-26T16:29:44	10	transect

Preliminary (expected) results

The regular launch of radiosondes offers detailed insights into the temporal evolution of meteorological parameters in the atmospheric column above and around *Polarstern* during the CONTRASTS expedition. This standard procedure allows that the data are transmitted near real time to the weather forecast centres via the GTS to be incorporated in the current weather forecast.

Radiosondes provide high vertical resolution measurements (approx. 5 m) of atmospheric temperature, humidity, wind speed, and wind direction (Fig. 3.1.3), extending from the deck of *Polarstern* up to the lower stratosphere (approx. 35 km). According to the manufacturer (www.vaisala.com), the measurement uncertainty is below 0.4 °C for temperature and below 1.5 % for relative humidity.

The resulting dataset is expected to be valuable for investigating the temporal development of synoptic events, including anticyclones (10-11 August), warm-air intrusions (22-24 July) or strong wind events (4 August), as illustrated in Figure 3.1.3. Such synoptic-scale events can substantially influence atmospheric thermodynamics, particularly the structure and dynamics

of the boundary layer during the Arctic melting season. These processes may enhance surface melting at the site or, under certain conditions, even induce short-lived freeze-up.

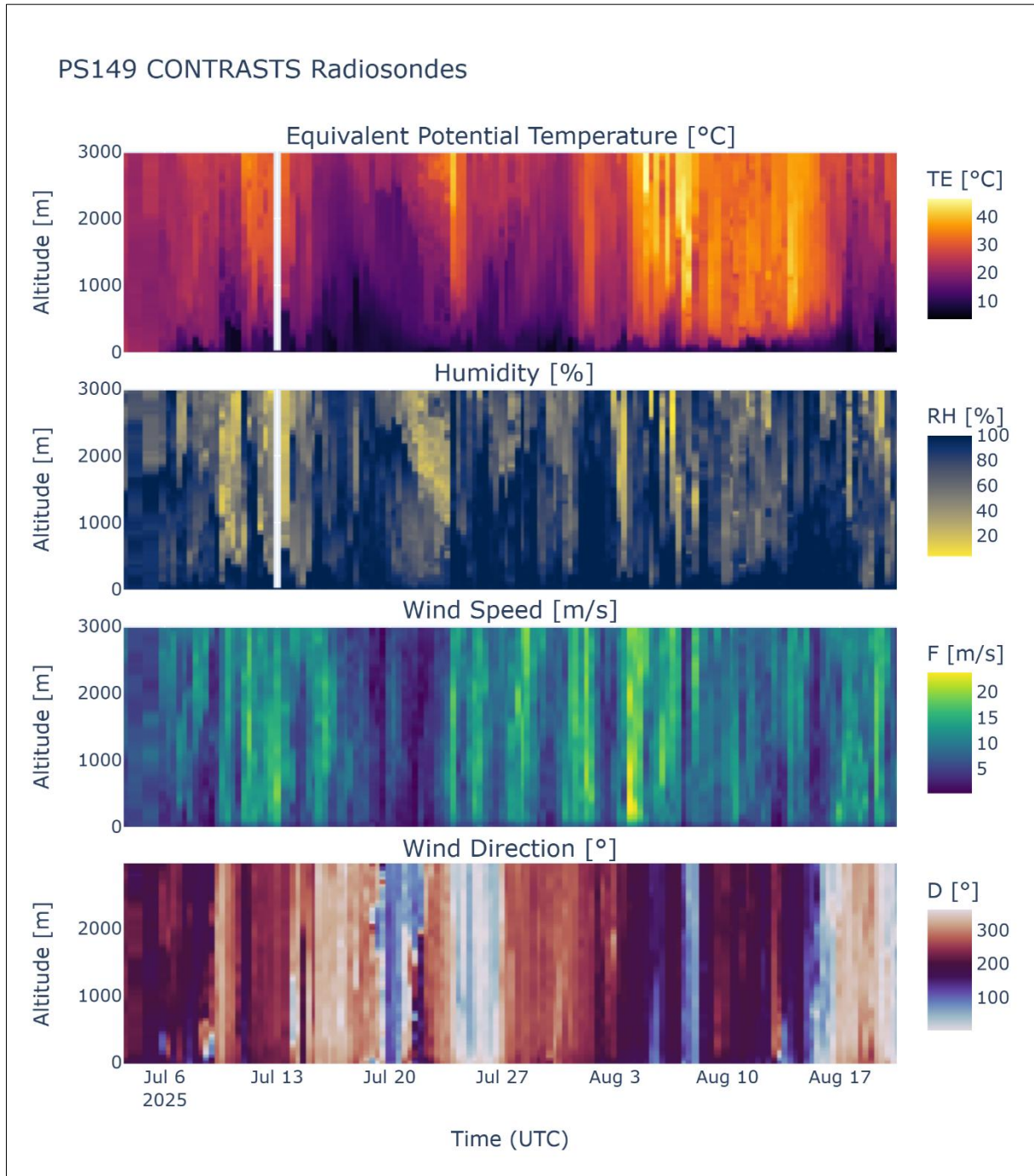


Fig. 3.1.3: Vertical profiles of meteorological parameters measured by radiosondes during PS149 CONTRASTS expedition. From top to bottom: temperature, relative humidity, wind speed, wind direction.

Further information about the vertical structure of the lower atmosphere, as well as its spatial gradients, are provided by the Mavic 3 drone flights with the onboard meteorological sensor pack. Figure 3.1.4 shows a comparison between temperature profiles collected from the drone and a parallel radiosonde profile from the same time and location. While the drone backpack has a small warm bias of $\sim 0.5^\circ\text{C}$, it can be seen that both the vertical temperature gradient, as well as the location of the warm temperature inversion around 975 hPa is captured properly by the drone. Lateral transect flights give insight into the spatial variability of lower level temperature and humidity fields, and its dependence on the surface type (i.e. flights over ice vs open water, as can be inferred from surface photos taken by the drone during the transect).

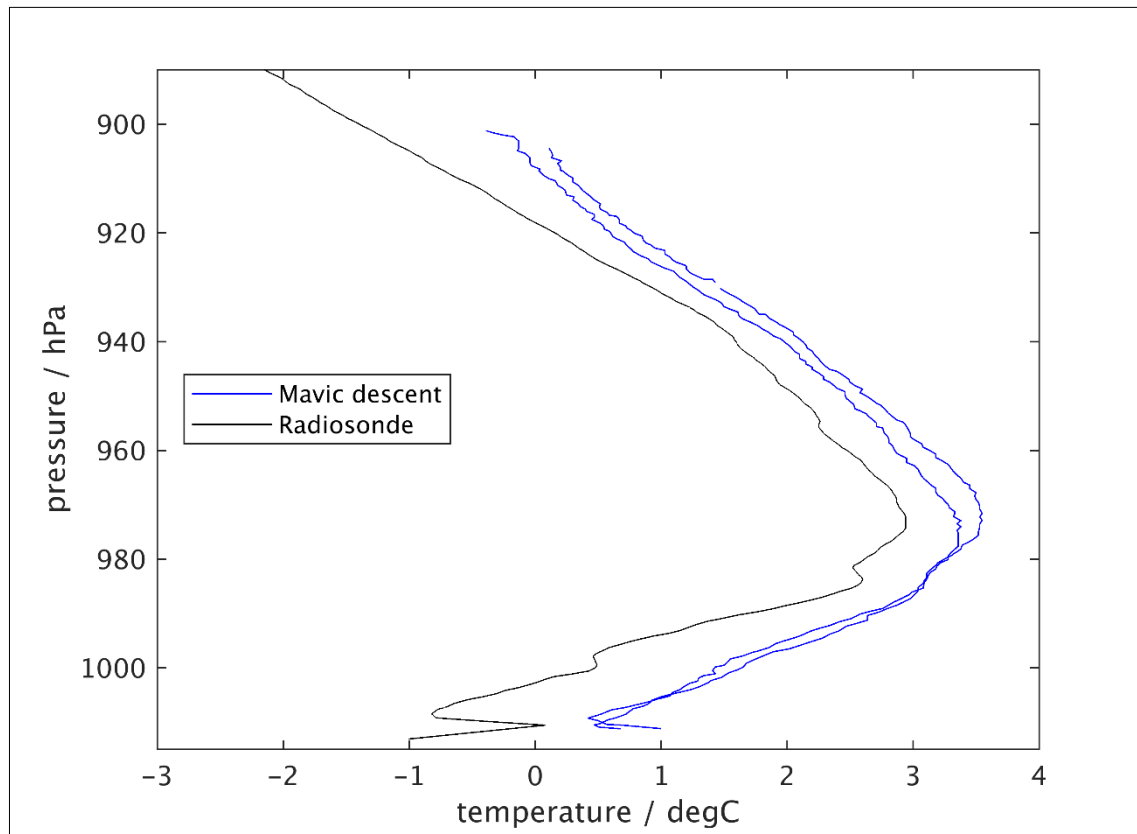


Fig. 3.1.4: Comparison of temperature profiles take from a radiosonde on 21 June, 23 UTC (black) and parallel, collocated drone profiles (blue).

3.2 Remote sensing of the atmosphere and the surface, and relation to surface properties

Work at sea

Atmospheric measurements

Within the Water Vapor, Mixed-Phase Clouds, and Sea Ice Emissivity over the Central Arctic Ocean – 2 (VAMPIRE-2) project, we operated a set of passive and active remote sensing instruments (cloud radars and microwave radiometers) to observe the thermodynamic structure of the atmosphere as well as the micro- and macrophysics of clouds. Additional instruments provide useful information for data processing and quality control:

Cloud radars:

- G-band differential absorption radar (GRaWAC; G-Band Radar for Water Vapor and Arctic Clouds; ID 11587), see Figure 3.2.1 b
- W-band cloud radar (MiRAC-A; Microwave Radar/Radiometer for Arctic Clouds – Active, ID 11588), see Figure 3.2.1 b

Microwave radiometers (MWRs):

- K- and V-band multi-channel MWR (RPG-HATPRO-G5, Humidity and Temperature Profiler; ID 12733), see Figure 3.2.1 a
- G-band and higher frequency MWR (RPG-LHUMPRO-243-340-G4 or short LHUMPRO or MiRAC-P; Low Humidity Profiler or Microwave Radar/Radiometer for Arctic Clouds – Passive; ID 11590), see Figure 3.2.1 a

Supplementary atmospheric measurements:

- OTT Parsivel² laser disdrometer for precipitation measurements (ID 11609), see Figure 3.2.1 b
- uSonic-3 (ultrasonic) anemometer for wind measurements (ID 11610), see Figure 3.2.1 b
- Total sky imager for observations of the cloud conditions (visible fish eye sensor Mx-O-SMA-S-6D016-X and infrared sensor Mx-O-SMA-TS-R079, ID 11611), see Figure 3.2.1 d

Additionally, we installed broadband radiation sensors from the Leibniz Institute for Tropospheric Research (TROPOS) in Leipzig – a Kipp & Zonen Pyranometer CMP21 (ID 12963) and a Kipp & Zonen Pyrgeometer SGR4-V (ID 12962) – on the mast at the bow of the ship to measure the downwelling shortwave and longwave radiation of the sun and the atmosphere, respectively (Fig. 3.2.1 c).

Surface microwave emission measurements

The MWRs HATPRO and MiRAC-P were also used for continuous surface measurements. Combined with the measurements of an infrared surface camera we will be able to derive the surface emissivity at discrete frequencies in the microwave spectrum between 22 and 340 GHz. Additional visible images taken by a GoPro camera help to interpret the surface observations. More specifically, the infrared and visible surface cameras are the following:

- GoPro Hero 11 Black camera for images in the visible spectrum (ID 11620)
- FLIR A315 infrared camera for images and temperatures in the infrared spectrum (ID 12049)

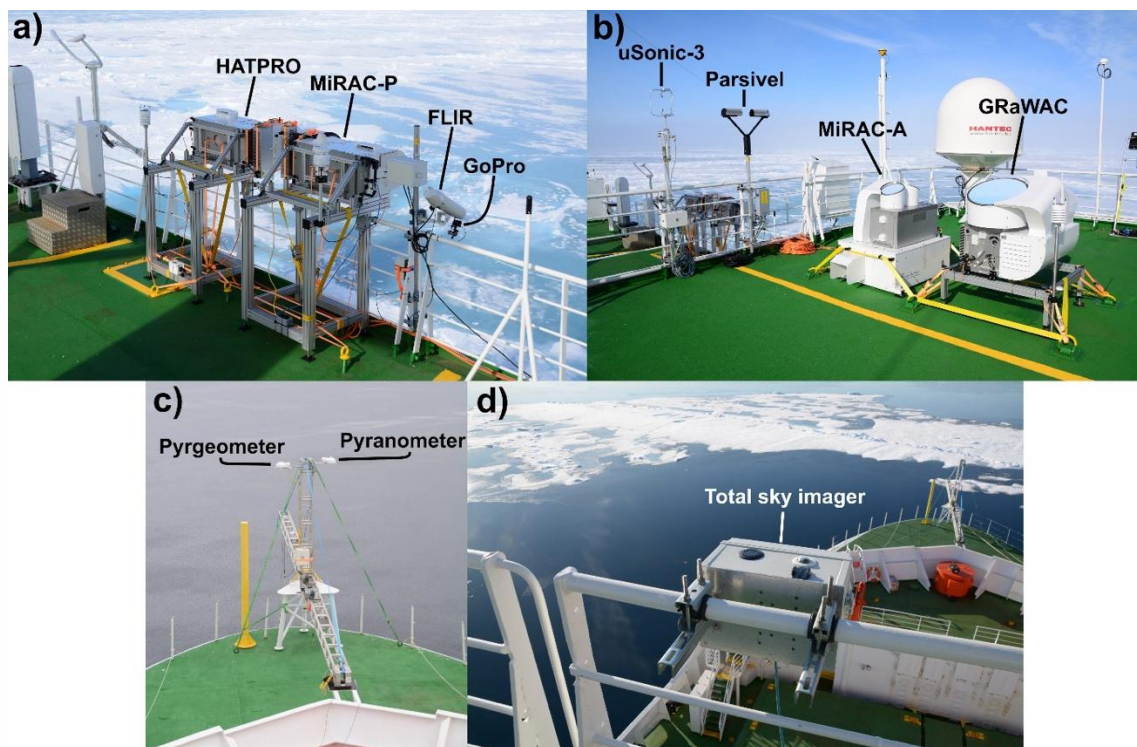


Fig. 3.2.1: Instruments installed on the lower and upper Peildecks and at the bow mast. (a) HATPRO, MiRAC-P, FLIR A315 and GoPro Hero 11 Black, (b) uSonic-3 anemometer, OTT Parsivel² disdrometer, MiRAC-A and GRaWAC, (c) Kipp & Zonen Pyrgeometer SGR4-V and Pyranometer CMP21, (d) Total sky imager (Mx-O-SMA-S-6D016-X and Mx-O-SMA-TS-R079). Photos: Andreas Walbröl/DE.UNI-Koeln

Installation

The instruments listed above (except for the pyranometer and pyrgeometer) were installed on the lower Peildeck (MWRs and surface cameras) and the upper Peildeck (cloud radars, disdrometer, ultrasonic anemometer and total sky imager). The upper Peildeck is 1.61 m above the lower Peildeck. The MWRs HATPRO and MiRAC-P were installed at the railing on portside of the lower Peildeck (Fig. 3.2.1 a and Fig. 3.2.2) as during PS144 to ensure an unobstructed view of the surface and the sky for nadir angles between 35 and 180° (180° equals zenith). Both MWRs point perpendicular to the ship's heading and can be operated in an upright position (for calibration and atmosphere-only observations) and tilted by 90° (combined surface

and atmosphere observations). The MWRs' receivers were as close together as possible to maximize the overlap of the footprints. Next to the MWRs towards the bow of the ship, the surface infrared FLIR A315 and GoPro Hero 11 Black cameras were installed at a nadir (incidence) angle of 53° (Fig. 3.2.1 a and Fig. 3.2.2). The two cloud radars were installed on the portside of the upper Peildeck where GRaWAC was located further to the bow of the ship than MiRAC-A next to it (Fig. 3.2.1 b and Fig. 3.2.2). Both radars were aligned to sample the same atmospheric volume. The instruments were positioned with the transmitter towards portside for MiRAC-A and towards starboard for GRaWAC. Next to the radars at the railing of the upper to the lower Peildeck, the OTT Parsivel² disdrometer and the uSonic-3 anemometer were installed on poles at 198 cm and 206 cm height, respectively (Fig. 3.2.1 b and Fig. 3.2.2). Despite limiting the height of the poles, both instruments experienced vibrations, especially during transit. The laser beam of the disdrometer pointed perpendicular to the ship's heading. uSonic-3 was aligned with its internal north arrow pointing towards the front of the ship. Both instruments were close to the crow's nest and are potentially affected by precipitation and wind shadowing effects. The total sky imager was installed at the railing towards the bow of the ship on the upper Peildeck (Fig. 3.2.1 d and Fig. 3.2.2). The instrument host computers were synchronised with the arktur.fs-polarstern.de time server from 6 July until the end of the expedition.

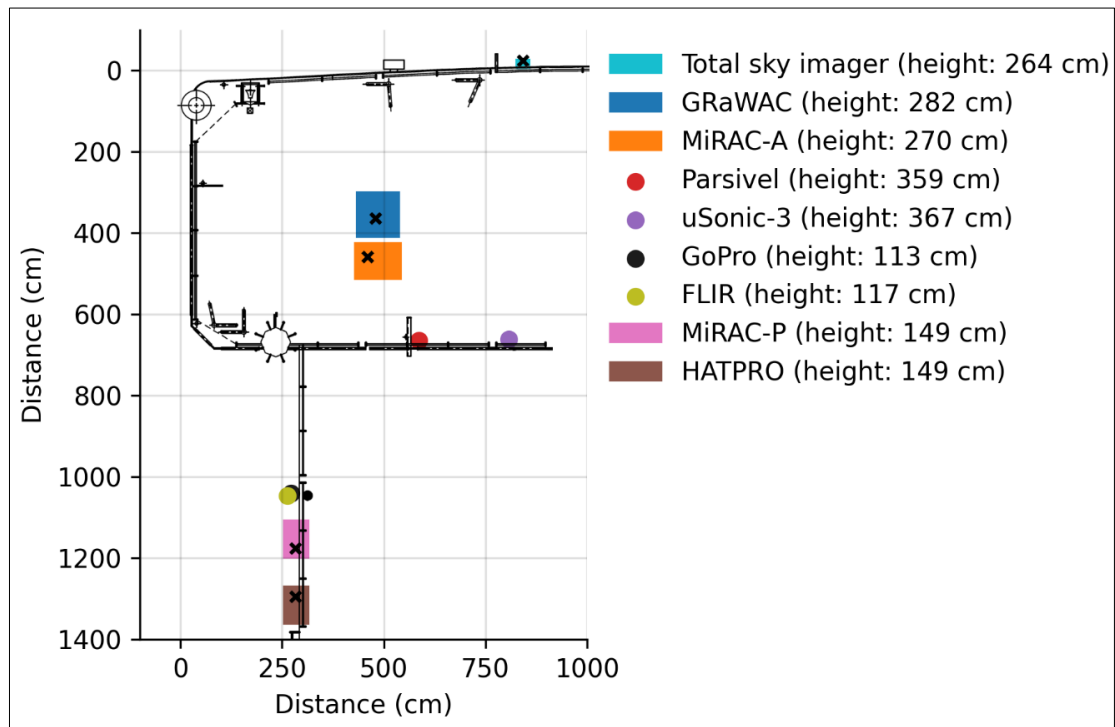


Fig. 3.2.2: Map of the lower and upper Peildeck (bow and portside of the ship are towards the upper left corner) with the location of the instruments illustrated as colored rectangles and circles. Black crosses indicate the locations of the sensors of the total sky imager, GRaWAC, MiRAC-A, MiRAC-P and HATPRO. The heights of the sensors given in the legend are relative to the lower Peildeck.

Settings

Initially and for the transit towards the sea ice edge, the MWRs were operated in the upright position that only allows atmospheric observations. MiRAC-P (HATPRO) measured in this mode from 4 July at 06:55:33 UTC (18:01:58 UTC) until 6 July at 08:00:41 UTC (08:00:29 UTC). In this operation mode, MiRAC-P only pointed in zenith direction (180° nadir angle) while HATPRO measured in zenith direction and performed boundary layer scans at nadir angles of 90°, 95.4°, 100.2°, 109.2°, 120°, 132° and 180°, every 20 minutes. On 6 July at 08:03 UTC, both MWRs were tilted by 90° for the combined surface and atmosphere observation mode with the same settings as during PS144:

- zenith: 180° (360 s)
- surface: 127° (15 s), 53° (155 s for HATPRO, 175 s for MiRAC-P, later also 155 s for MiRAC-P), 127° (15 s)
- surface scan: 35°, 45°, 55°, 65°, 115°, 125°, 135°, 145° (15 s each)
- boundary layer scan: 180°, 120°, 109.2°, 104.4°, 101.4°, 98.4°, 96.6°, 95.4°, 94.8°, 94.2° (10 s each)

The scans were started at 0 or 30 minutes past each hour in the following order: surface scan, zenith, surface, zenith, surface, boundary layer scan and zenith. The final zenith scan was shortened to 270 s. Both instruments performed gain calibrations for 10 s at the beginning of each zenith scan. On 31 July at 11:21 UTC, the duration of MiRAC-P's 53° surface observation was reduced from 175 to 155 s because that improved the temporal match of HATPRO and MiRAC-P observations in contrast to last year's experience. It seems that the newer HATPRO deployed this year adjusted the scanning mode at a similar pace as MiRAC-P while the older HATPRO from last year was slower. On 29 August at 12:00 UTC, HATPRO and MiRAC-P were flipped back to the upright position to observe the atmosphere for the rest of the expedition and during the subsequent expedition (PS150).

For GRaWAC, the chirp table settings GRaWAC 05 (Tab. 3.2.1) were used for the entire expedition (2 July at 13:47:00 UTC to 29 August at 12:00 UTC). MiRAC-A measurements started with MiRAC-A 04 settings on 2 July at 13:16 UTC. However, due to noise in the measurements, the settings were changed to MiRAC-A 00 from 5 July at 09:31 UTC to 8 July at 14:36 UTC. Afterwards, settings MiRAC-A 01 were used until the end of the measurements (29 August 12:00 UTC).

Tab. 3.2.1: Chirp settings for the two cloud radars

Instrument, chirp number	Min. height (m)	Max. height (m)	Resolution (m)	Chirp repetition	Doppler vel. max. (m s ⁻¹)
GRaWAC 05	150	1000	13.3	3584	4.3
	1000	4000	23.5	6144	3.4
	4000	10000	44.4	4096	2.5
MiRAC-A 04	150	1000	4.2	3072	8.3
	1000	4000	9.4	4096	3.9
	4000	10000	16.3	2048	1.9

Instrument, chirp number	Min. height (m)	Max. height (m)	Resolution (m)	Chirp repetition	Doppler vel. max. (m s ⁻¹)
MiRAC-A 00	100	400	3.2	4096	8.7
	400	1200	7.5	3072	8.2
	1200	3000	9.7	2048	4.0
	3000	12000	23.8	1536	3.1
MiRAC-A 01	150	1000	8.4	5120	9.2
	1000	4000	18.8	6144	6.9
	4000	10000	32.5	3072	3.2

FLIR A315, OTT Parsivel² as well as the pyranometer and pyrgeometer sampled with a rate of 1 Hz while the GoPro Hero 11 Black (total sky imager) took a photo every 2 s (60 s). The uSonic-3 anemometer operated with a sampling rate of 30 Hz and measurements were initiated on 2 July at 11:00 UTC. FLIR A315 measurements were only started on 6 July at 07:31 UTC after the first sea ice was observed. However, during ice transit we noticed that the image was blurry. We corrected the focus manually using the FLIR software on 8 July at 08:17 UTC. The total sky imager and GoPro Hero 11 Black measurements were started on 4 July at 08:10 UTC and at 17:44 UTC, respectively. No OTT Parsivel² disdrometer measurements are available before 7 July, 15:55 UTC because we had trouble establishing the remote connection to the instrument. The pyranometer and pyrgeometer measurements started on 6 July at 15:20 UTC. Minor alignment corrections were made on 7 July 2025 around 12 UTC. However, due to failure of the supporting rod holding one of the instruments, measurements were terminated on 15 July at 16:15 UTC when the instruments were recovered.

The surface observations of the FLIR A315 and GoPro Hero 11 Black were terminated on 28 August at 13:35:00 and 13:41:50 UTC, respectively. Parsivel and uSonic-3 data logging were stopped on 29 August at 12:15 and 13:15 UTC, respectively.

A full list of events, providing details on exact times when measurements of each instrument were started, interrupted, terminated or when configurations were changed, is given in the Appendix.

Calibration

Before *Polarstern* left Tromsø, the MWRs and cloud radars were calibrated with liquid nitrogen in the afternoon of the 2 July. Between 14:00 and 19:02 UTC on 6 August, the absolute calibration procedure was repeated to ensure high data quality until the end of the expedition. The calibration of MiRAC-A on 6 August required three attempts because the calibration target table was improperly positioned on the radar during the first two attempts (a small part of the frame was in the receiver field of view). We measured the temperature of the liquid nitrogen each time before the first attempt of a calibration. Additionally, we performed test measurements with the MWRs on the liquid nitrogen cooled targets after the calibration to confirm the success of the calibration. The weather conditions during the calibration on 6 August were not ideal as there was still a shallow and thin layer of fog around. However, the weather conditions do not seem to have impaired the calibrations and better weather conditions were not expected anytime soon.

Daily work and maintenance

As a daily routine, we checked each day (mostly in the morning) whether all instruments and backups were running as intended. Images taken by the GoPro Hero 11 Black had to be manually extracted each day by taking out the SD card and replacing it by another one. The images were then renamed according to their GPS time stamp and resized to save disk space. Additionally, we noted the time offsets of the radiometers and radars with respect to their host software and the offsets between the host software and the laptops where the software were running. During the expedition, all laptops where instruments were operated were well synchronised with the ship's time server. Quick looks of the data were generated for quality control.

Each day, we checked whether the lenses of the FLIR A315, the GoPro Hero 11 Black and the total sky imager require cleaning, whether the radomes on the radars and MWRs were intact and whether the heaters and blowers were functioning. The cleaning of the radomes may have caused brief brightness temperature outliers that need to be flagged. We manually dried the radome of GRaWAC on 31 July at 09:25 UTC and on 14 August at 08:50 UTC because water droplets accumulated on the far side of the radomes away from the blowers. Parts of the MWR radomes had to be manually dried on 3 August at 09:08 UTC and on 17 August at 10:47 UTC. Ice had accumulated on the surface-facing sides of the MWR radomes on 19 August that was carefully removed over the day.

Data availability

All instruments operated nearly continuously while *Polarstern* was within the sea ice. The daily sample count, relative to nominal sampling frequency, was close to 100 % on most days (Fig. 3.2.3). Most data gaps were connected to maintenance due to issues with the power connection. HATPRO lost connection on 31 July at 18:02:09 UTC because a fuse blew as a consequence of a short circuit when the power connector became soaked during strong rainfall. The short circuit may have damaged the noise diode used for internal calibrations. However, the quality of the measurements did not seem to be affected until the end of the expedition. The maintenance caused several data gaps until 3 August, 16:44 UTC when we tested different power cables, replaced one cable by a spare item and improved the weather protection of the power cables.

Similarly, MiRAC-P's power supply also got wet around the same time and resulted in several data gaps, of which the largest was due to a short circuit from 3 August from 14:43 UTC to 15:35 UTC. Also, the weather station attached to MiRAC-P seems to have been damaged during the rain event that caused the short circuits because its relative humidity sensor showed faulty measurements after 1 August, 21:00 UTC. Short MiRAC-P data gaps between 2 August, 10:03 UTC and 3 August, 16:58 UTC were related to the maintenance of HATPRO during this time. As the MWRs were turned off for several hours the data quality between these power losses and the absolute calibrations on 6 August may be impaired.

Other data gaps in the MWRs and radars were related to calibration or data connection loss. The measurements of the MWRs during "surface" measurement mode may also require further quality checks and events that impaired the data quality should be flagged (e.g., sun reflection during clear sky days, sudden changes in the ship's roll angle).

Water in the power connector at the protective housing of the Mobotix total sky imager caused data gaps from 9 July at 04:03 UTC to 12 July at 16:52 UTC and from 19 August at 11:51 UTC to 20 August at 10:21 UTC.

GoPro measurements between 14 July, 09:02 UTC and 15 July, 08:50 UTC require additional data processing because the wrong settings were selected after the camera had unexpectedly turned off. The alignment of the GoPro is slightly off between 1 August, 11:36 UTC and 5 August, 12:23 UTC.

GRaWAC's radar time synchronisation compared to the host computer degraded from 23 August on. On 25 August, the time difference was already 10 s when we tried solving it by restarting the radar software operating on the computer inside the radar. However, the connection was not reestablished after restarting the software. The connection loss resulted in several data gaps on 25 August between 11:14:30 and 16:58:47 UTC and could only be resolved by directly connecting a screen and a mouse to the internal computer.

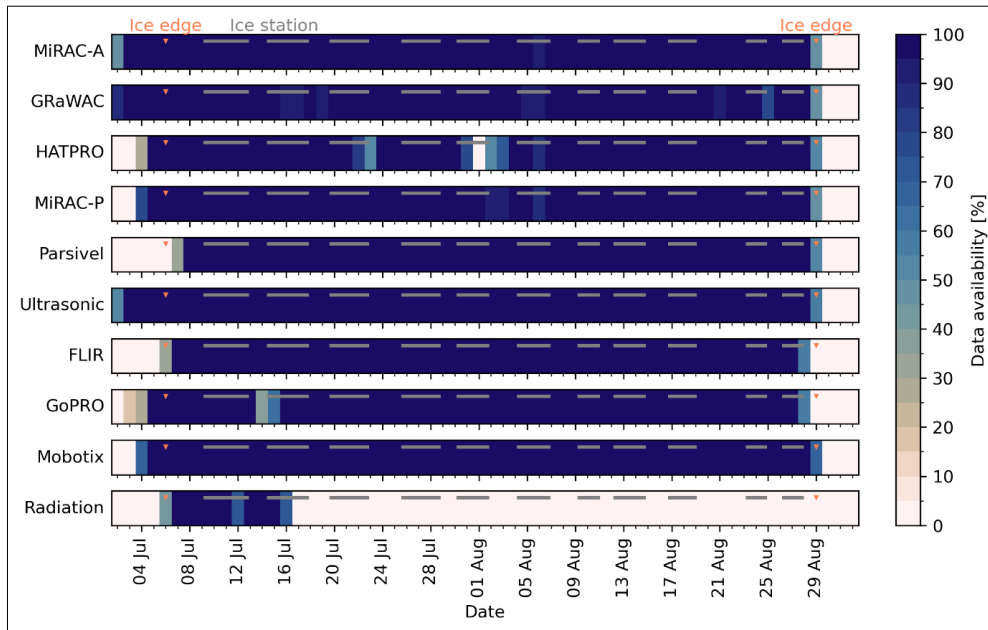


Fig. 3.2.3: Data availability of the underway devices installed on the lower and upper Peil decks and the bow mast. Shown over the course of the expedition from 2 July to 1 September 2025. Symbols indicate the ice edge and ice stations.

Preliminary (expected) results

Atmospheric measurements

The measurements from HATPRO and MiRAC-P provide temporally highly resolved (approx. 1 s) information on the vertically integrated water vapor (IWV), the total column cloud liquid (liquid water path (LWP)), as well as temperature and humidity profiles with a coarse vertical resolution. We applied a simple regression retrieval to the HATPRO measurements (Walbröl et al., 2022) and used also the synergistic retrieval combining HATPRO and MiRAC-P measurements (Walbröl et al., 2024) to derive the meteorological quantities listed above. Evaluating both retrievals with measurements from the radiosondes launched during the expedition (see Chapter 3.1) showed that the synergistic retrieval performed better than the HATPRO regression retrieval and that the errors are well within the expected range.

Figure 3.2.4 provides an overview over the MWR products over the campaign period and shows the radiosonde measurements for comparison. The first half of the expedition was characterised by relatively homogenous atmospheric conditions with IWV values mostly between 8 and 14 kg m⁻² until the second visit of regime 2 (2b, around 31 July). Figure 3.2.4 a also demonstrates the excellent agreement of the IWV between radiosondes and the MWR product. Only two very brief intrusions of moister and warmer air masses were observed on 11 and 24 July that increased the IWV up to 20 kg m⁻². The second half of the expedition started with much warmer and moister conditions, which is evident in all retrieved quantities and in the

radiosonde observations. The IWV was almost permanently above 15 kg m^{-2} and peaked at 29 kg m^{-2} on 4 August. Also, the liquid water path (LWP) denoted the highest values during this period (Fig. 3.2.4 b). Strong temperature inversions persisted in the first two weeks of August with temperatures around 0°C at the surface and partly more than 10°C at a few hundred meters height (Fig. 3.2.4 d, f). The MWRs also resolve the near-surface specific humidity inversion that can be seen in the radiosonde data (e.g., around 10 August).

The cloud radars MiRAC-A and GRaWAC provide reflectivity and Doppler velocity of cloud hydrometeors up to heights of 10 km, with a high temporal resolution, and the vertical resolution varying between 8.4 m and 44.4 m, depending on device and height. Through the combination of both radars sampling the same volume, we can detect cloud regions with smaller droplet sizes, an identifying factor of supercooled liquid droplets. The dual-frequency measurements of GRaWAC near the water absorption line at 183 GHz also allows for vertical profiling of water vapor.

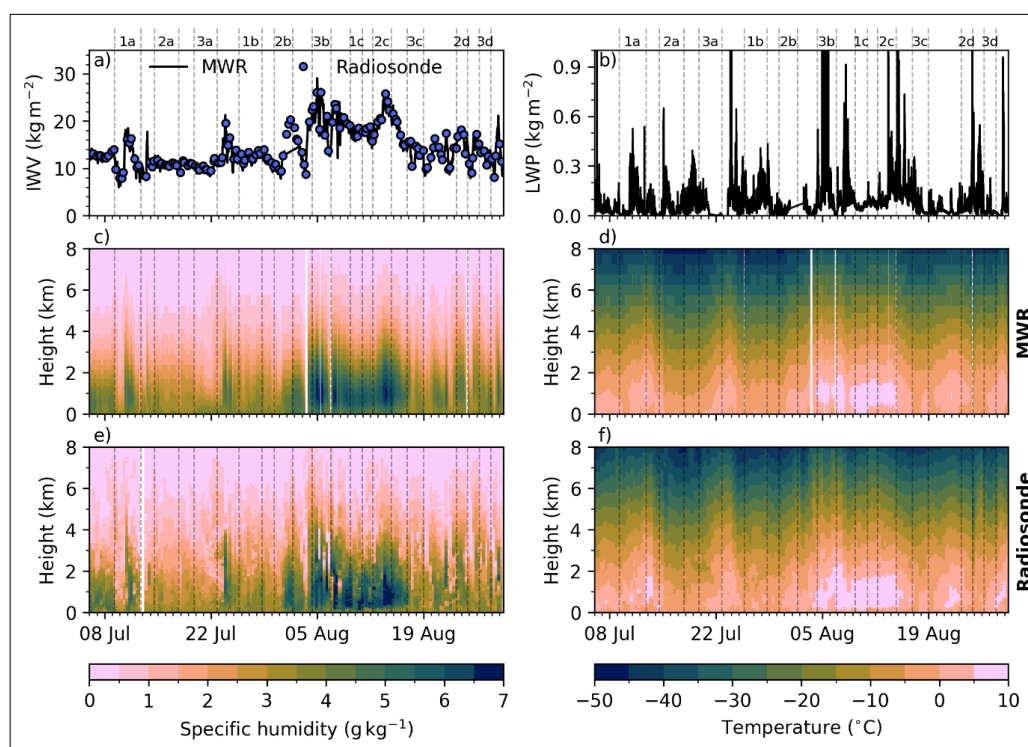


Fig. 3.2.4: Overview of retrieved quantities from the microwave radiometers HATPRO and MiRAC-P over the campaign period in comparison to radiosonde measurements. (a) integrated water vapor (IWV), (b) liquid water path (LWP), (c) and (d) specific humidity and temperature profiles from the MWRs, and (e) and (f) specific humidity and temperature profiles from the radiosondes, respectively. The dashed vertical lines indicate the start and end times of ice stations.

Figure 3.2.5 shows a case study of a mixed-phase cloud, with the radar reflectivities at 167.3 and 94 GHz (a and b) showing a stable cloud top at 1400 m, with updrafts in the upper 200 m, also visible in the Doppler velocity (e), where positive values indicate an upward movement of hydrometeors. Larger dual-frequency ratio (c) indicates larger hydrometeors. However, both liquid and gas attenuation in the different bands are not yet considered here, which will be calculated from the Differential Absorption Radar signal (d), the radiometer retrievals, and the frequently launched radiosondes (see Chapter 3.1).

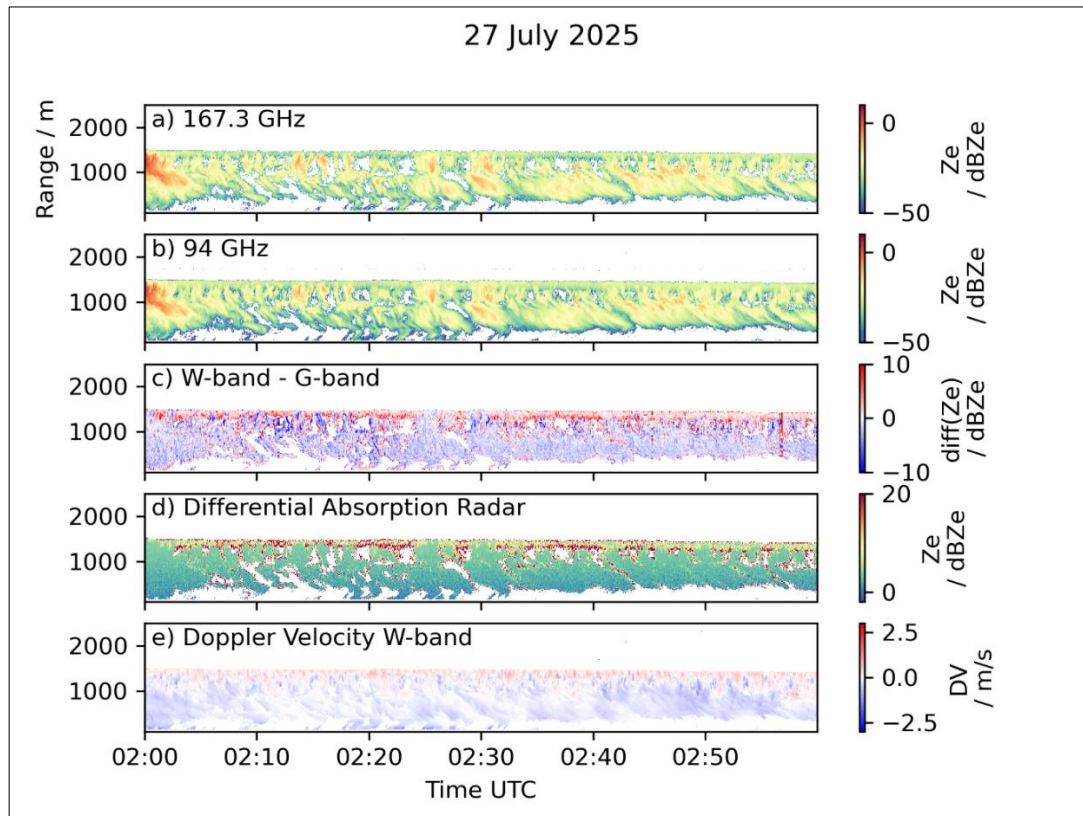


Fig. 3.2.5: Cloud radar measurements of (a) and (b) GRaWAC (167.3 GHz) and MiRAC-A (94 GHz) radar reflectivity, respectively, (c) dual wavelength ratio between MiRAC-A and GRaWAC reflectivities, (d) Differential Absorption Radar of GRaWAC, and (e) MiRAC-A Doppler velocity for a case study on 27 July from 02:00 to 03:00 UTC. Shown here are only measurements up to a height of 2500 m.

The data quality of the atmospheric observations looks promising to serve as reference data for various validation efforts (e.g., within the Global Energy and Water Exchanges (GEWEX) Water Vapor Assessment (G-VAP II) and to validate satellite products and reanalyses). For example, the MiRAC-A measurements will be compared with the space-borne radar measurements of EarthCARE. The large variety of cloud regimes observed during the expedition (ranging from low-level stratus to deep precipitating systems or only cirrus) also offer a great opportunity to test the in-cloud water profiling capabilities of GRaWAC that can be evaluated with the radiosonde and MWR measurements.

Surface microwave emission measurements

With the ice surface measurements from this expedition, we aim to increase the knowledge on the impact of the evolution of the sea ice and surface scattering layer over different time scales and for different ice regimes on the emissivity in the microwave spectrum. Our measurements captured first-year ice, leads that likely refroze in late winter or spring, and thick multi-year ice. Each ice regime featured different surface characteristics over the repeated visits, ranging from being almost totally flooded by melt ponds to a thin surface scattering layer and thin layers of fresh snow.

Figure 3.2.6 provides an overview of the brightness temperature (TB) measurements averaged over 1 hour before the first sampling was performed close to the MWR footprint on day 1 of each ice station. Note that the measurements from regime 3, visit b and regime 2, visit c were strongly affected by old and fresh anthropogenic activities (human footprints, traces of pulkas,

sledges and ski-doo) and therefore do not represent natural ice conditions. Additionally, regime 1, visit c was not the same floe that was sampled during visits a and b. Regime 1 changed from strongly ponded to fresh snow surface conditions between visit a and b, which is reflected in the increase of the TBs at all frequencies (left and middle columns of Fig. 3.2.6). The MWR footprint of the regime 2 floe experienced the opposite development: From a shallow layer of fresh snow (visit a) to heavy melting conditions (visit b), the TBs strongly decreased (especially at 31.4 and 51.26 GHz, left and middle columns of Fig. 3.2.6). The strong changes in TBs observed for regime 3 between visit a and b at 240 GHz might be a combination of changes in sea ice emissivity and atmospheric conditions as the troposphere became much warmer and more humid towards visit b. The TB changes with respect to regime 3, visit b, regime 2, visit c and d, and regime 1, visit c to the other visits of the respective regimes must be analysed with care because we did not observe the same part of the ice floe (more details in the following subordinate topic).

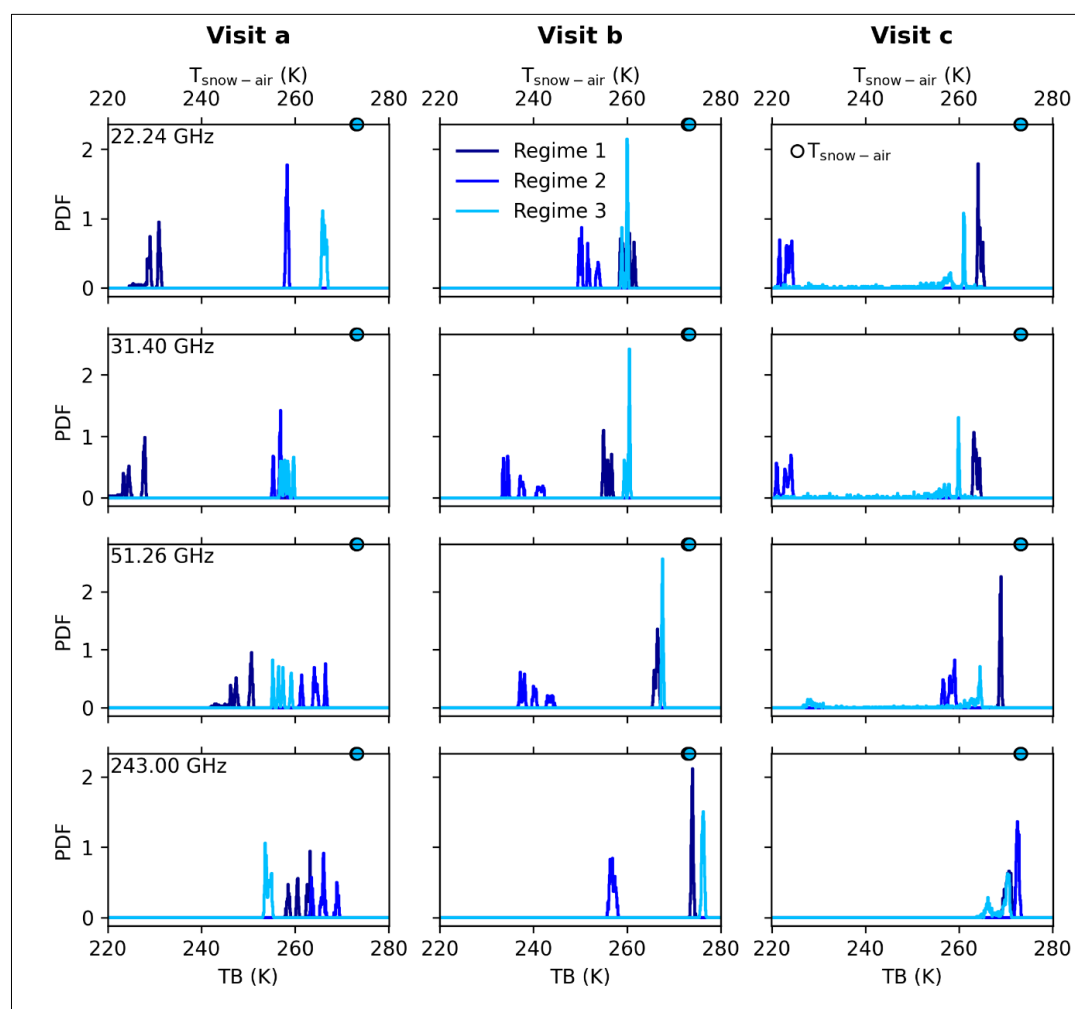


Fig. 3.2.6: Brightness temperatures (TB) at four frequencies (rows) averaged over 1 hour before the sampling on the first day of the visits a to c (columns) of each ice regime (colors). Colored circles indicate the average snow-air interface (skin) temperature sampled at each ice station close to the MWR footprint.

On 6 August, after the absolute calibrations, we performed measurements with an extended surface mode on from 19:13:24 to 19:34:57 UTC (19:13:12 to 19:35:06 UTC) for MiRAC-P (HATPRO) to observe the surface at a predefined region where we sampled the surface and ice core characteristics the days before. During this time, the ship was manoeuvred by the crew in such a way that the predefined region was in the footprint of the MWRs. We repeated this on 24 August from 15:34:36 to 16:19:41 UTC (15:34:19 to 16:19:50 UTC) for MiRAC-P (HATPRO), where we did not manage to capture the exact predefined region because another floe obstructed our path. However, we managed to measure in a footprint 5 to 10 meters apart from the original region which has similar surface characteristics. We also attempted a similar manoeuvre on 14 August between 17:26:50 and 17:32:52 UTC but did not successfully complete it because the predefined region broke apart.

Together with the observations of the downwelling atmospheric radiation at 127° and the skin temperature derived from the FLIR A315 measurements we will calculate the emissivity of the surface. However, further data processing – for example, filtering times when the MWR measurements of the ice were corrupted by human footprints and correcting the FLIR A315 measurements with the reference infrared targets (aluminium plates coated with Nextel Suede Coating 3101, 7329 S139 tiefschwarz) provided by Michael Haugeneder, Matthias Jaggi and Ruzica Dadic (Chapter 3.5) – is required and will be carried out after the expedition.

The extended data base of sea ice emissivities across different ice regimes that we observed during the expedition – both in transit for spatio-temporal variability and on station for detailed temporal variability – will be useful for current and future satellite missions that also use high-frequency microwave observations (e.g., Ice Cloud Imager, MicroWave Imager, AMSR3 or Arctic Weather Satellite).

Sampling snow and ice characteristics

As far as time and ship position allowed, we sampled the surface scattering layer or snow and sea ice characteristics on each day of each ice station near the footprint of the MWRs. The measurements close to the footprint are useful to relate the (micro)physical properties of the snow/surface scattering layer and ice to the brightness temperatures measured by the MWRs. The work on the sea ice started with a description of the general conditions (time, coordinates, weather conditions, 2 m temperature, 5 cm temperature), followed by measurements of the snow depth with a folding ruler (ID 5068), as well as the snow-air interface and ice-snow interface temperatures at up to 10 positions within a few metres. Afterwards, photos of the measurement site as well as of the snow/surface scattering layer were taken (Olympus E-M5II camera, ID 12070). The latter will be used to obtain the surface roughness using photogrammetry. We then used traditional snow pit techniques to sample the snow/surface scattering layer characteristics within the surface roughness area (temperature profile, density, grain size, grain type and hardness). Subsequently, the ice core was taken next to the snow pit with a 9 cm Kovacs Mark II corer (ID 12735). By drilling holes into the core with a 4 mm drill, we obtained temperature profiles of the core. Each temperature profile started at 2.5 cm depth and continued in steps of 5 cm until 17.5 cm, after which the next temperature was taken at 25 cm, followed by steps of 10 cm until the end of the core. After the temperature profile was sampled, the core was cut into pieces (5 cm thickness for depths between 0 and 20 cm, 10 cm thickness for depths beyond 20 cm) for density and salinity measurements. Afterwards, we measured the temperature and salinity of the water in the core hole. The salinity measurements were conducted with a Voltkraft LWT-100 salinometer (ID 6184). With an ice thickness gauge (ID 6179) we then measured the distance from the ice bottom to the water-air interface, to the ice-snow interface and the snow-air interface. These observations also allow us to estimate the freeboard and snow/surface thickness. Finally, we lower a GoPro Hero 10 Black (ID 12069) attached to a 4 m selfie stick into the core hole to record the under-ice topography around our sampling site.

Additionally, we used a Stevens HydraProbe Soil Sensor (ID 12071) to obtain the dielectric properties of the snow/surface scattering layer and of the upper and lower parts of the ice core. During the transit in between ice stations, we measured the salinity of the ice cores with the above mentioned Voltkraft LWT-100 salinometer as soon as they were fully melted. We noticed a discrepancy of the salinity, temperature and conductivity measurements between our device and the WTW Cond 3110 used in Chapter 2.11. For example, one core piece showed a temperature, salinity and conductivity of 20.2 °C, 2.7 PSU and 4410 µS, respectively, while the the Cond 3110 showed 19.5 °C, 3.6 PSU and 6550 µS, respectively.

Table 3.2.2 provides an overview of the samples taken at each ice station. On day 3 during ice station 3a (ID: 18-1) and 3b (ID: 30-1) and on day 2 during ice station 2d (ID: 46-1), we could only obtain ice core density/salinity samples for the upper quarter of the ice core because we ran out of boxes due to the thick ice. However, the lower parts of the ice core are also less relevant for the sea ice emissivity at the frequencies of our MWRs.

For ice stations 2c (ID: 36-1) and 3b (ID: 30-1), we did not sample the surface and ice characteristics close to the MWR footprint because the surface had been destroyed by fresh and past human activities related to the current and previous visits. During these ice stations, ice station logistics and safety did not allow us to have the ship positioned in a way to give us an undisturbed surface. Instead, we defined a region where we could sample the surface and ice characteristics and have the ship positioned in such a way that the MWRs observed this region for a few minutes right before departing from the ice station. This manoeuvre was successfully conducted on 6 August between 19:13 and 19:35 UTC (as noted above).

On ice station 2d (ID: 46-1), new sheet ice formed in the MWR footprint. We were able to sample fresh ice by rowing there on a zodiac. However, this was not possible for several days in a row, so we additionally selected a remote region where we sampled first and then had the ship manoeuvred so that we measured in the selected area. The MWR footprints where we measured on 24 August from 15:34 to 16:19 UTC was approximately 5 to 10 meters away from the original region we sampled but both had similar surface characteristics.

Tab. 3.2.2: Overview of the surface and sea ice samples taken on each day at each ice station

Station ID	Day number	Start time	End time	Surface roughness	Snow pit	Ice core temperature	Ice core density/salinity
13-1	1	2025-07-09 17:48	2025-07-09 18:56	No	No	Yes	Yes
	2	2025-07-10 12:50	2025-07-10 14:10	No	No	Yes	Yes
	3	2025-07-11 09:18	2025-07-11 11:03	Yes	Yes	Yes	No
16-1	1	2025-07-15 13:25	2025-07-15 15:05	Yes	Yes	Yes	Yes
	2	2025-07-16 12:50	2025-07-16 15:09	Yes	Yes	Yes	Yes
	3	2025-07-17 09:02	2025-07-17 09:52	Yes	Yes	No	No
18-1	1	2025-07-20 12:55	2025-07-20 15:15	Yes	Yes	Yes	Yes
	2	2025-07-21 12:47	2025-07-21 15:34	Yes	Yes	Yes	Yes
	3	2025-07-22 12:40	2025-07-22 14:21	Yes	Yes	Yes	Yes

Station ID	Day number	Start time	End time	Surface roughness	Snow pit	Ice core temperature	Ice core density/salinity
21-1	1	2025-07-26 12:42	2025-07-26 14:25	Yes	Yes	Yes	Yes
	2	2025-07-27 12:42	2025-07-27 14:11	Yes	Yes	Yes	Yes
	3	2025-07-28 09:15	2025-07-28 10:48	Yes	Yes	Yes	Yes
25-1	1	2025-07-30 13:03	2025-07-30 14:22	Yes	Yes	Yes	Yes
	2	2025-07-31 13:03	2025-07-31 14:22	Yes	Yes	Yes	Yes
	3	2025-08-01 12:52	2025-08-01 14:00	Yes	Yes	Yes	Yes
30-1	1	2025-08-04 12:52	2025-08-04 14:17	Yes	Yes	Yes	Yes
	2	2025-08-05 12:43	2025-08-05 14:02	Yes	Yes	Yes	Yes
	3	2025-08-06 10:21	2025-08-06 11:27	Yes	Yes	Yes	Yes
32-1	1	2025-08-09 15:52	2025-08-09 17:05	Yes	Yes	Yes	Yes
	2	2025-08-10 12:42	2025-08-10 13:52	Yes	Yes	Yes	Yes
36-1	1	2025-08-12 13:37	2025-08-12 14:59	Yes	Yes	Yes	Yes
	2	2025-08-13 12:41	2025-08-13 13:44	Yes	Yes	Yes	Yes
	3	2025-08-14 12:40	2025-08-14 14:23	Yes	Yes	Yes	Yes
41-1	1	2025-08-16 20:45	2025-08-16 21:57	Yes	Yes	Yes	Yes
	2	2025-08-17 12:42	2025-08-17 13:59	Yes	Yes	Yes	Yes
	3	2025-08-18 14:31	2025-08-18 16:56	Yes	Yes	Yes	Yes
46-1	1	2025-08-23 13:40	2025-08-23 14:22	Yes	No	No	No
	2	2025-08-24 12:41	2025-08-24 14:57	Yes	Yes	Yes	Yes
47-1	1	2025-08-26 12:42	2025-08-26 15:18	Yes	Yes	Yes	Yes
	2	2025-08-27 12:42	2025-08-27 14:08	Yes	Yes	Yes	Yes

Figure 3.2.7 shows the temperature, salinity and density measurements of the ice cores taken at each ice station. The ice cores taken in regime 3 are much thicker than those in regimes 1 and 2 because the latter were sampled in younger ice. One exception is the last day of the final visit of regime 2 where we took a core at a pressure ridge with an ice thickness of 319

cm. Consistent with the observations from Chapter 2.11 we can identify a desalinification and reduction of the density of the cores over time (middle and right column). The highest salinities we measured during the expedition were 4.2 PSU on 9 July (first day of the first visit of regime 1, ID: 13-1) and more than 5 PSU while sampling 1-2 cm thick nilas ice on 23 August (first day of the final visit of regime 2, ID: 46-1). In contrast, the salinity of the cores taken during the third and fourth visit of regime 3 barely reached 2 PSU. For regime 3, we also see a temperature increase over time that agrees with the observations shown in Chapter 2.11. The temperature tendencies are less clear for regimes 1 and 2 because we couldn't sample the same area over all visits because the area had either melted or disintegrated.

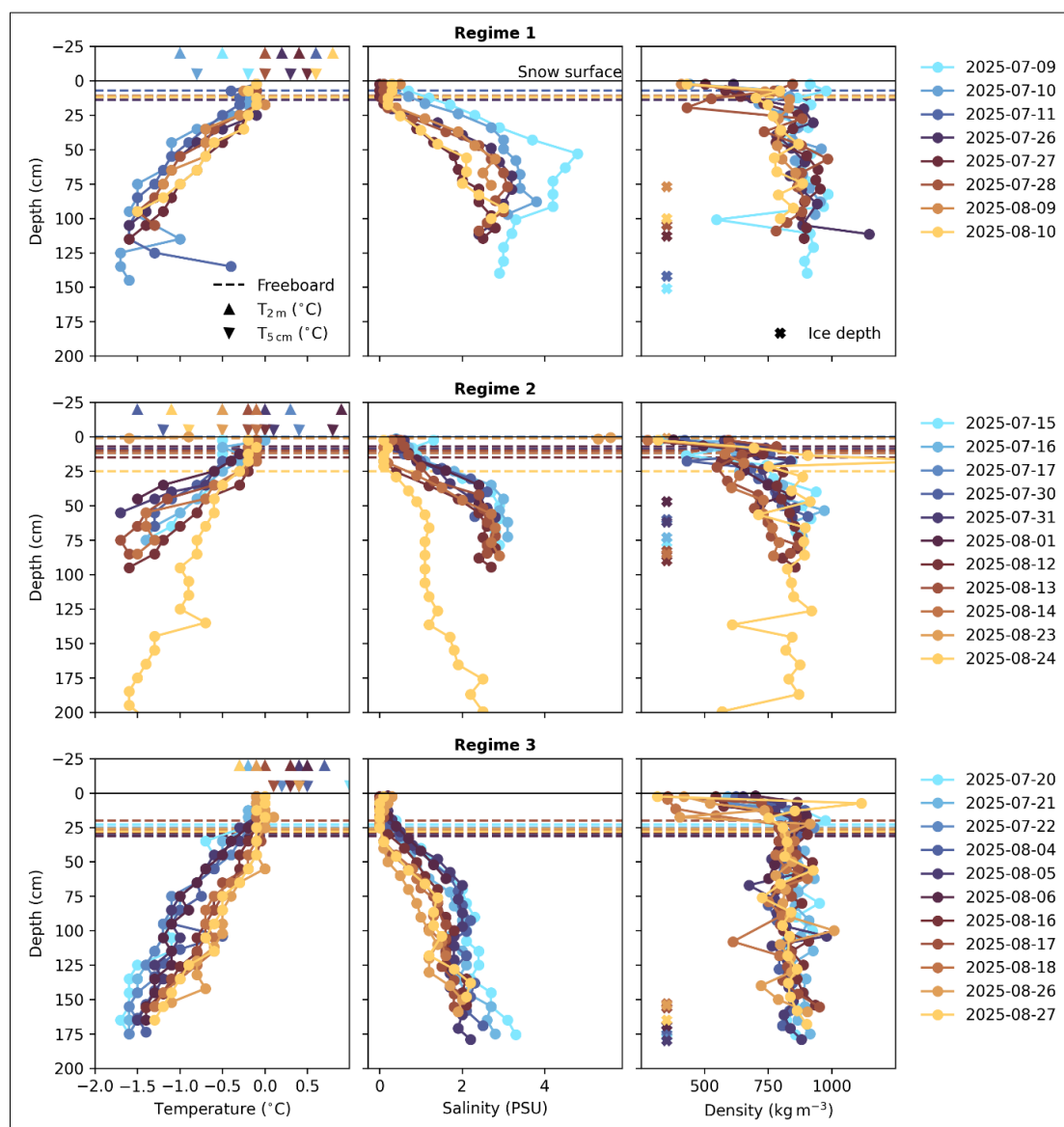


Fig. 3.2.7: Temperature, salinity and density (left, middle and right columns) of the uppermost 2 m of the ice cores taken during the ice station days (colors) in each regime (rows). The respective ice station ID can be inquired using the dates in the legend and Table 3.2.2. Dashed lines indicate the freeboard while upward (downward) pointing triangles show the 2 m (5 cm) temperature. The crosses show the total depth of the ice.

3.3 Autonomous measurements of surface turbulent heat fluxes and radiation components

Work at sea

During Ice Stations 1a, 2a, and 3a, autonomous Surface Energy Balance (SEB) towers were deployed in “MET-City” at an approximately representative location on each floe, about 20–30 m next to a 10 m met tower (see chapter 3.4). Each station measured at a height of 3 m and included:

- An ultrasonic anemometer (Campbell CSAT3B) combined with an open-path infrared gas analyzer (Licor LI7500RS) for turbulent energy flux densities.
- A net radiometer (CNR4) for upward and downward shortwave and longwave radiation flux densities.

The instruments were mounted on opposite sides of a crossbar. An inertial navigation system (INS SBG EllipseD) was installed on the anemometer housing to track heading, tilt, movement, and location, aided by two antennas attached to the crossbar. The base consisted of a 3 m telescope Campbell mast.

Net radiometer data along with anemometer tilt, INS measurements, and logger data were recorded every two seconds with a CR6 datalogger (Campbell). The anemometer wind vectors and sonic temperature, as well as the gas analyzer H_2O and CO_2 concentrations were recorded with a frequency of 20 Hz. Data was saved to an SD card hourly. The setups remained on the floes for the further expedition and were powered by a fuel cell power supply (EFOY Pro-Cube).

During ice stations 1c, 2d and 3d, an additional mobile net radiation sensor (CNR4) was deployed during the visit of the ship including two measurements located 50 cm above a melt pond (2d and 3d) close to MET-City.



Fig. 3.3.1: SEB tower after deployment at Ice Stations 1a (left), 2a (center) and 3a (right). Photos: Florian Gebhardt/DE.AWI

For the locations of the SEB towers, sites were chosen that were representative for the ice regime of that floe and on the other hand, offered a safe and stable ground for the tower. Therefore, one may compare the measured energy fluxes to the measurements above ponds for stations that had a higher melt pond fraction. During ice station 2c, the tower was moved to thicker ice, since the original site melted to very low ice thickness.



Fig. 3.3.2: Left photo: SEB tower after deployment at ice stations 1a – Florian Gebhardt/DE.AWI. The CNR4 net radiation sensor is facing the camera. The tower was located next to a refrozen lead (right) including some ponds and a small ridge (behind the tower). The area was dominated by flat undeformed first-year ice. Right photo: a drone picture during ice station 1b – Sandro Dahlke/DE.AWI. The small ridge is visible on the right-hand side, while the ice surface had brightened and the ponds inside the refrozen lead had deepened.



Fig. 3.3.3: Left photo: SEB tower after deployment at ice stations 2a – Florian Gebhardt/DE.AWI. The CNR4 net radiation sensor is pointing to the right. The tower was surrounded by melt ponds but was standing on thick ice. Right photo: a drone picture during ice station 2b – Sandro Dahlke/DE.AWI. The melt pond had deepened and extended towards the tower. At the bottom left there was an elevated spot of about half a meter height. The larger area was also dominated by melt ponds, but also medium-sized ridges as seen in Figure 3.3.1 (center).

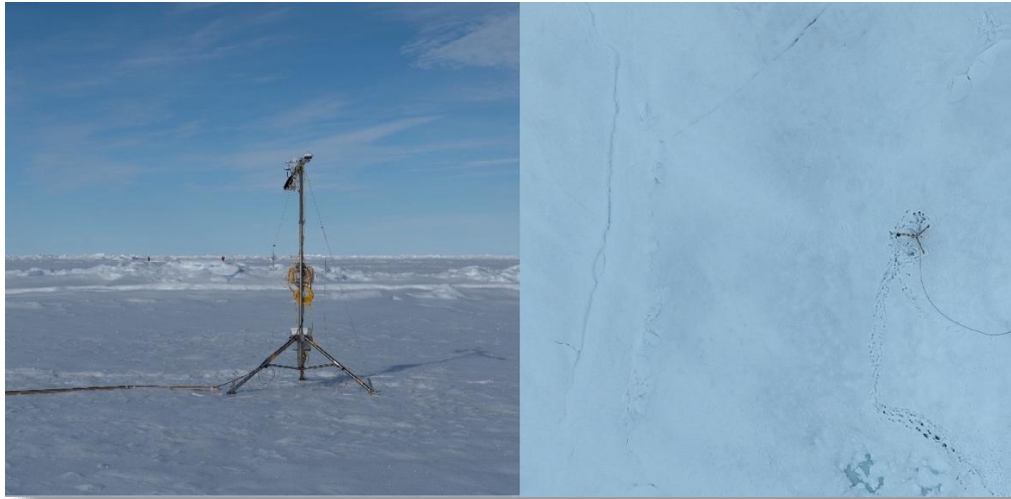


Fig. 3.3.4: Left photo: SEB tower after deployment at Ice Stations 3a – Florian Gebhardt/DE.AWI. The CNR4 net radiation sensor is facing the camera. The tower was surrounded by relatively thick ice. A major ridge with a maximum height of about 2 m was located approximately 10 m behind the tower. As the sonic anemometer was pointing towards that ridge, its effects on the flow dynamics is sampled. Right photo: a drone picture during ice station 3a – Sandro Dahlke/DE.AWI. The ridge is visible in the left-hand side of the image.

Tab. 3.3.1: List of device operations on the SEB station measurements

Event Label	Date/Time start	Date/Time end
PS149_13-1_ellipse_d1-1a	2025-07-10T19:53:00	2025-07-25T20:18:00
PS149_13-1_cnr4_1-1a	2025-07-10T19:53:00	2025-07-25T20:18:00
PS149_13-1_LB_LI7500RS_SN75H_3960-1a	2025-07-10T19:53:00	2025-07-25T20:18:00
PS149_13-1_CSI_CSAT3B_SN2121-1a	2025-07-10T19:53:00	2025-07-25T20:18:00
PS149_16-1_ellipse_d2-2a	2025-07-17T15:30:00	2025-08-12T13:00:00
PS149_16-1_cnr4_2-2a	2025-07-17T15:30:00	2025-08-12T13:00:00
PS149_16-1_LB_LI7500RS_SN75H_3023-2a	2025-07-17T15:30:00	2025-08-12T13:00:00
PS149_16-1_CSI_CSAT3B_SN1428-2a	2025-07-17T15:30:00	2025-08-12T13:00:00
PS149_36-1-ellipse_d2-2c	2025-07-12T17:30:00	2025-08-24T12:42:00
PS149_36-1-cnr4_2-2c	2025-07-12T17:30:00	2025-08-24T12:42:00
PS149_36-1-LB_LI7500RS_SN75H_3023-2c	2025-07-12T17:30:00	2025-08-24T12:42:00
PS149_36-1-CSI_CSAT3B_SN1428-2c	2025-07-12T17:30:00	2025-08-24T12:42:00
PS149_18-1_ellipse_d3-3a	2025-07-21T17:00:00	To be recovered on PS150
PS149_18-1_cnr4_3-3a	2025-07-21T17:00:00	To be recovered on PS150
PS149_18-1_LB_LI7500RS_SN75H_2656-3a	2025-07-21T17:00:00	To be recovered on PS150
PS149_18-1_CSI_CSAT3B_SN1365-3a	2025-07-21T17:00:00	To be recovered on PS150

Preliminary (expected) results

The described measurement setup of the SEB-towers described above allows the continuous observation of turbulent exchange of heat and moisture as well as radiative fluxes in shortwave and longwave that are the major parts of the SEB of the sea ice.

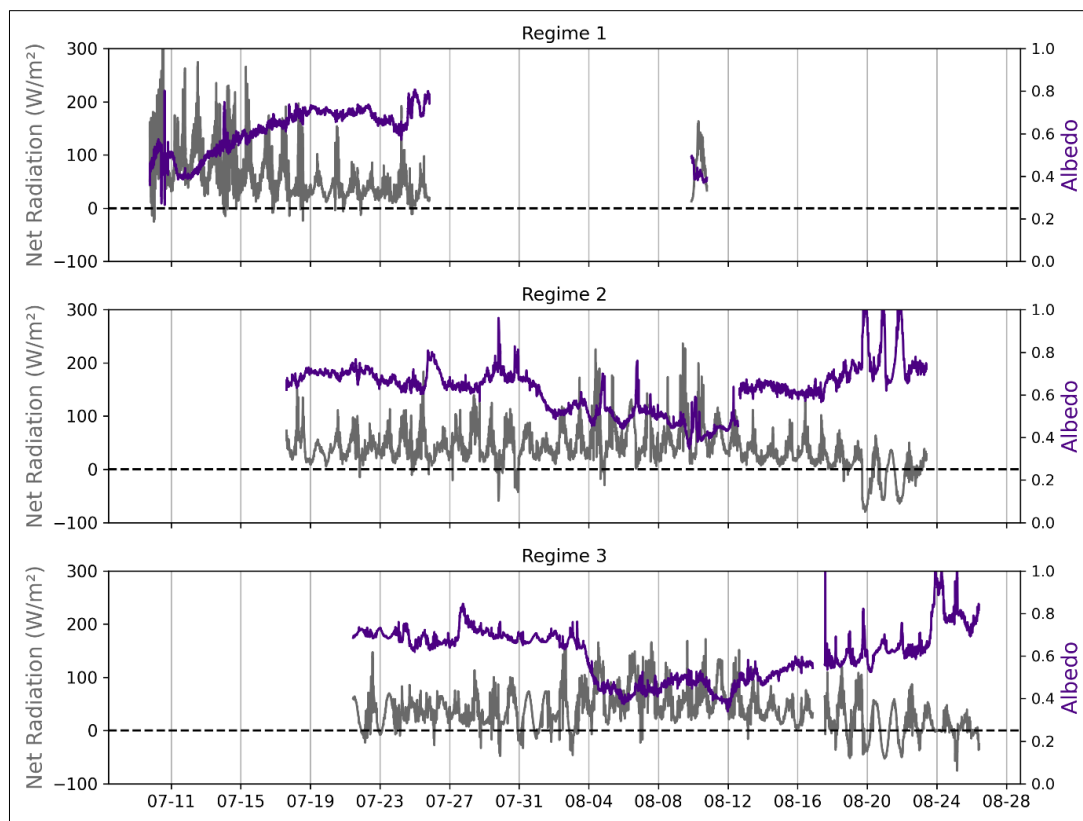


Fig. 3.3.5: The full time series of net radiation (grey) for all ice regimes and albedo (indigo). In regime 1, the original floe until 1b was measured and a short period of about one day was measured at 1c. In regime 2, the tower had to be moved which can be seen in the sudden shift in albedo after 16 August.

The net radiative energy (Figure 3.3.5) that is received by the surface is dominated by diurnal variation of incoming solar radiation where the strongest peaks often coincide with clear-sky and sunny conditions. Second dominating factor is the surface reflectivity that is closely related to the micro-structure of the surface layer and to the occurrence of snow events. The steady increase of albedo during the first half of the measurement period at ice station 1 is likely connected to a surface brightening due to the development of a surface scattering layer. This was also seen by the camera buoy and accompanied by a deepening and thus darkening of the melt ponds. Ice station 2 and 3 had already been relatively bright with a surface scattering layer on the ice (see Figure 3.3.1).

A sudden increase of surface reflectivity often indicates a snow fall event that shifts albedo to values above 0.8. Our data shows albedo peaks on 25 July at ice station 1, on 26 July at ice station 2 and on 27 July at station 3 that are likely the result of the same synoptic weather feature. The synoptic analysis of the respective days reveals a northward passing low with a passing occluded front north of it that could explain the westward passing snow precipitating area. Sharp peaks in albedo that can be seen at ice station 2 and ice station 3 are not necessarily snow events and can be due to measurement errors caused by direct sunlight into the downward facing sensor during times with low solar zenith angles. On the evening of 8

August at ice station 2 the tower had to be relocated due to the very low ice thickness at the original site. The thicker ice of the new location has a significantly higher albedo which explains the sudden shift from around 0.4 to 0.6.

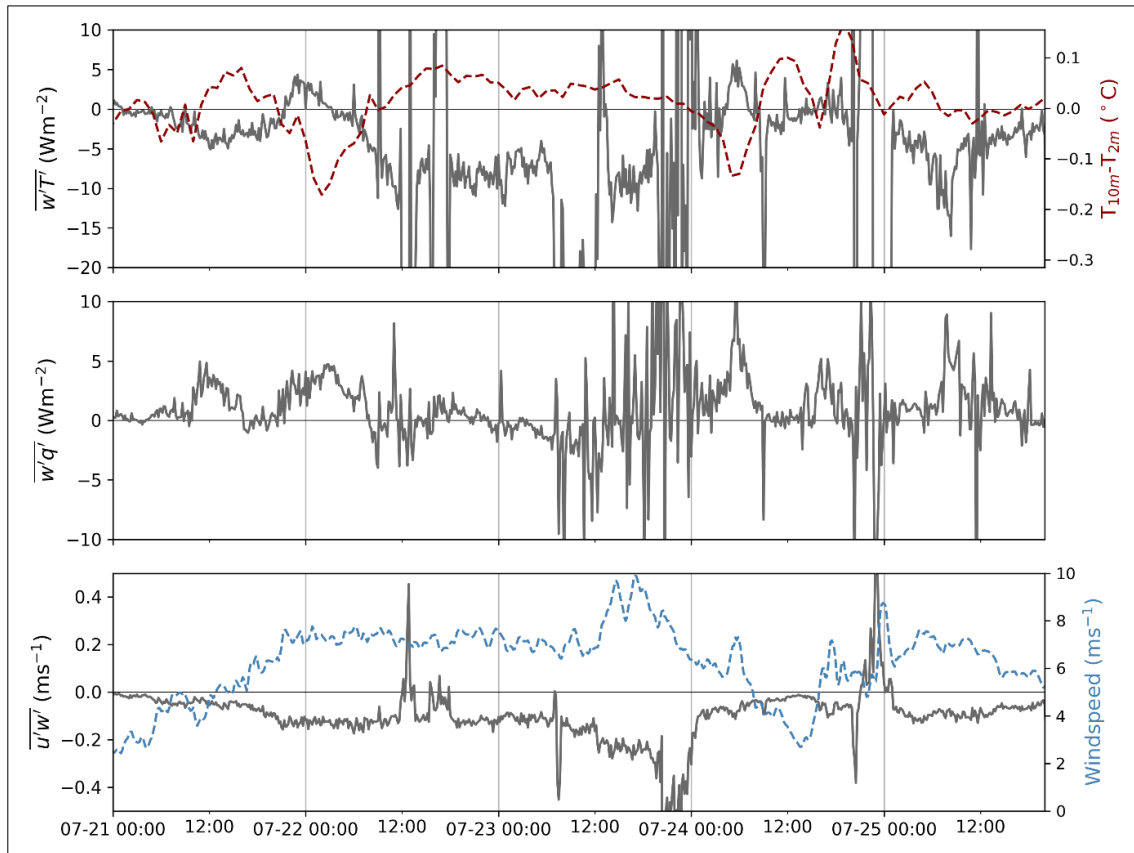


Fig. 3.3.6: Preliminary results of turbulent fluxes (positive upwards) at regime 1 based on high frequency sonic anemometer and gas analyzer. For this figure, Reynold's decomposition was based on 3 min averages and double-rotation of the 3d-wind components was based on 20 min running means. However, this might change in the final dataset where further corrections such as despiking and directional flagging will be applied. The temperature difference was measured by the 10 m tower.

The measured turbulent fluxes (Fig. 3.3.6, upper panel) were small since the lower boundary layer was mostly neutrally stratified which is a common feature of the Arctic summer. However, the small temperature differences between 10 m and 2 m level at the 10 m tower correlated well with the observed sensible heat fluxes. Positive temperature differences caused small negative (downward) fluxes and vice versa. Latent heat fluxes (Fig. 3.3.6, center) were mostly positive since moisture was taken up over the melting ice. Momentum fluxes (Fig. 3.3.6, lower panel) were usually negative caused by standard vertical wind gradients. However, short periods of positive fluxes occurred that would indicate low level wind maxima such as during shallow low-level jets. Further analysis needs to be done to justify whether these periods are physical or artefacts.

3.4 Autonomous measurements of near surface temperature- and humidity profiles from a 10 m tower

Work at sea

On the first visit on each of the floes R1-R3, a 10 m mast was deployed in “MET City”, in approximately 100 m distance to the edge of the corresponding ice floes, and adjacent to a surface energy balance station (see chapter 3.3). At 2, 6, and 10 m above the surface, heated temperature and humidity probes (Vaisala HMP-155A) were mounted to the mast. Each sensor was further mounted in a Vaisala DTR-13 weather hut, in order to be shielded from solar heating. Photographs of these installations are provided in Figure 2.4.1, respectively. Air temperature and relative humidity were logged every 2 seconds and stored on a SD card. After initial installation, the towers remained on the ice, measuring continuously, and were powered by LiFePo4 battery sets.

On ice station 1a, the tower was installed on 10 July on sea ice with a thickness of approximately 160 cm. A few days after the second visit of the floe, the stations drifted into Russian territory, and the station could not be recovered. The last data were retrieved on 28 July, yielding approximately 18 days of data.

On ice station 2, the tower was installed on 16 July on sea ice with a thickness of approximately 110 cm. During the second visit of the floe it was apparent that the melting had endangered the tower, leaving it on only 50 cm thick sea ice and located only a few meters away from the new edge of the floe. Because of that, the tower was taken down and repositioned approximately 250 m to a more stable part of the floe (270 cm ice thickness). This resulted in a data gap of several hours between 12 and 13 August. The tower was finally dismantled and the last data retrieved on 24 August.

On ice station 3, the tower was installed on 22 July on sea ice with a thickness of approximately 270 cm. The tower was left on the floe after the end of this expedition, and will only be recovered on PS150. Last data retrieval on this cruise happened on 27 August.

Geographical locations of the towers were collected with an external device (Columbus P1 Mark II GNSS Data Logger), which took one measurement every 30 minutes.

Tab. 3.4.1: List of device operations for the measurements on the 10 m meteorological towers

Event Label	Date/Time start	Date/Time end	Altitude [m]
PS149_13-1_hmp155a_2mt1-1a	2025-07-10T19:16:58	2025-07-28T13:44:20	2
PS149_13-1_hmp155a_6mt1-1a	2025-07-10T19:16:58	2025-07-28T13:44:20	6
PS149_13-1_hmp155a_10mt1-1a	2025-07-10T19:16:58	2025-07-28T13:44:20	10
PS149_16-1_hmp155a_2mt2-2a	2025-07-16T13:45:54	2025-08-12T13:45:00	2
PS149_16-1_hmp155a_6mt2-2a	2025-07-16T13:45:54	2025-08-12T13:45:00	6
PS149_16-1_hmp155a_10mt2-2a	2025-07-16T13:45:54	2025-08-12T13:45:00	10
PS149_36-1-hmp155a_2mt2-2c	2025-08-13T10:20:52	2025-08-24T12:58:14	2
PS149_36-1-hmp155a_6mt2-2c	2025-08-13T10:20:52	2025-08-24T12:58:14	6
PS149_36-1-hmp155a_10mt2-2c	2025-08-13T10:20:52	2025-08-24T12:58:14	10
PS149_18-1_hmp155a_2mt3-3a	2025-07-22T11:00:00	To be recovered on PS150	2

Event Label	Date/Time start	Date/Time end	Altitude [m]
PS149_18-1_hmp155a_6mt3-3a	2025-07-22T11:00:00	To be recovered on PS150	6
PS149_18-1_hmp155a_10mt3-3a	2025-07-22T11:00:00	To be recovered on PS150	10

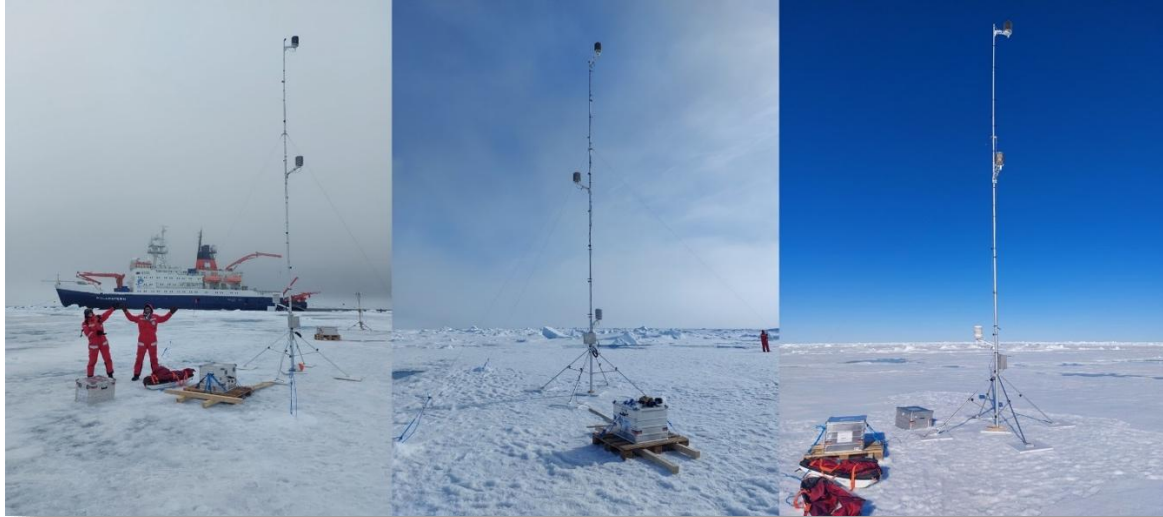


Fig. 3.4.1: 10 m meteorological towers with sensors at 2, 6, and 10 m above the ice. From left to right: R1 on July 12, 2025, R2 on July 16, 2025, and R3 on July 21, 2025. Photos: Sandro Dahlke/DE.AWI.

Preliminary (expected) results

The measurements of the 10 m towers will provide the backbone information of highest quality standard meteorological parameters, especially in the periods when the ship was away from the ice stations. While temperature variations and synoptic variability in the Arctic summer are considerably smaller than those during winter, the data give insight into the near surface meteorological conditions. Especially during the melt season, sea ice- and surface characteristics can be very sensitive even to small variations in temperature, which was around the melting point most of the time. Figure 3.4.2 shows time series of the first roughly two weeks of data after the installation of the 10 m towers. The data set illustrates the impact of synoptic variability, including warm periods, like in the beginning at Tower 1, as well as intermittent cold periods, often in relation to frontal systems of cyclones, which are picked up at different times at the different stations.

Relative humidity indicates how saturated the air is with respect to liquid water or ice surfaces, which can have large implications for latent processes. It can be seen that most of the time, the air is saturated at 100 %, but there are episodes of unsaturated air, which often indicate the absence of fog, low clouds or even correlate with clear sky conditions (e.g. 23 July at Tower 3).

Vertical temperature gradients give information about the static stability in the lowermost part of the atmospheric boundary layer above the sea ice. While these gradients are generally small in the summer season, and rarely exceed 0.5 °C in our case, they will prove useful when interpreting information on air pressure, wind speed and – direction, as well as turbulent fluxes of latent and sensible energy, that were measured in an adjacent station.

While the measurements of the 10 m tower are regarded quite robust, data should be interpreted with caution in periods of stale winds, when the sensors lack ventilation, as well as during periods of heavy icing on the weather huts and the sensors themselves.

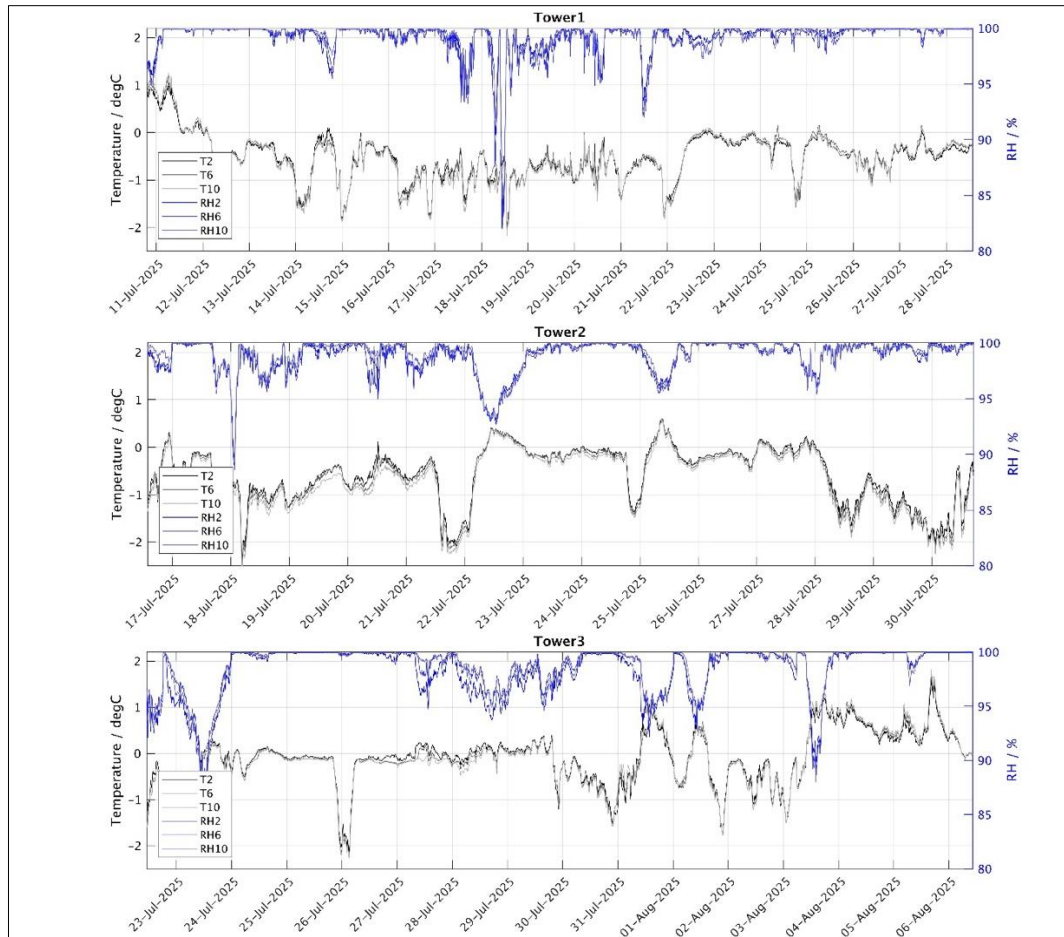


Fig. 3.4.2: Time series of the first approximately two weeks of data from each of the 10 m towers. Shown in red (blue) are temperatures (relative humidity) at 2,6, and 10 m height, respectively. Note the different time spans on the x-axis.

3.5 Mobile measurements of near surface turbulent heat fluxes over different surfaces

Work at sea

Our approach integrates high-resolution measurements of air and surface temperatures with wind and turbulence data collected at various atmospheric levels and diverse locations across the ice. This comprehensive data set allows us to gain more insight into the intricate processes within the near-surface atmospheric layer above the ice-covered areas as they interact with melt ponds and potential variability in surface morphology (e.g., ridges, leads, ponds). Our measurements, encompassing air and surface temperatures and turbulence data, serve as a valuable reference point for comparing and validating model results and help ensure that the models accurately represent the boundary layer processes over sea ice.

To measure atmospheric turbulence and heat exchange processes across different surfaces, we installed two mobile towers at distinct locations across a transition of surface morphology. Each tower carried a Campbell Scientific IRGASON (latent and sensible heat fluxes) at around 1 m above the surface and a Campbell Scientific CSAT3 at about 2 m above the surface. The setup of two towers furthermore allows us to estimate horizontal heat advection.



Fig. 3.5.1: Flux tower at the transition from lead to sea ice with an IRGASON at 1 m height and a CSAT3 at 2 m above the sea. Setup at station 1c. Photo: Michael Haugeneder/CH.WSL

We employed thermal imaging to investigate the spatio-temporal dynamics and stratification of the near-surface atmospheric layer above the ice and melt ponds. Our setup utilizes a high-resolution thermal Infrared camera (InfraTec VarioCam HD) aimed at synthetic screens. Changes in the surface temperature of these screens are indirect indicators of air temperature. This method has previously proven effective in studying atmospheric dynamics over patchy snow covers. This method aims to characterize the advection of sensible heat and the interaction with heat exchange processes. The camera will capture a sequence of frames at a rate of 30 Hz and provide a spatial resolution of 1024×768 pixels, which is essential for

capturing boundary layer dynamics. We set up two projection screens, a horizontal one with a height of 2 m and a length of 3 m and a vertical one with a height of 4 m and a length of 2 m across transitions in surface morphology (i.e. lead-sea ice, sea ice-pond, behind ridges). The screens were aligned with the prevailing wind direction. As a temperature reference, we also installed five thin-wire thermocouples at heights up to 2 m above the surface.



Fig. 3.5.2: Screen setup at the lead of station 1c. The wind blows from the ocean on the right over the ice. The thermal infrared camera pointing at the synthetic screens is shielded from direct radiation by the green tent. Photo: Michael Haugeneder/CH.WSL

In addition to the described setup, we deployed targets for aerial thermal infrared imagery. The targets are 3 mm thick aluminium plates coated with “Nextel Suede Coating 3101, 7329 S139 tiefschwarz” (emissivity 0.98). We brought three 50x50 cm² targets and eight 20x20 cm². Each of the targets has a PT1000 temperature probe mounted in the middle that can be connected to a logger box. We brought six different logger boxes (locations see in the map) that can log up to three targets each. For more information, check the events log and the AWI logbook.

Preliminary (expected) results

With our measurements, we strive at investigating the impact of heterogeneous surface morphologies (i.e. leads, ponds, bare sea ice, ridges) on the temperature stratification and turbulent exchange in the lowest meters of atmosphere adjacent to the surface. Generally, the surface temperature differences are low: Ice temperature is capped by the melting point, air directly adjacent to leads has a temperature close to the -1.8 °C of the ocean and temperatures of melt ponds are in the same ball park. However, we did measure changes in sensible and latent heat fluxes as shown in Fig. 3.5.3 for station 2a, where we deployed the setup close to the lead.

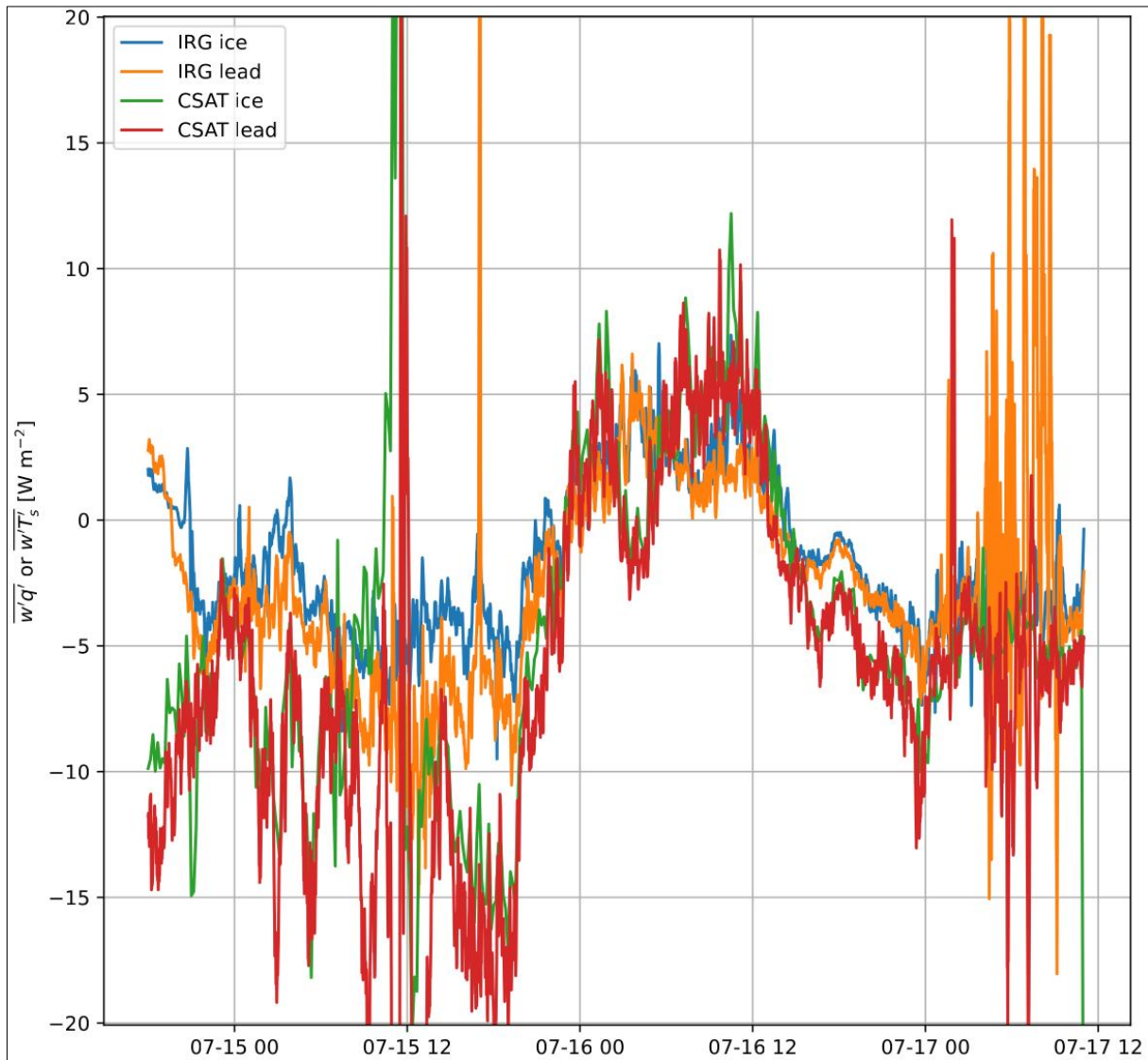


Fig. 3.5.3: Turbulent sensible (red and green) and latent (blue and orange) heat fluxes as measured on station 2a. The orange and the red curve were recorded over the lead, while the blue and the green curve were recorded about 20 m downwind over ice.

Besides the spiky artefacts that occurred due to very wet fog and water freezing at the sensors, fluxes range from -20 to $+10 \text{ W m}^{-2}$. We use the atmospheric notation here, labelling fluxes as negative (positive), when energy is transported into (out of) the surface. There is only little difference between the two tower locations (in this case, they were separated by about 20 m) and the respective instruments (orange and blue curve for latent heat fluxes at 1 m height, green and red curve for sensible heat fluxes at 2 m height). However, at the beginning of the measurement at station 2a and in the morning of 16 July, the latent heat fluxes at 1 m and the sensible heat fluxes at 2 m exhibit different directions. Furthermore, both sensible and latent heat fluxes are mostly negative except from the morning of 16 July. Although we need to investigate this more thoroughly, we assume that this is connected to the weather, as there was fog and low ceiling stratus in the morning of 16 July and clear sky otherwise. Connecting our measurements with the data from the 10 m tower (see Section 3.4), the surface energy balance station and other data collected at the ship, will help us to get a better overview.

To complement the point-based measurements described above, the IR screen setup adds spatial information on the near-surface temperature fields. Figure 3.5.4 depicts a screenshot of the measurements conducted directly at the lead edge on station 2a. A layer of colder air (blue colors) from over the lead is visible adjacent to the ice. Above, the air temperatures are about 1 °C warmer. The corresponding video visualizes the advection as cold air is constantly transported from the lead over the ice. With further analysis of the data, we aim at quantifying the influence of the lateral advection processes on the near surface atmosphere, by looking at mean vertical temperature profiles and variances thereof.

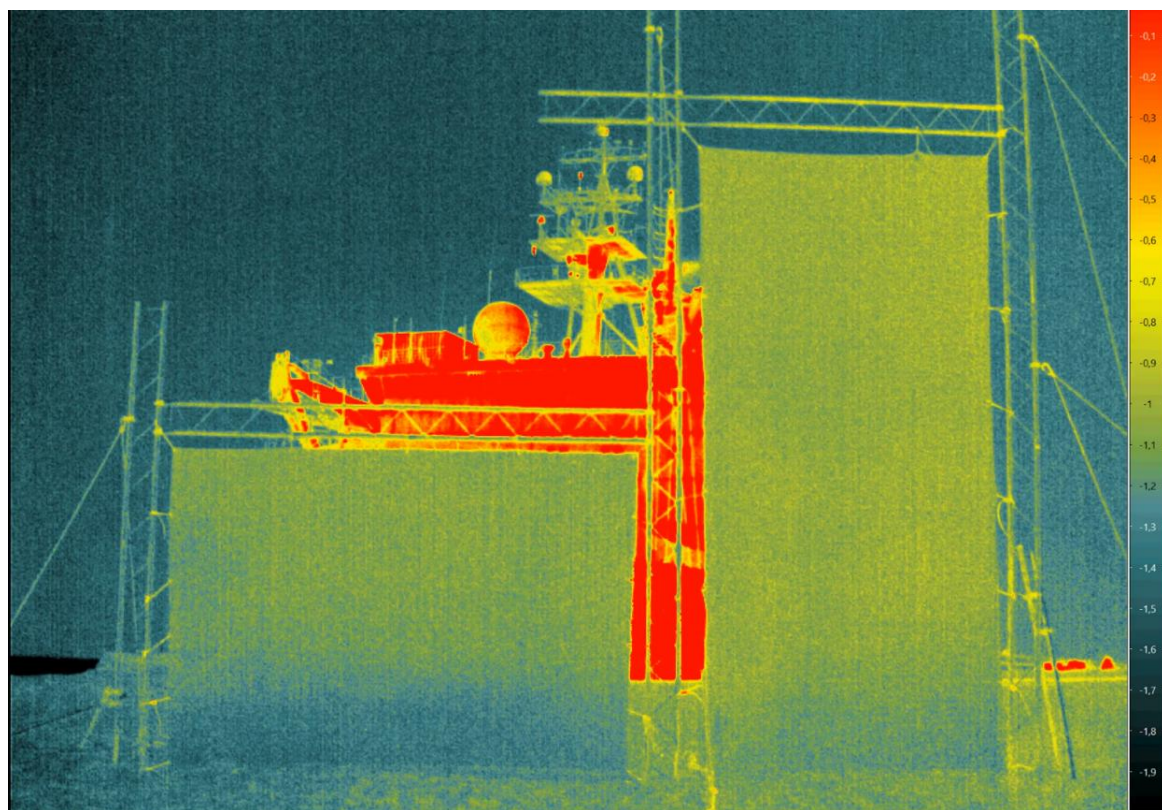


Fig. 3.5.4: Screenshot from the measurements at station 2a at the lead. The lead ends approximately 1 m upwind (left) of the left screen. Slightly colder air close to the surface advected from over ocean is visible in the image, while the temperature stratification is mostly neutral above. RV Polarstern is visible in the background.

As we conducted measurements at transitions of different surface morphologies (i.e. lead-ice, pond-ice, in the lee of ridges; see table below), we will assess their influence on the near-surface atmospheric boundary layer and the impacts for sea ice melt. Putting these findings in the context of the various other meteorological measurements allows us to relate our results to the rest of the atmosphere and is a first step towards generalizing.

Tab. 3.5.1: Overview of the different measurement sites at the ice stations. For further details, please refer to the AWI CONTRASTS logbook, where the individual stations are described in more detail.

Ice station	Surface morphology	Position tower 1	Position tower 2	Position IR screen
1a	Pond – ice	Melt pond	Ice	Melt pond - ice
2a	Lead – ice	Ice	Lead	lead - ice
3a	Ridge	Downwind of ridge	At the lead	Downwind of the ridge
1b	Pond – ice	Pond	ice	-
2b	Pond – ice	Pond	Ice	Pond - ice
3b	Lead/ridge	Lead	Behind ridge	Lead - ice
1c	Lead – ice	Lead	Ice	Lead - ice
2c	Pond – ice	ice	pond	-
3c	Lead/ridge	Lead	Downwind of ridge	Behind ridge
2d	Frozen pond	Frozen pond	Ice	-
3d	Bare ice	Ice closer to the lead	Ice behind the ridge	Bare ice

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (<https://www.pangaea.de>) within two years after the end of the expedition at the latest. By default, the CC-BY license will be applied.

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

This expedition was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 2, Subtopic 1 and 2.

The VAMPIRE-2 project is supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) through the Transregional Collaborative Research Centre TRR-172 “Arctic Amplification: Climate Relevant Atmospheric and Surface Processes, and Feedback Mechanisms (AC)3” (grant 268020496).

In all publications based on this expedition, the **Grant No. AWI_PS149_02 and AWI_PS149_07** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. <http://dx.doi.org/10.17815/jlsrf-3-163>.

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- Solomon A, Shupe M D et al. (2023) The winter central Arctic surface energy budget: A model evaluation using observations from the MOSAiC campaign, Elementa: Science of the Anthropocene 11(1). <https://doi.org/10.1525/elementa.2022.00104>

- Walbröl A, Crewell S, Engelmann R, Orlandi E, Griesche H, Radenz M, Hofer J, Althausen D, Maturilli M & Ebell K (2022) Atmospheric temperature, water vapour and liquid water path from two microwave radiometers during MOSAiC. *Scientific Data* 9:534. <https://doi.org/10.1038/s41597-022-01504-1>
- Walbröl A, Griesche HJ, Mech M, Crewell S & Ebell K (2024) Combining low- and high-frequency microwave radiometer measurements from the MOSAiC expedition for enhanced water vapour products. *Atmospheric Measurement Techniques* 17:6223–6245. <https://doi.org/10.5194/amt-17-6223-2024>

4. OCEANOGRAPHY

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Grant-No. AWI_PS149_01 and AWI_PS149_06

Outline and objectives

The main objectives of the ocean physics work are both (1) extensive meso-scale surveys, including autonomous instrumentation and helicopter-assisted manual surveys, around each planned ice station, and local (2) measurements of turbulence in the water column and right under the sea ice to estimate mass, heat and momentum fluxes; as well as processes associated with leads and the ice floe edge. Studying the strong links of ocean physical processes to the ecosystem and biogeochemistry will be facilitated by this multidisciplinary expedition.

CONTRASTS will enable quantification of the distribution and evolution of thin meltwater layers (under ice and in leads) under different sea ice regimes. The expedition will enable us to capture the temporal evolution and dissolution of these layers. Spatially, to capture the conditions that permit meltwater layers to persist into freeze-up, and the role that they play in pre-conditioning new ice formation. The side proposal LEAD will investigate the spatial impact of a lead in ocean dynamics and in primary production under the sea ice.

At each site, repeated measurements will allow us to connect the solar heating (quantified during the first visit) to the upper ocean thermohaline structure and resulting bottom and lateral melt rates (quantified during the second visit). Coordination with other teams will enable understanding of the impact of thin meltwater layers and false bottoms on coupled system processing including productivity and biogenic air-sea gas exchange. In particular, measurements in different sea ice regimes with widely varying sea ice thicknesses, optical conditions, and nutrient loads will allow us during CONTRASTS to address the outstanding question of how upper ocean optics in thin meltwater layers impact productivity rates.

Each subchapter presents the work at sea and its preliminary (expected) results separately.

Work at sea



Fig. 4.0.1: Team ocean group picture

4.1 On board CTD

The CTD/Rosette was operated using the standard SeaBird SBE911plus setup, equipped with double sensors for temperature, salinity, oxygen and one sensor each for pressure, substance fluorescence Chl-a (WET Labs ECO-AFL/FL), substance fluorescence of coloured dissolved organic matter (CDOM, WET Labs ECO CDOM),), yellow substance fluorescence (Dr. Haardt), beam transmission (WET Labs C-Star), photosynthetically active radiation (PAR/Logarithmic, Satlantic), and surface photosynthetically active radiation (SPAR/Linear, Satlantic). The sensor configuration is summarized in Table 4.1.1. In addition, 24 12-liter Niskin bottles for water sampling were attached to the Rosette. An altimeter was mounted to monitor the distance to the seafloor. During all casts, an Underwater Vision Profiler (UVP) was attached to the rosette to continuously record Plankton and particle images during the CTD downcast, recording data internally. The instrument was operated by Morten Iversen and the Eco team.

The CTD casts have mostly been carried out successfully, apart from a few minor problems due to ice floes interrupting the cast or spooling errors on the winch, which were all noted in the CTD protocols.

During CTD operations at station 13-2 a failure occurred in the acquisition system. During the planned deep cast down to the seafloor, the operating system started to freeze in infrequent intervals during the bottom approach, which lead to seafloor contact with the rosette. During the following upcast, the operating system crashed completely, and data logging was interrupted. The winch wire got damaged as a result, however there was no damage to the rosette nor the CTD sensors. Video drivers got updated on the CTD operating computer and the winch wire got repaired. No problems aside from occasional HDMI signal loss from the screen have been observed since. At cast 37_3, the CTD pump stopped functioning at 20 m depth. Therefore, both pumps were replaced, as well as the communication cable between the SBE911 and the pumps. Bottle number 24 of the rosette has not been closing reliably since the start of the cruise without an apparent reason. A series of fixes have been performed, to no avail. A new bottle got installed, yet still not reliably closing.

The initial configuration (conf1) of the SBE911+ CTD on the rosette remained unchanged throughout the cruise.

Water samples were taken throughout and were analyzed to correct for the temporal drift and pressure effects of the conductivity sensors. For the salinity samples the respective bottles were closed after at least 30 seconds of waiting time at the sampling depth. The samples will be used to finalize the data sets after the expedition using those bottle sample data as well as the manufacturer's calibration pre- and post-expedition. Additional samples for d18O water mass tracing were conducted and stored in the 4°C cooling chamber for a later analysis after the cruise. For calibration of the conductivity sensors, salinity samples were taken regularly and measured with the Optimare Precision Salinometer (OPS). Before measurement, samples were degassed by heating them to 30 degrees for one hour, letting out the overpressure, and letting them adjust to room temperature again.

In total 70 salinity samples were measured using the OPS-006 or OPS-007. As a standard the OPS-006 is the one to be used by scientists while OPS-007 is to be used by crew. The final calibration of the CTD data will be done based on the salinometer results in combination with the post-cruise manufacturer calibration of the sensors. We collected 161 water samples for d¹⁸O isotopes.

Tab. 4.1.1: Sensors

Parameter	SN	Calibration Date	Channel	Sensor Type
	525	--	-	Deckunit Seabird 11plus
Temperature 1	5112	11-Aug-21	F1	Seabird SBE3plus
Conductivity 1	3570	10-Aug-21	F2	Seabird SBE4
Pressure	0287	14-Nov-17	F3	
Temperature 2	5115	16-Jan-24	F4	Seabird SBE3plus
Conductivity 2	3290	09-Jan-24	F5	Seabird SBE4
Oxygen 1	4305	13-Jul-23	V0	Seabird SBE43
Oxygen 2	4303	11-Jul-23	V1	Seabird SBE43
Altimeter	51533	--	V2	Teledyne (Benthos) PSA-916
CDOM fluorescence	7239	21-Dec-23	V3	WETlabs ECO CDOM
Chl-a fluorescence	8103	20-Apr-23	V4	WETlabs ECO Chl-a
Beam Transmission	1220	07-Sep-22	V5	WETlabs C-Star
Yellow Substance	03	--	V6	Dr. Haardt Fluorometer
PAR	2197	30-Nov-21	V7	Seabird PAR-LOG
SPAR	2335	09-Jan-24	SPAR voltage	Seabird PAR-LIN

Tab. 4.1.2: Casts

Station	Date	Time	Latitude	Longitude	Water Depth [m]	Max Depth [m]
003_01	06-Jul-25	03:13:40	81 35.574 N	17 40.488 E	1636	1647
012_02	07-Jul-25	20:27:13	82 41.196 N	20 8.442 E	3969	2033
013_02	09-Jul-25	11:37:09	83 46.872 N	20 47.802 E	4075	4107
013_07	11-Jul-25	14:11:45	83 46.428 N	22 29.820 E	4071	1014
013_11	11-Jul-25	16:17:45	83 46.536 N	22 36.576 E	4071	101
015_01	13-Jul-25	15:19:09	84 40.020 N	20 45.870 E	4056	2040
016_02	14-Jul-25	16:29:37	85 1.458 N	13 36.162 E	3066	2544
016_09	15-Jul-25	12:54:27	84 57.108 N	14 6.804 E	3666	274
017_01	18-Jul-25	14:28:09	84 34.716 N	0 18.036 E	3910	2033
018_02	19-Jul-25	21:31:38	84 29.118 N	17 56.292 W	3387	3055
018_07	20-Jul-25	13:35:45	84 27.708 N	17 53.514 W	3404	411
021_02	25-Jul-25	21:02:41	82 40.224 N	27 2.112 E	3965	3055
021_06	26-Jul-25	13:23:09	82 37.308 N	26 42.858 E	3979	372
022_03	29-Jul-25	11:50:14	83 15.114 N	21 54.546 E	4070	2033
025_09	31-Jul-25	08:29:42	83 42.324 N	17 4.926 E	4071	379
025_11	31-Jul-25	11:42:14	83 42.846 N	17 17.592 E	4072	3055
028_02	02-Aug-25	17:37:42	83 48.960 N	6 55.536 E	3860	2032
030_12	05-Aug-25	08:57:29	83 37.098 N	11 26.316 W	3977	490
030_13	05-Aug-25	12:24:27	83 37.524 N	11 21.930 W	3873	3363
032_07	10-Aug-25	08:24:19	83 16.860 N	33 55.116 E	3864	355
032_10	10-Aug-25	10:20:15	83 17.502 N	33 56.808 E	3867	245
032_12	10-Aug-25	12:46:45	83 18.222 N	33 59.910 E	3865	3056

Station	Date	Time	Latitude	Longitude	Water Depth [m]	Max Depth [m]
033_02	11-Aug-25	11:07:22	83 40.290 N	27 52.884 E	4061	2032
036_07	12-Aug-25	21:19:38	84 30.132 N	22 6.564 E	4062	3056
036_09	13-Aug-25	08:26:31	84 30.480 N	22 6.882 E	4062	292
037_03	15-Aug-25	20:59:27	84 9.828 N	1 27.726 W	3017	102
041_02	16-Aug-25	22:26:12	83 3.426 N	12 56.124 W	3374	3056
041_09	17-Aug-25	12:50:27	82 56.382 N	12 48.474 W	3162	377
043_02	20-Aug-25	20:52:49	83 41.658 N	15 31.668 E	4071	2034
046_02	23-Aug-25	12:56:18	84 11.664 N	18 8.220 E	3754	340
046_06	23-Aug-25	16:06:57	84 11.148 N	18 8.610 E	3734	3055
047_02	26-Aug-25	11:23:09	82 27.264 N	5 49.548 W	4694	3055
047_05	26-Aug-25	14:10:45	82 27.672 N	5 37.134 W	4763	354

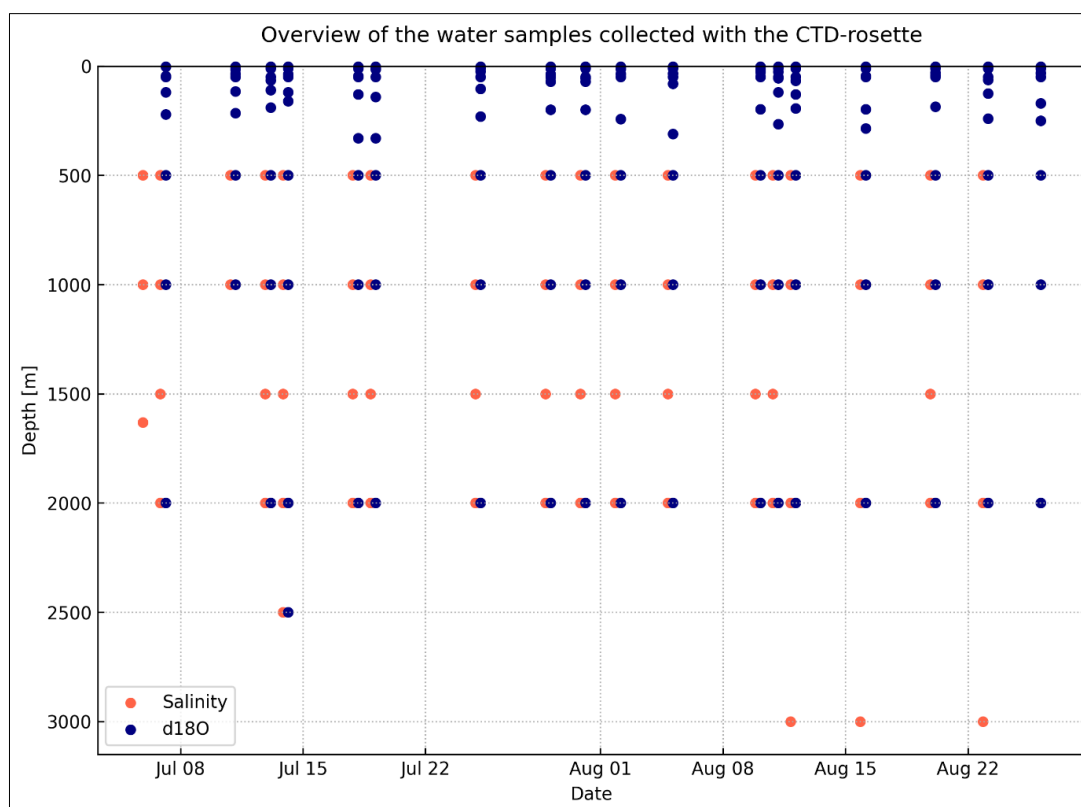


Fig. 4.1.1: Overview of the water samples collected with the CTD-rosette

4.2 Ship ADCP

Polarstern is equipped with an Ocean Surveyor 150kHz (RD-Instruments) Acoustic Doppler Current Profiler (SADCP) to monitor ocean currents. For protection against ice, the Ocean Surveyor is mounted behind a window, flooded with water, in the ship's hull. The data from the SADCP was merged online with the corresponding navigation data (i.e., the vessel's GPS system) and stored on the hard disk using the program VMDAS. Pitch, roll and heading data are converted from NMEA. Current speed data were collected in beam coordinates to apply corrections during post processing. Processing during the cruise was conducted using UHDAS (University of Hawaii Data Acquisition System). Final data processing and quality control will be done at AWI after the field campaign. The SADCP was operated using these settings:

```
; Restore factory default settings in the ADCP
cr1
; set the data collection baud rate to 9600 bps,
; no parity, one stop bit, 8 data bits
; NOTE: VmDas sends baud rate change command after all other commands in
; this file, so that it is not made permanent by a CK command.
cb411
; Set for narrowband single-ping profile mode (NP), 100 (NN) 4 meter bins (NS),
; 2 meter blanking distance (NF), 390 cm/s ambiguity vel (WV)
WP000
NP001
NN080
NS0400
NF0400
;WV390
; Disable single-ping bottom track (BP),
; Set maximum bottom search depth to 1200 meters (BX)
BP000
;BX12000
; output velocity, correlation, echo intensity, percent good
ND111100000
; Ping as fast as possible
TP000000
; Since VmDas uses manual pinging, TE is ignored by the ADCP
; and should not be set.
;TE0000000
; Set to calculate speed-of-sound, no depth sensor, external synchro heading
; sensor, pitch or roll being used, no salinity sensor, use internal transducer
; temperature sensor
EZ1022201
; Output beam data (rotations are done in software)
EX00000
; Set transducer misalignment (hundredths of degrees).
; Ignored here but set in VmDAS options.
;EA00000
; Set transducer depth (decimeters)
ED00110
; Set Salinity (ppt)
ES35
;set external triggering and output trigger; no trigger
;CX0,0
;set external triggering and output trigger
CX1,3
; save this setup to non-volatile memory in the ADCP
CK
```

4.3 xCTD programme

The grid of temperature and salinity profiles and the transect of those are being collected using expendable CTDs (XCTD; deck unit MK150 by TSK, probes TSK/Lockheed-Martin Sippican XCTD-1 and XCTD-4) profiling system. The probes were deployed using a standard hand-held launcher connected to a MK150 deck unit, either from the ship or by helicopter operations involving landing near the main ice floe and deploying XCTDs along the lead edge (Fig. 4.3.1). A total of 107 XCTD probes (95 of XCTD-1 and 12 of XCTD-4) were deployed during PS149 (Tab. 4.3.1) to collect profiles of temperature and salinity within a 30km radius around the main floe and two Northeast-Southwest transects between 3°W and 11°W. The most of profiles achieved a maximum depth of at least 800 m. Seven probes were defect or did not reach the depth of 800 m before ceasing to respond. Figure 4.3.2 Overview map of XCTD deployments during the PS149 expedition. During the expedition of PS149, the results of potential temperature and salinity profiles are respectively shown in Figure 4.3.3 and Figure 4.3.4.



Fig. 4.3.1: An XCTD was deployed along the lead edge of ice floe. Photo credit: Ke-Hsien Fu

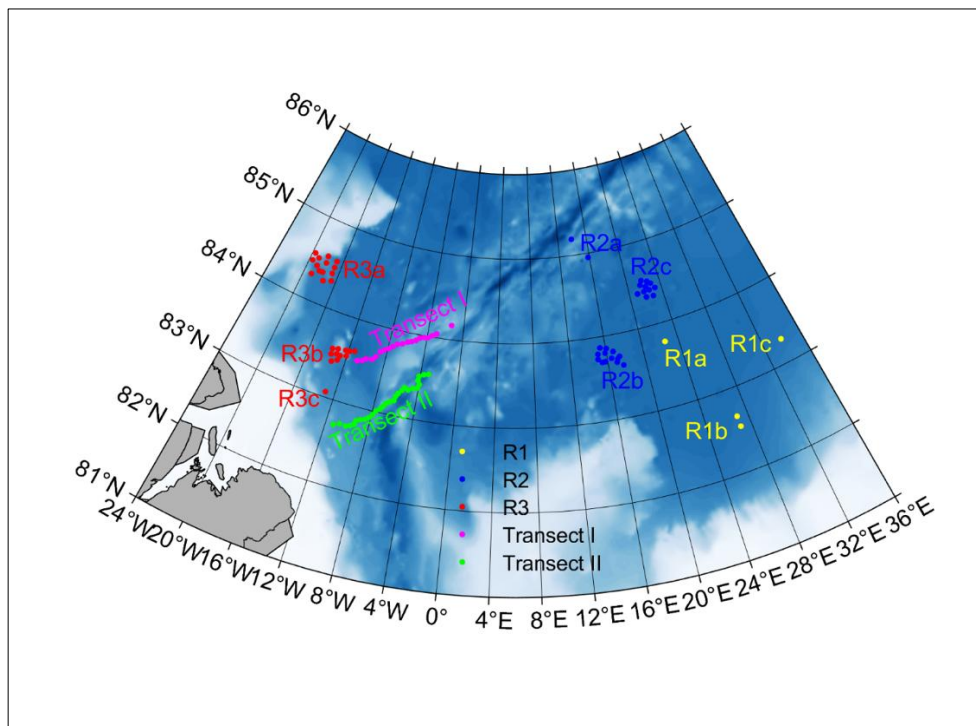


Fig. 4.3.2: Overview map of XCTD deployments during the PS149 expedition

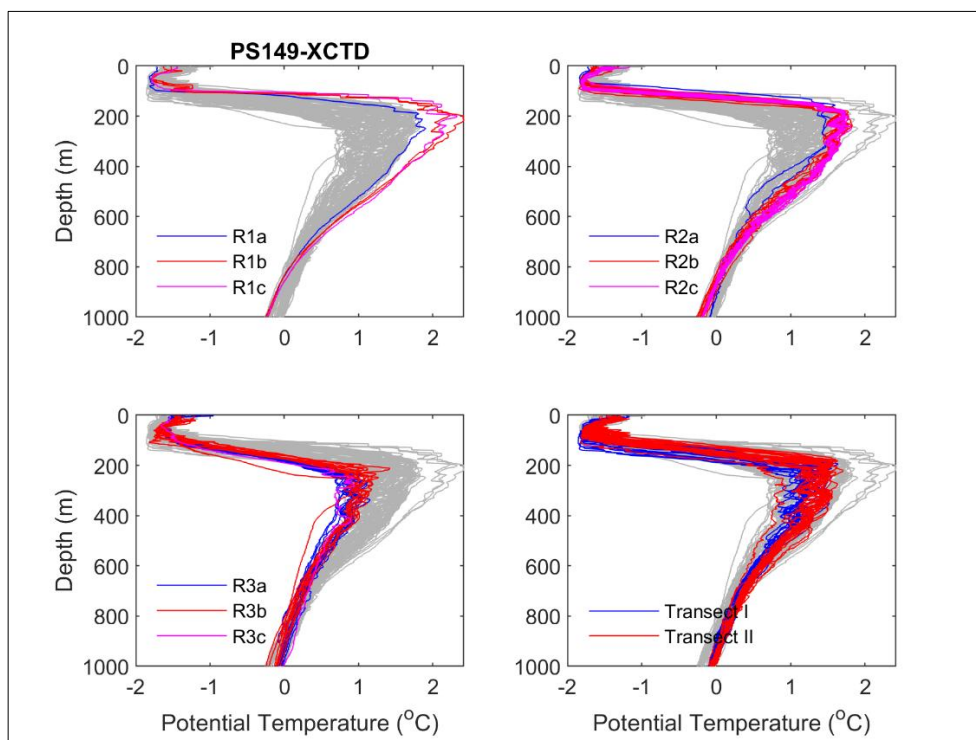


Fig. 4.3.3: Potential temperature profiles observed during each ice floe station (R1 to R3) and along two transects of the PS149 expedition. Gray lines indicate all temperature profiles shown for reference.

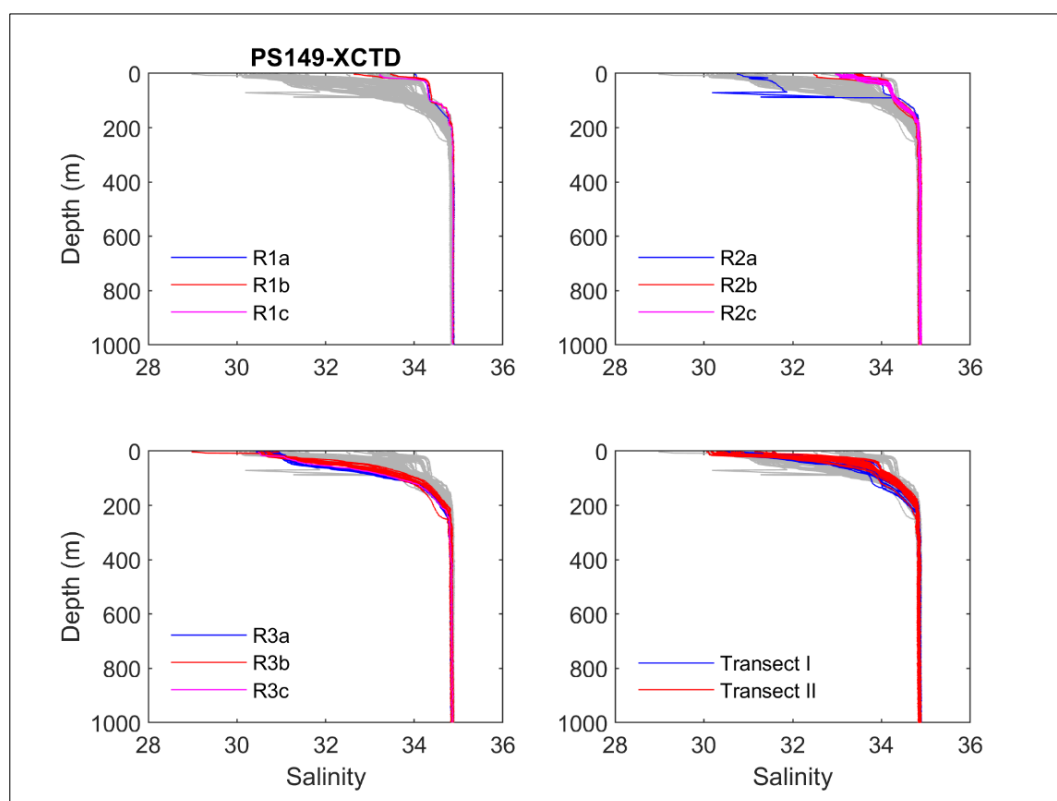


Fig. 4.3.4: Salinity profiles observed during each ice floe station (R1 to R3) and along two transects of the PS149 expedition. Gray lines indicate all salinity profiles shown for reference.

Tab. 4.3.1: Overview of XCTD deployments

XCTD Station	Date/Time start (UTC)	Lat	Lon	Max. Depth (m)	SN	File name
PS149_13-9-XCTD_MK150_1	2025-07-11T14:58:00	83.7748	22.5412	1000	24113638	0001
PS149_16-1-XCTD_MK150_1-01	2025-07-14T17:20:00	84.9494	15.8077	1000	24113639	0002
PS149_16-1-XCTD_MK150_1-02	2025-07-14T18:03:00	85.1912	13.9024	1000	24113641	0003
PS149_18-4-XCTD_MK150_1	2025-07-19T22:56:00	84.4875	-17.9248	863	24113642	0004
PS149_18-1-XCTD_MK150_1-01	2025-07-20T14:36:00	84.4752	-16.7866	1000	24113643	0005
PS149_18-1-XCTD_MK150_1-02	2025-07-20T15:06:00	84.5503	-16.7842	1000	24113640	0006
PS149_18-1-XCTD_MK150_1-03	2025-07-20T15:40:00	84.5685	-18.0363	1000	24113646	0007
PS149_18-1-XCTD_MK150_1-04	2025-07-20T16:13:00	84.5422	-19.6528	823	24113645	0008
PS149_18-1-XCTD_MK150_1-05	2025-07-20T16:50:00	84.4151	-18.8380	1000	24113644	0009
PS149_18-1-XCTD_MK150_1-06	2025-07-21T09:44:00	84.3150	-16.5295	1000	24113649	0010

XCTD Station	Date/Time start (UTC)	Lat	Lon	Max. Depth (m)	SN	File name
PS149_18-1-XCTD_MK150_1-07	2025-07-21T10:20:00	84.2790	-17.4639	1000	24113648	0011
PS149_18-1-XCTD_MK150_1-08	2025-07-21T11:00:00	84.3009	-19.0606	1000	24113647	0012
PS149_18-1-XCTD_MK150_1-09	2025-07-22T11:19:00	84.3713	-17.8972	1000	24113662	0013
PS149_18-1-XCTD_MK150_1-10	2025-07-22T14:16:00	84.4015	-16.7636	1000	24113650	0014
PS149_18-1-XCTD_MK150_1-11	2025-07-22T14:50:00	84.5059	-18.9973	909	24113663	0015
PS149_18-1-XCTD_MK150_1-12	2025-07-22T15:22:00	84.4530	-19.6141	838	24113651	0016
PS149_18-1-XCTD_MK150_1-13	2025-07-22T15:55:00	84.3676	-18.3276	1000	24113652	0017
PS149_21-4-XCTD_MK150_1	2025-07-25T22:37:00	82.6629	26.9832	1000	24113653	0018
PS149_21-1-XCTD_MK150_1-01	2025-07-27T13:08:00	82.5369	26.9893	1000	24113655	0019
PS149_24-1-XCTD_MK150_1	2025-07-29T20:07:00	83.6217	17.6186	1000	24113654	0020
PS149_24-2-XCTD_MK150_1-01	2025-07-29T21:04:00	83.6699	16.9943	278	24113666	0021
PS149_24-2-XCTD_MK150_1-02	2025-07-29T21:07:00	83.6702	16.9886	486	24113664	0022
PS149_24-3-XCTD_MK150_1	2025-07-29T22:06:00	83.7268	16.4696	1000	24113668	0023
PS149_24-4-XCTD_MK150_1	2025-07-29T23:19:00	83.8022	16.7612	1000	24113665	0024
PS149_24-5-XCTD_MK150_1	2025-07-30T00:46:00	83.8517	16.0775	1000	24113670	0025
PS149_24-6-XCTD_MK150_1	2025-07-30T01:59:00	83.8713	15.3989	1000	24113673	0026
PS149_24-7-XCTD_MK150_1	2025-07-30T03:22:00	83.8003	15.0718	1000	24113669	0027
PS149_24-8-XCTD_MK150_1	2025-07-30T04:18:00	83.7399	14.9991	1000	24113671	0028
PS149_24-9-XCTD_MK150_1	2025-07-30T05:51:00	83.6993	15.7634	1000	24113667	0029
PS149_25-10-XCTD_MK150_1	2025-07-31T09:04:00	83.7069	17.1148	1000	24113672	0030
PS149_26-1-XCTD_MK150_1	2025-08-01T23:05:00	83.7326	17.3629	1000	24113656	0031
PS149_26-2-XCTD_MK150_1	2025-08-02T01:20:00	83.8007	15.8602	1000	24113659	0032
PS149_29-1-XCTD_MK150_1	2025-08-03T16:13:00	83.6082	-11.8982	1000	24113658	0033
PS149_29-2-XCTD_MK150_1	2025-08-03T17:11:00	83.5421	-12.0625	909	24113695	0034

XCTD Station	Date/Time start (UTC)	Lat	Lon	Max. Depth (m)	SN	File name
PS149_29-3-XCTD_MK150_1-01	2025-08-03T18:51:00	83.5232	-12.6962	231	24113696	0035
PS149_29-3-XCTD_MK150_1-02	2025-08-03T19:01:00	83.5232	-12.6928	889	24113657	0036
PS149_29-4-XCTD_MK150_1	2025-08-03T19:50:00	83.5300	-13.0780	1000	24113697	0037
PS149_29-5-XCTD_MK150_1	2025-08-03T22:14:00	83.5918	-13.1091	1000	24113692	0038
PS149_29-6-XCTD_MK150_1-01	2025-08-04T00:02:00	83.5745	-13.6953	160	24113693	0039
PS149_29-6-XCTD_MK150_1-02	2025-08-04T00:17:00	83.5740	-13.6761	1000	24113694	0040
PS149_29-7-XCTD_MK150_1	2025-08-04T01:52:00	83.5078	-13.6426	914	24113690	0041
PS149_29-8-XCTD_MK150_1	2025-08-04T03:03:00	83.4283	-13.3766	1000	24113686	0042
PS149_29-9-XCTD_MK150_1	2025-08-04T03:55:00	83.4635	-12.8296	1000	24113691	0043
PS149_30-1-XCTD_MK150_1-01	2025-08-04T11:14:00	83.6048	-12.3049	1000	24113687	0044
PS149_30-1-XCTD_MK150_1-02	2025-08-05T12:38:00	83.6263	-11.3661	1000	24113689	0045
PS149_32-8-XCTD_MK150_1	2025-08-10T09:01:00	83.2844	33.9274	1000	24113688	0046
PS149_35-1-XCTD_MK150_1	2025-08-11T21:02:00	84.3333	22.7601	927	24113708	0047
PS149_35-2-XCTD_MK150_1	2025-08-11T22:06:00	84.3401	21.9113	1000	24113709	0048
PS149_35-3-XCTD_MK150_1	2025-08-11T23:10:00	84.4094	21.7824	1000	24113707	0049
PS149_35-4-XCTD_MK150_1	2025-08-11T23:58:00	84.4122	22.463	1000	24113705	0050
PS149_35-5-XCTD_MK150_1	2025-08-12T00:48:00	84.4194	23.2132	1000	24113701	0051
PS149_35-6-XCTD_MK150_1	2025-08-12T01:37:00	84.4837	22.8324	1000	24113706	0052
PS149_35-7-XCTD_MK150_1	2025-08-12T02:42:00	84.5167	22.473	1000	24113703	0053
PS149_35-8-XCTD_MK150_1	2025-08-12T04:03:00	84.4935	21.5274	1000	24113702	0054
PS149_35-9-XCTD_MK150_1	2025-08-12T05:12:00	84.4031	20.968	1000	24113698	0055
PS149_35-10-XCTD_MK150_1	2025-08-12T06:35:00	84.4618	22.1391	1000	24113704	0056
PS149_36-12-XCTD_MK150_1	2025-08-13T20:12:00	84.5435	21.8172	1000	24113700	0057
PS149_37-2-XCTD_MK150_1	2025-08-15T20:03:00	84.1696	-1.436	593	24113661	0058

XCTD Station	Date/Time start (UTC)	Lat	Lon	Max. Depth (m)	SN	File name
PS149_39-1-XCTD_MK150_1	2025-08-16T00:11:00	84.0456	-2.99042	1000	24113660	0059
PS149_39-2-XCTD_MK150_1	2025-08-16T00:48:00	84.017	-3.45595	1000	24113699	0060
PS149_39-3-XCTD_MK150_1	2025-08-16T01:39:00	83.9856	-3.89282	1000	24113675	0061
PS149_39-4-XCTD_MK150_1	2025-08-16T02:44:00	83.9786	-4.3423	1000	24113674	0062
PS149_39-5-XCTD_MK150_1	2025-08-16T03:27:00	83.9637	-4.79025	1000	24113678	0063
PS149_39-6-XCTD_MK150_1	2025-08-16T04:14:00	83.9284	-5.16573	1000	24113679	0064
PS149_39-7-XCTD_MK150_1	2025-08-16T05:00:00	83.9032	-5.62523	1000	24113676	0065
PS149_39-8-XCTD_MK150_1	2025-08-16T05:37:00	83.8877	-6.04973	1000	24113681	0066
PS149_39-9-XCTD_MK150_1	2025-08-16T06:24:00	83.8559	-6.56992	1000	24113680	0067
PS149_39-10-XCTD_MK150_1	2025-08-16T07:08:00	83.8363	-7.11578	1000	24113682	0068
PS149_39-11-XCTD_MK150_1	2025-08-16T08:05:00	83.7981	-7.55033	1000	24113685	0069
PS149_39-12-XCTD_MK150_1	2025-08-16T08:41:00	83.7638	-7.89528	1000	24113677	0070
PS149_39-13-XCTD_MK150_1	2025-08-16T09:25:00	83.7353	-8.32652	1000	24113684	0071
PS149_39-14-XCTD_MK150_1	2025-08-16T09:51:00	83.7028	-8.72432	1000	24113683	0072
PS149_39-15-XCTD_MK150_1	2025-08-16T10:30:00	83.6324	-9.03247	1000	24113723	0073
PS149_39-16-XCTD_MK150_1	2025-08-16T11:05:00	83.5897	-9.36933	1000	24113722	0074
PS149_39-17-XCTD_MK150_1	2025-08-16T11:50:00	83.5781	-9.96855	1000	24113727	0075
PS149_39-18-XCTD_MK150_1	2025-08-16T12:20:00	83.5475	-10.3243	1000	24113726	0076
PS149_39-19-XCTD_MK150_1	2025-08-16T13:15:00	83.5259	-10.8372	1000	24113724	0077
PS149_41-1-XCTD_MK150_1-01	2025-08-16T21:27:00	83.0647	-12.9308	1000	24113725	0078
PS149_42-1-XCTD_MK150_1	2025-08-19T01:56:00	82.7252	-11.2608	1000	24113730	0079
PS149_42-2-XCTD_MK150_1	2025-08-19T02:46:00	82.7547	-10.7217	1000	24113732	0080
PS149_42-3-XCTD_MK150_1	2025-08-19T03:38:00	82.7465	-10.1274	1000	24113728	0081
PS149_42-4-XCTD_MK150_1	2025-08-19T04:06:00	82.7658	-9.71467	885	24113731	0082

XCTD Station	Date/Time start (UTC)	Lat	Lon	Max. Depth (m)	SN	File name
PS149_42-5-XCTD_MK150_1	2025-08-19T04:36:00	82.7936	-9.38962	1000	24113729	0083
PS149_42-6-XCTD_MK150_1	2025-08-19T05:03:00	82.8396	-9.30678	1000	24113715	0084
PS149_42-7-XCTD_MK150_1	2025-08-19T05:43:00	82.8662	-8.91177	1000	24113713	0085
PS149_42-8-XCTD_MK150_1	2025-08-19T06:15:00	82.8854	-8.50683	1000	24113714	0086
PS149_42-9-XCTD_MK150_1	2025-08-19T06:44:00	82.9167	-8.18695	1000	24113711	0087
PS149_42-10-XCTD_MK150_1	2025-08-19T07:15:00	82.9574	-7.90805	1000	24113712	0088
PS149_42-11-XCTD_MK150_1	2025-08-19T07:51:00	83.0083	-7.69395	1000	24113710	0089
PS149_42-12-XCTD_MK150_1	2025-08-19T08:16:00	83.0404	-7.36932	1000	24113718	0090
PS149_42-13-XCTD_MK150_1	2025-08-19T08:40:00	83.0795	-7.12373	1000	24113717	0091
PS149_42-14-XCTD_MK150_1	2025-08-19T09:09:00	83.1246	-6.90605	1000	24113717	0092
PS149_42-15-XCTD_MK150_1	2025-08-19T09:36:00	83.1518	-6.56577	1000	24113721	0093
PS149_42-16-XCTD_MK150_1	2025-08-19T10:01:00	83.1779	-6.18793	706	24113720	0094
PS149_42-17-XCTD_MK150_1	2025-08-19T10:34:00	83.2309	-6.1017	1000	24113719	0095
PS149_42-18-XCTD_MK150_2	2025-08-19T11:07:00	83.271	-5.90277	1904	24117970	0096
PS149_42-19-XCTD_MK150_2	2025-08-19T11:36:00	83.3135	-5.60377	1963	24117972	0097
PS149_42-20-XCTD_MK150_2	2025-08-19T12:08:00	83.3528	-5.3872	1729	24117971	0098
PS149_42-21-XCTD_MK150_2	2025-08-19T12:39:00	83.3335	-4.98452	2000	24117973	0099
PS149_42-22-XCTD_MK150_2	2025-08-19T13:11:00	83.3616	-4.51642	1440	24117974	0100
PS149_42-23-XCTD_MK150_2	2025-08-19T13:35:00	83.3774	-4.08345	2000	24117975	0101
PS149_42-24-XCTD_MK150_2	2025-08-19T14:02:00	83.4215	-3.96228	1851	24117976	0102
PS149_42-25-XCTD_MK150_2	2025-08-19T14:35:00	83.4669	-4.16358	488	24117977	0103
PS149_42-26-XCTD_MK150_2	2025-08-19T15:43:00	83.517	-4.13685	1859	24117978	0104
PS149_42-27-XCTD_MK150_2	2025-08-19T16:30:00	83.5446	-3.66432	1964	24117979	0105
PS149_42-28-XCTD_MK150_2	2025-08-19T17:08:00	83.5585	-3.18487	2000	24117980	0106

XCTD Station	Date/Time start (UTC)	Lat	Lon	Max. Depth (m)	SN	File name
PS149_43-4- XCTD_MK150_2	2025-08-20T22:20:00	83.6969	15.4153	2000	24117981	0107

4.4 On-ice short term deployments

Ice-Ocean boundary layer observation at floe 3

IOBL measurements were carried out to quantify turbulent heat and dissolved oxygen (DO) fluxes during the melting season. To characterize the hydrodynamic conditions during the observation period, an Acoustic Doppler Current Profiler (ADCP; Signature1000, Nortek) and a mini-mooring were deployed at Station 3 in collaboration with AWI. Turbulence measurements were performed using an eddy covariance system consisting of a Rinko-EC (ARO-EC-CM, JFE Advantech) and a Vector (Nortek). These instruments were synchronized to acquire data simultaneously: the Rinko-EC recorded dissolved oxygen and temperature, while the Vector measured three-dimensional velocity. The beneath-ice measurements were obtained using the CrioTec system, equipped with conductivity and temperature sensors, a velocity sensor, and GPS positioning. The mini-mooring was equipped with a temperature logger (SBE56, Sea-Bird Electronics) and an ACTW-WF-L (JFE Advantech). A detailed schematic of the mooring configuration is provided in Figure 4.4.1. All instruments were deployed on multi-year sea ice (>3 years old) in the Greenland Sea. The initial position of the ice floe was 84°25'2"N, 17°58'50"W. Deployment sites on the ice are indicated by distinct symbols in Figure 4.4.2, with instruments positioned in proximity, separated by horizontal distances of approximately 10–30 m.

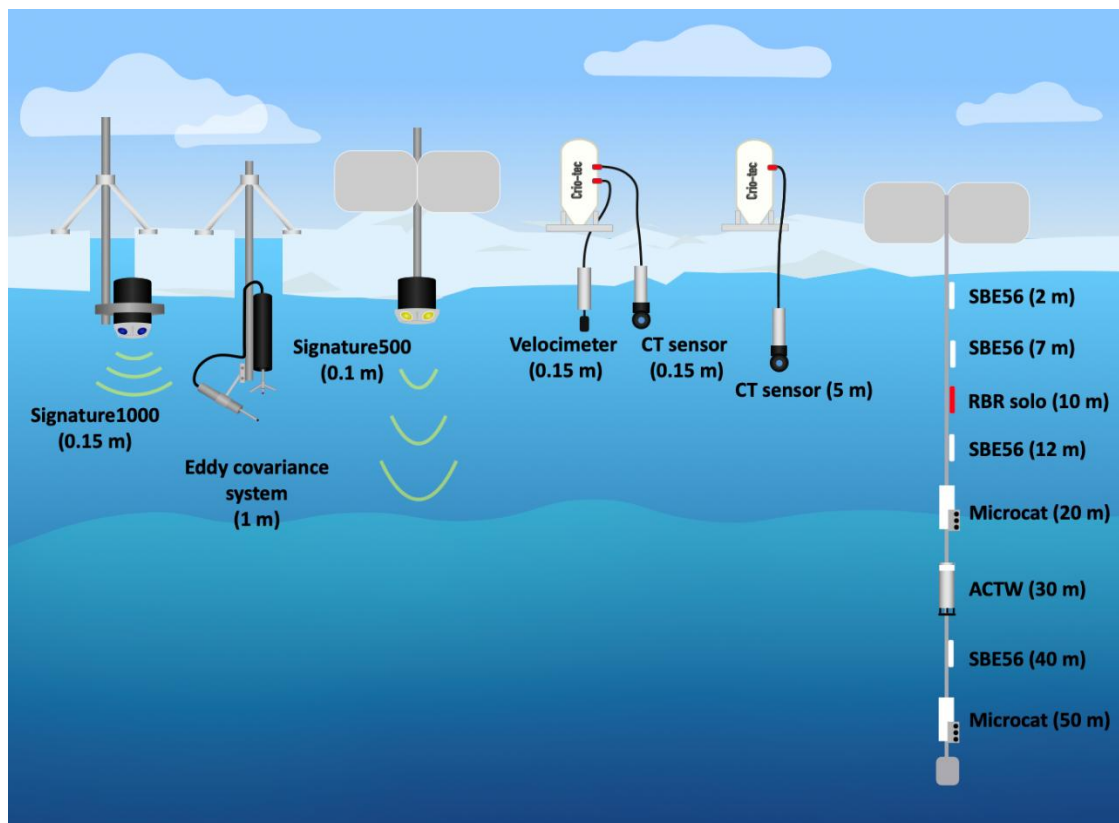


Fig. 4.4.1: Schematic of IOBL observation. Signature500, RBR solo, and MicroCats are AWI's Instruments. The number in the parentheses indicates the sensor's depth below the sea ice.

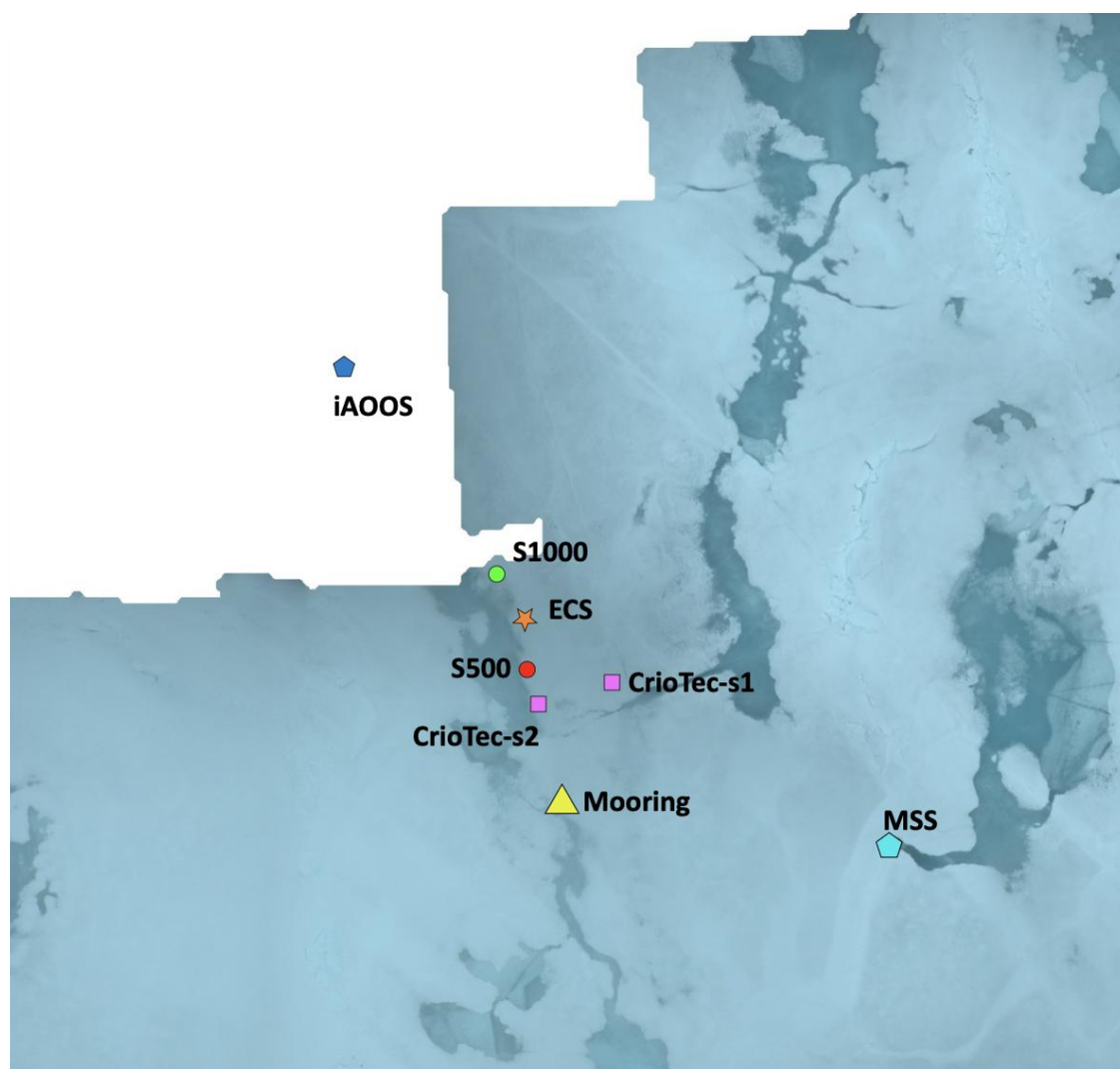


Fig. 4.4.2: Deployment location of Ocean city from the air-borne photo. All sensors are marked with different symbols.

Deployment details (First visit, station event 18-1, 20 Jul 2025)

Eddy covariance system (ECS)

Time: Starts at Jul 20 15:00 UTC

The sensing point locates around 1 m below the sea ice bottom

Sea ice thickness: 138 cm

Deployment configuration

```

=====
Deployment : P14931
Current time : 2025/07/20 13:02:29
Start at : 2025/07/20 15:00:00
Sampling rate (Hz) : 8
Nominal vel. range (m/s) : 0.30
Burst interval (s) : 900
Samples per burst : 2048
Sampling volume (mm) : 14.9
Transmit length (mm) : 4.0
Assumed duration (days) : 15.0
Battery utilization (%) : 96.0
Battery level (V) : 13.4
Recorder size (MB) : 3773
Recorder free space (MB) : 3526.700
Memory required (MB) : 79.9
Vertical vel. range (m/s) : 0.2
Horizon. vel. range (m/s) : 0.8

```

```

-----
Instrument ID : VEC14347
Head ID : VEC 5418
Firmware version : 3.43
ProLog ID : 1915
ProLog firmware version : 4.24

```

```

-----
Vector Version 1.39.09
Copyright (C) Nortek AS
=====

```

Signature1000

Time: Starts at Jul 20 16:00 UTC (deployment)
 Beam locates about 15 cm below the sea ice bottom.

Deployment configuration

Average mode

Start of profile (blanking distance) = 0.1 m

End of profile = 28 m

Cell size = 1 m

Average interval = 60 sec, (real = 42 sec)

Interval = 5 minutes

Coordination system = ENU

Number of cells = 29

CrioTec

Time: Starts at Jul 20 deployed around 18:30 UTC

Deployment depth

Sensors	CT sensor	Velocimeter
S/N 0001	15 cm below sea ice bottom	20 cm below sea ice bottom
S/N 0002	5 m below sea ice bottom	none

Mini-Mooring

Time: SBE56 starts at Jul 20 12:00 UTC, ACTW starts at 17:30

Remarks

- Mooring is attached to AWI'S mini mooring that contains 10 m RBR solo, 20m and 50 m MicroCat.

Deployment depth

- SBE56: 2 m, 7 m, 12 m, 40 m
- ACTW-WF-L: 30 m

Deployment details (Second visit, station event 30-1, 04 August 2025)

Eddy covariance system (ECS)

Time: Starts at Aug 04 14:30 UTC (2-1)

Remarks: All configurations are the same as in the first deployment.

The Rinko-EC recorded anomalous temperature values (approximately -11°C), and we are currently consulting with the manufacturer to investigate the issue. The velocity data from the Vector, however, appears reliable and can be used. All previously stored data have been erased to free space on the device. For verification, the ECS was recovered and its data were checked on the morning of August 5 (~08:30 UTC). In this case, the temperature measurements were within the expected range. The instrument has since been redeployed in the same borehole with the same configuration. For this deployment, an RBR-Solo from AWI was attached to the Rinko-EC to provide both confirmation of measurements and a backup temperature record.

Time: Starts at 11:30 UTC Aug 05 (re-deploy; 2-2)

RBR solo: S/N 236856 starts at Aug 5 11:30 UTC, sampling rate at 2 Hz (7 cm from Rinko-EC sensing part)

Signature1000

Time: Starts at Aug 04 14:30 UTC

Remarks: All configurations are the same as in the first deployment.

Mini-Mooring

Time: Starts at Aug 04 13:00 UTC

Remark: Deployed at the same position, attached to AWI's mooring. The ACTW sampling interval was adjusted to 6 minutes (previously, 5 samples every 5 minutes) to optimize battery usage. T-loggers record measurements every 5 seconds.

Deployment details (Third visit, station event 41-1, 17 August 2027)

Sea ice thickness: 1.56 m (from ECS hole)

Eddy covariance system (ECS)

Time: Starts at Aug 17 09:00 UTC

Remarks: All configurations are the same as in the first deployment. For this deployment, an RBR-Solo from AWI was attached to the Rinko-EC to provide both confirmation of measurements and a backup temperature record.

RBR solo: S/N 236856 starts at Aug 17 09:00 UTC, sampling rate at 2 Hz (7 cm from Rinko-EC sensing part)

Signature1000

Time: Starts at Aug 17 09:00 UTC

Remarks: All configurations are the same as in the first deployment.

Mini-Mooring

Time: Starts at Aug 17 09:00 UTC

Remark: Deployed at the same position, attached to AWI's mooring. The ACTW sampling interval was adjusted to 6 minutes (previously, 5 samples every 5 minutes) to optimize battery usage. T-loggers record measurements every 5 seconds.

Recovery details (Fourth visit, station event 47-1, 26 August 2025)

Eddy covariance system (ECS)

Time: Recovered 14:30 UTC Aug 27

Remarks: RBR solo (S/N 236856, sampling rate at 2 Hz, 7 cm from Rinko-EC sensing part)

Signature1000

Time: Recovered 09:00 UTC Aug 26

CrioTec

Time: Recovered 09:00 UTC Aug 26

Mini-Mooring

Time: Recovered 09:00 UTC Aug 26

Preliminary results

During the observation period, several strong upper-ocean current events with speeds reaching $\sim 0.4 \text{ m s}^{-1}$ were recorded, suggesting a high likelihood of eddy activity. These events persisted for approximately 3–10 days. Associated with the current intensification, turbulent

kinetic energy beneath the sea ice increased markedly, accompanied by a rise in friction velocity (Fig. 4.4.3ab). During these events, near-surface temperature increased to -1.2°C , compared with the local freezing point of -1.8°C . In particular, vertical heat flux exhibited pronounced variability from August 8 to 9, reaching up to eight times stronger in both upward and downward directions (Fig. 4.4.3c). Dissolved oxygen flux also showed significant enhancement during periods of strong current (Fig. 4.4.3d). In contrast, during the latter part of the observation, vertical heat flux diminished along with a decrease in near-surface temperature, while dissolved oxygen flux increased sharply after August 15. During entire observation, sea ice drift was in between 0.05 m s^{-1} to 0.25 m s^{-1} with the strong signal of inertial motion (Fig. 4.4.4a). From August 03, sea ice floe was under the eddy's influence with the vertically stretched salinity (Fig. 4.4.4b). During the eddy event, temperature showed low temperature core inside of the eddy with the anomalously warm water layer near 20 m (Fig. 4.4.4c).

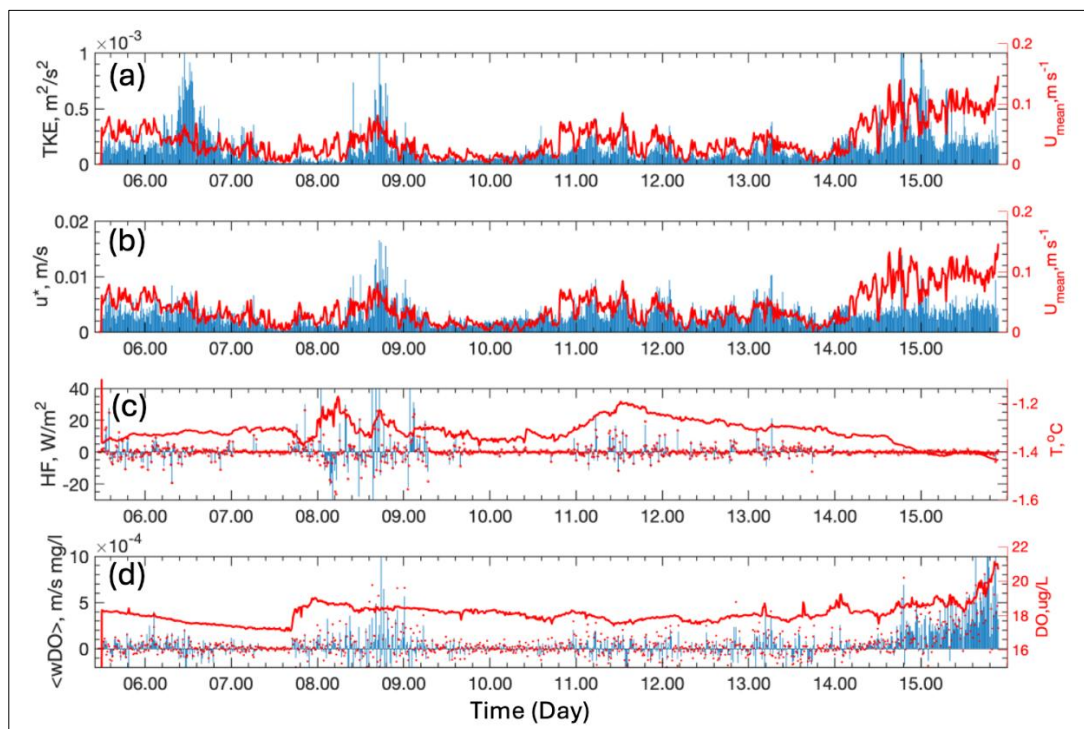


Fig. 4.4.3: August time series of (a) turbulent kinetic energy, (b) friction velocity, (c) vertical heat flux, and (d) dissolved oxygen. The red line in each panel represents the corresponding mean values of velocity, temperature, and dissolved oxygen, respectively.

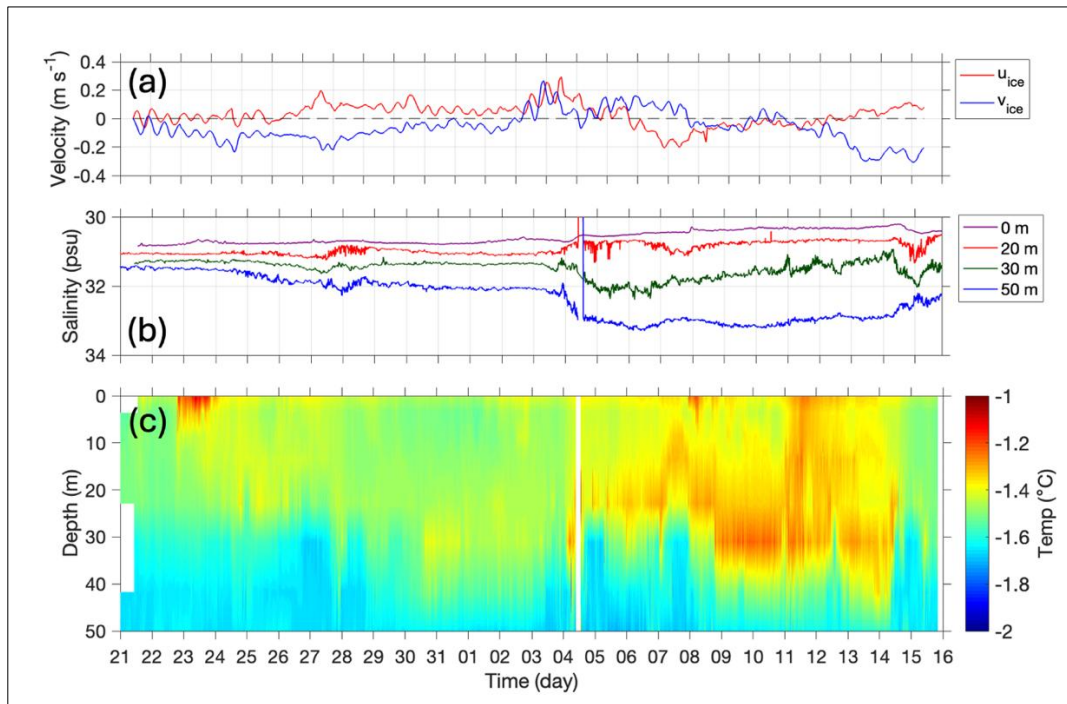


Fig. 4.4.4: Timeseries of (a) sea ice drift from GPS data, (b) salinity, and (c) temperature from mini mooring during first and second visit

Under-ice deployments

At Stations 1 to 3, Acoustic Doppler Current Profilers (ADCP; WHS300, S1000, and S500) were deployed to measure current velocity. At each station, a mini-mooring was installed approximately 10 m away from each ADCP to monitor temperature and salinity variations (Fig. 4.4.5).

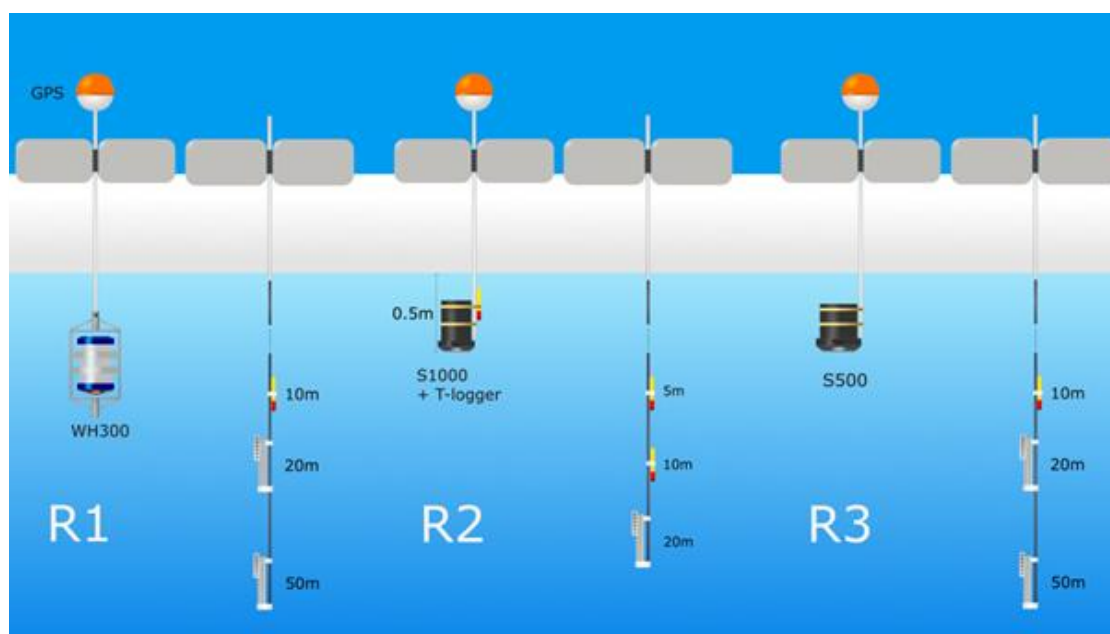


Fig. 4.4.5: Schematic of the deployment setup for the different floes

At Station 1, one WHS300 and a mini-mooring line were deployed (see Fig. 4.4.5). Initially, these were installed on a refrozen lead; however, during the second visit, the refrozen lead had melted and transformed into a lead site. For safety reasons, the instruments were relocated further inward. As the ice floe drifted into the Russian EEZ, recovery was not possible at that time. However, on August 21, when the Station 1 ice floe had drifted back out of the Russian EEZ waters, the recovery was successfully carried out.

At Station 2, to directly measure the turbulent fluxes in the ice-ocean boundary layer (IOBL) at the different ice conditions, high-resolving ADCP (Nortek Signature 1000 SN 104403, 107676, 107686, 107674) were deployed at Station 2. These instruments were configured to take average current measurements in the upper 18 m with a bin size of 0.2 m continuously, using an average interval of 60 s. In addition, the instrument ran in continuous Burst mode with a sampling rate of 4 Hz. In addition, the High Resolution (HR) firmware was active and configured to 2.5 m with a cell size of 0.05 m. Each S1000 was accompanied by an RBR-Solo T logger mounted 0.1 m above to monitor surface temperature changes (Fig. 4.4.5). During the second visit to Station 2 (2025-07-30 to 2025-08-01), a leakage occurred in the S1000 instrument, prompting a relocation of the nearby mini-mooring sensors, which led to changes in both mooring design and positioning.

At Station 3, the initial mooring design targeted measurements at 10 m, 20 m, and 50 m only, but in collaboration with Hokkaido University and the Kitami Institute of Technology, the design was enhanced to incorporate T-loggers and CTD sensors at 2 m, 7 m, 12 m, 30 m, and 40 m, allowing for expanded vertical resolution of the observations (Fig. 4.4.1). During the fourth visit to Station 3, one S1000 and one RBR Solo were deployed for recovery during the PS150 expedition. To measure turbulence, they were set to operate in HR mode at a depth of 0.3 m beneath the ice.

In all areas from Station 1 to 3, a large amount of algae was observed, which attached to the mooring devices and was recovered along with them.



Fig. 4.4.6: Original deployment at R2 mini-mooring before relocation (Station 2)
(Photo credit: Yeon Choi)

One of the mini-moorings (R2), placed behind the ridge at Station 2, was re-deployed on 2025-07-31 due to the risk of loss caused by melting sea ice, and was subsequently moved to the C1 site on 2025-08-01 (Fig. 4.4.6).

During the third visit of Station 2, the ocean site ridge had disappeared, making it impossible to deploy instruments in R1 and R2 site. Instead, new locations were designated (Melt pond region: M1; same location as before, Ice floe outer edge: O1, and Inner side of ice floe: C1b), for the S1000 and temperature logger. For the mini-mooring, in order to increase the vertical resolution during the final observation period, three mooring devices were concentrated at one site, and a 50 m mooring line was installed.

Ice station instruments were calibrated *in-situ* using the ship-based CTD/Rosette system during 3 casts (Tab. 4.4.1). The regular SBE37 microcats, SBE37-ODO were mounted on dedicated metal rods with a total space for up to 14 instruments. The sampling interval was set to 10 s for regular SBE37, 90 s for SBE37-ODO.

Tab. 4.4.1: Overview of instrument calibration casts for the mooring deployment

CTD cast	Date	Time (UTC)	Depth (m)	Instrument type	Serial numbers (sample interval)
PS149_12-2	2025-07-07	19:45	2000	SBE37	7728 (10s), 8128 (10s)
PS149_15-1	2025-07-13	15:00	2000	SBE37-SMP SBE37-ODO	7730 (10s), 8127 (10s), 8131 (10s), 13488 (90s)
PS149_17-1	2025-07-18	14:00	2000	SBE37-SMP	2817 (10s), 8130 (10s)

Tab. 4.4.2: Station 1 under-ice deployment info

Station 1					
Round	1 (R1a)		Depth (m)		4074
Deployment 1 (2025-07-09 to 10)					
Device starts at 2025-07-09 17:30 UTC (WHS300) Device starts at 2025-07-09 20:00 UTC (Mini-mooring)					
Location	Instruments	SN (depth, instrument)	Longitude	Latitude	Time to deploy
Ocean site	WHS300	GPS (AWI-UT-0021) WHS300 (# 9271)	20.9668	83.7416	2025-07-09 18:03 UTC
	Mini-mooring	# 238334 (RBR-solo; 10m) # 8128 (SBE37SMP; 20m) # 7728 (SBE37SMP; 50m)			2025-07-09 18:22 UTC
Recovery 1 (2025-07-25)					
Location	Instruments	SN (depth, instrument)	Device Retrieve	Data collection	Device start time for redeployment
Ocean site	WHS300	GPS (AWI-UT-0021) WHS300 (# 9271)	O	O	2025-07-26 08:30 UTC
	Mini-mooring	# 238334 (RBR-solo; 10m) # 8128 (SBE37SMP; 20m) # 7728 (SBE37SMP; 50m)	O O O	O O O	2025-07-26 10:00 UTC
Deployment 2 (2025-07-26)					
Device starts at 25/07/26 09:45:00.00 (WHS300)					
Round	2 (R1b)		Depth		3966
Location	Instruments	SN (depth, instrument)	Longitude	Latitude	Time to deploy
Ocean site	WHS300	GPS (AWI-UT-0021) WHS300 (# 9271)	26.9908	82.6639	2025-07-26 10:05 UTC
	Mini-mooring	# 238334 (RBR-solo; 10m) # 8128 (SBE37SMP; 20m) # 7728 (SBE37SMP; 50m)			2025-07-26 09:40 UTC
Recovery 2 (2025-08-21)					
Location	Instruments	SN (depth, instrument)	Device Retrieve	Data collection	Device start time for redeployment
Ocean site	WHS300	GPS (AWI-UT-0021) WHS300 (# 9271)	O O	O O	- -
	Mini-mooring	# 238334 (RBR-solo; 10m) # 8128 (SBE37SMP; 20m) # 7728 (SBE37SMP; 50m)	O O O	O O O	- - -

Tab. 4.4.3: Station 2 under-ice deployment info (next page)

Station 2					
Round		1 (R2a)		Depth (m)	4000
Deployment 1 (2025-07-15 to 16)					
• Device starts at 2025-07-15 08:00 UTC (S1000) • Device starts at 2025-07-16 11:00 UTC (Mini-mooring)					
Location	Instruments	SN (depth, instrument)	Longitude	Latitude	Ice thickness, Time to deploy
M1	S1000 [§] +RBR-solo	# 107676 (surf; S1000) # 236855 (surf; RBR-solo)	84.9750	14.0322	1.45 m 2025-07-15T10:19 UTC
	Mini-mooring	# 238332 (5m; RBR-solo)* # 238335 (10m; RBR-solo) # 13488 (20m; SBE37-ODO)**			2025-07-16T09:30 UTC
C1	S1000+ RBR-solo	# 107674 (S1000) # 236856 (RBR-solo) # GPS (AWI-UT-0023)	84.9722	14.0417	1.42 m 2025-07-15T10:50 UTC
	Mini-mooring	# 238330 (5m; RBR-solo) # 238331 (10m; RBR-solo) # 8127 (20m; SBE37-SMP)***			2025-07-16T09:42 UTC
R1	S1000+ RBR-solo	# 104403 (S1000) # 236857 (RBR-solo)	84.9786	14.0133	1.33 m 2025-07-15T11:10 UTC
	Mini-mooring	# 238327 (5m; RBR-solo) # 238329 (10m; RBR-solo) # 8131 (20m; SBE37-SMP)			2025-07-16T10:06 UTC
R2	S1000+ RBR-solo	# 107686 (S1000) # 236858 (RBR-solo) # GPS (AWI-UT-0024)	84.9756	14.0489	0.90 m 2025-07-15T11:30 UTC
	Mini-mooring	# 238325 (5m; RBR-solo) # 238326 (10m; RBR-solo) # 7730 (20m; SBE37-SMP)			2025-07-16T10:25 UTC
§ : Internal battery only ** : sampling period 90s * : sampling period 1s *** : sampling period 60s					
Recovery 1 (2025-07-30)					
Location	Instruments	SN (depth, instrument)	Device Retrieve	Data collection	Device start time for redeployment
M1	S1000 [§] +RBR-solo	# 107676 (surf; S1000) # 236855 (surf; RBR-solo)	O O	O O	2025-07-31 08:30 UTC
	Mini-mooring	# 238332 (5m; RBR-solo)* # 238335 (10m; RBR-solo) # 13488 (20m; SBE37-ODO)**	O O O	O O O	2025-07-30 18:00 UTC
C1	S1000+ RBR-solo	# 107674 (S1000) # 236856 (RBR-solo) # GPS (AWI-UT-0023)	O O	O O	2025-07-31 08:30 UTC
	Mini-mooring	# 238330 (5m; RBR-solo) # 238331 (10m; RBR-solo) # 8127 (20m; SBE37-SMP)***	O O O	O O O	2025-07-30 18:00 UTC
R1	S1000+ RBR-solo	# 104403 (S1000) # 236857 (RBR-solo)	O O	O O	2025-07-31 08:30 UTC
	Mini-mooring	# 238327 (5m; RBR-solo) # 238329 (10m; RBR-solo) # 8131 (20m; SBE37-SMP)	O O O	O O O	2025-07-30 18:00 UTC
R2	S1000+ RBR-solo	# 107686 (S1000) # 236858 (RBR-solo) # GPS (AWI-UT-0024)	O O	O O	2025-07-31 08:30 UTC
	Mini-mooring	# 238325 (5m; RBR-solo) # 238326 (10m; RBR-solo) # 7730 (20m; SBE37-SMP)	O O O	O O O	2025-07-30 18:00 UTC
§ : Internal battery only ** : sampling period 90s * : sampling period 1s *** : sampling period 60s					
Deployment 2 (2025-07-30 to 31)					
• Device starts at 2025-07-31 08:30 UTC (S1000) • Device starts at 2025-07-30 18:00 UTC (Mini-mooring)					

Location	Instruments	SN (depth, instrument)	Longitude	Latitude	Time to deploy
M1	S1000+ RBR-solo	# 107676 (surf; S1000) # 236855 (surf; RBR-solo) # GPS (AWI-UT-0023)	17.2102	83.7100	2025-07-31T10:19 UTC
	Mini-mooring	# 238330 (3m; RBR-solo) # 238332 (5m; RBR-solo) # 238335 (10m; RBR-solo) # 13488 (20m; SBE37-ODO)**			2025-07-30T09:30 UTC
C1	S1000+ RBR-solo	-	17.5175	83.7112	
	Mini-mooring	# 238331 (3m; RBR-solo) # 238325 (5m; RBR-solo) # 238326 (10m; RBR-solo) # 7730 (20m; SBE37-SMP)			2025-08-01T16:00 UTC
R1	S1000+ RBR-solo	# 104403 (S1000) # 236857 (RBR-solo)	17.1644	83.7083	2025-07-31T11:10 UTC
	Mini-mooring	# 8127 (3m; SBE37)*** # 8131 (5m; SBE37-SMP) # 238329 (10m; RBR-solo) # 238327 (20m; RBR-solo)			2025-07-30T10:06 UTC
R2	S1000+ RBR-solo	# 107686 (S1000) # 236858 (RBR-solo) # GPS (AWI-UT-0024)	17.2056	83.7103	2025-07-31T11:30 UTC
	Mini-mooring	# 238331 (3m; RBR-solo) # 238325 (5m; RBR-solo) # 238326 (10m; RBR-solo) # 7730 (20m; SBE37-SMP)			2025-07-30T10:25 UTC
** : sampling period 120s *** : sampling period 60s : Moved from R2 to C1 due to loss risk (1st AUG 16:00 UTC)					
Recovery 2 (2025-08-12)					
Location	Instruments	SN (depth, instrument)	Device Retrieve	Data collection	Device start time for redeployment
M1	S1000+ RBR-solo	# 107676 (surf; S1000) # 236855 (surf; RBR-solo) # GPS (AWI-UT-0023)	O O	O O O	2025-08-13 08:30 UTC
	Mini-mooring	# 238330 (3m; RBR-solo) # 238332 (5m; RBR-solo) # 238335 (10m; RBR-solo) # 13488 (20m; SBE37-ODO)**	O O O O	O O O O	2025-08-13 11:30 UTC
C1	S1000+ RBR-solo	-	-	-	-
	Mini-mooring	# 238331 (3m; RBR-solo) # 238325 (5m; RBR-solo) # 238326 (10m; RBR-solo) # 7730 (20m; SBE37-SMP)	O O O O	O O O O	2025-08-13 11:30 UTC
R1	S1000+ RBR-solo	# 104403 (S1000) # 236857 (RBR-solo)	O O	O O	2025-08-13 08:30 UTC
	Mini-mooring	# 8127 (3m; SBE37)*** # 8131 (5m; SBE37-SMP) # 238329 (10m; RBR-solo) # 238327 (20m; RBR-solo)	O O O O	O O O O	2025-08-13 11:30 UTC
R2	S1000+ RBR-solo	# 107686 (S1000) # 236858 (RBR-solo) # GPS (AWI-UT-0024)	O O	O O O	2025-08-13 08:30 UTC
Deployment 3 (2025-08-13)					
- Device starts at 2025-08-13 08:30 UTC (S1000) - Device starts at 2025-08-13 11:30 UTC (Mini-mooring)					

Location	Instruments	SN (depth, instrument)	Longitude	Latitude	Time to deploy
O1	S1000+ RBR-solo	# 107686 (surf; S1000) # 236858 (surf; RBR-solo) # GPS (AWI-UT-0024)	22.1169	84.5056	2025-08-13 09:18 UTC
M1	S1000+ RBR-solo	# 107676 (surf; S1000) # 236855 (surf; RBR-solo) # GPS (AWI-UT-0023)	22.1147	84.5056	2025-08-13 09:34 UTC
C1b [⊕]	S1000+ RBR-solo	# 104403 (surf; S1000) # 236857 (surf; RBR-solo)	22.1156	84.5061	2025-08-13 09:51 UTC
	Mini-mooring	# GPS (AWI-UT-0025) # 236325 (3m; RBR-solo) # 8127 (5m; SBE37) # 236326 (7m; RBR-solo) # 7730 (10m; SBE37) # 236327 (15m; RBR-solo) # 8131 (20m; SBE37) # 236329 (25m; RBR-solo) # 236330 (30m; RBR-solo) # 236331 (35m; RBR-solo) # 236332 (40m; RBR-solo) # 236335 (45m; RBR-solo) # 13488 (50m; SBE37-ODO)**	22.1180	84.5058	2025-08-13 10:12 UTC
: Ice floe outer edge [⊕] : Inner side of ice floe ** : sampling period 120s					
Recovery 2 (2025-08-24)					
Location	Instruments	SN (depth, instrument)	Device Retrieve	Data collection	Device start time for redeployment
O1	S1000+ RBR-solo	# 107686 (surf; S1000) # 236858 (surf; RBR-solo) # GPS (AWI-UT-0024)	O O O	O O O	-
M1	S1000+ RBR-solo	# 107676 (surf; S1000) # 236855 (surf; RBR-solo) # GPS (AWI-UT-0023)	O O O	O O O	-
C1b	S1000+ RBR-solo	# 104403 (surf; S1000) # 236857 (surf; RBR-solo)	O O	O O	-
	Mini-mooring	# GPS (AWI-UT-0025) # 236325 (3m; RBR-solo) # 8127 (5m; SBE37) # 236326 (7m; RBR-solo) # 7730 (10m; SBE37) # 236327 (15m; RBR-solo) # 8131 (20m; SBE37) # 236329 (25m; RBR-solo) # 236330 (30m; RBR-solo) # 236331 (35m; RBR-solo) # 236332 (40m; RBR-solo) # 236335 (45m; RBR-solo) # 13488 (50m; SBE37-ODO)**	O O O O O O O O O O O O O O O	O O O O O O O O O O O O O O O	-

Tab. 4.4.4: Station 3 under-ice deployment info (next page)

Station 3			
Round	1 (R3a)	Depth (m)	3403
Deployment 1 (2025-07-20)			
• Device starts at 2025-07-20 19:00 UTC (S500) • Device starts at 2025-07-20 13:00 UTC (Mini-mooring)			

Location	Instruments	SN (depth, instrument)	Longi- tude	Latitude	Time to deploy
Ocean site	S500	# 103942 (surf; S500) # AWI-UT-0015 (GPS)	- 17.9806	84.4172	2025-07-20 19:15 UTC
	Mini-mooring	# 238333 (10m; RBR-solo) # 2817 (20m; SBE37) # 8130 (50m; SBE37)) T and CTD sensors (Hokkaido Univ. & Kitami Tech) deployed at 2, 7, 12, 30, and 40 m			2025-07-20 15:30 UTC
Recovery 1 (2025-08-04)					
Location	Instruments	SN (depth, instrument)	Device Retrieve	Data collec- tion	Device start time for redployment
Ocean site	S500	# 103942 (surf; S500) # AWI-UT-0015 (GPS)	O	O O	2025-08-04 15:00 UTC
	Mini-mooring	# 238333 (10m; RBR-solo) # 2817 (20m; SBE37) # 8130 (50m; SBE37)) T and CTD sensors (Hokkaido Univ. & Kitami Tech) deployed at 2, 7, 12, 30, and 40 m	O O O O	O O O O	2025-08-04 14:00 UTC
Deployment 2 (2025-08-04)					
Round	2 (R3b)		Depth (m)		3966
Location	Instruments	SN (depth, instrument)	Longi- tude	Latitude	Time to deploy
Ocean site	S500	# 103942 (surf; S500) # AWI-UT-0015 (GPS)	- 12.1658	83.6081	2025-08-04 15:00 UTC
	Mini-mooring	# 238333 (10m; RBR-solo) # 2817 (20m; SBE37) # 8130 (50m; SBE37)) T and CTD sensors (Hokkaido Univ. & Kitami Tech) deployed at 2, 7, 12, 30, and 40 m			2025-08-04 15:00 UTC
Recovery 2 (2025-08-16)					
Location	Instruments	SN (depth, instrument)	Device Retrieve	Data collec- tion	Device start time for redployment
Ocean site	S500	# 103942 (surf; S500) # AWI-UT-0015 (GPS)	O	O O	2025-08-17 09:14 UTC
	Mini-mooring	# 238333 (10m; RBR-solo) # 2817 (20m; SBE37) # 8130 (50m; SBE37)) T and CTD sensors (Hokkaido Univ. & Kitami Tech) deployed at 2, 7, 12, 30, and 40 m	O O O O	O O O O	2025-08-17 11:00 UTC
Deployment 3 (2025-08-17)					
Round	3 (R3c)		Depth (m)		3195
Location	Instruments	SN (depth, instrument)	Longi- tude	Latitude	Time to deploy
Ocean site	S500	# 103942 (surf; S500) # AWI-UT-0015 (GPS)	- 12.8193	82.9563	2025-08-17 09:15 UTC
	Mini-mooring	# 238333 (10m; RBR-solo) # 2817 (20m; SBE37) # 8130 (50m; SBE37)) T and CTD sensors (Hokkaido Univ. & Kitami Tech) deployed at 2, 7, 12, 30, and 40 m			2025-08-17 10:00 UTC
Recovery 4 (2025-08-26)					
Location	Instruments	SN (depth, instrument)	Device Retrive	Data collec- tion	Device start time for redployment
Ocean site	S500	# 103942 (surf; S500) # AWI-UT-0015 (GPS)	O	O O	

	Mini-mooring	# 238333 (10m; RBR-solo) # 2817 (20m; SBE37) # 8130 (50m; SBE37) +) T and CTD sensors (Hokkaido Univ. & Kitami Tech) deployed at 2, 7, 12, 30, and 40 m	O O O O	O O O O	
Deployment 4 (2025-08-27)					
Round	4 (R3d)		Depth (m)		3782
Location	Instruments	SN (depth, instrument)	Longi- tude	Latitude	Time to deploy
Buoy site	S1000+ RBR-solo	# 107686 (surf; S1000) # 238333 (surf; RBR-solo) # AWI-UT-0015 (GPS)	-4.5608	82.3752	2025-08-27 14:00 UTC (Will be recovered during PS150)

Current measurements on floe 2

Using a downward-looking Nortek Signature 250 kHz ADCP (SN 102778; hereafter referred to as S250 ADCP) mounted on a NAMR surface buoy system equipped with a Xeox Apollo GPS beacon and an external dual-GPS antenna (Fig. 4.4.7), we aimed to obtain current measurements under the ice floe from the depth range from 4 m to 180 m at R2 ice floe. During the first deployment at R2a, we attempted for the first time to provide accurate heading data to the S250 ADCP using the external dual-GPS antenna. However, although the S250 ADCP started measuring prior to deployment, it failed to record data once in the water due to unknown technical issues of external antenna when we recovered on 30 July 2025 at R2b. The S250 ADCP was then redeployed on 1 August 2025 at R2b without the external antenna, and successfully collected current measurements from 1 to 12 August 2025 during the third revisit at R2c. The S250 ADCP was configured to take average current measurements in the upper 200 m with a bin size of 2 m, sampling 180 seconds with an average interval of 4 minutes. We recovered the S250 ADCP at 11:00 on 24 August and retrieved current measurements from 12 to 24 August during the fourth revisit of R2d. Figure 4.4.8 show the preliminary plot of meridional (u) and zonal (v) components of ocean current velocities. During revisit of R3d, we redeploy S250 ADCP (Fig. 4.4.9) at 1330 on 27 August in the ROV hole and it will plan to recover during the PS150. The S250 ADCP during R4d was configured to take average current measurements in the upper 200 m with a bin size of 2 m, sampling 120 seconds with an average interval of 15 minutes.



Fig. 4.4.7: Deployment of NAMR surface buoy system equipped with a GPS beacon a dual GPS antenna and a downward-looking Nortek Signature 250 kHz ADCP

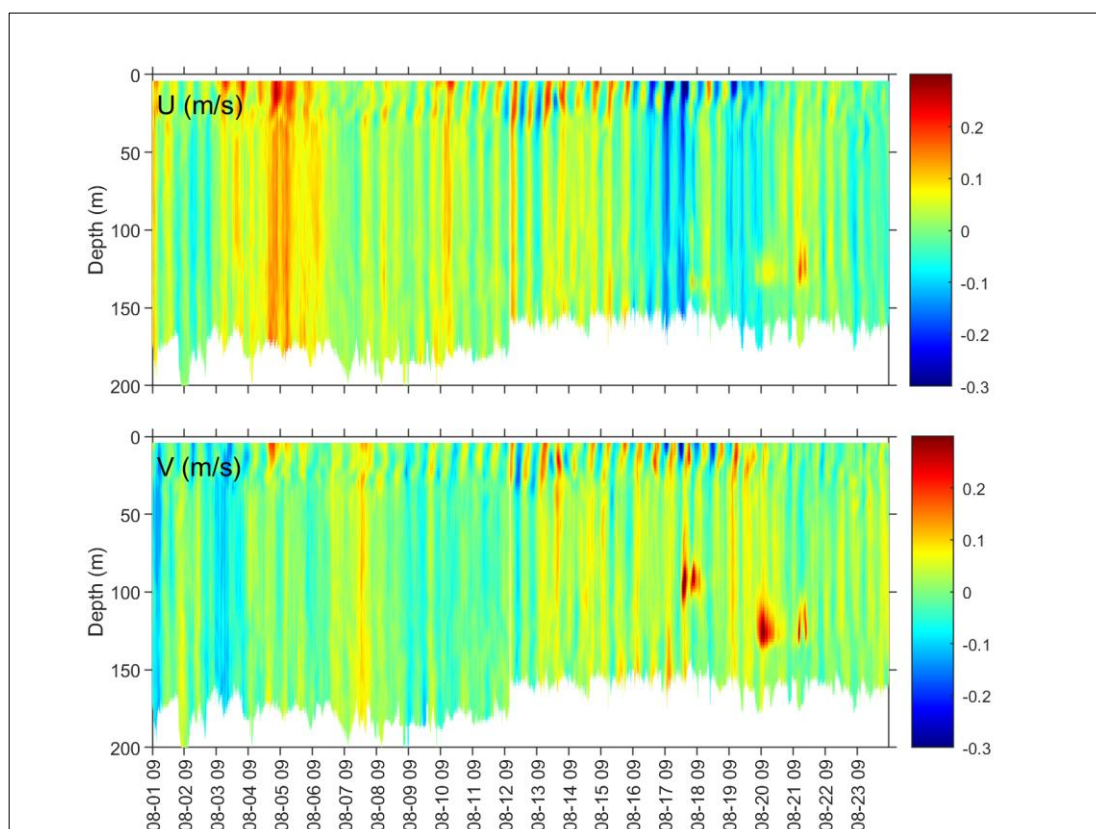


Fig. 4.4.8: Preliminary plot of meridional (u) and zonal (v) components of ocean current velocities



Fig. 4.4.9: The S250 ADCP buoy redeployed on the revisit R3d ice floe

4.5 MSS sampling

During most ice stations, we deployed a microstructure profiler (MSS90L, Sea&Sun Technologies, Germany) through ice boreholes to measure key physical and biogeochemical parameters—temperature, salinity, dissolved oxygen, chlorophyll-a fluorescence, and shear—to investigate turbulent exchange processes. Two profiler units (serial number 075 and 097) were used, equipped with a consistent sensor suite (see Tab. 4.4.1). This included two parallel airfoil shear probes (type PNS6), a fast-response thermistor (FP07) with a small sensor guard, an accelerometer for detecting instrument vibration, standard CTD sensors (SST) for high-precision measurements, a Turner Designs Cyclops-7 in vivo chlorophyll/blue sensor, and a fast-response optical oxygen sensor (SST). All sensor channels recorded data at a sampling rate of 512 Hz. Due to a GPS failure, positional data (latitude and longitude) were manually entered.



Fig. 4.5.1: MSS casting during the expedition

Tab. 4.5.2: Overview of shear sensors mounted on the MSS profilers 075 and 097

MSS SN	Sensor	Sensor SN
075 (2025-07-14 to 08-04)	Shear 1	6183 (2025-07-21 changed; Casts 01-040)
		6184*
		6185*
	Shear 2	6180 (2025-07-31 changed; Casts 01-085)
		6204 (Casts 086-094)
097 (2025-08-05 ~)	Shear 1	6326 (Casts 97 -)
	Shear 2	6327 (Casts 97 -)
* : The sensor was replaced, but it remains non-functional due to a board unit issue		

At ocean sites, MSS casts were conducted by drilling 3 to 5 holes using an auger at locations approximately 100 to 300 m away from the vessel. At lead sites, smaller holes were drilled compared to ocean sites, using a Makita drill and a long hand saw. All casts were performed manually by lowering the winch wire by hand, ensuring that all sensors were pointed downward. The profiler was deployed at a free-fall speed of 0.5 to 0.7 m s⁻¹. At ocean sites, the MSS was typically deployed down to approximately 200 m, while at lead sites, casts were limited to about 100 m. Due to abnormal readings after the last deployment at Station 2, data from the Shear1 sensor were excluded from the analysis. Instrument data were pre-processed using the MSP toolbox (Schulz, 2022). To align with ADCP measurements, most MSS casts at ocean sites were conducted 10 to 20 m away from the corresponding station's ADCP location.

Tab. 4.5.2: Overview of MSS measurements during ice stations

Event Label	MSS SN	Date	Start time	Number of profiles	Note
PS149_13-1-MSS_90D_075-1,2	075	2025-07-10	11:10	9	100m, R1
PS149_13-1-MSS_90D_075-3	075	2025-07-10	15:00	3	200m, R1
PS149_16-1-MSS_90D_075-1	075	2025-07-16	13:00	3	Lead1, R2
PS149_16-1-MSS_90D_075-2	075	2025-07-16	13:30	3	Lead2, R2
PS149_16-1-MSS_90D_075-3	075	2025-07-16	14:00	3	Lead3, R2
PS149_16-1-MSS_90D_075-4	075	2025-07-16	14:45	3	Lead4, R2
PS149_16-1-MSS_90D_075-5	075	2025-07-16	15:50	3	200m, R2
PS149_16-1-MSS_90D_075-6	075	2025-07-17	14:10	4	200m, R2
PS149_18-1-MSS_90D_075-1	075	2025-07-21	09:15	3	Lead1, R3
PS149_16-1-MSS_90D_075-2	075	2025-07-21	09:40	3	Lead2, R3
PS149_18-1-MSS_90D_075-3	075	2025-07-21	14:10	3	200m, R3
PS149_18-1-MSS_90D_075-4	075	2025-07-22	09:30	3	200m, R3
PS149_18-1-MSS_90D_075-5	075	2025-07-22	13:30	3	200m, R3
PS149_21-1-MSS_90D_075-1	075	2025-07-26	14:00	6	Lead, R3
PS149_21-1-MSS_90D_075-2	075	2025-07-27	10:30	3	200m, R1
PS149_21-1-MSS_90D_075-3	075	2025-07-28	09:15	6	200m, R1
PS149_25-1-MSS_90D_075-1	075	2025-07-30	09:50	3	Lead1, R2

Event Label	MSS SN	Date	Start time	Number of profiles	Note
PS149_25-1- MSS_90D_075-2	075	2025-07-30	10:24	2	Lead2, R2
PS149_25-1- MSS_90D_075-3	075	2025-07-30	10:50	3	Lead3, R2
PS149_25-1- MSS_90D_075-4	075	2025-07-30	14:00	3	Lead4, R2
PS149_25-1- MSS_90D_075-5	075	2025-07-31	09:30	3	200m, R2
PS149_25-1- MSS_90D_075-6	075	2025-07-31	13:00	3	200m, R2
PS149_25-1- MSS_90D_075-7	075	2025-07-31	15:24	3	200m, R2
PS149_25-1- MSS_90D_075-8	075	2025-07-31	18:48	3	200m, R2
PS149_25-1- MSS_90D_075-9	075	2025-08-01	09:56	2	100m, R2
PS149_25-1- MSS_90D_075-10	075	2025-08-01	13:06	3	200m, R2
PS149_25-1- MSS_90D_075-11	075	2025-08-01	15:30	4	200m, R2
PS149_30-1- MSS_90D_075	075	2025-08-04	15:00	2	200m, R3
PS149_30-1-mss_90L_097-1	097	2025-08-05	10:00	3	Lead1, R3
PS149_30-1-mss_90L_097-2	097	2025-08-05	10:28	2	Lead2, R3
PS149_30-1-mss_90L_097-3	097	2025-08-05	13:25	3	200m, R3
PS149_30-1-mss_90L_097-4	097	2025-08-05	16:00	3	200m, R3
PS149_30-1-mss_90L_097-5	097	2025-08-05	19:00	3	200m, R3
PS149_30-1-mss_90L_097-6	097	2025-08-06	09:30	3	200m, R3
PS149_30-1-mss_90L_097-7	097	2025-08-06	13:00	3	200m, R3
PS149_32-1-mss_90L_097-1	097	2025-08-09	16:50	3	Lead, R1.5c
PS149_32-1-mss_90L_097-2	097	2025-08-09	18:50	3	Lead, R1.5c
PS149_32-1-mss_90L_097-3	097	2025-08-09	19:30	3	200m, R1.5c
PS149_32-1-mss_90L_097-4	097	2025-08-10	08:52	3	200m, R1.5c
PS149_32-1-mss_90L_097-5	097	2025-08-10	12:43	3	200m, R1.5c
PS149_32-1-mss_90L_097-6	097	2025-08-10	15:37	3	200m, R1.5c
PS149_32-1-mss_90L_097-7	097	2025-08-10	19:50	3	200m, R1.5c
PS149_36-1-mss_90L_097-1	097	2025-08-13	12:50	3	200m, R2c
PS149_36-1-mss_90L_097-2	097	2025-08-13	15:40	3	200m, R2c
PS149_36-1-mss_90L_097-3	097	2025-08-13	19:45	2	200m, R2c
PS149_36-1-mss_90L_097-4	097	2025-08-14	09:10	3	200m, R2c
PS149_36-1-mss_90L_097-5	097	2025-08-14	10:00	3	100m, R2c
PS149_36-1-mss_90L_097-6	097	2025-08-14	10:30	3	100m, R2c
PS149_36-1-mss_90L_097-7	097	2025-08-14	13:30	3	200m, R2c
PS149_36-1-mss_90L_097-8	097	2025-08-14	15:30	3	200m, R2c
PS149_41-1-mss_90L_097-1	097	2025-08-17	10:00	3	200m, R3c
PS149_41-1-mss_90L_097-1	097	2025-08-17	12:50	3	200m, R3c
PS149_41-1-mss_90L_097-1	097	2025-08-17	15:20	3	200m, R3c
PS149_41-1-mss_90L_097-1	097	2025-08-18	09:30	3	200m, R3c

4.6 Fishing rod CTD

In order to investigate under-ice hydrographic conditions, a fishing rod CTD system was employed during the cruise. Vertical hydrographic profiles were collected using a CTD48 instrument (Sea & Sun Technology GmbH, Germany), which is equipped with conductivity, temperature and pressure sensors at the Ocean Site.

The CTD48 was deployed manually through augered boreholes in the sea ice, enabling high-resolution measurements of the water column beneath the ice cover. Raw data were recorded in the manufacturer's proprietary. SRD format. Please refer station number and map to refer the location.

The CTD48 provided high-quality vertical profile data, contributing to the characterization of the hydrographic structure in under-ice environments during the Arctic cruise.

Tab. 4.6.1: Fishing Rod CTD specifications

Sensor	Principle	Range	Accuracy	Resolution	Response time
Pressure	piezo resistive	5, 10, 20, 50, 100, 200, 400, 600 bar	up to 0.05 % full scale in the range of $-5...35^{\circ}\text{C}$	0.002 % full scale	150 ms
Temperature	Pt 100 4-pole	$-2 - 36^{\circ}\text{C}$ $-2 - 60^{\circ}\text{C}$	$\pm 0.002^{\circ}\text{C}$ $\pm 0.005^{\circ}\text{C}$	0.0005°C 0.0005°C 150 ms	150 ms
Conductivity	7-pole-cell	0 – 1 mS/cm 0 – 6 mS/cm 0 – 10 mS/cm 0 – 70 mS/cm	± 0.002 mS/cm	0.0005 mS/cm	150 ms

Tab. 4.6.2: Fishing Rod CTD cast numbers

Cast No	File name	Start time	Remarks
1	J8041925_1.SRD	2025/08/04 15:08:03	St3-2-1 (event No.30-1)
2	J8041925_2.SRD	2025/08/04 16:04:31	St3-2-1 (event No.30-1)
3	J8052008_1.SRD	2025/08/05 10:28:47	St3-2-2 (event No.30-1)
4	J8052008_2.SRD	2025/08/05 12:45:18	St3-2-2 (event No.30-1)
5	J8052008_3.SRD	2025/08/05 14:05:07	St3-2-2 (event No.30-1)
6	J8052008_4.SRD	2025/08/05 15:03:48	St3-2-2 (event No.30-1)
7	J8052008_5.SRD	2025/08/05 16:56:37	St3-2-2 (event No.30-1)
8	J8052008_6.SRD	2025/08/05 18:38:12	St3-2-2 (event No.30-1)
9	J8111932_1.SRD	2025/08/06 09:58:31	St3-2-3 (event No.30-1)
10	J8121656_1.SRD	2025/08/12 16:14:21	St2-3-1 (event No.36-1)
11	J8131933_3.SRD	2025/08/13 09:08:48	St2-3-2 (event No.36-1)
12	J8131933_4.SRD	2025/08/13 13:14:34	St2-3-2 (event No.36-1)
13	J8131933_5.SRD	2025/08/13 13:58:53	St2-3-2 (event No.36-1)
14	J8022308_24.SRD	2025/08/14 13:48:52	St2-3-3 (event No.36-1)
15	J8022308_25.SRD	2025/08/14 14:15:13	St2-3-3 (event No.36-1)

Cast No	File name	Start time	Remarks
16	J8022308_26.SRD	2025/08/14 14:30:37	St2-3-3 (event No.36-1)
17	J8022308_27.SRD	2025/08/14 14:49:06	St2-3-3 (event No.36-1)
18	J8141651_1.SRD	2025/08/14 16:02:46	St2-3-3 (event No.36-1)
19	J8141651_2.SRD	2025/08/14 16:22:58	St2-3-3 (event No.36-1)
20	J8171506_1.SRD	2025/08/17 09:39:24	St3-3-2 (event No.39-1)
21	J8171506_2.SRD	2025/08/17 13:27:31	St3-3-2 (event No.39-1)
22	J8171506_3.SRD	2025/08/17 13:54:44	St3-3-2 (event No.39-1)
23	J8171506_4.SRD	2025/08/17 14:23:29	St3-3-2 (event No.39-1)
24	J8171506_5.SRD	2025/08/17 14:42:03	St3-3-2 (event No.39-1)
25	J8171842_1.SRD	2025/08/17 15:55:55	St3-3-2 (event No.39-1)
26	J8171842_2.SRD	2025/08/17 16:22:06	St3-3-2 (event No.39-1)
27	J8171842_3.SRD	2025/08/17 16:35:58	St3-3-2 (event No.39-1)
28	J8181240_2.SRD	2025/08/18 09:01:14	St3-3-3 (event No.39-1)
29	J8181240_3.SRD	2025/08/18 09:14:50	St3-3-3 (event No.39-1)
30	J8181240_4.SRD	2025/08/18 10:40:57	St3-3-3 (event No.39-1)
31	J8181240_5.SRD	2025/08/18 10:57:53	St3-3-3 (event No.39-1)
32	J8181451_2.SRD	2025/08/18 13:05:38	St3-3-3 (event No.39-1)
33	J8181451_3.SRD	2025/08/18 13:20:22	St3-3-3 (event No.39-1)
34	J8181451_4.SRD	2025/08/18 13:35:35	St3-3-3 (event No.39-1)
35	J8181451_5.SRD	2025/08/18 13:49:35	St3-3-3 (event No.39-1)
36	J8181451_6.SRD	2025/08/18 14:03:37	St3-3-3 (event No.39-1)
37	J8181451_7.SRD	2025/08/18 14:17:35	St3-3-3 (event No.39-1)
38	J8181719_2.SRD	2025/08/18 15:07:58	St3-3-3 (event No.39-1)
39	J8181719_3.SRD	2025/08/18 15:26:09	St3-3-3 (event No.39-1)
40	J8181719_4.SRD	2025/08/18 15:40:08	St3-3-3 (event No.39-1)
41	J8181719_5.SRD	2025/08/18 15:53:44	St3-3-3 (event No.39-1)
42	J8181719_6.SRD	2025/08/18 16:06:33	St3-3-3 (event No.39-1)
43	J8181719_7.SRD	2025/08/18 16:20:02	St3-3-3 (event No.39-1)
44	J8181719_8.SRD	2025/08/18 16:33:09	St3-3-3 (event No.39-1)
45	J8181719_9.SRD	2025/08/18 16:48:28	St3-3-3 (event No.39-1)
46	J8231308_4.SRD	2025/08/23 09:33:17	St2-4-1 (event No.46-1)
47	J8231308_5.SRD	2025/08/23 09:46:55	St2-4-1 (event No.46-1)
48	J8231308_6.SRD	2025/08/23 10:00:33	St2-4-1 (event No.46-1)
49	J8231308_7.SRD	2025/08/23 10:21:33	St2-4-1 (event No.46-1)
50	J8231308_8.SRD	2025/08/23 10:42:10	St2-4-1 (event No.46-1)
51	J8231308_10.SRD	2025/08/23 11:00:38	St2-4-1 (event No.46-1)
52	J8231308_11.SRD	2025/08/23 11:14:35	St2-4-1 (event No.46-1)
53	J8231308_12.SRD	2025/08/23 11:27:33	St2-4-1 (event No.46-1)
54	J8231308_13.SRD	2025/08/23 11:40:44	St2-4-1 (event No.46-1)
55	J8231308_14.SRD	2025/08/23 12:01:28	St2-4-1 (event No.46-1)
56	J8231308_15.SRD	2025/08/23 12:15:50	St2-4-1 (event No.46-1)
57	J8231308_16.SRD	2025/08/23 12:28:21	St2-4-1 (event No.46-1)
58	J8231308_17.SRD	2025/08/23 12:41:29	St2-4-1 (event No.46-1)
59	J8231308_18.SRD	2025/08/23 12:53:22	St2-4-1 (event No.46-1)

Cast No	File name	Start time	Remarks
60	J8231512_1.SRD	2025/08/23 13:15:02	St2-4-1 (event No.46-1)
61	J8231512_2.SRD	2025/08/23 13:32:28	St2-4-1 (event No.46-1)
62	J8231512_3.SRD	2025/08/23 13:44:08	St2-4-1 (event No.46-1)
63	J8231512_4.SRD	2025/08/23 13:56:26	St2-4-1 (event No.46-1)
64	J8231512_5.SRD	2025/08/23 14:08:19	St2-4-1 (event No.46-1)
65	J8231512_6.SRD	2025/08/23 14:22:02	St2-4-1 (event No.46-1)
66	J8231512_7.SRD	2025/08/23 14:43:36	St2-4-1 (event No.46-1)
67	J8231512_8.SRD	2025/08/23 14:57:42	St2-4-1 (event No.46-1)
68	J8231703_1.SRD	2025/08/23 15:17:12	St2-4-1 (event No.46-1)
69	J8231703_2.SRD	2025/08/23 15:31:41	St2-4-1 (event No.46-1)
70	J8231703_3.SRD	2025/08/23 15:45:12	St2-4-1 (event No.46-1)
71	J8231703_4.SRD	2025/08/23 15:59:23	St2-4-1 (event No.46-1)
72	J8231703_5.SRD	2025/08/23 16:12:51	St2-4-1 (event No.46-1)
73	J8231703_6.SRD	2025/08/23 16:26:04	St2-4-1 (event No.46-1)
74	J8231703_7.SRD	2025/08/23 16:39:25	St2-4-1 (event No.46-1)
75	J8232001_1.SRD	2025/08/23 17:10:10	St2-4-1 (event No.46-1)
76	J8232001_2.SRD	2025/08/23 17:24:24	St2-4-1 (event No.46-1)
77	J8232001_3.SRD	2025/08/23 17:39:02	St2-4-1 (event No.46-1)
78	J8232001_4.SRD	2025/08/23 17:54:23	St2-4-1 (event No.46-1)
79	J8232001_5.SRD	2025/08/23 18:15:31	St2-4-1 (event No.46-1)
80	J8232001_6.SRD	2025/08/23 18:30:33	St2-4-1 (event No.46-1)
81	J8232001_7.SRD	2025/08/23 18:42:40	St2-4-1 (event No.46-1)
82	J8232001_8.SRD	2025/08/23 18:54:21	St2-4-1 (event No.46-1)
83	J8232001_9.SRD	2025/08/23 19:06:21	St2-4-1 (event No.46-1)
84	J8232001_10.SRD	2025/08/23 19:18:19	St2-4-1 (event No.46-1)
85	J8232001_11.SRD	2025/08/23 19:29:50	St2-4-1 (event No.46-1)
86	J8232001_12.SRD	2025/08/23 19:42:05	St2-4-1 (event No.46-1)
87	J8241100_2.SRD	2025/08/24 8:45:36	St2-4-2 (event No.46-1)
88	J8241100_3.SRD	2025/08/24 9:02:17	St2-4-2 (event No.46-1)
89	J8241100_4.SRD	2025/08/24 9:17:12	St2-4-2 (event No.46-1)
90	J8241100_5.SRD	2025/08/24 9:33:25	St2-4-2 (event No.46-1)
91	J8241100_6.SRD	2025/08/24 9:55:28	St2-4-2 (event No.46-1)
92	J8241100_7.SRD	2025/08/24 10:09:22	St2-4-2 (event No.46-1)
93	J8241100_8.SRD	2025/08/24 10:25:03	St2-4-2 (event No.46-1)
94	J8241100_9.SRD	2025/08/24 10:39:09	St2-4-2 (event No.46-1)
95	J8241528_1.SRD	2025/08/24 11:05:50	St2-4-2 (event No.46-1)
96	J8241528_2.SRD	2025/08/24 11:18:19	St2-4-2 (event No.46-1)
97	J8241528_3.SRD	2025/08/24 11:31:28	St2-4-2 (event No.46-1)
98	J8241528_4.SRD	2025/08/24 11:43:40	St2-4-2 (event No.46-1)
99	J8241528_6.SRD	2025/08/24 11:54:53	St2-4-2 (event No.46-1)
100	J8241528_8.SRD	2025/08/24 12:07:24	St2-4-2 (event No.46-1)
101	J8241528_9.SRD	2025/08/24 12:21:23	St2-4-2 (event No.46-1)
102	J8241528_11.SRD	2025/08/24 12:34:48	St2-4-2 (event No.46-1)
103	J8241528_12.SRD	2025/08/24 12:46:54	St2-4-2 (event No.46-1)

Cast No	File name	Start time	Remarks
104	J8241528_13.SRD	2025/08/24 13:08:53	St2-4-2 (event No.46-1)
105	J8241528_14.SRD	2025/08/24 13:22:40	St2-4-2 (event No.46-1)
106	J8241528_15.SRD	2025/08/24 13:36:25	St2-4-2 (event No.46-1)
107	J8241528_16.SRD	2025/08/24 13:51:12	St2-4-2 (event No.46-1)
108	J8241528_17.SRD	2025/08/24 14:11:26	St2-4-2 (event No.46-1)
109	J8241528_19.SRD	2025/08/24 14:25:54	St2-4-2 (event No.46-1)
110	J8241528_20.SRD	2025/08/24 14:39:42	St2-4-2 (event No.46-1)
111	J8261042_2.SRD	2025/08/26 8:53:01	St3-4-1 (event No.47-1)
112	J8261042_3.SRD	2025/08/26 9:11:22	St3-4-1 (event No.47-1)
113	J8261042_4.SRD	2025/08/26 9:29:11	St3-4-1 (event No.47-1)
114	J8261042_5.SRD	2025/08/26 9:48:04	St3-4-1 (event No.47-1)
115	J8261042_6.SRD	2025/08/26 10:11:07	St3-4-1 (event No.47-1)
116	J8261042_7.SRD	2025/08/26 10:28:12	St3-4-1 (event No.47-1)
117	J8261436_1.SRD	2025/08/26 10:48:55	St3-4-1 (event No.47-1)
118	J8261436_3.SRD	2025/08/26 11:10:44	St3-4-1 (event No.47-1)
119	J8261436_4.SRD	2025/08/26 11:26:36	St3-4-1 (event No.47-1)
120	J8261436_5.SRD	2025/08/26 11:42:56	St3-4-1 (event No.47-1)
121	J8261436_6.SRD	2025/08/26 11:59:58	St3-4-1 (event No.47-1)
122	J8261436_7.SRD	2025/08/26 12:17:40	St3-4-1 (event No.47-1)
123	J8261436_8.SRD	2025/08/26 12:39:52	St3-4-1 (event No.47-1)
124	J8261436_9.SRD	2025/08/26 12:57:40	St3-4-1 (event No.47-1)
125	J8261436_10.SRD	2025/08/26 13:12:48	St3-4-1 (event No.47-1)
126	J8261436_11.SRD	2025/08/26 13:27:09	St3-4-1 (event No.47-1)
127	J8261436_12.SRD	2025/08/26 13:41:27	St3-4-1 (event No.47-1)
128	J8261436_13.SRD	2025/08/26 13:56:20	St3-4-1 (event No.47-1)
129	J8261436_15.SRD	2025/08/26 14:10:56	St3-4-1 (event No.47-1)
130	J8261759_1.SRD	2025/08/26 14:46:08	St3-4-1 (event No.47-1)
131	J8261759_2.SRD	2025/08/26 15:02:30	St3-4-1 (event No.47-1)
132	J8261759_3.SRD	2025/08/26 15:18:11	St3-4-1 (event No.47-1)
133	J8261759_4.SRD	2025/08/26 15:35:24	St3-4-1 (event No.47-1)
134	J8261759_5.SRD	2025/08/26 15:52:28	St3-4-1 (event No.47-1)
135	J8261759_6.SRD	2025/08/26 16:15:45	St3-4-1 (event No.47-1)
136	J8261759_7.SRD	2025/08/26 16:35:42	St3-4-1 (event No.47-1)
137	J8261759_8.SRD	2025/08/26 16:51:18	St3-4-1 (event No.47-1)
138	J8261759_9.SRD	2025/08/26 17:03:08	St3-4-1 (event No.47-1)
139	J8261759_10.SRD	2025/08/26 17:16:47	St3-4-1 (event No.47-1)
140	J8262237_1.SRD	2025/08/26 18:10:51	St3-4-1 (event No.47-1)
141	J8262237_2.SRD	2025/08/26 18:31:09	St3-4-1 (event No.47-1)
142	J8262237_3.SRD	2025/08/26 18:49:03	St3-4-1 (event No.47-1)
143	J8262237_4.SRD	2025/08/26 19:07:24	St3-4-1 (event No.47-1)
144	J8262237_5.SRD	2025/08/26 19:24:24	St3-4-1 (event No.47-1)
145	st3d272.SRD	2025/08/27 8:42:24	St3-4-2 (event No.47-1)
146	st3d273.SRD	2025/08/27 8:57:16	St3-4-2 (event No.47-1)
147	st3d274.SRD	2025/08/27 9:18:40	St3-4-2 (event No.47-1)

Cast No	File name	Start time	Remarks
148	st3d275.SRD	2025/08/27 9:33:39	St3-4-2 (event No.47-1)
149	st3d276.SRD	2025/08/27 9:47:48	St3-4-2 (event No.47-1)
150	st3d277.SRD	2025/08/27 10:02:03	St3-4-2 (event No.47-1)
151	st3d278.SRD	2025/08/27 10:24:18	St3-4-2 (event No.47-1)
152	st3d279.SRD	2025/08/27 10:37:05	St3-4-2 (event No.47-1)
153	st3d2710.SRD	2025/08/27 10:54:00	St3-4-2 (event No.47-1)
154	st3d2711.SRD	2025/08/27 11:11:19	St3-4-2 (event No.47-1)
155	st3d2712.SRD	2025/08/27 11:32:06	St3-4-2 (event No.47-1)
156	st3d2713.SRD	2025/08/27 11:47:53	St3-4-2 (event No.47-1)
157	st3d2714.SRD	2025/08/27 12:02:01	St3-4-2 (event No.47-1)
158	J8271415_1.SRD	2025/08/27 12:38:25	St3-4-2 (event No.47-1)
159	J8271415_2.SRD	2025/08/27 12:54:32	St3-4-2 (event No.47-1)
160	J8271415_3.SRD	2025/08/27 13:09:53	St3-4-2 (event No.47-1)
161	J8271415_4.SRD	2025/08/27 13:24:58	St3-4-2 (event No.47-1)
162	J8271415_5.SRD	2025/08/27 13:39:39	St3-4-2 (event No.47-1)
163	J8271415_6.SRD	2025/08/27 13:59:51	St3-4-2 (event No.47-1)
164	J8272106_2.SRD	2025/08/27 14:45:53	St3-4-2 (event No.47-1)
165	J8272106_3.SRD	2025/08/27 15:01:06	St3-4-2 (event No.47-1)
166	J8272106_4.SRD	2025/08/27 15:15:56	St3-4-2 (event No.47-1)
167	J8272106_5.SRD	2025/08/27 15:39:20	St3-4-2 (event No.47-1)
168	J8272106_6.SRD	2025/08/27 15:53:56	St3-4-2 (event No.47-1)
169	J8272106_7.SRD	2025/08/27 16:08:47	St3-4-2 (event No.47-1)

4.7 L-Arm Transmittance

Sunlight transmitted through the sea ice cover into the upper ocean is a critical parameter for solar heating of the mixed layer and primary productivity. The proportion of incoming sunlight that is transmitted ('transmittance') can vary from less than 5% to greater than 60%, depending on the surface conditions (e.g., ponded or snow-covered), ice thickness, and the inherent optical properties of the ice. There is considerable spatial heterogeneity in these properties—and consequently the transmittance—both within individual sea ice floes and between different sea ice regimes. In particular, prior work has observed notable variability in the optical properties of melt ponds. However, the physical reasons for this optical variability are not fully understood and the sea ice submodels of many Earth System Models and Numerical Weather Prediction systems (e.g., CICE) use the same inherent optical properties for all melt ponds. The objective of this work was to create a dataset of spectral transmittance and albedo co-located with detailed physical characterization of ice properties. This dataset will be used to explore the physical drivers of optical properties and support model development.

Transmittance measurements were made with a pair of TriOS RAMSES Advanced Cosine Collector spectral radiometers. These sensors measure spectral irradiance at 190 channels between 320 and 950 nm in air or underwater. One sensor was mounted on a tripod, pointing upwards, to measure the incident solar irradiance. For under-ice irradiance measurements, the other sensor was mounted on an 'L-arm': a hinged rod with flotation that enabled the sensor to be deployed through a hole in the ice and point vertically-upward towards the ice from a horizontal distance of approximately 1.22 m away from the hole (Fig. 4.7.1).



Fig. 4.7.1: Underwater photo of L-arm deployment. The radiometer is on the left side of the image and is pointing upwards at the ice bottom. In this case, the radiometer is not fully vertical due to it being dragged by the drift. Subsequent modifications of the floatation resolved this issue.

Both sensors were connected to a field laptop via an IPS104 unit and controlled with the MSDA_XE software. Simultaneous measurement of downwelling spectral irradiance in air and underwater enable the computation of spectral transmittance. Spectral albedo measurements were made by removing one of the hinged sections of the L-arm and positioning the sensor over the measurement site pointing downwards (Fig. 4.7.2). For most measurement sites, the objective was to have a spatially uniform sea ice cover within the radiometer footprint.



Fig. 4.7.2: Photo of using the L-arm to measure albedo of a pond. The sensor was held approximately 25 cm above the surface.

Transmittance measurements were always accompanied by spectral albedo measurements. On some occasions, spectral albedo measurements were made an Advanced Spectral Devices (ASD) FieldSpec 3 spectral radiometer in collaboration with the albedo team (Section 2.1). Surface type, ice thickness and snow/surface scattering layer depth or pond depth were always made with transmittance measurements. Measurements on unpounded ice prioritized co-locating with measurements of ice properties and potential biogenic light absorbing impurities. The measurements included the main physical (Section 2.11) and biological (Section 5) coring site, the WISELIGHT measurements (Section 2.12) and the DIAMOND measurements (Section 4.10). Melt pond measurement sites were chosen to survey a variety of pond types. The factors considered were qualitative pond color ('light' vs. 'dark' ponds), ice age, and deformation. Starting with the second ('b') visits to each regime, melt pond cores were recovered and analyzed for density, texture, salinity (Section 2.11) and stored for future x-ray micro-Computer Tomography measurements. When possible, ponded ice measurements were co-located with hyperspectral camera imagery (Section 2.5). L-arm measurements were also co-located with ROV (Section 2.13) under-ice measurements at stations 2b and 2c.

The underwater radiometer suffered unexplained failures on 20 July, 31 July, and 4 August. After the third radiometer was rendered unusable, L-arm transmittance measurements were

halted for the remainder of the expedition. Following this date, the measurement program was continued as feasible by combining ASD spectral albedo measurements with ROV transmittance measurements.

See Station Plan (Section A.7) for the L-arm events.

Preliminary (expected) results

Substantial variability in light transmittance was observed with spectral peak values ranging from approximately 0.1 for snow-covered ice to 0.8 for melting, ponded ice. In general, as ponds melted their transmittance increased (e.g., Fig. 4.7.3). Whereas for bare ice the evolution of transmittance was strongly impacted by ephemeral events (e.g., snow fall, rain fall, surface inundation). Future work will investigate the relationships between the physical (e.g., density, Fig. 4.7.3) and optical properties of the ice.

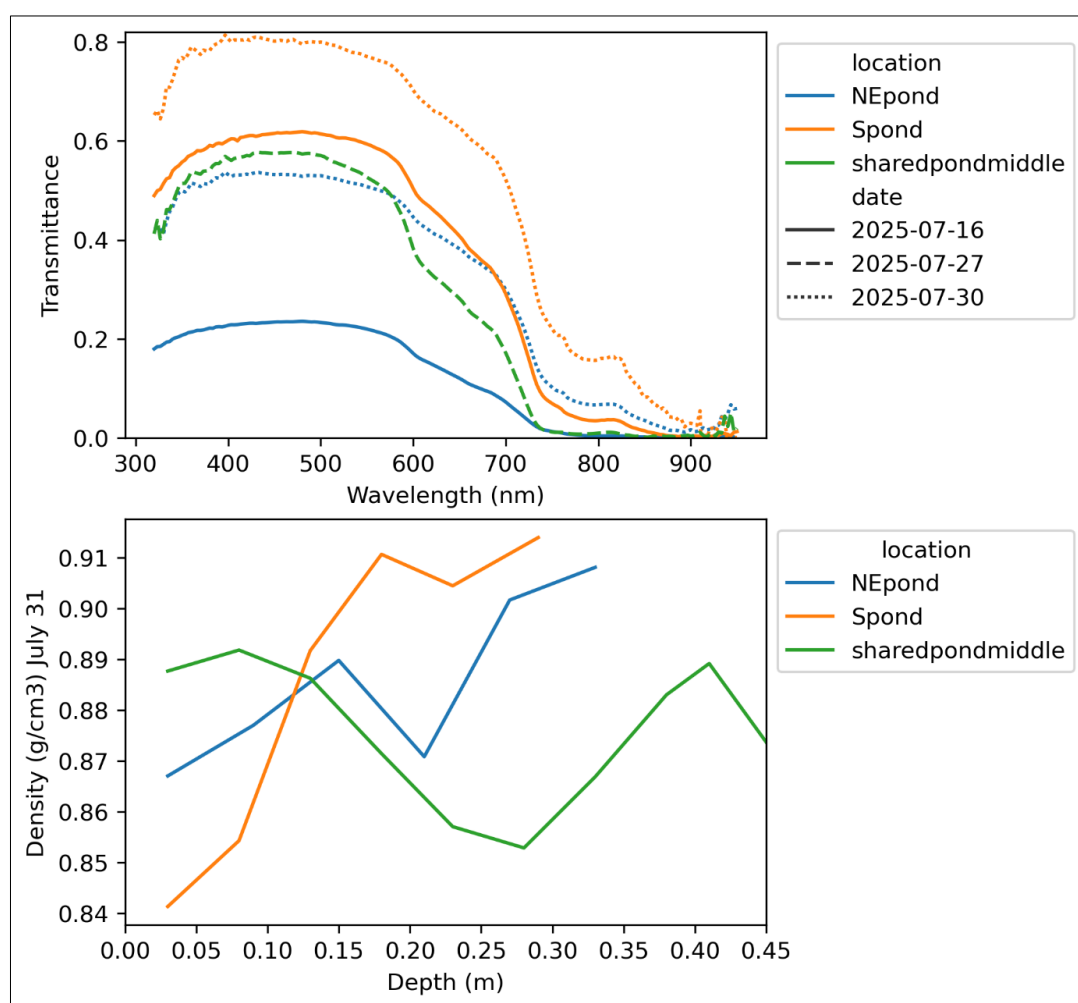


Fig. 4.7.3: Spectral transmittance (top) and ice density profiles (bottom) for three ponds. All three ponds were first-year ice, but Spond was considerably more transparent than NEpond or sharedpondmiddle. The density profile of Spond also differs, from the others, although further work is needed to interpret the differences. NEpond and Spond were measured twice, with two weeks intervening. During the intervening time, both ponds became much more transparent.

4.8 Shallow CTD measurements

Thin, under-ice meltwater layers have previously been observed beneath Arctic sea ice (notably at MOSAiC, a.k.a. PS122), but have not been universally observed (e.g., they were not observed on ArcWatch 1). These layers can impact the fluxes of heat, momentum, salt, and biogeochemical materials between the ice and the ocean (Smith et al., 2022). A primary objective of the CONTRASTS shallow CTD (conductivity, temperature, depth) measurements was to look for under ice meltwater layers and, when found, characterize their thickness and spatial distribution.

Shallow CTD measurements were made with a YSI ProDSS handheld water quality meter (hereafter 'YSI') with sensors for temperature, conductivity, optical dissolved oxygen, and turbidity. The YSI was deployed at depths down to seven meters through holes in the ice (generally 5 cm auger holes) and at lead edges. The YSI depth measurements were found to be unreliable in the presence of strong temperature and salinity gradients (such as occur with under-ice meltwater), so depths were also recorded manually using a scale marked on the cable. For the depths at which under ice meltwater layers were found (up to 12 cm below the ice bottom), the conductivity sensor experiences essentially no deflection from vertical because part of the instrument is still held vertically by the hole in the ice.

See Station Plan (Section A.7) for the shallow ctd events.

Preliminary (expected) results

Thin (<12 cm) under-ice meltwater layers were found at stations 1c (PS149_32-1) and 3c (PS149_41-1). At these stations, the meltwater layer was widely spatially distributed. For example, at station 1c, meltwater was found in 78% of shallow CTD casts, including within 10 m of the lead edge (Fig. 4.8.1). Under-ice meltwater was not found at other stations.

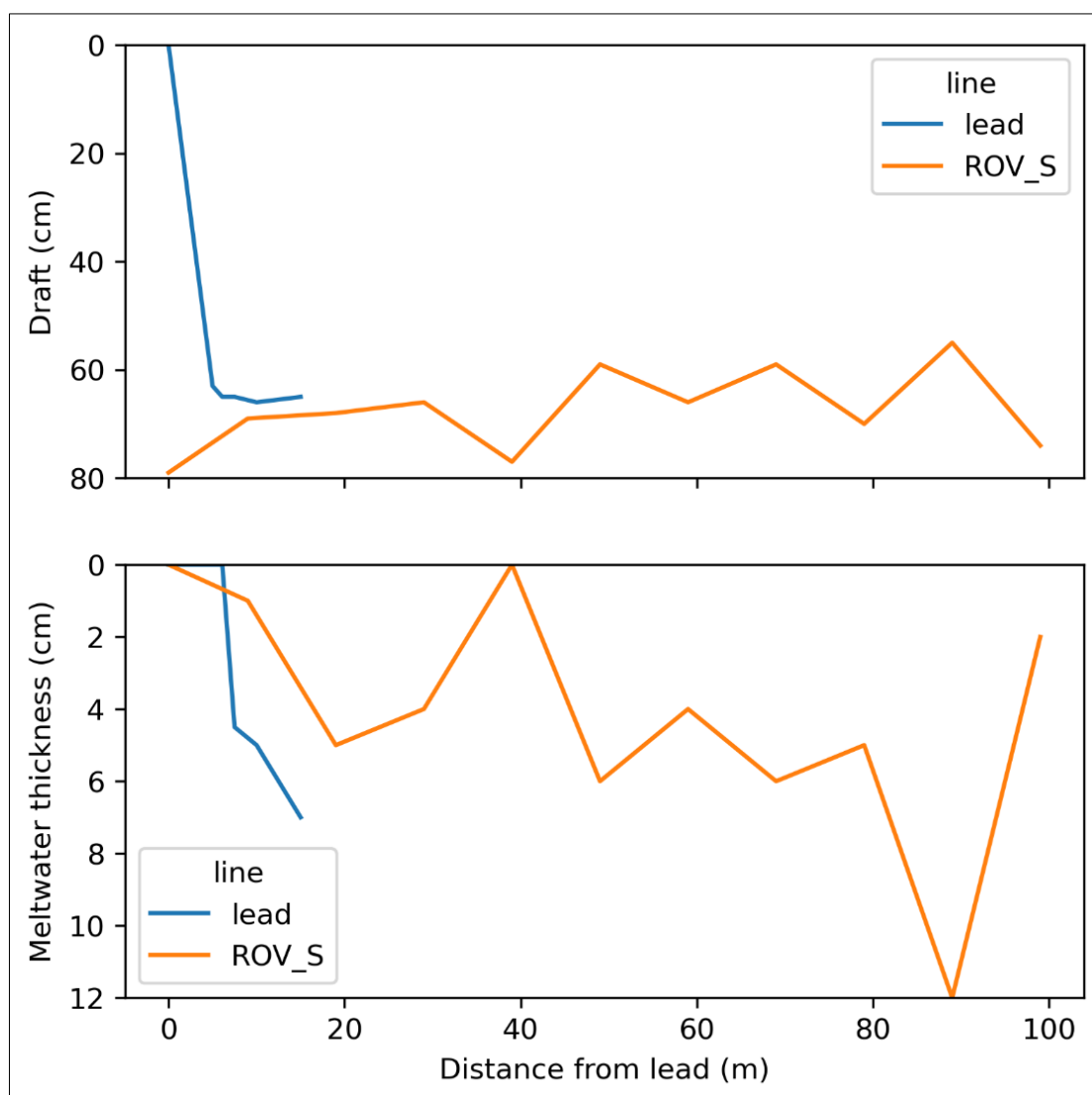


Fig. 4.8.1: Ice draft (top) and under-ice meltwater lens thickness (bottom) along two transect lines from the lead edge into floe 1c. Note that both y-axes are reversed (i.e., ice with deeper draft is represented as lower down on the plot). The meltwater lens was thickest at local draft minima away from the edge of the lead.

4.9 Autonomous platforms

Wave buoys

Five OpenMetBuoys (Rabault et al., 2022; hereafter referred to as ‘wave buoys’) were deployed. Wave buoys are a low-cost platform for measuring the vertical wave spectra. For CONTRASTs the buoys were configured to transmit data via satellite every 2 hours. Waves are most important in the marginal ice zone. So, two wave buoys were deployed within a few kilometers of the Tara drifting station, which began its drift in the marginal ice zone on 6 July 2025. Tara’s measurements of the ice state evolution can be used to contextualize the wave spectra observed by these buoys. The other three buoys were deployed on the first visit of each floe. At floe 1a, the wave buoy was deployed approximately 10 meters from the iAOOS buoy. At floes 2a and 3a, the wave buoys were deployed at the main ocean city measurement site. On visit 2d the wave buoy was recovered from floe 2 and on visit 3d the wave buoy was relocated from ocean city to the where all buoys were left for PS150 (the former ROV hole area).

See Station Plan (Section A.7) for the wave buoy events.

CTD buoys (PG SVP5S)

The concept for the CTD buoys was to have a network of CTD buoys, iAOOS profilers and CTD mini moorings to cover the mesoscale and its transition to the sub mesoscale, in order to measure eddies and front dynamics.

The CTD buoy consists of a transmitting buoy on top, the SVP5S by Pacific Gyre. It sends position and CTD data every 10 minutes and is able to float, once it reaches the open water. Attached to the buoy is 100m of inductive cable, on which 5 Seabird CTDs (SBE37) are attached, one at 10, 25, 50, 75 and 100m). They are set to a sampling interval of 120 seconds, so it is possible to get a higher frequency of the dataset if we are able to recover the buoys. Therefore, we wanted to deploy 3 CTD buoys in a rectangular position to each other with a distance of 2-3km to the main area, on each floe. Due to the availability of the buoys, we could only deploy two buoys at floe 2. Floe 1 and 3 were set up with three buoys. Because of ice conditions we couldn’t go any further for the deployments on floe 3 than 1,5km and 1,0km. The buoys were deployed using Skidoos or by ship when we left the main floe to deploy the MUC.

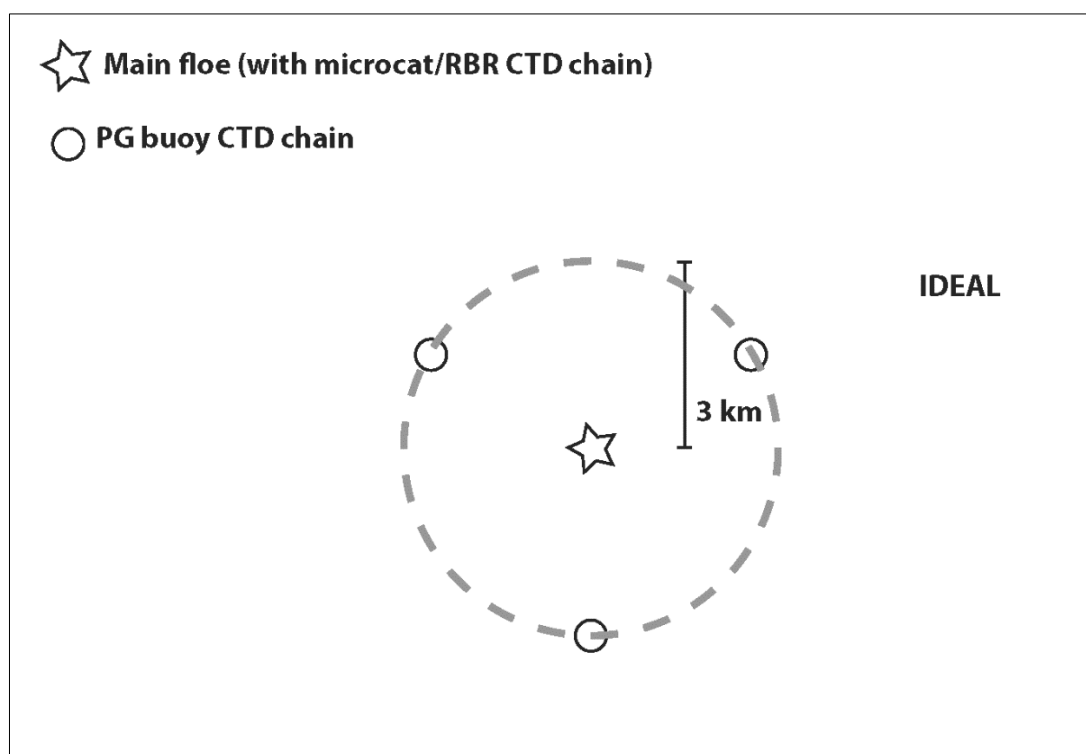


Fig. 4.9.1: Concept for the deployments by Benjamin Rabe

Tab 4.9.1: Deployments

Station	Instrument	Date [UTC]	Distance [km]	Ice thickness [cm]
PS149_13-1-2025O30	SVP5S-0018	2025-07-11 14:50:00	2,5	154
PS149_13-1-2025O31	SVP5S-0019	2025-07-11 16:30:00	2,8	158
PS149_14-1 (2025O29)	SVP5S-0017	2025-07-12 19:46:09	at MUC	148
PS149_16-1-2025O27	SVP5S-0013	2025-07-15 14:30:00	2,6	131
PS149_16-1-2025O28	SVP5S-0014	2025-07-17 19:10:00	at MUC	108
PS159_18-1-2025O33	SVP5S-0012	2025-07-21 17:20:00	1,6	152
PS159_18-1-2025O34	SVP5S-0006	2025-07-21 18:10:00	1,0	181
PS149_18-1-2025O32	SVP5S-0003	2025-07-22 19:00:00	at MUC	120



Fig. 4.9.2: Recovery and deployment of the CTD buoys. Left: Transport of the equipment and buoy on a Nansen sled with skidoos. Right: CTD buoy after deployment on sea ice. Photos: Jacob Allerholt

Tab 4.9.2: Recoveries

Area	Instrument (Short name)	Position		Date [UTC]	Comment
		Lat	Long		
Floe 1	SVP5S-0018 (2025O30)	83.238742	31.546386	2025-08-21 21:00:00	recovered
Floe 1	SVP5S-0019 (2025O31)	83.3605	36.137861	2025-08-19 04:10:00	broke for unknown reasons
Floe 1	SVP5S-0017 (2025O29)	82.942825	34.94825	2025-08-06 08:50:00	broke for unknown reasons
Floe 2	SVP5S-0013 (2025O27)	84.206969	18.053086	2025-08-23 14:40:00	recovered
Floe 2	SVP-0014 (2025O28)	84.212475	17.322939	2025-08-24 18:10:00	recovered
Floe 3	SVP5S-0012 (2025O33)	82.453665	-5.495881 E	2025-08-26 15:00:00	recovered
Floe 3	SVP5S-0006 (2025O34)	82.454245	-5.602375 E	2025-08-26 14:30:00	recovered
Floe 3	SVP5S-0003 (2025O32)	82.342212	-4.667411 E	2025-08-27 19:30:00	recovered

During the 4th visit of floe 3, we redeployed SVP5S-0014 at the former iAOOS site (PS149_47-1-2025O28), so it can measure till PS150 and through the winter.

IAOOS platforms

We deployed three LOCEAN IAOOS platform (one at each floe). The IAOOS platform is composed of a surface unit mounted in/on a large floatation, and an ocean profiler that climbs/descends along an 800 m inductive modem tether. The profilers are equipped with SeaBird CTDs as a standard, and optional optical sensors for oxygen and turbidity. On the

third floe, the cable length was only 350m and the profiler is a bioprofiler with in addition to the CTD and DO sensor, has an Ecotriplet for chlorophyll a fluorescence, turbidity and CDOM (Carbon Dissolved Organic Matter) and a nitrate sensor. The IAOOS profiler uses buoyancy to control profiler depth. It also measures basic meteorological parameters, and includes a SIMBA (sea ice mass balance buoy) mounted on the surface float. Profiles are conducted 1-2 times per day.

The IAOOS platform on floe 2 never worked because of a default in the ballasting of the profiler. It was recovered on 02 August 2025 during the second revisit of the floe. The IAOOS platform at floe 1 was picked up on 21 August 2025 from the ship. The IAOOS platform at floe 3 was picked up on 17 August 2025.

Tab. 4.9.3: IAOOS deployments

Station	Instrument	Date [UTC]
PS149_13-1-iaos1	IAOOS1	2025-07-12 14:30:00
PS149_13-1-iaos2	IAOOS2	2025-07-19 10:30:00
PS149_14-1-iaos3	IAOOS3	2025-07-22 10:30:00

ARVOR Argo float deployments

Together with the three APEX argo floats, four ARVOR argo floats from nke instrumentation (2 French and 2 German) were deployed successfully on Sunday, July 6th, 2025.

After a visual inspection, the four floats were found to be in a good general state without any scratches and all protective plugs got removed from all the sensors. After each magnet removal the 15 buzzer beeps were heard, which indicates that the float is armed. This was followed by a self-test for the sensors by the float and a pump activation. The self-tests of the first three floats were successful within the first attempt and the slow buzzer beep was heard, which indicates that the float is ready to be deployed. For the fourth float the first attempt failed, but within the second attempt the self-test was successful as well.

Therefore, all of them got deployed manually as planned together with the three APEX floats on a transect with 3 knots ship speed, one every five minutes, close to the aft of the ship on starboard side. The last ARVOR float was deployed later on, right before meeting Tara Polar Station. During the whole deployment process the sea conditions were very calm with waves <1m.

Tab. 4.9.4: Deployments of the Argo Floats

	WMO	Deployment (UTC)	Lat (deg)	Lon (deg)	Depth (m)	
Argo 2 ARVOR 2 (AI4600-25FR002)		06.07.2025 04:11:35	81.591402	17.691359	1607.2	
Argo 1 ARVOR I NAOS (AI2600-25FR001)		06.07.2025 04:16:07	81.594106	17.714130	1620.5	
Argo BSH2 ARVOR 2 (AI4600-25DE002)	1902772	06.07.2025 04:30:47	81.605969	17.765231	1829.6	Ice detection
Argo BSH1 ARVOR 2 (AI4600-25DE001)	1902759	06.07.2025 08:28:52	82.102415	19.885013	3671.9	Ice detection

APEX floats

A series of APEX argo floats was successfully deployed on 06.07.2025 during the *Polarstern* Contrasts expedition (PS149).

For calibration the boxes with the floats were lifted with the crane from the working deck to the observation deck (deck A) in upright position and under clear sky. The pre-deployment procedures followed the instructions of Olaf Boebel and were successfully executed; the floats were responsive and reported nominal function. The floats were then lowered back to the working deck via a crane. Ice protective whiskers were successfully attached, and the floats were stored outside the crates at the future deployment site close to the aft of the ship at the starboard side. The floats were manually deployed under calm sea conditions at times and coordinates found in the table below.

The deployment procedure as described per Olaf Boebel was successfully followed, deployment was without incident. The floats are contributing data to the international Argo program and will transmit observations via satellite to the appropriate Data Assembly Center.

Tab. 4.9.5: Deployments of the APEX Floats

Serial Number	Datetime (UTC)	Lat (deg)	Lon (deg)	Depth (max in m)	Speed (kn)	Wind Velocity (Bf)	Wind Dir	Station
10997	06.07.2025 04:20:24	81.597348	17.727989	1673.4	3	4.8	197.0	5-1
10996	06.07.2025 04:25:13	81.601134	17.743936	1776.4	4	4.6	195.0	6-1
10995	06.07.2025 04:35:47	81.609404	17.779625	1915.7	3	4.6	194.0	8-1

4.10 Lead sampling program

The goal of our work was to characterize the lead system and its influence on the primary production in the adjacent sea ice and the uppermost water column. This was done across a transect perpendicularly from the lead with sites at lead edge, 5, 20 and about 50m away at some sites. This transect was run at every station.

The sampling was split into two foci: i) physical sampling of water at sea ice-water interface and 1m depth, and the bottom 5cm from sea ice (pooled, 4 to 5 cores excl. nutrient core) for standard bulk parameters, and ii) instrument deployments of MSS for turbulence, CTD and RAMSES measurement in collaboration with D. Clemens-Sewell, A Blueye ROV transect for visual inspection of the lead.

Nutrient cores were stored in Whirl-pak bags and the pooled in cooler jugs. Ice thickness and freeboard were measured with an ice thickness gauge. Interface water and 1m water was collected with a peristaltic pump from the coring holes and lead surface water by filling collection containers directly at the surface. Biological and biogeochemical parameters were processed onboard the ship. Temperature and salinity were measured from each sample at the end of the processing. The different samples are presented below.

Inorganic nutrients

Samples were filtered through 0.7 μm Whatmann GF/F filters into acid washed vials. Inorganic nutrients will be analyzed at UiT – The Arctic University of Norway on a Total Organic Carbon analyzer (Shimadzu, Japan). Samples for inorganic nutrients were taken in duplicate.

Dissolved O_2 and dissolved inorganic carbon (DIC)

Samples for the analysis of dissolved oxygen and *in situ* dissolved inorganic carbon were transferred into 15 mL exetainers via glass syringe without headspace. Samples were immediately poisoned with saturated mercury chloride (HgCl_2). Dissolved oxygen samples were taken in triplicate and *in situ* DIC samples were taken in duplicate. Both dissolved oxygen and DIC samples will be analyzed at UiT – The Arctic University of Norway using winkler titration and a Total Organic Carbon analyzer (Shimadzu, Japan), respectively.

Flow cytometry

Samples for flow cytometry were collected to determine the size-fractionated abundance of cells within samples. Samples for flow cytometry were taken in triplicate by adding 4 mL of sample to cryovials and fixing with 25% glutaraldehyde for a 0.5% final concentration. Samples were left to fix at temperature for approx. 5 minutes before storage at -80°C . Flow cytometry samples will be analyzed at UiT – the Arctic University of Norway.

Sea-ice algae and phytoplankton taxonomy

Samples for taxonomic identification via light microscopy were taken to understand the community composition of both sea-ice algae and phytoplankton. Depending on the estimated concentration of cells, either 60 mL, 90 mL or 190 mL of sample was transferred to amber glass bottles and fixed with Acidic Lugol's solution (0.4% final concentration). Samples were stored at 4°C and will be analyzed at UiT – the Arctic University of Norway.

Ice/Seawater filtrations

Filtrations of melted sea ice cores and seawater were performed onboard either immediately after the water returned to the ship (under ice water) or the following day after ice was collected and melted (sea ice cores). All samples were filtered at low vacuum pressure (< 200) to insure cell integrity.

Chl a

Chlorophyll a was collected as total chlorophyll on 25 mm 0.7 µm Whatman GFF filters. Chlorophyll samples were kept dark after collection and filtered out of direct sunlight. Samples were immediately folded in aluminium foil pouches and stored at -80°C until further processing at UiT.

HPLC

Samples for HPLC measurement of pigment composition of the samples was collected for assessment of community composition and photoacclimation. Samples were collected on Whatman GF/F filters, up to 500 ml or until color present on the filters. Samples were immediately folded in aluminium foil pouches and stored at -80°C until further processing at UiT.

POC/PON

Water for POC/PON (duplicates) was filtered onto burned GF/F, volumes were depending upon coloration on the filter and water available. Samples were frozen at -20°C into brunt aluminium foil pouches. Some blank were taken that was filtered with 500mL milliQ water. Samples will be analyzed at UiT.

Seaphox Sensor

The SeaPhox sensor was deployed at stations 1b,2b, 3b, 1c, 2c and 3c. A SeapHOx instrument was deployed for between 20-48 hours at 1.5 m below the ice surface. The instrument contains a MicroCAT combined with a SeaFET sensor package for the time series measurements of conductivity, temperature, pressure, pH and dissolved oxygen.

Licor Measurements

Data on photosynthetically active radiation (PAR) were collected as nearly instantaneous measurements using Li-COR sensors with Li-COR datalogger. A Li-COR underwater quantum four-pi spherical sensor was deployed beneath the sea ice (i.e. below the ocean-ice interface), facing the direction of the sun, using a mechanical arm that allowed measurements from directly beneath the sea ice subsurface. Use of the arm positioned the under-ice sensor approximately 1 meter away from the augured hole of deployment. These integrated PAR measurements (µmol of photons m⁻² s⁻¹) were completed immediately before ice sample collection at coring locations to ensure measurement under a pristine snow surface. Measurements of downwelling and upwelling irradiance were also collected with a two-pi sensor directly after or during the measurements of underwater transmitted irradiance at the same sample site. These were collected by positioning the sensor on the sea ice after having flatten the surface. These measurements were only performed during station R1 and R2 in the third round. For all the deployments events, please look at the appendix tables for more information.

4.11 Unmanned surface vehicle

An Unmanned surface vehicle (USV) from Maritime Robotics (Otter Pro USV) was tested for the first time in leads. The Otter was deployed from the ship using the crane and a slip-hook. We tested successfully the navigation system, the Nortek ADCP S500, the lowered CTD (AML-CTD), and the 360 degree camera (SeaSight). An additional SBE56 temperature logger was added on the side of the platform to measure the surface temperature of the lead. The data collected by the otter will complement the datasets from the lead sampling (section 4.10).



Fig. 4.11.1 The otter in the lead at station 3 (Photo Stefanie Brechtelsbauer)

Tab. 4.11.1: Deployment and recoveries of the Otter during PS149

Device Operation	Device Operation Label	Event Time	Action	Latitude (deg)	Longitude (deg)
PS149_21-13	otter_pro_usv_124	27/07/2025 09:35	station start	82.541965	26.829656
PS149_21-13	otter_pro_usv_124	27/07/2025 10:50	station end	82.540792	26.866347
PS149_21-14	otter_pro_usv_124	28/07/2025 10:35	station start	82.486268	28.168763
PS149_21-14	otter_pro_usv_124	28/07/2025 11:23	station end	82.485845	28.189424
PS149_25-13	otter_pro_usv_124	31/07/2025 13:15	station start	83.715147	17.454656

Device Operation	Device Operation Label	Event Time	Action	Latitude (deg)	Longitude (deg)
PS149_25-13	otter_pro_usv_124	31/07/2025 15:28	station end	83.707360	17.682024
PS149_30-15	otter_pro_usv_124	05/08/2025 14:52	station start	83.626301	-11.333890
PS149_30-15	otter_pro_usv_124	05/08/2025 15:56	station end	83.626352	-11.326170
PS149_36-11	otter_pro_usv_124	13/08/2025 15:09	station start	84.512996	21.855262
PS149_36-11	otter_pro_usv_124	13/08/2025 16:18	station end	84.521572	21.827106
PS149_41-11	otter_pro_usv_124	18/08/2025 11:00	station start	82.773366	-12.833729
PS149_41-11	otter_pro_usv_124	18/08/2025 11:51	station end	82.770152	-12.832573

Data management

All data will be delivered to the data base PANGAEA – Publishing Network for Geoscientific & Environmental Data at the World Data Center for Marine Environmental Sciences (WDC-MARE) (www.pangaea.de) or the Arctic Data Center (<https://arcticdata.io>). This guarantees long term storage and open access availability. The time frame of delivery will depend on the data processing, sample analysis and quality assessment which depends largely on the various methods. All data will be available to the public latest 2 years after their final processing. In-situ electronically measured data, e.g., CTD or weather station data, will be available to the public after 6 months. Most of the ice buoys will be available in near-real time through the online portal meereisportal.de and will be embedded into different international data bases. Some units will report data directly into the Global Telecommunication System (GTS), such that their data may be immediately used for weather forecast and ice services. From the ice station work, collected ice cores and snow samples will be partly melted and analyzed on board. The other ice samples will be stored frozen for later analysis in the home laboratories and replicates will be archived and stored at AWI in Bremerhaven. DNA data will be deposited in NCBI's Sequence Read Archive. Meta data and station books are recorded on board through the DSHIP and SENSOR systems. This allows direct linkage of all data to sensor meta data. Since this system focusses on on-vessel stations, the system will be extended to the ice floes, enabling complete documentation of all samples and data recording during ice stations, incl. their relative locations. We do not expect legal conflicts with any of the data and samples. Data ownership and curation responsibilities are with the principal investigator of the respective instrument / method and is defined in the SENSOR system.

This expedition is supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 2, Subtopic 1.

In all publications based on this expedition, the **Grant No. AWI_PS149_03** or **AWI_PS149_06** or, in case of multidisciplinary work, **AWI_PS149_00** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. <http://dx.doi.org/10.17815/jlsrf-3-163>.

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5. ECOLOGY AND BIOGEOCHEMISTRY

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Grant-No. AWI_PS149_04

Outline

The rapidly changing climate is driving unprecedented transformations in the Central Arctic Ocean (CAO). The decline in sea ice coverage, at a rate of approximately 13% per decade relative to the mean September extent for 1981–2010 (Serreze and Meier, 2019), along with increasing temperatures and reduced ice thickness (Kwok 2018), is reshaping Arctic ecosystems. These changes influence primary production (Wassmann and Reigstad, 2011) and have major implications for the food web, pelagic-benthic coupling, and biogeochemical cycles (Wiedmann et al., 2020). However, the complex interplay of environmental drivers, combined with the logistical challenges of accessing the Arctic, makes predicting future ecosystem shifts and carbon fluxes difficult. During the CONTRASTS expedition, we will investigate the effects of distinct sea-ice regimes on productivity, carbon export, biodiversity, ecosystem structure, trophic interactions, remineralization, and carbon sequestration. This will be done through repeated visits to three different ice regimes with different origin of the ice, melting state of the ice, and potentially different ecology and biogeochemical pathways. Our findings will contribute to a better understanding of the ongoing transformations in the CAO.

Objectives

The overarching aim of the Ecology and Biogeochemistry Team on the CONTRAST expedition is to analyze the distribution of organisms, biodiversity, and ecosystem functions in relation to environmental drivers in the changing Arctic physical-chemical-biological system. CONTRAST provides a unique opportunity to conduct process studies in three distinct sea-ice regimes and compare the results to previous Arctic expeditions, including IceArc II (ArcWatch-1) and TransArc II (ArcWatch-2). Given the challenges of studying long-term changes in the biological system in the remote CAO, the repeated visits offer a unique chance to follow how the physical and chemical environment impact biology and biogeochemistry in three distinct ice regimes. Specifically, we aim to:

- Compare the taxonomic composition, functional community structure, and biodiversity in the contrasting sea-ice regimes in relation to environmental drivers, including key physical and biogeochemical properties of sea ice, the ice-water interface, melt ponds, and melt-water layers.

- Identify potential geographic sources (Pacific vs. Atlantic) of phytoplankton and zooplankton taxa, which act as potential seed areas for the influx of new species into the Arctic and adjoining seas.
- Quantify and compare key ecosystem functions and biogeochemical processes, including primary production, secondary production of prokaryotes and eukaryotes, trophic carbon flux, and vertical carbon export.
- Assess the functioning of the biological carbon pump across different ice regimes to understand how ice conditions, presence or absence of ice-algae, and cryogenic mineral content influence its efficiency.
- Compare the trophic connections between sea ice and the mesopelagic realm in the three regimes, with an emphasis on the role of stratification, ice-melt, frequency of ridges, meltwater ponds, and presence or absence of false bottoms beneath the ice floes.
- Investigate processes controlling recruitment and priming winter survival in ecological key taxa, such as diatoms, *Calanus* copepods, ice amphipods, and polar cod, as well as conducting population genomics and transcriptomics.
- Examine surface sediments for benthic foraminifera.
- Understand the trophic structure and functioning of the central Arctic Ocean food web under cumulative stress from warming and (increasing) anthropogenic pollution, such as microplastics and persistent organic substances (PFAS, PCBs) (Helmholtz Young Investigator Group *Double Trouble*).

Work at sea

We will take biological and biogeochemical samples from a) the water column during transit between the three focus areas and during ice stations, and b) the sea-ice, including the under-ice-water (UIW) and melt ponds during ice stations. Parallel sampling of bacteria, phytoplankton, ice-algae, zooplankton, benthic foraminifera, and biogeochemical parameters will ensure a system perspective on the biodiversity and its associated biological and biogeochemical processes in the three sea-ice regimes. Sampling, experiments, and measurements will be conducted according to internationally acknowledged standard operating procedures (SOP) developed during MOSAiC, ArcWatch-1, ArcWatch-2, and FRAM / LTER HAUSGARTEN.

Microbial communities, including phytoplankton and ice algae

We sampled phytoplankton, ice algae and other microbes from filtered samples from:

- a) Water column: water collected between 2,000 m depth and the surface with Niskin bottles mounted to the CTD rosette.
- b) Sea ice: water samples from the UIW, and from melt ponds was collected with hand pumps; sea-ice samples was collected with ice corers and melted in the ship's laboratories according to previously established protocols during ArcWatch-1.
- c) Handnets for phytoplankton sampling was deployed from the ship in parallel to the CTD rosette deployments and from sea-ice in parallel to the ice sediment trap deployments.

These samples will be used to analyze the taxonomic composition (species composition, abundance, and biomass), and biodiversity of microbial and protist communities based on eDNA sequences, microscopic analysis, as well as a planktoscope, with which we will directly analyze samples from water column and ice onboard. Furthermore, abundance and biomass estimates based on flow cytometry (particularly smaller organisms), imaging flow cytometry,

and the concentration of chlorophyll and other pigments, and trophic biomarker sampling (sterols, fatty acids, amino acids and stable isotopes) will be carried out in the home laboratory. Additionally, we will conduct incubation experiments to estimate primary production using the radioisotope carbon-14 (the ^{14}C method), identify mixotrophy, and quantify silicification degree of diatoms through the fluorophore PDMPO.

Zooplankton and sea-ice fauna

- a) Water column: The mesozooplankton community composition and depth distribution will be sampled with a MultiNet midi (Hydrobios, Kiel Germany) equipped with five nets of 150 μm mesh size, that allow to five depths layers (1,500-1,000-500-200-50-0 m). To analyze the vertical distribution of zooplankton species in the upper 3,000 m of the water column with high spatial resolution, we used two *in-situ* optical systems ROSINA equipped with the JellyCam and the Underwater Vision Profiler (UVP5). These optical systems can capture the vertical distribution of zooplankton at decimeter resolution and in addition to capturing the dominating copepods, ostracods and chaetognaths very well, the optical system can also capture fragile zooplankton such as gelatinous plankton which is often destroyed by the net. The UVP was deployed on the frame of the water rosette and activate for every CTD cast. The UVP takes images directly into the water and therefore delicate organisms remain intact, however, the resolution of the images is lower than those obtained by the ROSINA, and do not allow to determine mesozooplankton genera. In addition, planktonic foraminifera composition and depth distribution will be sampled using a MultiNet midi equipped with five nets of 50 μm mesh size from the same five depths layers as the mesozooplankton samples. Benthic foraminifera will be sampled with a Multiple Corer (MUC). The foraminifera samples will be immediately preserved in 70% ethanol.
- b) Sea ice: Under-ice fauna and zooplankton living at the ice-water-interphase and down to 50 m below was sampled under the sea ice with a net mounted on the ROV (Beast) of the sea-ice physics group, the ROVnet (Wollenburg et al., 2020). This net is both capable of scraping the underside of sea ice and collecting the animals falling down, and of sampling animals dwelling in the water underneath the ice. Animals living within the sea-ice matrix (sea-ice meiofauna) will be collected from sea-ice samples collected with ice corers and processed according to the MOSAiC sampling standards for sea-ice meiofauna. We additionally deployed a small Underwater Vision Profiler (UVP6) as profiles under the ice and down to 100 m and, at selected stations, as ~24 hours deployment at five meters below the ice. These images will provide information about abundance and species composition of zooplankton below the ice.

Animals for biochemical analyses (e.g. trophic biomarkers) will be sampled with a bongo net and from the ROVnet and preserved frozen at -80°C . Taxonomic samples from the multinet and the ROVnet will be preserved in buffered formaldehyde-seawater solution. In the laboratories at AWI, they will be digitized with a ZooScan. The organisms on the images from ZooScan, ROSINA, JellyCam, and UVP will be determined to the lowest taxonomical level possible via the internet application EcoTaxa. After standardizing these data with the volume of water sampled by the respective devices, we will determine zooplankton species composition and abundance. EcoTaxa also automatically provides the sizes of the organisms, and they will be used to calculate biomasses according to Cornils et al. (2022). Apart from net catches, the biodiversity and taxonomic composition of zooplankton, sea-ice fauna, and nekton will be determined from sequences of the eDNA samples also collected for microbe and protist community analysis (see above).

Cryogenic minerals

Cryogenic minerals will be collected from ice-cores, catches with a cryogenic gypsum-net mounted in the ROVnet, water collected with the Niskin bottles of the CTD and potentially from algae aggregates pipetted from the sediment surface of MUC cores. The minerals, their abundance, vertical and spatial distribution will be analysed in respect to sea ice type, temperature, area, and ballasting potential. Cryogenic mineral analyses from algae aggregates will provide direct information on the importance of cryogenic minerals as ballasting source.

Biogeochemical parameters

Samples for the measurement of inorganic nutrients (nitrate, nitrite, ammonium, silicic acid and phosphate) will be collected from melted ice cores, melt ponds, meltwater layers, and the surface ocean. The samples were analyzed for ammonium directly onboard and the samples for the additional nutrients were stored frozen and will be analyzed in the laboratory of the AWI using an AA3 Seal Analytical segmented continuous flow auto-analyzer.

In parallel to microbial eDNA and pigment samples from the sea ice and the water column, we also filtered water from melted ice cores, melt ponds, meltwater layers, and the water column for the determination of particulate organic carbon, particulate organic nitrogen, particulate organic phosphorous, biogenic silica, particulate inorganic carbon, and size-fractionated chlorophyll.

To study particle dynamics, we will use the vertical profiles of the CTD rosette mounted UVP, ROSINA, and the under-ice UVP6. These images will provide vertical size-distribution and abundance of different types of aggregates. In addition we deployed two types of sediment traps, one for collections of biogeochemical fluxes of the same parameters that we were filtering water for (particulate organic carbon, particulate organic nitrogen, particulate organic phosphorous, biogenic silica, particulate inorganic carbon, and pigments and chlorophyll a) and a second type of sediment traps that contained a viscous gel, which preserved the fragile structure and size of sinking particles, allowing us to determine the aggregate type, composition, size, and structure for individual settling aggregates at different depths. Additionally, we deployed marine snow catchers to capture intact organic settling aggregates from the upper 100 meters of the water column. The aggregates collected by the marine snow catcher was used to measure size-specific settling velocity and microbial degradation on different types of individual aggregates. Together these measurements will provide information about the functioning of the biological carbon pump in the three different ice regimes.

5.1 Nutrients and biogeochemistry

Ice sampling for biogeochemical parameters (coring, melt ponds, under-ice water)

We sampled for biogeochemical parameters in the ice regimes by collecting nine sea-ice cores (Biocores 1-9; Fig. 5.1.1), seawater directly under the ice (UIW), and meltpond water (MPW). In total we sampled at ice stations 1a, 1b, 1c, 2a, 2b, 2c, 2d, 3a, 3b, and 3c. Nine cores for biogeochemical parameters, phytoplankton, primary production, and microbial diversity were sectioned into a bottom part (lower 10 cm), a middle part (10 cm to 50 cm), and a top part (50 cm to surface). On board, the top parts of the nine cores were carefully broken apart to accelerate melting, which was done at room temperature until near complete melt when they were transferred to 10°C until complete melt. The pieces from the nine top parts of the cores were pooled together to ensure enough melt-water for the biogeochemical analyses. The bottom parts of the nine cores were melted whole and individually at 10°C until complete melt. Thereafter all the bottom parts were pooled. The middle parts of the nine cores were melted whole and individually at room temperature until near complete melt when they were transferred to 10°C until complete melt. Hereafter all the middle parts were pooled. From all melted ice-core sections, the volume and the salinity of the melt-water were determined. The pooled samples of top, middle, and bottom sections, as well as UIW and MPW were subsampled for analyses of the following particulate parameters: phytoplankton cell counts, pigments (HPLC), particulate biogenic silicate (PbSi), particulate organic carbon and nitrogen (POC/PON), particulate inorganic carbon (PIC), particulate organic phosphate (POP), microscopy taxonomy, nutrients, net primary productivity (NPP), and microbial and eukaryotic diversity via environmental DNA (eDNA).



Fig. 5.1.1: Images of ice-core sampling procedure. A) Ice-core sampling using the Kovacs Corer (9 cm). B) Placing the ice-core into the half pipe for length determination. C) Dividing the ice core into the three sections; bottom 10 cm, middle part (10 cm to 50 cm), and the top part (from 50 cm to the surface). Picture credits: A) Julia Wenzel (DWD), B) Julia Wenzel (DWD), Lena Eggers (AWI).

Particulate biogeochemical parameters in the water column

At each ice-stations and during the transit between ice stations, we sampled the vertical distribution of particulate organic and inorganic matter using the CTD rosette to collect seawater from five different depths; ocean surface (typically 3 m depth), 10 m depth, depth of chlorophyll maximum, 50 m depth, 100 m depth, and the temperature maximum (proxi for Atlantic water). Aliquots were filtered for biogeochemical parameters using gentle vacuum filtration (<300 mBar): pigments (HPLC; filtered onto a GF/F filter), particulate biogenic silica (PbSi; filtered onto a 0.8 μm CA filter), particulate organic carbon and nitrogen (POC/PON; filtered onto a pre-combusted GF/F filter), particulate inorganic carbon (PIC; filtered onto a pre-combusted GF/F filter), and particulate organic phosphate (POP; filtered onto a pre-combusted GF/F filter). Furthermore, unfiltered water samples from all depths, except 100 m, were fixed with formaldehyde (final concentration 2%) for later quantitative assessment of the phytoplankton community through inverted microscopy. We also sampled 45 ml of water for nutrient samples in the home-laboratory, while ammonium was measured directly on board (Tab. 5.1.1).

Tab. 5.1.1: Overview of stations sampled for ammonium during PS149 and the type of samples collected.

StationID	CTD rosette water	Ice cores	Under Ice water and meltpond water	MUC (water close to the seafloor)	Extra Ice core ("dirty ice")
PS149_12-2	X	-	-	-	-
PS149_13-1	-	-	X	-	-
PS149_13-7	X	-	-	-	-
PS149_15-1	X	-	-	-	-
PS149_16-1	-	X	X	-	-
PS149_16-2	X	-	-	-	-
PS149_17-1	X	-	-	-	-
PS149_18-1	-	X	X	-	-
PS149_18-2	X	-	-	-	-
PS149_21-1	-	X	X	-	-
PS149_21-2	X	-	-	-	-
PS149_21-15	-	-	-	X	-
PS149_25-1	-	X	X	-	X
PS149_25-11	X	-	-	-	-
PS149_30-1	-	X	X	-	-
PS149_30-13	X	-	-	-	-
PS149_30-17	-	-	-	X	-
PS149_32-1	-	X	X	-	-
PS149_32-10	X	-	-	-	-
PS149_32-14	-	-	-	X	-
PS149_36-1	-	X	X	-	-
PS149_36-7	X	-	-	-	-
PS149_41-1	-	X	-	-	-

Preliminary (expected) results

All samples will be analysed in the home laboratory.

5.2 Net primary production and nutrient uptake rates

Net primary production (NPP) was analysed using the ^{14}C uptake method (Steemann Nielsen, 1952) at a total of 9 stations (1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, and 3c). We determined NPP from the UIW, melt-water from the top, middle and bottom part of the ice-cores, MPW, and from seawater-samples collected using the CTD-Rosette (surface ocean (3 m) and chlorophyll a maximum). For each sample, subsamples (triplicates) were taken for dissolved inorganic carbon (DIC) analysis. Then 200 ml of sample was spiked with $0.1 \mu\text{Ci mL}^{-1}$ of ^{14}C -labelled sodium bicarbonate and distributed in 10 clear bottles (20 mL each). Subsequently, the samples were incubated for 8h at 0°C under different scalar irradiances ($0\text{--}530 \mu\text{mol photons m}^{-2} \text{ s}^{-1}$), which were measured with a spherical sensor (Spherical Micro Quantum Sensor USSQS/L, Heinz Walz, Effeltrich, Germany). At the end of the incubations, samples were filtered onto $0.2 \mu\text{m}$ cellulose mixed nitrate and acetate filters and the particulate radioactive carbon uptake was determined by liquid scintillation counting using filter count scintillation cocktail (Perkin Elmer, Waltham, USA). The carbon uptake values in the dark were subtracted from the carbon uptake values measured in the light incubations.

To investigate functional biodiversity, a total of 23 on-board incubation experiments were performed to explore silica incorporation and mixotrophy (see Tab. 5.2.1.). Between 18 and 60 litres from the Chl a maximum were sampled with the CTD Niskin rosette, passed through a $150 \mu\text{m}$ mesh to exclude grazers, and up-concentrated using reverse filtration to final volumes of 37 to 47 ml ($3 \mu\text{m}$ polycarbonate filter).

Silicification was under differing silicic acid and light levels was investigated using the fluorophore PDMPO ((2-(4-pyridyl)-5-[(4-(2-dimethylamino-ethylaminocarbamoyl)methoxy)-phenyl]oxazole) which is incorporated into newly formed biogenic silica. The concentrated phytoplankton were added to 36 cell culture flasks containing seawater with a silicic acid gradient (0, 5, or $20 \mu\text{M}$ added silicic acid) and additional nutrients in excess (nitrate, phosphate, F/2 metal and vitamin mix). These flasks were then incubated at zero degrees Celsius for 48 hrs at three light levels (3, 10, and $71 \mu\text{E m}^{-2} \text{ s}^{-1}$). Afterwards, the samples were fixed with formalin (final concentration 2%) to subsequently assess differences in silica incorporation with an Amnis Multispectral Imaging Flow Cytometer (Amnis ImageStreamX Mk II Imaging Flow Cytometer) at AWI.

Mixotrophy was assessed at 12 stations via microsphere ingestion rates and Chl a autofluorescence detection with the Amnis Multispectral Imaging Flow Cytometer. Fluorescent microspheres (Polysciences Fluoresbrite) in three sizes (0.5 , 3 , and $6 \mu\text{m}$ diameter) were used. Three aliquots (12-15 ml) of the concentrated plankton were transferred into Falcon tubes and microspheres added at approximately 2% of expected bacterial abundance. They were then subsampled immediately and after 25 and 60 minutes. Samples were incubated at zero degrees Celsius under moderate light ($10 \mu\text{E m}^{-2} \text{ s}^{-1}$) and fixed according to the Sherr et al. (1993) method to prevent egestion. Sample processing will be performed at AWI using the Amnis MIFC.

Additionally, on 27 occasions across 15 stations, MIFC samples were taken via reverse filtrations from the Chl a maximum, UIW, or MPW. Samples were fixed with formalin (2% final concentration) to assess community composition and develop automated phytoplankton species recognition using the Amnis MIFC. On 10 occasions, 6 ml subsamples were acquired with the Planktoscope as an intercomparison study between the Amnis MIFC and Planktoscope.

Tab. 5.2.1: Overview of stations sampled for silicification, mixotrophy, and MIFC during PS149

Station ID	Silicification	Mixotrophy	MIFC (water mass)	Planktoscope intercomparison
PS149_13-11	X	X	Chl a max	X
PS149_16-9	X	X	Chl a max	
PS149_18-7	X	X	Chl a max	
PS149_21-6	X	X	Chl a max	
PS149_22-3			Chl a max	
PS149_25-1			MPW, UIW	
PS149_25-9	X	X	Chl a max	
PS149_28-2	X		Chl a max	X
PS149_30-12	X	X	Chl a max	X
PS149_32-1			MPW, UIW	
PS149_32-7	X	X	Chl a max	X
PS149_36-1			MPW, UIW	
PS149_36-9	X	X	Chl a max	X
PS149_37-3			Chl a max	X
PS149_41-1			MPW, UIW	
PS149_41-9	X	X	Chl a max	X
PS149_43-2			Chl a max	X
PS149_36-1		X	MPW, UIW	
PS149_46-2	X	X	Chl a max	X
PS149_47-5		X	Chl a max	X

Preliminary results

Net primary productivity (NPP)

Photosynthesis vs. irradiance (PI) curves are preliminary as calculations are based on assumed DIC values for all sample types (Fig. 5.2.1). Overall, NPP ranged from 0 to 100 $\mu\text{mol C L}^{-1} \text{d}^{-1}$ with both temporal changes and differences between ice regimes. Regime 1 showed a strong increase in NPP from visit A to B, particularly in Chl a max waters, although all water types increased in NPP except from the ice core sections which remained relatively stable. Since Station 1c was a separate ice floe, we cannot extrapolate the trends in NPP for regime 1. Regime 2 showed similar starting conditions as regime 1, but increased substantially between the rounds. As with regime 1, MPW and UIW showed the most consistent increase in NPP over time although the ice core sections were less similar to each other than with regime 1. Regime 3 showed the clearest initial distinction in water type with the water column reaching the highest NPP rates in round A and C, albeit with the most prominent photo inhibition. As with the other regimes, the MPW NPP rates increased over time, showing no photoinhibition, particularly during visit b. Contrastingly, the UIW NPP dropped off after visit A, with rates dropping to nearly 0 $\mu\text{g C L}^{-1} \text{d}^{-1}$. Preliminary results show photoinhibition in the Chl a max waters seems to be weakly linked to the depth of the chlorophyll maximum at time of sampling, with early inhibition (i.e. at low light levels) where Chl a max depth was greater (e.g. 2c – 67m and 3c – 36m) but this is not consistent and there are notable exceptions (e.g. 1c shows photoinhibition from 180 μE with a Chl a max depth of 18m).

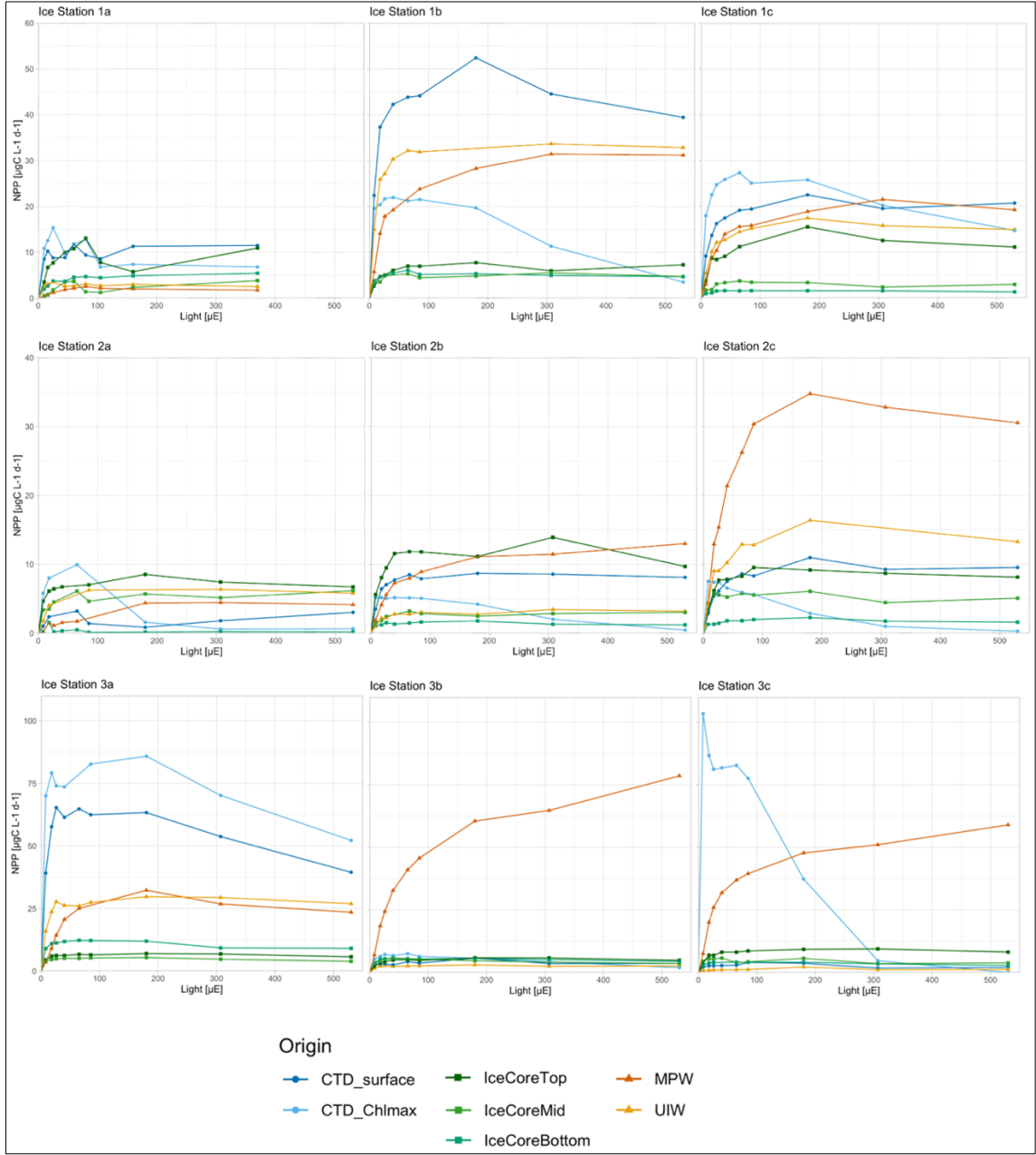


Fig. 5.2.1: Preliminary photosynthesis vs. irradiance curves for all ice regimes coloured by sample origin

5.3 Phytoplankton and microbial biodiversity

Seawater samples from surface ocean (3 m), 10 m depth, chlorophyll maximum, temperature maximum, 1,000 m depth, and 2,000 m depth were collected by the CTD-Rosette Water Sampler and aliquots were filtered for microbial biodiversity (Tab. 5.3.1). Furthermore, unfiltered water samples were fixed with formol (final concentration 0.5 – 1.0%) and lugol (final concentration 2%) for later quantitative assessment of the phytoplankton community and a comparison of the fixation methods.

Phytoplankton microscopy and Planktoscope analyses

The objectives of the phytoplankton microscopy work were:

- To establish a biodiversity baseline of microplankton based on phytoplankton net samples and to photographically document diversity, morphological variation and life cycle stages
- To use this microscopy data set for comparison to the data collected using a Planktoscope and to aid identification and validation of Planktoscope images.
- To test the scope of the Planktoscope to replace, at least partially manual microscopy sampling in future.
- To establish a set of cultures of microplankton for laboratory experiments back in Bremerhaven. A particular focus here was *Melosira arctica* and its potential parasites

At each station, phytoplankton net hauls were carried out to a depth of ca. 20 m, in parallel to the CTD-Rosette deployment, to study the morphology, species richness and distribution of live phytoplankton. In the onboard laboratory the net samples were directly analyzed with the inverted microscope to provide a baseline inventory of the phytoplankton community and in addition were processed with the Planktoscope device (Fig. 5.3.1, Tab. 5.3.1).

Tab. 5.3.1: Sampling locations for hand nets and planktoscope analyses

Sampling date	Ice station	Event label	Hand net	Planktoscope
05/07/2025	na	PS149_1-2	X	X
07/07/2025	na	PS149_12-3	X	X
07/07/2025	1a	PS149_13-2	X	X
10/07/2025	1a	PS149_13-1-HN_PS-001	X	X
11/07/2025	1a	PS149_13-8	X	X
13/07/2025	na	PS149_15-2	X	X
14/07/2025	2a	PS149_16-3	X	X
15/07/2025	2a	PS149_16-1-HN_PS-001	X	X
18/07/2025	na	PS149_17-2	X	X
19/07/2025	na	PS149_18-2	X	X
20/07/2025	3a	PS149_18-1-HN_PS-001	X	X
20/07/2025	3a	PS149_18-1-HN_PS-002	X	X
20/07/2025	3a	PS149_18-1-HN_PS-003	X	X
20/07/2025	3a	PS149_18-1-HN_PS-004	X	
20/07/2025	3a	PS149_18-1-HN_PS-005	X	
21/07/2025	3a	PS149_18-1-HN_PS-006	X	
21/07/2025	3a	PS149_18-1-HN_PS-007	X	
22/07/2025	3a	PS149_18-1-HN_PS-008	X	

Sampling date	Ice station	Event label	Hand net	Planktoscope
25/07/2025	1b	PS149_21-2	X	X
26/07/2025	1b	PS149_21-1_PS001	X	X
26/07/2025	1b	PS149_21-1_PS002	X	
26/07/2025	1b	PS149_21-1_PS003	X	X
29/07/2025	na	PS149_22-2	X	X
30/07/2025	2b	PS149_25_1_PS001	X	X
31/07/2025	2b	PS149_25-11	X	X
02/08/2025	na	PS149_38-3	X	X
04/08/2025	2c	PS149_30-1_PS001	X	X
05/08/2025	na	PS149_30_1	X	X
09/08/2025	3a	PS149_32-1_PS001	X	X
10/08/2025	3a	PS149_32_11	X	X
11/08/2025	na	PS149_33-3	X	X
12/08/2025	3b	PS149_36-8	X	X
14/08/2025	3b	PS149_36_1_PS001	X	X
15/08/2025	na	PS149_37-4	X	X
16/08/2025	3c	PS149_41-3	X	X
18/08/2025	3c	PS149_41-1_PS001	X	X
20/08/2025	na	PS149_43_3	X	X
24/08/2025	2d	PS149_46_1_PS001	X	X
23/08/2025	2d	PS149_46-7	X	X
26/08/2025	3d	PS149_47-3	X	X
27/08/2025	3d	PS149_47-3_PS001	X	X

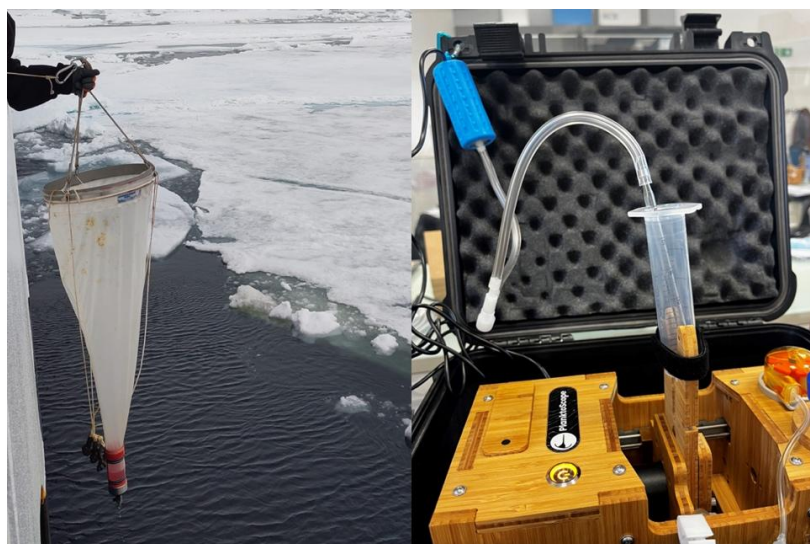


Fig. 5.3.1: Image of hand net (left) and Planktoscope (right). Picture credits: left image was taken by Sina Müller, the right image was taken by Alexandra Kraberg.

Preliminary results

In total 35 hand net analyses via microscopy and 29 Planktoscope analyses are included in this report. The microscopy analyses resulted in a taxon list of 113 phytoplankton taxa and 84 taxon categories were needed in the Planktoscope. While the Planktoscope appears to achieve a lower taxonomic resolution, it has to be kept in mind that the microscopy data set

comprised not only identified species but also a number of unidentified morphotypes. It has not yet been attempted to also use these in the Planktoscope training set but this will be done in more detailed future analyses in the context of the BMFTR project indifun-ai. The major (most species rich) groups were diatoms, dinoflagellates and ciliates (Fig. 5.3.2).

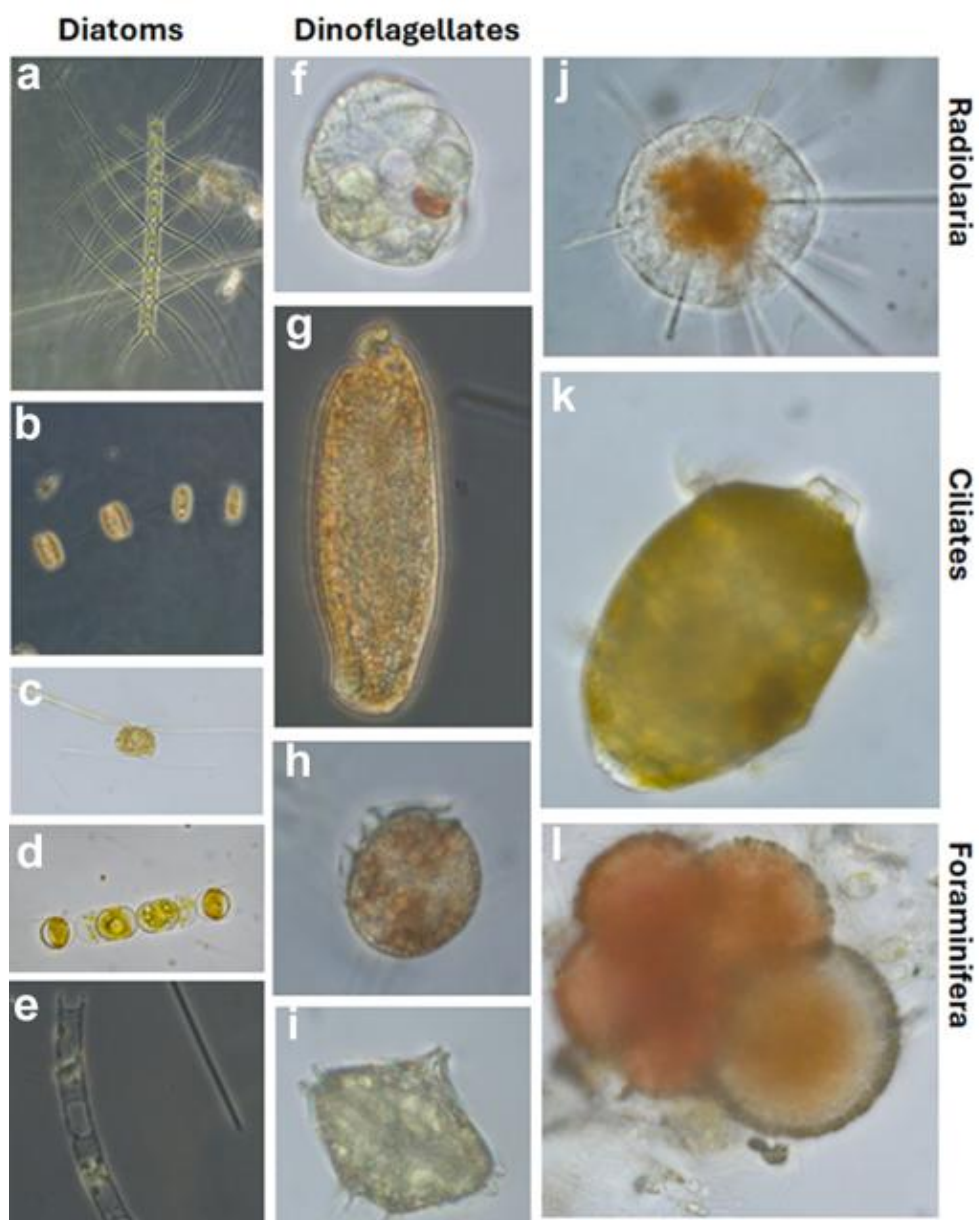


Fig. 5.3.2: Example image of some of the major phytoplankton groups in the net samples, analysed by microscopy (a-e: diatoms, f-i: dinoflagellates, j: Radiolaria, k: Ciliates, l: Foraminifera)

Different *Chaetoceros* species were most abundant in samples from station 1b onwards rather than at particular ice station. That their abundance decreased again in the last 2 samples of the cruise could indicate the end of a diatom bloom phase occurring over large spatial scales rather than communities specific to the different ice regimes (Fig. 5.3.3). There were exceptions with silicoflagellate and choanoflagellates as well as the haptophyte *Phaeocystis* also very abundant in some samples. The silicoflagellate *Dictyocha speculum* was abundant mainly on the transit stations.

Samples from all sites showed a high degree of variability with no apparent pattern between ice regimes, probably resulting from the low abundance of ice associate algae (in particular *Melosira arctica* but also *Nitzschia frigida*, *Synedropsis*, and others). *Melosira arctica* in particular were rare in all samples irrespective of the analysis method (Planktoscope or manual microscopy). This was also apparent in the Principal Co-ordinates Analysis carried out separately for both data sets (Fig. 5.3.4). While biplots showed some clustering, the clusters contained stations from all ice regimes, with the exception of sites 1 and 3 in the analysis based on manual microscopy (Fig. 5.3.4a). The different transit stations each had similarities to a small number of ice stations, but themselves formed no coherent patterns (as shown by the large areas of the convex hulls), indicating that different water masses were traversed and this might have influenced the sample species composition more than algal communities actually known to be associated with ice.

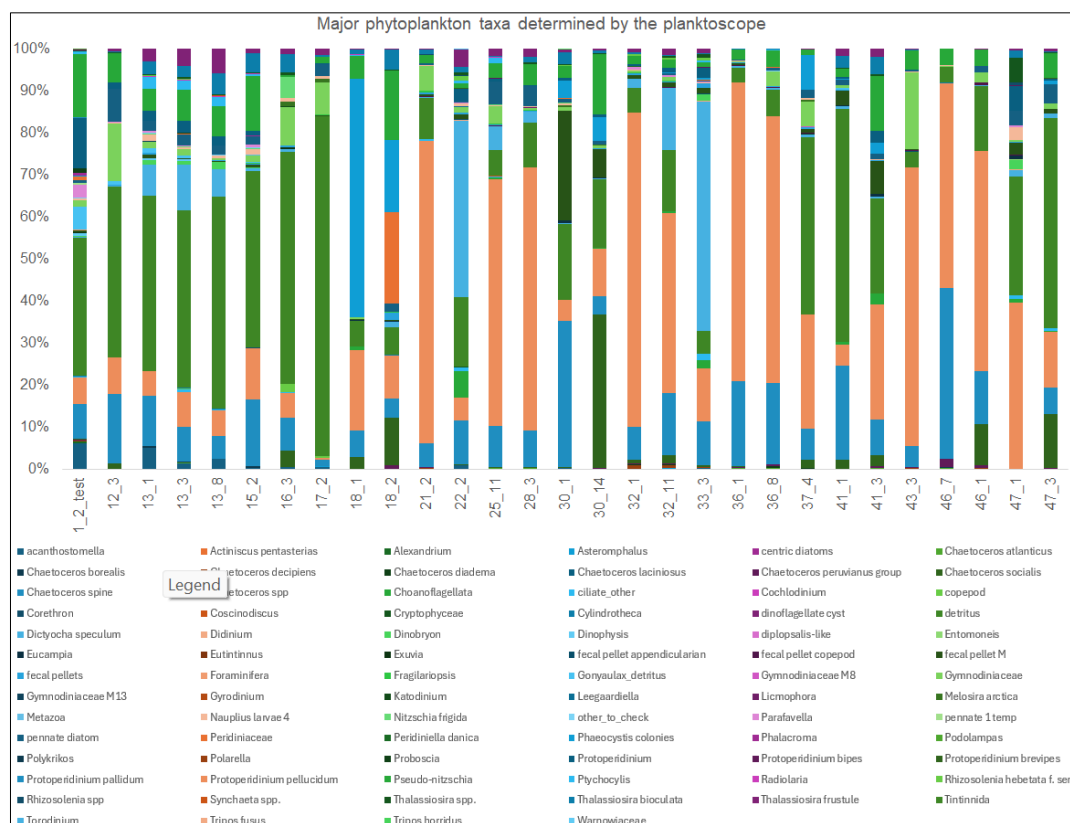


Fig. 5.3.3: Bar plot of preliminary planktoscope results for phytoplankton between 15 and 200 micrometers in size

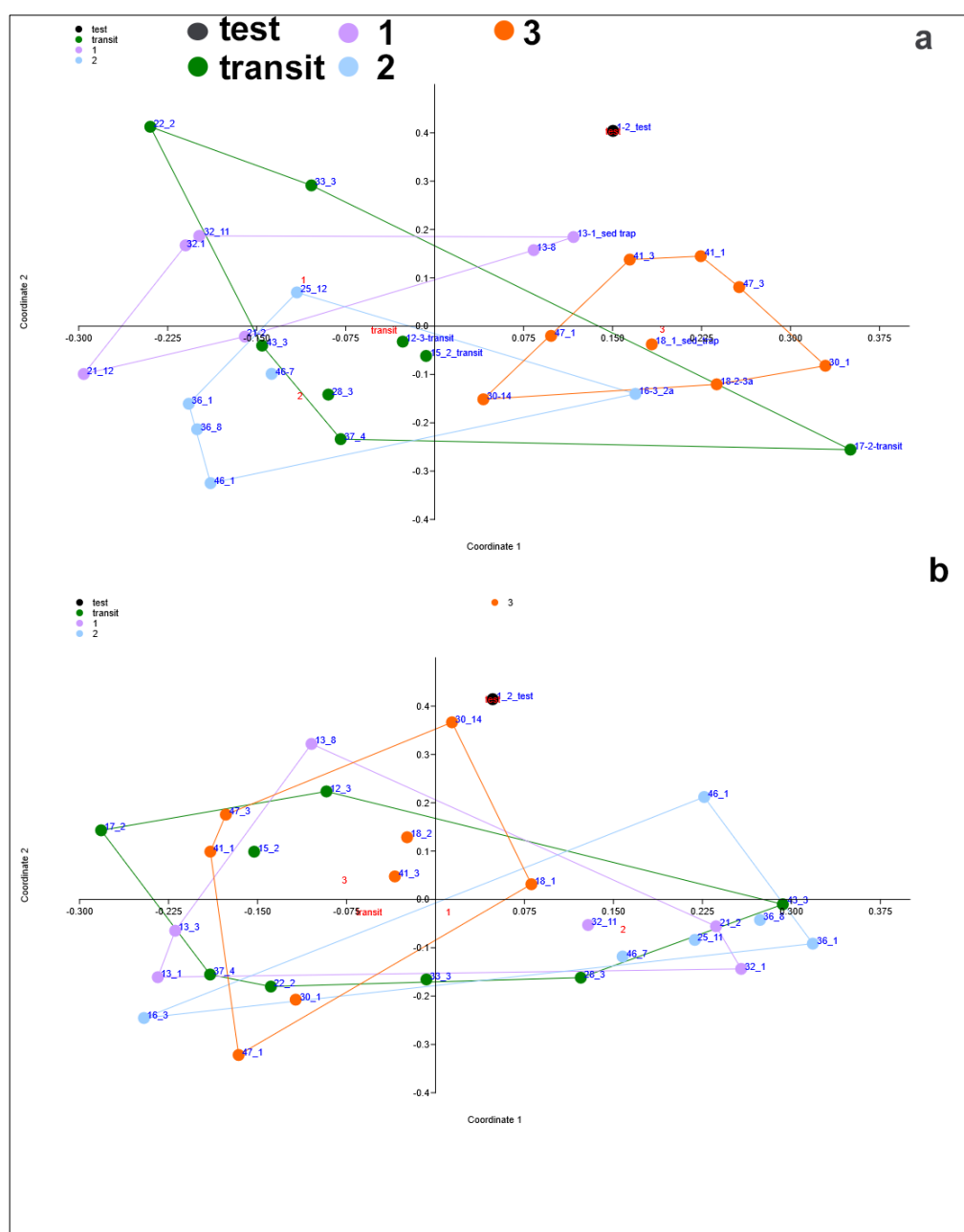


Fig. 5.3.4: Principal co-ordinates analyses based on microscopy and Planktoscope analyses (only samples that were analysed with both methods were used in the analysis; top: PCCoord based on microscopy, bottom: PCCoord based on Planktoscope data. The points in each site group are connected by convex hulls.

Microbial diversity based on DNA analyses

Water samples for analyses of microbial eukaryotes and fractionated chlorophyll a were taken from the CTD rosettes from 5 depths, concerning the surface (3 m), 10 m, chlorophyll maximum, 50 m and 100 m (Tab. 5.3.2). The water samples were filtered via bottle-top filtration sequentially on filters with pore size of 10 μM , 3 μM and 0.4 μM . In addition, fractionated chlorophyll a samples were also taken from the ice cores during stations. Subsequent to filtration, samples were directly frozen at -80°C to preserve eDNA, to be extracted in the home lab.

At every ice station a subsample for eukaryotic DNA (filtered onto 0.2 µm Sterivex filters) from the pooled and melted bottom (~1 l) and middle (~3 l) sections of the ice corers. Similarly, samples for prokaryotic community composition were samples at every ice station from the meltpond water, under ice water, and from the bottom, middle, and top section of the ice cores. The sampling for prokaryotic community composition was done by filtering each water samples onto 0.2 µm Sterivex filters and storing at -80°C.

Tab. 5.3.2: Overview of stations sampled for eukaryotic eDNA and fractionated Chlorophyll a (Chl a) during PS149

StationID	eDNA& fractionated Chl a CTD rosette water (>10µm; 3-10 µM; 0.4 -3µM for analyses of eukaryotic microbial biodiversity)	fractionated Chl a Ice cores (>3µm; 0.4 -3µM for analyses of eukaryotic microbial biodiversity)
PS149_13-7	X	-
PS149_15-1	X	-
PS149_16-1	-	X
PS149_16-2	X	-
PS149_17-1	X	-
PS149_18-1	-	X
PS149_18-2	X	-
PS149_21-1	-	X
PS149_21-2	X	-
PS149_25-1	-	X
PS149_25-11	X	-
PS149_28-2	X	-
PS149_30-1	-	X
PS149_30-13	X	-
PS149_32-1	-	X
PS149_32-10	X	-
PS149_36-1	-	X
PS149_36-9	X	-
PS149_37-3	X	-
PS149_41-1	-	X
PS149_41-2	X	-
PS149_43-2	X	-
PS149_46-1	-	X
PS149_46-6	X	-

Preliminary (expected) results

All samples will be analysed in the home laboratory.

5.4 Biodiversity of mesozooplankton

The Helmholtz Young Investigator Group *Double-Trouble* aims at investigating major trophic relationships and interactions in high-Arctic food webs as well as the presence and distribution of anthropogenic pollutants, such microplastics and persistent organic substances (PFAS, PCBs), in these food webs. The overall aim is to understand the trophic structure and functioning of the central Arctic Ocean food web under cumulative stress from warming and (increasing) anthropogenic pollution. The PS149 samples ought to complement samples and datasets obtained during PS144 and the AO2024 expedition led by the Norwegian Polar Institute.

Zooplankton and sea-ice fauna

We sampled invertebrates from a) the water column during transit between the three focus areas and during ice stations, and b) the ice-water interface (IWI) during ice stations. Sampling of zooplankton and under-ice fauna specimens for trophic biomarkers (lipids, stable isotopes) was complemented with samples of particulate organic matter (POM) filtered from the CTD rosette (pelagic POM- PPOM) and from melted sea-ice cores (ice-associated POM- IPOM), respectively. Sampling, and measurements were conducted according to internationally acknowledged standard operating procedures (SOP) developed during MOSAiC (<https://mosaic-expedition.org/>) and the Norwegian Nansen Legacy project (<https://arvenetternansen.com/>).

- a) **Water column:** The mesozooplankton community composition and depth distribution was sampled with a MultiNet midi (Hydrobios, Kiel Germany) equipped with five nets of 150 μm mesh size that allows sampling at five depths layers (1,500-1,000-500-200-50-0 m). The Multinet was deployed using a winch EL30 at a speed of 0.5 m/s (Fig. 5.4.1A). Samples from Multinet deployments were transferred to 200 mL Kautex bottles and preserved at 4% hexamethylenetetramine buffered formaldehyde for subsequent abundance and biomass analysis at AWI. Bongo nets (300 μm mesh, non-filtering cod-ends) were deployed to up to 100 m depth to collect additional specimens for trophic biomarker and pollutant analyses on behalf of the Helmholtz Young Investigator Group Double Trouble (Fig. 5.4.1B).
- b) **Sea ice:** Under-ice fauna and zooplankton living at the ice-water interface (IWI) and at 10 m below the ice were sampled with a 150 μm mesh net mounted on the ROV of the sea-ice physics group, the ROVnet (Wollenburg et al., 2020; Fig. 5.4.1C-D). This net is both capable of scraping the underside of sea ice and collecting the animals detaching from the ice, and of sampling animals dwelling in the water underneath the ice. Zooplankton and under-ice fauna for trophic biomarker and pollutant analysis were removed and the remainder was preserved in 4% hexamethylenetetramine buffered formaldehyde for later abundance and biomass analysis at AWI.

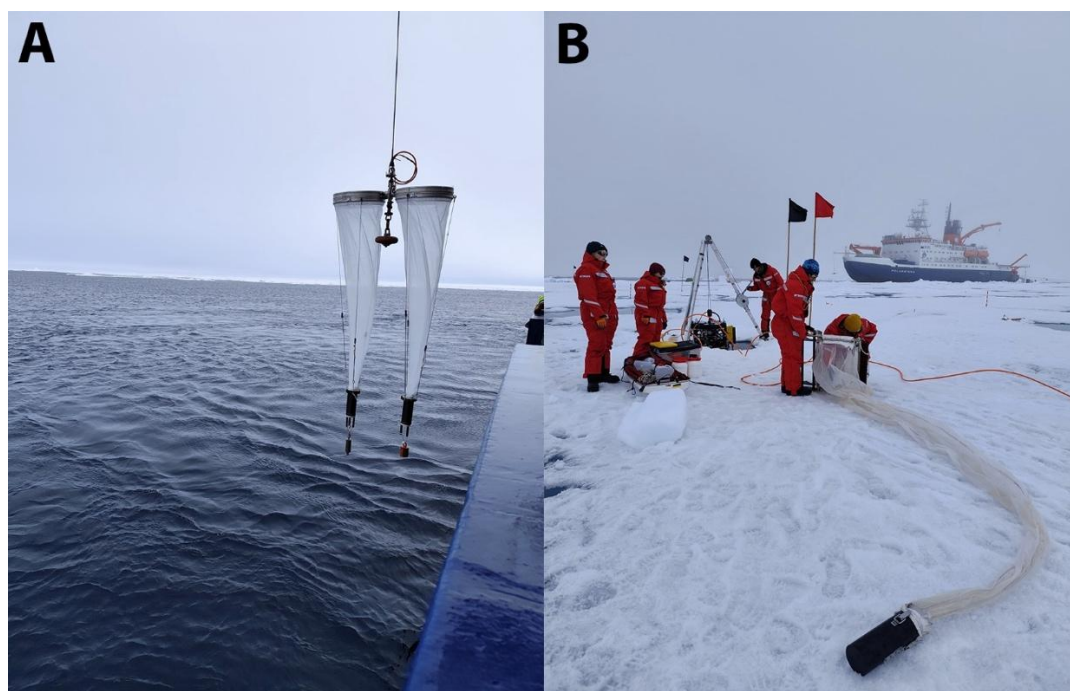


Fig. 5.4.1: A) Bongo net deployed from Polarstern, B) Deployment of the ROVnet with the ROV "Beast" on the sea-ice. Picture credit: A) Nahid Welteke (AWI), B) Nahid Welteke (AWI).

Zooplankton and sea-ice fauna

During the expedition, three types of zooplankton nets were deployed across 19 stations between 7 July and 27 August 2025. A total of 19 multinet casts were conducted, almost exclusively reaching 1500 m depth, and distributed evenly throughout the cruise from the first deployment on 7 July at 82.7°N to the last on 27 August at 82.4°N. These deep hauls provided the vertical distribution of zooplankton across the full water column at all major hydrographic stations. Complementing the multinet sampling, 11 Bongo net sampling events were carried out between 15 July and 23 August. Each Bongo net sampling event consisted of multiple consecutive net deployments, so that the total number of Bongo net casts was 26. These casts typically targeted the upper 100 m (65–100 m maximum depth), and were frequently paired with multinet deployments to collect animals for trophic marker and pollutant analyses. ROVnet operations comprised 25 deployments at nine stations between 17 July and 27 August, focusing on the 0–10 m layer to investigate under-ice and near-surface communities. Multiple short ROVnet casts were often conducted consecutively at the same station to obtain additional samples for trophic marker and pollutant analyses. Together, the three net types provided complementary spatial and vertical resolution of the zooplankton community, from the ice–ocean interface to bathypelagic depths. A summary of all sampling events for zooplankton and biomarkers / pollutants is provided in Table 5.4.1.

Tab. 5.4.1: Sampling events for zooplankton and trophic biomarker filters

Event	Date	Device	Lat. (°N)	Lon. (°E)	Max depth (m)	Target feature
PS149_12-4	7/7/2025	MULTINET	82.686	20.204	1500	
PS149_13-1-SI		Icecorer	83.692	22.021		bottom_10cm
PS149_13-4	7/9/2025	MULTINET	83.758	20.856	1500	
PS149_13-11	7/11/2025	CTD	83.775	22.594		CTD_ChI _{max}
PS149_15-3	7/13/2025	MULTINET	84.663	20.790	1500	
PS149_16-4	7/14/2025	MULTINET	85.027	13.616	1500	
PS149_16-6	7/15/2025	BONGO	84.995	13.921	100	
PS149_16-9	7/15/2025	CTD	84.959	14.106		CTD_ChI _{max}
PS149_16-1_ROV-1	7/17/2025	ROVnet	85.023	13.513	10	
PS149_16-1_ROV-2	7/17/2025	ROVnet	85.023	13.513	0	under ice
PS149_16-1_ROV-3	7/17/2025	ROVnet	85.023	13.513	10	
PS149_16-1-SI		Icecorer	85.023	13.513		bottom_10cm
PS149_17-4	7/18/2025	MULTINET	84.578	-0.265	1500	
PS149_18-1	7/19/2025	Icecorer	84.482	-17.876		
PS149_18-7	7/20/2025	CTD	84.463	-17.901		CTD_ChI _{max}
PS149_18-5	7/20/2025	MULTINET	84.466	-17.937	1500	
PS149_18-10	7/20/2025	BONGO	84.456	-17.880	100	
PS149_18-8	7/20/2025	BONGO	84.459	-17.885	100	
PS149_18-9	7/20/2025	BONGO	84.458	-17.881	100	
PS149_18-1_ROV-4	7/21/2025	ROVnet	84.482	-17.876	10	
PS149_18-1_ROV-5	7/21/2025	ROVnet	84.482	-17.876	0	under ice
PS149_18-1_ROV-6	7/21/2025	ROVnet	84.482	-17.876	0	under ice
PS149_18-1-SI		Icecorer	84.482	-17.876		bottom_10cm
PS149_21-9	7/26/2025	BONGO	82.616	26.707	100	
PS149_21-6	7/26/2025	CTD	82.625	26.717		CTD_ChI _{max}
PS149_21-5	7/26/2025	MULTINET	82.632	26.784	1500	
PS149_21-8	7/26/2025	BONGO	82.617	26.709	100	
PS149_21-7	7/26/2025	BONGO	82.619	26.711	100	
PS149_21-1_ROV-4	7/27/2025	ROVnet	82.701	27.119	0	under ice
PS149_21-1_ROV-5	7/27/2025	ROVnet	82.701	27.119	10	
PS149_21-1_ROV-6	7/27/2025	ROVnet	82.701	27.119	10	
PS149_21-1-SI		Icecorer	82.701	27.119		bottom_10cm
PS149_22-1	7/29/2025	MULTINET	83.245	21.853	1500	
PS149_25-4	7/30/2025	BONGO	83.747	16.053	100	
PS149_25-3	7/30/2025	MULTINET	83.756	15.926	1500	
PS149_25-9	7/31/2025	CTD	83.705	17.060		CTD_ChI _{max}
PS149_25-1-SI		Icecorer	83.756	15.810		bottom_10cm
PS149_28-1	8/2/2025	MULTINET	83.820	6.782	1500	
PS149_30-9	8/4/2025	BONGO	83.608	-12.085	65	
PS149_30-8	8/4/2025	BONGO	83.608	-12.095	65	
PS149_30-6	8/4/2025	BONGO	83.608	-12.113	65	
PS149_30-2	8/4/2025	MULTINET	83.599	-12.411	1500	

Event	Date	Device	Lat. (°N)	Lon. (°E)	Max depth (m)	Target feature
PS149_30-5	8/4/2025	BONGO	83.608	-12.121	65	
PS149_30-4	8/4/2025	BONGO	83.607	-12.132	65	
PS149_30-7	8/4/2025	BONGO	83.608	-12.104	65	
PS149_30-12	8/5/2025	CTD	83.616	-11.455		CTD_Chlmax
PS149_30-1_ROV_4	8/5/2025	ROVnet	83.586	-12.566	0	under ice
PS149_30-1_ROV_5	8/5/2025	ROVnet	83.586	-12.566	10	
PS149_30-1_ROV_6	8/5/2025	ROVnet	83.586	-12.566	10	
PS149_30-1-SI		Icecorer	83.586	-12.566		bottom_10cm
PS149_32-3	8/9/2025	MULTINET	83.228	33.732	1500	
PS149_32-6	8/9/2025	BONGO	83.232	33.723	80	
PS149_32-4	8/9/2025	BONGO	83.231	33.724	80	
PS149_32-5	8/9/2025	BONGO	83.232	33.724	80	
PS149_32-1_ROV_7	8/10/2025	ROVnet	83.304	33.638	0	under ice
PS149_32-1_ROV_8	8/10/2025	ROVnet	83.304	33.638	0	under ice
PS149_32-1_ROV_9	8/10/2025	ROVnet	83.304	33.638	10	
PS149_32-1-SI		Icecorer	83.304	33.638		bottom_10cm
PS149_32-7	8/10/2025	CTD	83.279	33.914		CTD_Chlmax
PS149_33-1	8/11/2025	MULTINET	83.662	27.831	1500	
PS149_36-5	8/12/2025	BONGO	84.491	21.917	81	
PS149_36-3	8/12/2025	MULTINET	84.480	22.012	1500	
PS149_36-4	8/12/2025	BONGO	84.490	21.921	81	
PS149_36-6	8/12/2025	BONGO	84.492	21.913	81	
PS149_36-9	8/13/2025	CTD	84.509	22.110		CTD_Chlmax
PS149_36-1_ROV_6	8/13/2025	ROVnet	84.474	22.172	0	under ice
PS149_36-1_ROV_7	8/13/2025	ROVnet	84.474	22.172	0	under ice
PS149_36-1_ROV_8	8/13/2025	ROVnet	84.474	22.172	10	
PS149_36-1-SI		Icecorer	84.474	22.172		bottom_10cm
PS149_37-1	8/15/2025	MULTINET	84.184	-1.402	1500	
PS149_41-7	8/17/2025	BONGO	82.956	-12.819	80	
PS149_41-6	8/17/2025	BONGO	82.958	-12.819	81	
PS149_41-5	8/17/2025	BONGO	82.961	-12.819	80	
PS149_41-10	8/17/2025	MULTINET	82.935	-12.804	1500	
PS149_41-9	8/17/2025	CTD	82.943	-12.810		CTD_Chlmax
PS149_41-1_ROV_5	8/18/2025	ROVnet	83.079	-12.948	0	under ice
PS149_41-1_ROV_6	8/18/2025	ROVnet	83.079	-12.948	0	under ice
PS149_41-1_ROV_7	8/18/2025	ROVnet	83.079	-12.948	10	
PS149_41-1-SI		Icecorer	83.079	-12.948		bottom_10cm
PS149_43-1	8/20/2025	MULTINET	83.707	15.654	1500	
PS149_46-3	8/23/2025	BONGO	84.194	18.144	80	
PS149_46-5	8/23/2025	CTD	84.192	18.150	80	
PS149_46-4	8/23/2025	BONGO	84.193	18.148	80	
PS149_46-2	8/23/2025	CTD	84.195	18.130		CTD_Chlmax
PS149_46-8	8/23/2025	MULTINET	84.183	18.116	1500	

Event	Date	Device	Lat. (°N)	Lon. (°E)	Max depth (m)	Target feature
PS149_46-1_ROV	8/24/2025	ROVnet	84.201	18.150	11.5	
PS149_46-1_ROV	8/24/2025	ROVnet	84.201	18.150	0	under ice
PS149_46-1-SI		Icecorer	84.201	18.150		bottom_10cm
PS149_47-5	8/26/2025	CTD	82.461	-5.653		
PS149_47-6	8/26/2025	MULTINET	82.462	-5.583	1500	
PS149_47-1_BEAST	8/27/2025	ROVnet	82.434	-4.867	0	
PS149_47-1_BEAST	8/27/2025	ROVnet	82.434	-4.867	10	

Overall, the three net types provided complementary material: multinet for quantitative taxonomy and abundance spanning multiple depth layers, bongos for biochemical and pollutant analyses of zooplankton inhabiting the upper ocean, and the ROVnet bridging both approaches in the near-surface under-ice environment. In total, 384 zooplankton samples were collected during the expedition for two purposes: trophic biomarker and pollutant analyses, and taxonomy and abundance studies (Tab. 5.4.2).

Tab. 5.4.2: Number of samples taken for trophic biomarker and pollutant as well as taxonomy analyses per sampling device.

	Bongo		MN_S5_PS	ROVnet		Grand Total
Station	T. biomarkers / pollutants	Taxonomy & abundance	Taxonomy & abundance	T. biomarkers / pollutants	Taxonomy & abundance	Total
12			5			5
13			6			6
15			5			5
16	13	1	5	12	3	34
17			5			5
18	21	1	5	7	2	36
21	20	1	5	15	2	43
22			5			5
25	21	1	5			27
28			5			5
30	22	1	5	12	2	42
32	17	1	5	5	2	30
33			5			5
36	22		9	13	2	46
37			5			5
41	14	1	5		2	22
43			5			5
46		1	5		2	8
Total	150	8	95	64	17	334

Preliminary results

Multinet deployments contributed 96 samples, all preserved for taxonomy and abundance, providing the main dataset on vertical community structure across the full water column. Bongo nets accounted for the largest number of samples, 169 in total, of which 160 will be used for trophic biomarkers and pollutant analyses and 9 for taxonomy. ROVnet operations yielded 118 samples, split between trophic biomarkers and pollutants (100) and taxonomy (18). Most samples were collected during the extended sea-ice stations. During transit, we focused on multinet sampling, with few additional Bongo net samples. A summary of the zooplankton samples collected during PS149 is provided in Table 5.4.2. The majority of the trophic biomarker and pollutant samples were copepods (*Calanus* spp., *Paraeuchatha* spp.), but we also collected significant numbers of ctenophores, amphipods, chaetognats and appendicularians (Tab. 5.4.3; Fig. 5.4.2).

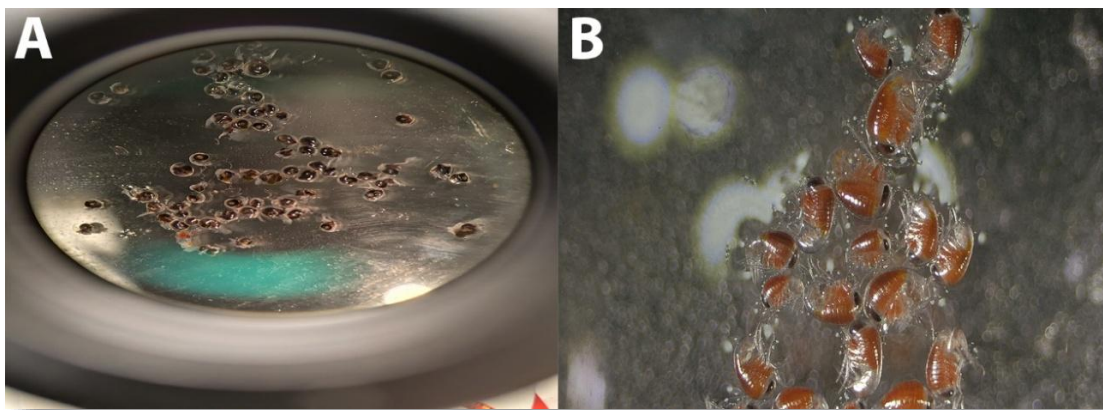


Fig. 5.4.2: Examples of animals collected for trophic biomarker and pollutant analyses. A) *Limacina helicina*, B) *Themisto abyssorum*. Picture credit: A) Nahid Welteke (AWI), B) Insa Kaphegyi (AWI)

Tab. 5.4.3: Numbers of samples collected per taxa/species for trophic biomarker and pollutant analyses

Taxon	Bongo	ROVnet	Total
<i>Apherusa glacialis</i>		25	25
<i>Beroe</i> spp.	2		2
<i>Beroe cucumis</i>	1	1	2
<i>Boroecia maxima</i>	6		6
<i>Calanus glacialis</i>	27	14	41
<i>Calanus hyperboreus</i>	28	12	40
<i>Chaetognatha</i>	19	6	25
<i>Clione limacina</i>	2		2
<i>Jaschnovia</i> spp.		3	3
<i>Limacina helicina</i>	10	9	19
<i>Mertensia</i> spp.	1		1
<i>Mertensia ovum</i>	1	1	2
<i>Oikopleura</i> spp.	18	14	32
<i>Onisimus</i> spp.	1		1
<i>Paraeuchaeta</i> spp.	21	2	23
<i>Paraeuchaeta glacialis</i>	1		1
<i>Themisto abyssorum</i>	11	3	14
<i>Themisto libellula</i>	6	8	14
<i>Thysanoessa</i> spp.	4	1	5
<i>Thysanoessa longicaudata</i>	1	1	2
Total	160	100	260

POM sampling for trophic marker analysis was conducted at 11 stations between 13 July and 26 August, with each station contributing one ice-core sample (IPOM, except station 47) and three to five water-column samples (PPOM). At the first four stations, we took blank samples of filtered MilliQ water. A total of 47 POM samples were collected for trophic marker analyses, consisting of 37 PPOM samples from the water column and 10 IPOM samples from sea ice cores (Tab. 5.4.4).

Tab. 5.4.4: Number of samples collected for trophic biomarker analysis of pelagic particulate organic matter (PPOM), ice-associated POM (IPOM), and blank filters

Station	IPOM	PPOM	Blank	Total
13	1	3	2	6
16	1	3	2	6
18	1	5	1	7
21	1	5	1	7
25	1	3		4
30	1	3		4
32	1	3		4
36	1	3		4
41	1	3		4
46	1	3		4
47		3		3
Total	10	37	6	53

All samples will be analysed in AWI laboratories to determine the abundance, biomass and species composition of zooplankton and under-ice fauna, the relative importance of sea ice algae and phytoplankton to the food web, and the presence and concentration of pollutants in ecologically important zooplankton species.

5.5 Settling particles and export flux

Underwater Vision Profiler (UVP)

The (Underwater Vision Profiler) UVP (version 5HD, SN202) was integrated as part of the CTD-Rosette frame (Fig. 5.5.1) in order to capture vertical abundance and size-distribution of particles and zooplankton during every CTD cast. The UVP is an *in situ* optical tool that images particles and zooplankton within a size-range between 100 μm and ~ 5 cm. In total, we deployed the UVP along with all 36 CTD-Profiles, including the test station. The data were semi-processed during the cruise and we made “vignettes” (or crops) of zooplankton, as well as histograms of particle size-distributions. This partial processing provided 5 size-classes of particle types. However, to have a full resolution distribution and recognition of zooplankton species, the dataset must be uploaded and finally processed by the artificial intelligence algorithms: eco-part (<https://ecopart.obs-vlfr.fr/>) and eco-taxa (<https://ecotaxa.obs-vlfr.fr/>) respectively.

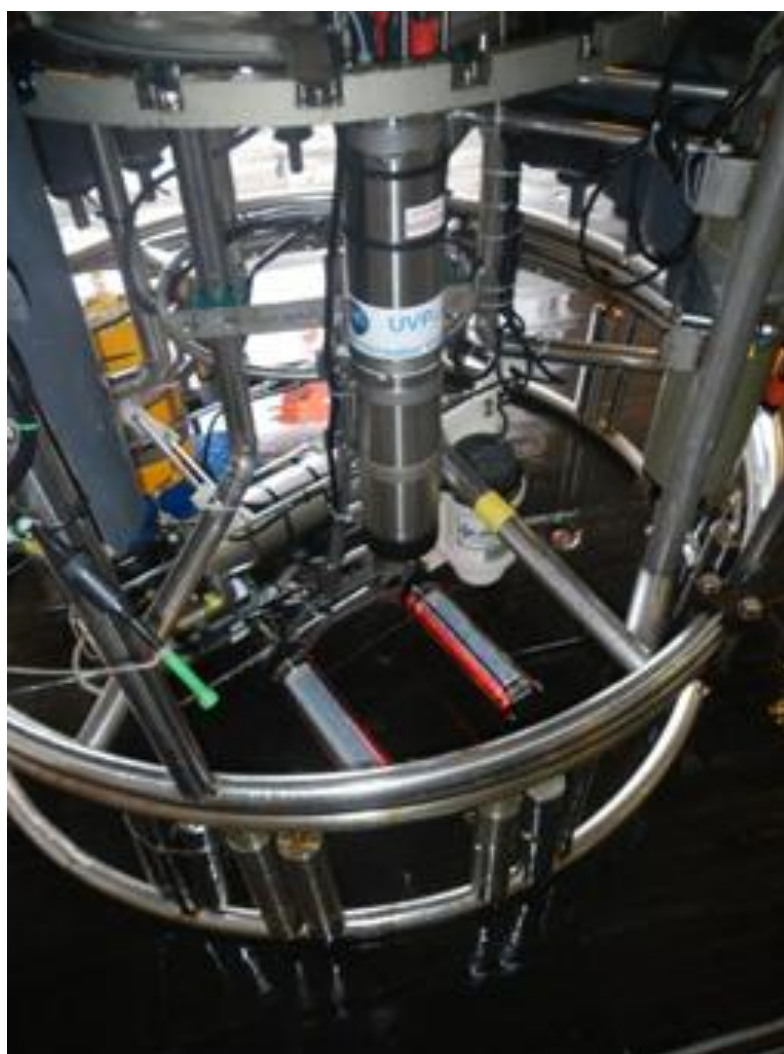


Fig. 5.5.1: The Underwater Vision Profiler (UVP) integrated into the CTD-Rosette.
Picture credit: Laurent Oziel (AWI).

ROSINA and JellyCam

The modular *in situ* imaging system ROSINA was deployed at each ice-regime, however, due to technical issues ROSINA was only deployed during the first two visits to each of the three regimes and we only obtained four full vertical profiles with the ROSINA system (Tab. 5.5.1).

Tab. 5.5.1: Deployments of the modular *in situ* imaging system ROSINA

Ice Station	StationID	Date	Profile Depth ROSINA	Profile Depth JellyCam
1a	PS149_13-6	11.07.2025	No profile	1500m, Downcast
2a	PS149_16-5	14.07.2025	1500m, Downcast	1500m, Downcast and Upcast
3a	PS149_18-12	20.07.2025	1500m, Downcast	1500m, Downcast and Upcast
1b	PS149_21-10	26.07.2025	1500m, Downcast	1500m, Downcast and Upcast
2b	PS149_25-8	30.07.2025	1500m, Downcast	1500m, Downcast and Upcast

The ROSINA system consists of two different camera systems that combined measured vertical profiles of particle and zooplankton abundance and size-distribution through the water column. The ROSINA system (Fig. 5.5.2) included the JellyCam and the ROSINA camera system (Remotely ObServing IN-situ camera for Aggregates), and a CTD (OceanSeven 310, Idronaut S.r.l). The whole system was deployed via a coaxial winch cable and continuously sent data and images to the winch control room via a telemetry unit, which allowed the user to control the camera and light setting during deployment.

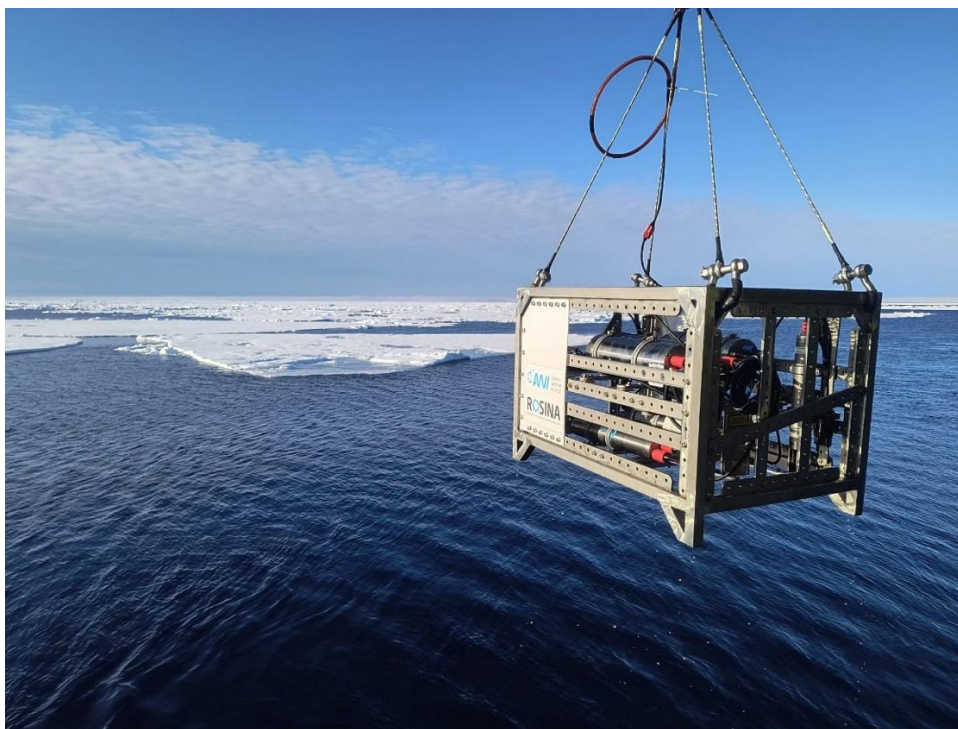


Fig. 5.5.2: ROSINA frame with the ROSINA camera system, Jelly camera and the Idronaut CTD.
Image by Morten Iversen

ROSINA (Remotely ObServing IN-situ camera for Aggregates)

The profiling particle camera ROSINA is a highly flexible and modular system that consists of a measurement unit and a control unit. The measurement unit contains the optical system (camera, lenses and light sources), computing unit, standalone CTD, battery and telemetry. The optical system consists of a 24 MPixel camera and macro-lens, which allows to image particles with either reflected light or as shadow images. The size-range of captured particles is between 20 μm and 5 cm. Since the system is equipped with telemetry, the operator is able to observe the measurement and make changes via the control unit during deployment. The control unit consists of the telemetry, which provides the communication interface and power for the measurement unit, and an operator workstation.

Jelly Camera (JellyCam)

The JellyCam consists of an industrial camera with backend electronics for timing, image acquisition and storage of data. The camera is equipped with variable focal length lens, which can be adjusted from the ship while the camera is deployed. Custom made light-sources were encapsulated with resin and triggered via the electronics. The system was controlled online by the operator via the ROSINA telemetry unit. With that configuration the operator can change various parameters, including exposure time, flash trigger, gain, zoom, focus, and lights. The captured images were saved on the deployed system but a screen-shot was monitored online in the winch control room during the deployments.

OceanSeven 310 CTD (Idronaut S.r.l.)

The ROSINA platform was equipped with an OceanSeven 310 CTD that measured pressure, temperature, conductivity, oxygen, turbidity, and chlorophyll a (Chl a). The system was deployed in an unattended with a sampling rate of 2 Hz.

Under Ice Sediment Traps

We deployed two sediment trap arrays in parallel under the ice at each ice station. One trap array was equipped with viscous gels at each collection depth. This sediment trap array consisted of two sediment trap tubes that attached gyroscopically at each collection depth (5 m, 15 m, 40 m, and 90 m under the ice, Fig. 5.5.3). One of the two tubes contained a gel trap insert. The gels preserved the size and structure of the settling aggregates, allowing to quantify the export of different particles types under the sea-ice. The remaining sediment trap tube at each depth was used to collect material for particulate organic carbon and particulate organic nitrogen measurements. The second sediment trap array was used to collect biogeochemical samples, this array was similar to the gel-trap array, but without the gel trap inserts in one of the tubes. Hence, both tubes at each depth collected biogeochemical fluxes for flux determinations of HPLC measurements of pigments, particulate organic carbon and nitrogen, particulate inorganic carbon, particulate organic phosphorus, and biogenic silica. The biogeochemical traps also collected particle flux from four different depths below the ice: 5 m, 15 m, 40 m, and 90 m. After recovery of the under-ice traps, the samples were split into subsamples and filtered for biogeochemical parameters on board. The particles collected in the gel traps were photographed with a digital camera on board and frozen for further detailed investigations in the home laboratory. The image analyses of the gel traps will be used to determine the composition, abundance and size distribution of the sinking particles.

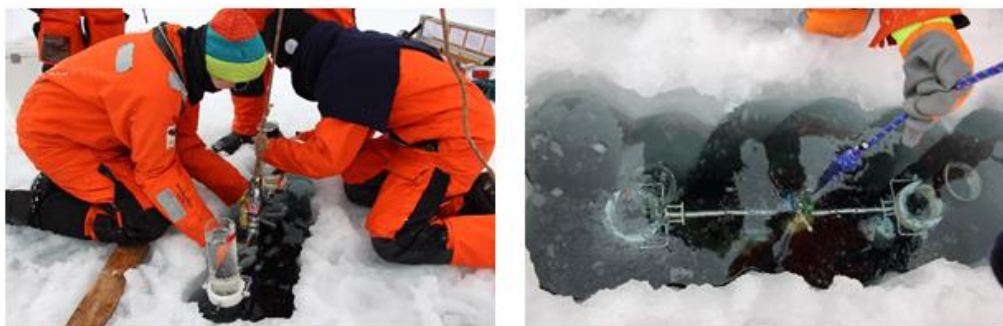


Fig. 5.5.3: Deployment of under ice sediment traps. Similar trap types were used for the gel traps and for the biogeochemical sampling. The only difference was that both trap tubes at each depth were used for biogeochemical fluxes for the biogeochemical traps and for the gel traps one tube was used for particulate organic carbon and nitrogen flux measurements and the other trap tube contained a gel insert with the gel trap, which preserved the size and structure of individual settling aggregates.
Images taken by Tim Kalvelage during PS138

In total we deployed 23 sediment traps under the ice for ~24 hours per deployment. Table 5.5.2 provides an overview of the trap deployments.

Tab. 5.5.2: Deployments of under ice sediment traps. Two types of traps were deployed, gel traps and biogeochemical traps. The different ice stations, trap IDs, deployment and recovery times (yyyy-mm-dd hh:mm:ss), as well as the type of traps (gel or biogeochemical).

Ice Station	Trap ID	Deployment	Recovery	Type
PS149_13-1	_shortterm_sedtrap_lice-001	2025-07-10 10:18:00	2025-07-12 09:30:00	Gel trap & Biogeochemical
PS149_16-1	_shortterm_sedtrap_lice-001	2025-07-15 14:23:00	2025-07-16 13:40:00	Gel Trap
PS149_16-1	_shortterm_sedtrap_lice-002	2025-07-16 14:34:00	2025-07-17 13:47:00	Biogeochemical trap
PS149_18-1	_shortterm_sedtrap_lice-001	2025-07-20 14:34:00	2025-07-21 13:05:00	Gel Trap
PS149_18-1	_shortterm_sedtrap_lice-002	2025-07-21 14:21:00	2025-07-22 13:07:00	Biogeochemical trap
PS149_21-1	_shortterm_sedtrap_lice-001	2025-07-26 13:45:00	2025-07-27 09:20:00	Gel Trap
PS149_21-1	_shortterm_sedtrap_lice-002	2025-07-27 13:38:00	2025-07-28 15:06:00	Biogeochemical trap
PS149_25-1	_shortterm_sedtrap_lice-001	2025-07-30 10:51:00	2025-07-31 09:42:00	Gel Trap
PS149_25-1	_shortterm_sedtrap_lice-002	2025-07-31 10:25:00	2025-08-01 10:30:00	Biogeochemical trap
PS149_30-1	_shortterm_sedtrap_lice-001	2025-08-04 10:38:00	2025-08-05 09:25:00	Gel Trap
PS149_30-1	_shortterm_sedtrap_lice-002	2025-08-05 10:23:00	2025-08-06 10:25:00	Biogeochemical trap

Ice Station	Trap ID	Deployment	Recovery	Type
PS149_32-1	_shortterm_sedtrap_lice-001	2025-08-09 17:02:00	2025-08-10 19:07:00	Gel Trap
PS149_32-1	_shortterm_sedtrap_lice-002	2025-08-09 17:15:00	2025-08-10 19:27:00	Biogeochemical trap
PS149_36-1	_shortterm_sedtrap_lice-001	2025-08-12 14:56:00	2025-08-13 15:38:00	Gel Trap
PS149_36-1	_shortterm_sedtrap_lice-002	2025-08-12 15:04:00	2025-08-13 15:55:00	Biogeochemical trap
PS149_36-1	_shortterm_sedtrap_lice-003	2025-08-13 16:42:00	2025-08-14 15:50:00	Biogeochemical trap
PS149_41-1	_shortterm_sedtrap_lice-001	2025-08-16 22:31:00	2025-08-17 19:18:00	Gel Trap
PS149_41-1	_shortterm_sedtrap_lice-002	2025-08-16 22:48:00	2025-08-17 19:36:00	Biogeochemical trap
PS149_41-1	_shortterm_sedtrap_lice-003	2025-08-17 19:55:00	2025-08-18 16:19:00	Biogeochemical trap
PS149_46-1	_shortterm_sedtrap_lice-001	2025-08-23 10:20:00	2025-08-24 10:21:00	Gel Trap
PS149_46-1	_shortterm_sedtrap_lice-002	2025-08-23 10:30:00	2025-08-24 10:42:00	Biogeochemical trap
PS149_47-1	_shortterm_sedtrap_lice-001	2025-08-26 11:11:00	2025-08-27 10:20:00	Gel Trap
PS149_47-1	_shortterm_sedtrap_lice-002	2025-08-26 11:26:00	2025-08-27 10:40:00	Biogeochemical trap

Preliminary results

The majority of samples obtained during this cruise were frozen and stored until later processing and analysis in the home lab, thus few preliminary results are available yet. We expect to observe a strong impact of ice-regimes on the pelagic and ice-associated plankton communities, which will directly influence the efficiency and magnitude of carbon export to deeper water depths. Furthermore, release of cryominerals will ballast organic aggregates and potentially enable them to cross the salinity gradients at the base of the meltwater layer. This will result in sporadic export events, where a large fraction of the organic matter that was retained in the meltwater layer is exported to the deep sea and seafloor. We expect this mechanism to be a driving factor for the biological carbon pump in the central Arctic Ocean. During periods with little to low ballasting from cryo-minerals and very low to no abundance of ice-algae, we expect low carbon export and an ecosystem that rely on recycled organic matter as an energy source. The phytoplankton aggregates that may form are porous and will be retained at the salinity gradient, allowing extended time for microbial degradation and zooplankton grazing on the aggregates. This means that strongly stratified regions below Arctic sea-ice are characterized by retention and only little export takes place without ballasting from cryo-minerals. The dominating export mechanism is expected to be via zooplankton fecal pellets.

The majority of the aggregates that sank out of the upper mixed layer consisted of zooplankton fecal pellets. Ice regime 1, showed low export of phytoplankton aggregates and zooplankton fecal pellets during the first visit (Fig. 5.5.4), but high abundance of swimmers in the traps. During the second visit the number of swimmers in the gel traps had decreased and the trap placed at 90 m depth now had zooplankton fecal pellets. During the third visit we observed an

increase in the number of exported copepod fecal pellets at 20 m, but those were only present in lower abundance at 40 m and 90 m depth.



Fig. 5.5.4: Overview images of the gel traps collected 5 m, 20 m, 40 m, and 90 m at the ice stations in ice regime 1.

Ice regime 2, was visited four times and did not show strong differences in the amount or type of exported material between the different visits (Fig. 5.5.5). Generally, there was very low export to 5 m depth and high export to 90 m depth. The main difference was, that during the first visit we observed phytoplankton aggregates and appendicularian houses in the gel traps, while the export flux was more dominated by zooplankton fecal pellets during the three later visits.

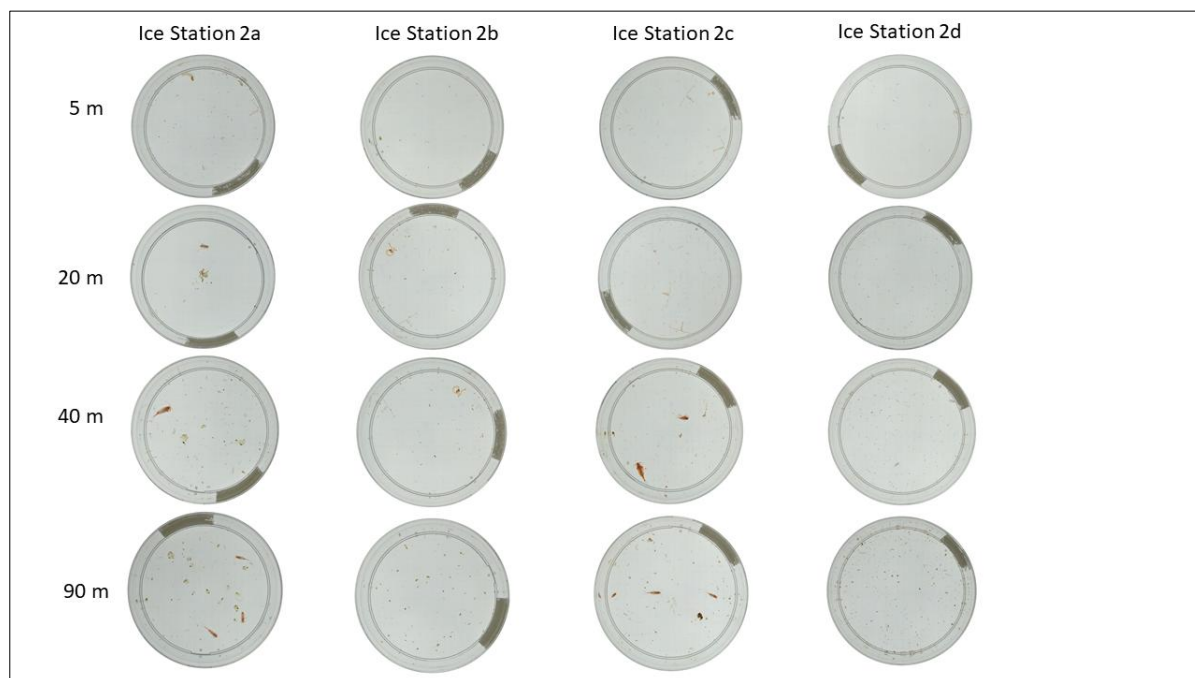


Fig. 5.5.5: Overview images of the gel traps collected 5 m, 20 m, 40 m, and 90 m at the ice stations in ice regime 2.

Ice regime 3, was dominated by pteropods in the 5 m and 20 m traps during all four visits. There was generally very low abundance of zooplankton fecal pellets and phytoplankton aggregates at 5 m and 20 m during all visits. However, the trap collecting at 40 m and 90 m depths had high numbers of zooplankton fecal pellets, which peaked during the second visit and thereafter became gradually less for each visit (Fig. 5.5.6).

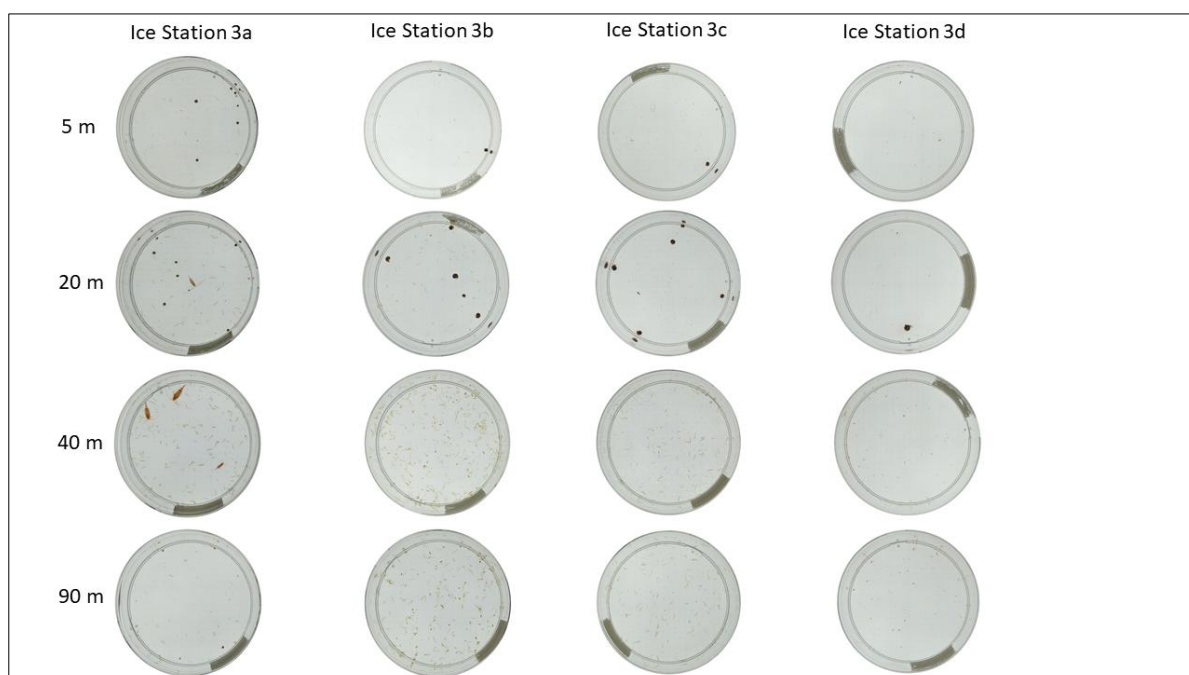


Fig. 5.5.6: Overview images of the gel traps collected 5 m, 20 m, 40 m, and 90 m at the ice stations in ice regime 3.

Under Ice Cameras

At every ice station we deploy an *in-situ* camera (Underwater Vision Profiler, UVP6) from the same position as the sediment traps. We either deployed the UVP6 as a vertical profile from the surface to ~100 m or by hanging it for ~24 hours directly under the ice at 3 m to 8 m below the ice. The UVP6 was programmed to take an image every second and imaged a known water volume by shining a laser sheet in from of the camera. The pixel-size of the camera was 78 μm per pixel. The UVP6 detected the size-distribution and abundance of particles in the water column. We stored every image, allowing us to analyze more parameters for each imaged particles and zooplankton organism. However, towards the end of the cruise, the UVP6 no longer stored the images and we only obtained the size and abundance of the imaged objects (Tab. 5.5.3).

Tab. 5.5.3: Deployments of Underwater Vision Profiler (UVP6). The UVP6 deployments at each station with the UVP ID, deployment date and time, depth of deployment, storage of images, and whether the UVP6 was deployed as a vertical profile or as a long-term deployment at one depth for ~24 hours.

Ice Station	UVP ID	Deployment	Depth (m)	Images	Profile or long-term
PS149_13-1	_ice-uvp-001	2025-07-09 18:18:30	150	yes	Profile
PS149_13-1	_ice-uvp-002	2025-07-10 15:57:23	20	yes	Profile
PS149_13-1	_ice-uvp-003	2025-07-12 10:02:24	95	yes	Profile

Ice Station	UVP ID	Deployment	Depth (m)	Images	Profile or long-term
PS149_16-1	_ice-uvp-001	2025-07-15 13:37:15	95	no	Profile
PS149_16-1	_ice-uvp-002	2025-07-16 14:43:00	95	no	Profile
PS149_16-1	_ice-uvp-003	2025-07-17 13:41:17	95	yes	Profile
PS149_18-1	_ice-uvp-001	2025-07-20 13:31:34	95	no	Profile
PS149_18-1	_ice-uvp-002	2025-07-21 13:39:32	95	yes	Profile
PS149_18-1	_ice-uvp-003	2025-07-22 13:28:30	100	yes	Profile
PS149_21-1	_ice-uvp-001	2025-07-26 10:21:21	109	yes	Profile
PS149_21-1	_ice-uvp-002	2025-07-27 13:02:29	100	yes	Profile
PS149_21-1	_ice-uvp-003	2025-07-28 15:25:06	100	yes	Profile
PS149_25-1	_ice-uvp-001	2025-07-30 10:17:28	106	yes	Profile
PS149_25-1	_ice-uvp-002	2025-07-31 09:54:53	103	yes	Profile
PS149_25-1	_ice-uvp-003	2025-08-01 10:42:11	103	yes	Profile
PS149_30-1	_ice-uvp-001	2025-08-04 10:02:45	101	yes	Profile
PS149_30-1	_ice-uvp-002	2025-08-05 09:41:40	108	yes	Profile
PS149_30-1	_ice-uvp-003	2025-08-06 10:41:03	109	yes	Profile
PS149_32-1	_ice-uvp-001	2025-08-09 16:24:25	101	yes	Profile
PS149_32-1	_ice-uvp-002	2025-08-10 19:41:28	100	yes	Profile
PS149_36-1	_ice-uvp-001	2025-08-12 13:57:38	95	yes	Profile
PS149_36-1	_ice-uvp-002	2025-08-13 16:05:25	94	yes	Profile
PS149_36-1	_ice-uvp-003	2025-08-13 16:27:50	8	yes	Long-term
PS149_36-1	_ice-uvp-004	2025-08-14 16:16:40	100	yes	Profile
PS149_41-1	_ice-uvp-001	2025-08-16 21:16:33	95	yes	Profile
PS149_41-1	_ice-uvp-002	2025-08-17 19:45:25	8	no	Long-term
PS149_41-1	_ice-uvp-003	2025-08-18 16:36:13	100	yes	Profile

Ice Station	UVP ID	Deployment	Depth (m)	Images	Profile or long-term
PS149_46-1	_ice-uvp-001	2025-08-23 09:35:00	102	no	Profile
PS149_46-1	_ice-uvp-002	2025-08-23 11:06:00	6	no	Long-term
PS149_46-1	_ice-uvp-003	2025-08-24 10:58:00	99	no	Profile
PS149_47-1	_ice-uvp-001	2025-08-26 10:43:00	94	no	Profile
PS149_47-1	_ice-uvp-002	2025-08-26 11:17:00	3	no	Long-term
PS149_47-1	_ice-uvp-003	2025-08-27 10:54:00	100	no	Profile

Preliminary results

The (Underwater Vision Profiler) UVP6 was capturing aggregates and zooplankton within the size-range between 100 μm and $\sim 5\text{ cm}$ during the under-ice deployments (Fig. 5.5.7).

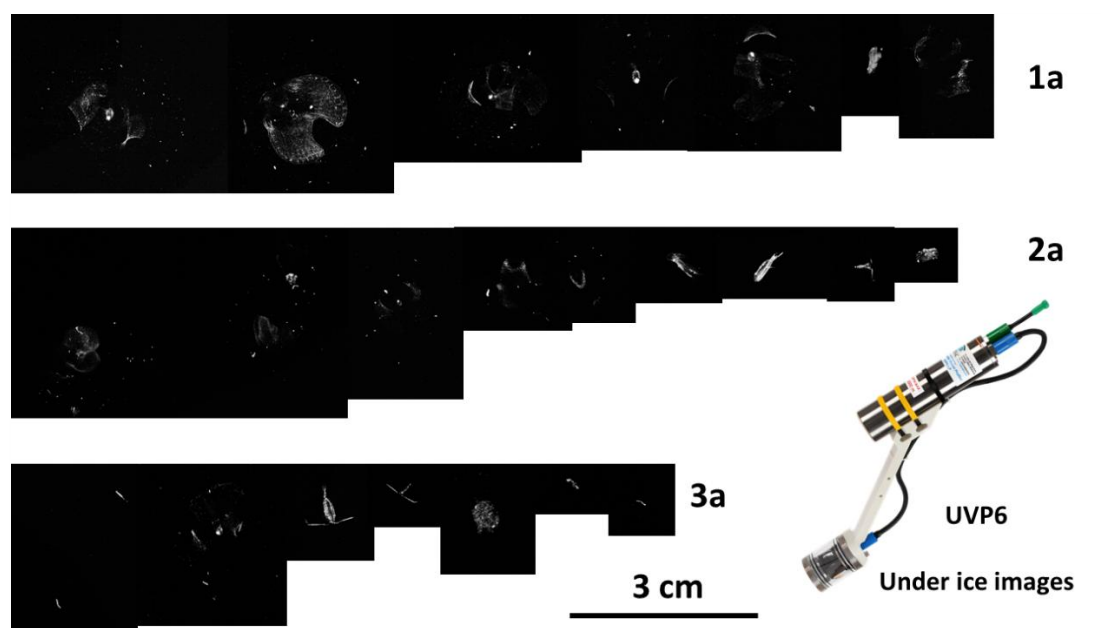


Fig. 5.5.7: Examples of image crops, vignettes, obtained by the UVP6 from the under-ice profiles after the first visit to all ice regimes. The vignettes shows that appendicularians dominated at station 1a and that appendicularians and copepods dominated at station 2a and 3a.

This partial processing provides 5 size-classes of particles (Fig. 5.5.8). The vertical distribution of aggregates and zooplankton showed higher abundances near the surface, which was particularly pronounced at station 3a compared to 1a and 2a. Furthermore, the vertical abundance distribution shows that especially the small aggregates had higher abundance in the surface ocean compared to the deeper depths. While, larger aggregates showed similar abundances at all depths. The data set will need to be further investigated after full processing, and combined with other complementary imagery systems (JellyCam, ROSINA, UVP on the CTD-Rosette), sediment traps, and sinking velocities and microbial degradation of aggregates to give a full overview of the vertical carbon fluxes during the expedition ArcWatch-1.

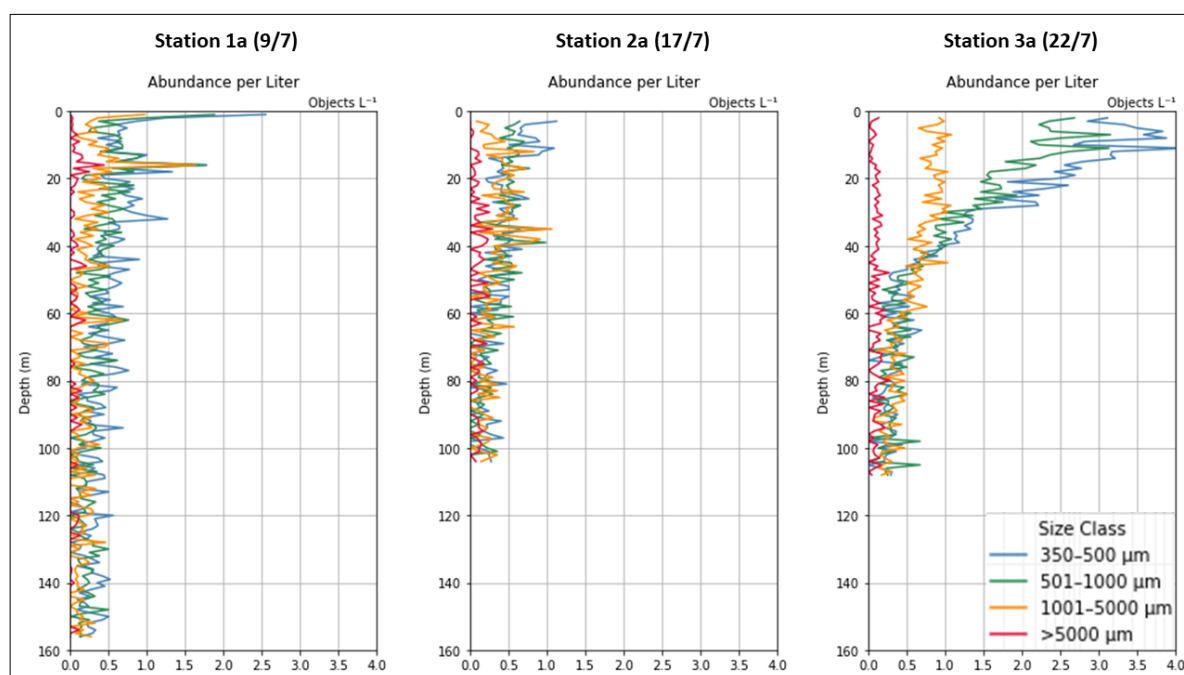


Fig. 5.5.8: Vertical size-distribution and abundance of aggregates and zooplankton from the UVP6 deployment under the sea ice.

Marine Snow Catcher

A large volume water sampler, the Marine Snow Catchers (MSC), was used to collect *in situ* formed marine snow and other particles at every ice station (Fig. 5.5.9). The MSC consists of a 100 L cylindrical water sampler with a particle collection tray at the bottom and was deployed to a target depth using the ship's winch system. Once at the target depth, a messenger weight and a release system were used to close the MSC. The closed MSC was placed on deck for ~12 hours to allow the collected particles to sink to the collection tray. The fairly long settling time of the MSC on deck was chosen due to the often very slow settling velocities of the collected aggregates. After gently draining the water from the 100 L cylinder, the collection tray that contained the settling particles was removed and brought to the laboratory where the size, type, composition, settling velocity, and microbial respiration was measured as a function of the size of each collected aggregate type. Each aggregate was individually frozen in an Eppendorf tube at -20°C and at the end of the cruise the aggregates were pooled according to size, type, and settling velocities and filtered onto pre-combusted GF/F filters for determination of their particulate organic carbon and nitrogen content in the home laboratory.



Fig. 5.5.9: Marine Snow Catcher during deployment at PS149. The Marine Snow Catcher collects intact settling aggregates, allowing for direct measurements of aggregate size-specific settling velocity and microbial respiration on board. Picture taken by Runa Reuter

The size-specific settling velocities and microbial respiration of each of the collected aggregates was measured on board in a vertical flow chamber at *in situ* temperatures. Individual aggregates were placed in the flow chamber, whereby the upward flow was increased until the aggregate remained suspended. The sinking velocity of each aggregate was calculated from the flow rate divided by the cross-sectional area of the flow chamber. Microbial respiration was measured using oxygen microsensors to determine the oxygen gradients through the aggregate-water interface. From the gradient, Fick's First Law was used to calculate the oxygen flux [$\mu\text{mol O}_2 \text{ cm}^{-2} \text{ s}^{-1}$] into the aggregate, by multiplying by the total aggregate surface area, we calculated the total oxygen consumption via microbial respiration per day.

Preliminary results

At each ice station we collected settling aggregates using the marine snow catchers and measured individual aggregates for size-specific settling velocities and microbial respiration in the flow chamber. We did not observe large differences in the size-specific settling velocities between the individual ice stations, though we did see large differences in size-specific settling velocities between the different particle types. Looking across all aggregate types, we observed the highest settling velocities at ice regime 2 and the lowest settling velocities at ice regime 1 (Fig. 5.5.10).

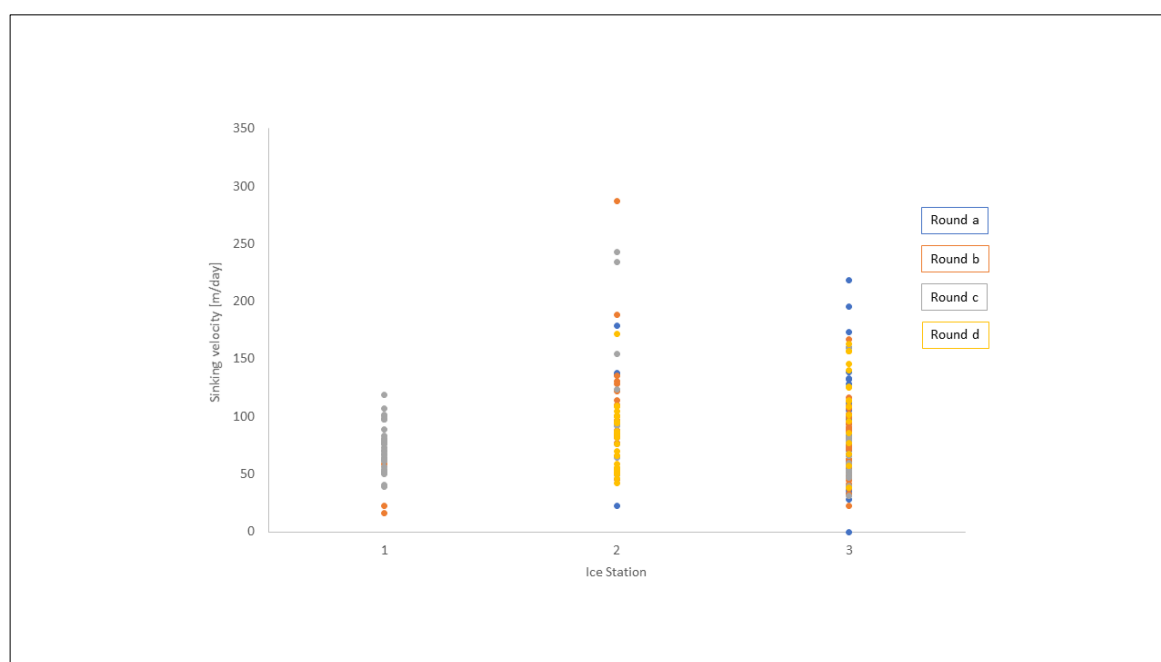


Fig. 5.5.10: Settling velocities of the aggregates collected by the marine snow catcher at the different ice regimes

5.6 Cryogenic minerals and foraminifera

Foraminifera (benthic and planktic)

Living benthic and planktonic foraminifera have been collected across the Arctic Ocean by AWI since 1987 and 2015, respectively. Hereby, resampling sites over this long time-span allows to document recent Arctic Ocean warming and Atlantification with the most suitable microfossil group to document such changes since the beginning of life on earth. For the Arctic Ocean hereby, recent changes documented in the collection of living foraminifera over several decades can be compared with changes that occurred during previous interglacials. The structure of the Contrasts expedition with the revisit of sites over roughly two months, allows to compare site-foraminiferal faunal changes over the expedition with changes in primary and export production reported during sampling. From each multicorer (MUC) cast three tubes (10 cm²) were sampled in 1-cm thick slices from the sediment surface to 10 cm sediment depth (Tab. 5.6.1). Each subsample was transferred into a Kautex bottle and topped with a sample equivalent volume of 96% ethanol/Rose Bengal mixture, shaken well to homogenize sediment and ethanol, and the bottles were finally stored at 4°C until further processing in the home laboratory of the Alfred Wegener Institute in Bremerhaven. As benthic foraminifera live on benthic metazoa, stones, the sediment surface or at certain depths within the uppermost 10-15 cm of sediments, the down-core sampling strategy allowed to catch the whole living community with the species preferred habitat depth. The planktonic foraminifera were sampled via deployments of a multinet equipped with 5 nets with a 55 µm mesh-size, which allowed to catch the planktic foraminifera fauna at depths of 0-50 m, 50-200 m, 200-500 m, 500-1,000 m and 1,000-1,500 m (Tab. 5.6.2).

Tab. 5.6.1: Deployment of the Multicorer at the different stations with deployment and recovery data and time, latitude, longitude, and deployment depth

Station 1:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Depth [m]
PS149_15-4	13/07/2025 18:45	13/07/2025 22:46	84.658176	20.824772	3996
PS149_21-15	28/07/2025 17:00	28/07/2025 19:55	82.496585	28.446951	3770
PS149_32-14	10/08/2025 18:16	10/08/2025 21:37	83.318255	34.130123	3810
Station 2:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Depth [m]
PS149_16-10	17/07/2025 18:19	17/07/2025 21:25	84.692452	13.8797660	3497
PS149_25-14	01/08/2025 17:43	01/08/2025 20:45	83.740552	19.00503	4009
PS149_36-13	14/08/2025 12:37	14/08/2025 15:45	84.597646	21.59276	3994
Station 3:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Depth [m]
PS149_20-1	24/07/2025 10:30	24/07/2025 14:48	83.735946	11.134481	3573
PS149_30-17	06/08/2025 10:58	06/08/2025 13:58	83.692199	-11.097621	3872
PS149_41-12	18/08/2025 12:30	18/08/2025 15:36	82.767675	-12.831417	2849

Tab. 5.6.2: Deployment of the Multinets at the different stations with deployment and recovery data and time, latitude, longitude, and instrument abbreviation deployment depth. All Multinet deployments were done with depths intervals of 0-50 m, 50-200 m, 200-500 m, 500-1,000 m and 1,000-1,500 m.

Station 1:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Abbreviation
PS149_13-5	09/07/2025 17:09	09/07/2025 19:54	83.744823	20.941865	MN_S5_PS_55
-	-	-	-	-	-
PS149_32-2	09/08/2025 14:09	09/08/2025 16:13	83.227845	33.731921	MN_S5_PS_55
Station 2:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Abbreviation
PS149_16-8	15/07/2025 09:26	15/07/2025 12:17	84.990502	13.978464	MN_S5_PS_55
PS149_25-2	30/07/2025 10:04	30/07/2025 12:01	83.757859	15.83944	MN_S5_PS_55
PS149_36-2	12/08/2025 09:58	12/08/2025 11:47	84.476909	22.14426	MN_S5_PS_55
Station 3:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Abbreviation
PS149_18-6	20/07/2025 10:15	20/07/2025 12:58	84.466815	-17.943484	MN_S5_PS_55
PS149_30-3	04/08/2025 12:02	04/08/2025 13:53	83.605512	-12.240357	MN_S5_PS_55
PS149_41-4	17/08/2025 08:00	17/08/2025 09:59	82.975149	-12.814353	MN_S5_PS_55

Cryogenic minerals

Cryogenic minerals form in brine channels from supersaturated brine water within the sea ice. Observations on the release of cryogenic gypsum are scarce (Wollenburg et al., 2020; Wollenburg et al., 2018), and to understand the importance of gypsum and associated cryogenic minerals as ballast mineral requires additional well-designed and comprehensive field studies. The set-up of the Contrasts expedition allowed us to revisit three sites. This enables us to verify the collected cryogenic mineral assemblage and quantity in respect to sea ice thickness, structure, and origin. Moreover, supplementary investigation of the ecology and biogeochemistry group on carbon export and primary production will provide important information on their ballasting capacity. Cryogenic minerals were collected with the CTD-rosette, the ROV-net/gypsum-net, and from ice cores. With the CTD-rosette, 12 L of the surface water, the halocline, the chlorophyll maximum, and the temperature maximum each were sampled and filtered over a 10 µm mesh with vacuum pumps, and the residue with the mesh stored in an ethanol filled Falcon Tube (Tab. 5.6.3).

Tab. 5.6.3: Deployment of the CTD-Rosette for surface water sampling for gypsum minerals at the different stations with deployment and recovery date and time, latitude, longitude, and action

Station 1:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Action
PS149_13-7	11/07/2025 13:31	11/07/2025 14:52	83.755626	22.210481	Deployment
PS149_21-6	26/07/2025 12:29	26/07/2025 13:55	82.624897	26.717374	Deployment
PS149_32-7	10/08/2025 08:05	10/08/2025 08:47	83.279149	33.914036	Deployment
Station 2:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Action
PS149_16-9	15/07/2025 12:21	15/07/2025 13:18	84.959241	14.1056910	Deployment
PS149_25-9	31/07/2025 08:03	31/07/2025 08:59	83.704535	17.059764	Deployment
PS149_36-9	13/08/2025 08:03	13/08/2025 08:56	84.508659	22.110049	Deployment
Station 3:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Action
PS149_18-7	20/07/2025 13:03	20/07/2025 14:08	84.463485	-17.901072	Deployment
PS149_30-12	05/08/2025 08:05	05/08/2025 09:42	83.61622	-11.454504	Deployment
PS149_41-9	17/08/2025 12:30	17/08/2025 13:19	82.942534	-12.810274	Deployment

The gypsum net is a handmade nylon net with an opening of 10 cm by 15 cm and a mesh size of 30 μm that was mounted in the ROV-zooplankton net (with a mesh size of 500 μm , see Flores, 2018). The concentrated particulate material of the cryogenic gypsum net was collected in a 2 L polyethylene bottle attached to the cod end of the net. A gauze-covered window in the cod-end bottle allowed seawater to drain out. Both nets were mounted on the aft end of a M500 (Ocean Modules, Sweden) observation class ROV, the Beast (Katlein et al., 2017). After each ROVnet deployment, the nets were rinsed with ambient seawater to concentrate the sample in the cod end of the net (Tab. 5.6.4). The ROVnet sampled horizontal profiles in the water directly below the sea ice. Standard ROVnet profiles were conducted at the ice–water interface and 10 m depths. The distance covered by a 10 minutes dive. The residue of the collected material was vacuum filtered over a 10 μm mesh and stored in ethanol until further investigations at the Alfred Wegener Institute in Bremerhaven.

Tab. 5.6.4: Deployment of the ROVnets for gypsum minerals at the different stations with deployment and recovery date and time, and sampling depths

Station 1:			
Event label	Date/Time start	Date/Time end	Sampling depths
PS149_13-1	-	-	-
PS149_21-1-BEAST-4	2025-07-27T16:32:00	2025-07-27T16:44:00	Nets 1, shallow
PS149_21-1-BEAST-5	2025-07-27T16:54:00	2025-07-27T17:05:00	Nets 2, 10 m depth
PS149_21-1-BEAST-6	2025-07-27T17:19:00	2025-07-27T17:30:00	Nets 3, 10 m depth
PS149_32-1-BEAST-7	2025-08-10T16:25:00	2025-08-10T16:35:00	Nets 1, shallow
PS149_32-1-BEAST-8	2025-08-10T16:43:00	2025-08-10T16:54:00	Nets 2, shallow
PS149_32-1-BEAST-9	2025-08-10T17:00:00	2025-08-10T17:11:00	Nets 3, 10 m
Station 2:			
Event label	Date/Time start	Date/Time end	Description
PS149_16-1-BEAST-4	2025-07-17T10:19:00	2025-07-17T10:32:00	Nets 1, shallow
PS149_16-1-BEAST-5	2025-07-17T10:41:00	2025-07-17T10:51:00	Nets 2, shallow
PS149_16-1-BEAST-7	2025-07-17T14:38:00	2025-07-17T14:54:00	Nets 1, 10 m
PS149_25-1	-	-	-
PS149_36-1-BEAST-4	2025-08-13T14:22:00	2025-08-13T14:35:00	Nets 1, shallow
PS149_36-1-BEAST-5	2025-08-13T14:43:00	2025-08-13T14:54:00	Nets 2, shallow
PS149_36-1-BEAST-6	2025-08-13T15:08:00	2025-08-13T15:24:00	Nets 3, 10 m
PS149_46-1-BEAST-5	2025-08-27T09:43:00	2025-08-27T09:53:00	Nets 1, shallow
PS149_46-1-BEAST-6	2025-08-27T10:01:00	2025-08-27T10:11:00	Nets 2, 10 m

Station 3:			
Event label	Date/Time start	Date/Time end	Description
PS149_18-1-BEAST-4	2025-07-21T15:58:00	2025-07-21T16:16:00	Nets 1, shallow
PS149_18-1-BEAST-5	2025-07-22T16:28:00	2025-07-21T16:53:00	Nets 2, shallow
PS149_18-1-BEAST-6	2025-07-22T17:19:00	2025-07-21T17:30:00	Nets 3, 10 m
PS149_30-1-BEAST-4	2025-08-05T10:22:00	2025-08-05T10:34:00	Nets 1, shallow
PS149_30-1-BEAST-5	2025-08-05T10:38:00	2025-08-05T10:50:00	Nets 2, 10 m
PS149_30-1-BEAST-6	2025-08-05T10:55:00	2025-08-05T11:10:00	Nets 3, 10 m
PS149_41-1-BEAST-5	2025-08-18T09:43:00	2025-08-18T09:56:00	Nets 1, shallow
PS149_41-1-BEAST-6	2025-08-18T10:02:00	2025-08-18T10:12:00	Nets 2, shallow
PS149_41-1-BEAST-7	2025-08-18T10:20:00	2025-08-18T10:30:00	Nets 3, 10m
PS149_47-1-BEAST-5	2025-08-27T09:35:00	2025-08-27T09:48:00	Nets 1, shallow
PS149_47-1-BEAST-6	2025-08-27T09:58:00	2025-08-27T10:10:00	Nets 2, 10 m

At each station, two ice cores were taken for cryogenic minerals, whereas, one was stored at -20°C, the other was cut in 10 cm thick slices (Tab. 5.6.5). For this purpose, a 2 L measuring cup was half-filled with tap water, a piece of ice core was added, and the rise in water level was recorded as ice volume. After a few seconds, the contents of the measuring cup were emptied over a 10 µm mesh and the process was repeated until all the ice had melted. The cryogenic minerals isolated in this way were placed in a container filled with ethanol together with the mesh and stored at 4°C until further processing at the Alfred Wegener Institute. This preparation method was applied to all processed ice core sections.

Tab. 5.6.5: Collections of ice cores for sampling for gypsum minerals at the different stations with deployment and recovery date and time, latitude, longitude, and description

Station 1:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Description
PS149_13-1-SI_corer_9cm-001	2025-07-11T09:20:00	2025-07-11T11:30:00	84.8591667	22.76055556	Gypsum Core Archive
PS149_13-1-SI_corer_9cm-002	2025-07-11T09:20:00	2025-07-11T11:30:00	84.8591667	22.76055556	Gypsum Core Sample
PS149_21-1-SI_corer_9cm-001	2025-07-26T09:08:00	2025-07-26T10:48:00	82.62980167	26.77741667	Gypsum Core Archive
PS149_21-1-SI_corer_9cm-002	2025-07-26T09:08:00	2025-07-26T10:48:00	82.62980167	26.77741667	Gypsum Core Sample
PS149_30-1-SI_corer_9cm-001	2025-08-04T09:32:45	2025-08-04T11:19:39	83.228668	33.734111	Gypsum Core Archive
PS149_30-1-SI_corer_9cm-002	2025-08-04T09:32:45	2025-08-04T11:19:39	83.228668	33.734111	Gypsum Core Sample
Station 2:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Description
PS149_16-1-SI_corer_9cm-001	2025-07-15T09:07:00	2025-07-15T11:30:00	84.990695	13.940757	Gypsum Core Archive
PS149_16-1-SI_corer_9cm-002	2025-07-15T09:07:00	2025-07-15T11:30:00	84.990695	13.940757	Gypsum Core Sample
PS149_25-1-SI_corer_9cm-001	2025-07-30T09:26:06	2025-07-30T11:09:32	83.75553	15.809883	Gypsum Core Archive
PS149_25-1-SI_corer_9cm-002	2025-07-30T09:26:06	2025-07-30T11:09:32	83.75553	15.809883	Gypsum Core Sample
PS149_30-1-SI_corer_9cm-001	2025-08-04T09:32:45	2025-08-04T11:19:39	84.477711	22.103875	Gypsum Core Archive
PS149_30-1-SI_corer_9cm-002	2025-08-04T09:32:45	2025-08-04T11:19:39	84.477711	22.103875	Gypsum Core Sample

Station 3:					
Event label	Date/Time start	Date/Time end	Latitude	Longitude	Description
PS149_18-1-SI_corer_9cm-001	2025-07-20T08:54:00	2025-07-20T11:30:00	84.467331	-17.944028	Gypsum Core Archive
PS149_18-1-SI_corer_9cm-002	2025-07-20T08:54:00	2025-07-20T11:30:00	84.467331	-17.944028	Gypsum Core Sample
PS149_30-1-SI_corer_9cm-001	2025-08-04T09:32:45	2025-08-04T11:19:39	83.597814	-12.444196	Gypsum Core Archive
PS149_30-1-SI_corer_9cm-002	2025-08-04T09:32:45	2025-08-04T11:19:39	83.597814	-12.444196	Gypsum Core Sample
PS149_41-1-SI_corer_9cm-001	2025-08-17T08:51:46	2025-08-17T11:20:00	82.968464	-12.81238	Gypsum Core Archive
PS149_41-1-SI_corer_9cm-002	2025-08-17T08:51:46	2025-08-17T11:20:00	82.968464	-12.81238	Gypsum Core Sample

Preliminary (expected) results

All samples will be analysed in the home laboratory.

5.7 Incubations with fluorescently labelled polysaccharides (FLA-PS)

Incubations to study polysaccharide uptake mechanism

Two fluorescently labelled polysaccharides (FLA-PS) of marine origin were used for incubations to study their local degradability and substrate utilization mechanism (external or internal enzyme processing) in pelagic bacteria. Laminarin, a common storage compound in brown algae, is widely degraded by bacteria due to its simple structure (Becker et al., 2020). Fucoidan on the other hand is a structurally complex polysaccharide integrated into the cell wall of brown algae like *Fucus vesiculosus*. This complexity makes fucoidan enzymatically costly and more challenging to break down for bacteria (Sichert et al., 2020).

Water samples were taken at the three different ice regimes during the first visit with a Kemmerer Water Sampler. Sampling depth within the epipelagic varied from 20 to 60 m depending on the location and were based on *in situ* salinity >30 PSU as measured with a handheld salinometer. 300 mL were measured into 500 mL LDPE plastic bottles (Fig. 5.7.1) and then spiked with one of two polysaccharides at a final concentration of 3.5 μ M monomer equivalent. Each treatment was set up in triplicate alongside a single control of unspiked seawater. 300 mL of seawater was also heated to 170°C for 2 h to stop all enzyme activities. 30 mL subsamples were then set up as negative (killed) controls for each polysaccharide treatment and the control. T0 samples were taken every 10 to 15 mins after setup. Bottles were incubated in the dark at 0°C unless stated otherwise.



Fig. 5.7.1: Example of an ongoing FLA-PS incubation. Image taken by Margret Menke.

Timepoint samples of all treatments and killed controls were taken at the same time as the original setup occurred on days 3, 6, 9, 12, and 15. At each timepoint, we collected 20 mL samples and fixed them at a final concentration of 1% formaldehyde for 1 h at room

temperature. Afterwards, the samples were filtered onto 0.2 µm polycarbonate filters with a vacuum pump (max. 200 mbar) for later analysis of fluorescent *in situ* hybridization (FISH), total cell counts (TCC), and polysaccharide uptake mechanisms in the home laboratory. Additionally, 10 mL from each treatment and replicate were filtered onto 0.2 µm polycarbonate filters for later bacterial community analysis (16S). 2 mL subsamples of the flowthrough were allocated for later external enzyme activity (EEA) via gel permeation chromatography and the remaining 8 mL was kept for other potential chemical analyses (monosaccharides, etc.). All timepoint samples were stored at -20°C.

Amendment incubations

It has previously been shown that a short pre-exposure to certain polysaccharides can significantly alter microbial responses to substrates during later incubation, by e.g. impacting cell numbers and uptake mechanisms of organic matter (Brown et al., 2024).

Fucose-containing sulphated polysaccharides (FCSPs) produced by the diatom *Chaetoceros socialis* have been detected to remain at high concentrations in the North Sea for several weeks during temperate phytoplankton blooms, thus demonstrating their short-term resistance to bacterial degradation (Vidal-Melgosa et al., 2021). To investigate this resistance in a polar environment, as well as testing the potential effect of short-term spikes with polysaccharides of varying complexity on the degradability, an amendment incubation was carried out. A fraction of the polysaccharide cell extract from a large culture (60 L) of *C. socialis*, consisting of large fragments (>10 kDa) and containing quantifiable amounts of fucose, was fluorescently labelled prior to the expedition (total 1.5 mg glucose equivalent; henceforth “extract”).

At station 1b, *C. socialis* along with other *Chaetoceros* sp. was observed in the local phytoplankton community (A. Kraberg, pers. communication). Water samples were taken at the chlorophyll a maximum of 25 m. During 48 h pre-incubations, pelagic bacterial communities were exposed to one of three polysaccharides (5 mg monomer equivalent L⁻¹ of fucoidan, laminarin or *C. socialis* cell extract) or none at all (control). Fucoidan and laminarin were chosen to represent the major monomers of FCSPs. After 48 h, incubations from pre-treatments were set up for each labelled polysaccharide in triplicates along with one control without FLAPS addition and killed controls for each FLA-PS treatment (Fig. 5.7.2).

Due to FLA-PS limitation, smaller incubations of 190 mL were used for the main experiment (except for the last triplicate: Extract pre-incubation -> extract FLA-PS consisting of only 144 mL incubations). Timepoint samples were taken right after the pre-incubation setup as well as at the end of 48 h. For the following FLA-PS incubation samples were taken after 0 h, 1 d, 2 d, 5 d, and 10 d.

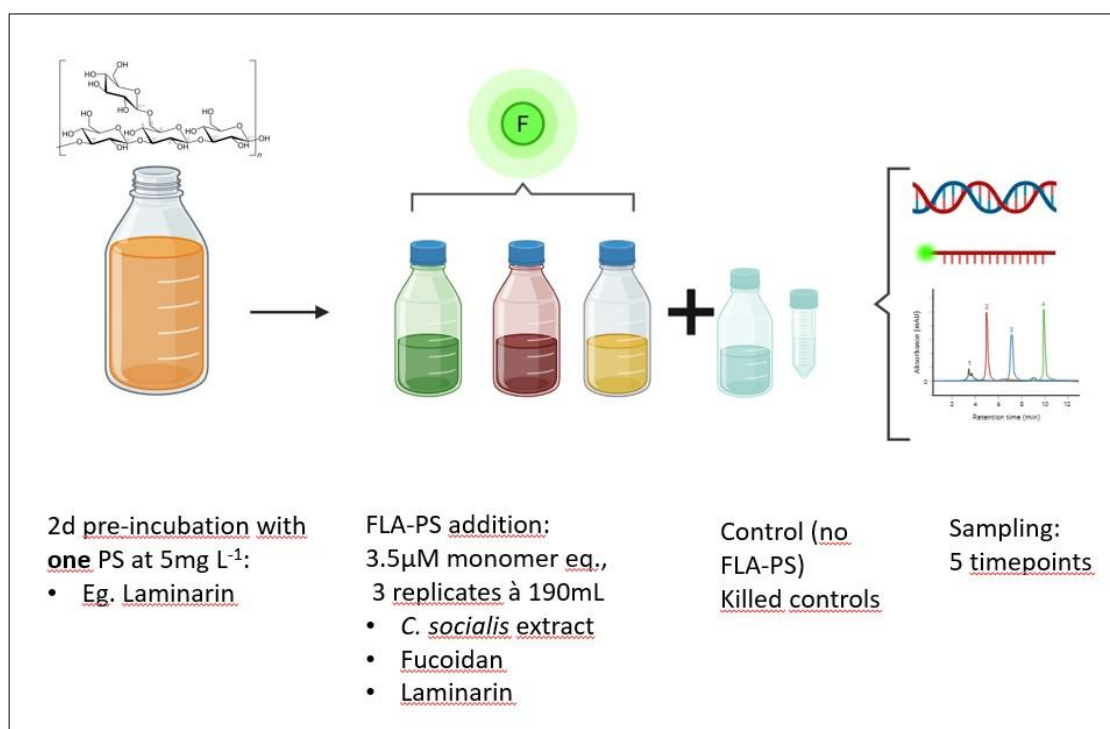


Fig. 5.7.2: Overview of amendment experiment with laminarin as an example. PS = polysaccharide.
Created with Biorender

ICE incubation

At station 3c, a short-term (6 d) incubation was carried out to investigate potential differential responses of pelagic vs ice-associated bacteria to two structurally distinct polysaccharides, as well as a mixture of the two. The bottom 10 cm of three 9 cm diameter (resulting in 1.5 L of water) ice cores were sawed into three cm slices. These were mixed with 2.5 L of under ice water retrieved by handpump from 1 m below the ice to simulate an environment of immediate melt release. The mixture was left to melt at 0°C/4°C for 12 h before being transferred to 10°C for 1 h. Afterwards, 300 mL incubations were set up in 500 mL LDPE plastic bottles for fucoidan, laminarin, and a mixture of the two (3.5 µM monomer equivalent of each) in triplicates alongside an unspiked control and killed controls as previously described. Timepoint samples were collected on days 0, 2, 4, and 6. Metadata was collected on days 0 (T0) and 6 (T3).

Aggregation experiment with FLA-PS

To observe how laminarin and fucoidan can impact phytoplankton aggregation processes during the melt season, an incubation was carried out in roller tanks for 16 days. Around 22 L of seawater were collected at 20 m depth at station 3a and filtered through a 3 µm filter. Phytoplankton samples were taken at the same location and depth using a 20 µm hand net. After that, the phytoplankton community was analyzed through a Planktoscope and uploaded into EcoTaxa (see description in the phytoplankton chapter of this expedition report) to access the concentration as cell mL⁻¹ and the main groups present in the sample (Fig. 5.7.3). The seawater and the concentrated phytoplankton were pooled together to achieve around 1000 cells mL⁻¹ as the start concentration for the incubations and left to acclimatize for 2 d. Afterwards, ~1.1 L incubations were set up in triplicates for fucoidan and laminarin (3.5 µM monomer equivalent of each) alongside an unspiked control (just seawater and phytoplankton).

and killed controls, as described previously. The roller tanks were kept in $15 \mu\text{E m}^{-2} \text{s}^{-1}$ in a 24/7 light cycle.

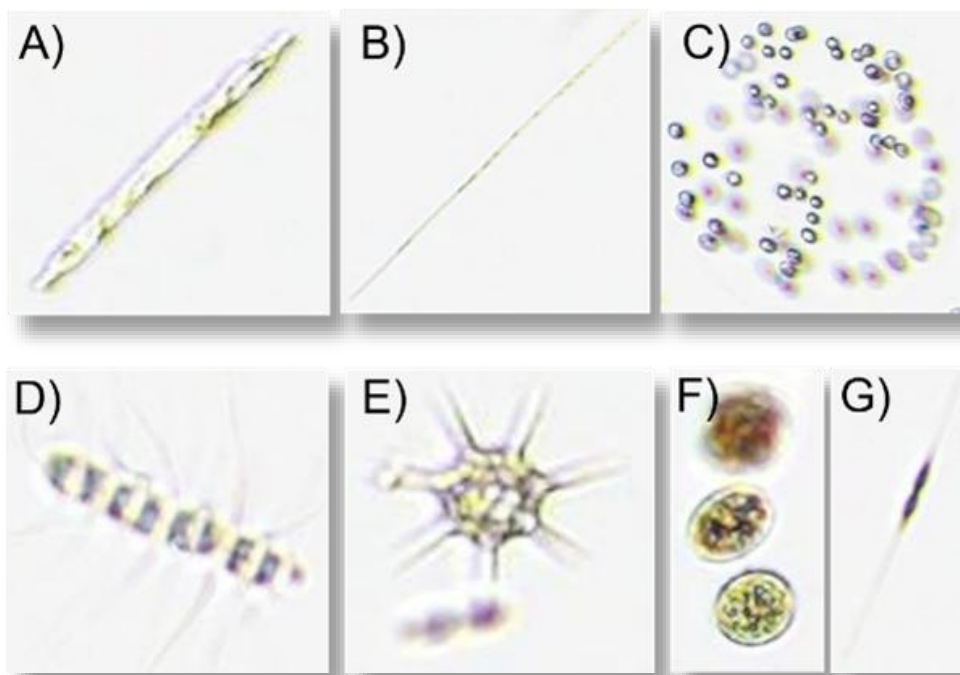


Fig. 5.7.3: Example of images taken with the Planktoscope and sorted on EcoTaxa to characterize the initial phytoplanktonic community used for the incubations. A, G) Pennate diatom B) *Pseudo-nitzschia* sp. C) *Phaeocystis* sp. D) *Chaetoceros* sp. E) *Silicoflagellate* F) *Thalassiosira* sp. All images taken by Alexandra Kraberg

To preserve the aggregates formed during this period, samples were taken only at T0 (start of the incubation) and on the last day (day 16). Additionally, videos were recorded from day 6 (at the time-point when the first aggregates were visible in the roller tanks) to 16 for each roller tank to observe the aggregate formation, their size-distribution, abundance, and size-specific settling velocity throughout the experiment. Once the roller tanks were stopped, we allowed the aggregates to settle overnight before sampling, this long settling time was due to their very slow settling velocities. On the next day (11.07.25), the particles that had sunk to the bottom of the tanks were removed using a pipette. The samples were thus separated into a settling (aggregates at the bottom of the roller tank) and a suspended fraction (suspended aggregates and phytoplankton) for further sample processing. The parameters taken during this experiment for both timepoints can be observed on Table 5.7.1. Examples of aggregates that formed in the roller tanks during the experiment can be observed on Fig. 5.7.4.

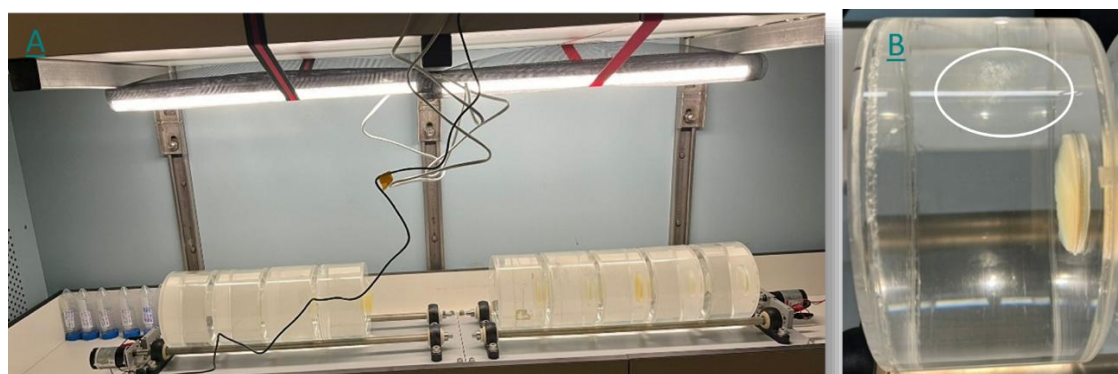


Fig. 5.7.4: Picture of the experimental set-up (A) and example of roller tank with big aggregate formed during the experiment where the back circles mark the position of the aggregates (B).
Image taken by Margret Menke

Tab. 5.7.1: Overview of parameters sampled for each treatment on days 0 and 16 during the experiment. T0_SW = day zero, seawater, no FLAPS added; T0_SW_PP = day zero, seawater + phytoplankton, no FLAPS added; T0_Lam = day zero, laminarin treatment; T0_Fuc = day zero, fucoidan treatment; T1_sus_control = day 16, suspended, phytoplankton + seawater, no FLAPS; T1_sus_Lam = day 16, suspended, laminarin treatment; T1_sus_Fuc = day 16, suspended, fucoidan treatment; T1_part_control = day 16, particulate, phytoplankton + seawater, no FLAPS; T1_part_Lam = day 16, particulate, laminarin treatment; T1_part_Fuc = day 16, particulate, fucoidan treatment.

	POC/N	BSi	DOC	Nutrients	Monos- acharides	EPS	Ammonium	DNA for 18S rRNA
T0_SW	na	na	na	na	Yes	na	na	na
T0_SW_PP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
T0_Lam	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
T0_Fuc	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
T1_sus_control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
T1_sus_Lam	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
T1_sus_Fuc	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
T1_part_control	Yes	Yes	Yes	Yes	Yes	Yes	na	Yes
T1_part_Lam	Yes	Yes	Yes	Yes	Yes	Yes	na	Yes
T1_part_Fuc	Yes	Yes	Yes	Yes	Yes	Yes	Na	Yes

Preliminary (expected) results

All samples will be analysed in the home laboratory.

Data management

Environmental data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (<https://www.pangaea.de>) within two years after the end of the expedition at the latest. By default, the CC-BY license will be applied.

Molecular data (DNA and RNA data) will be archived, published and disseminated within one of the repositories of the International Nucleotide Sequence Data Collaboration (INSDC, www.insdc.org) comprising of EMBL-EBI/ENA, GenBank and DDBJ).

All imaging data from sensors such as UVP and planktoscope will be uploaded to the ECOTAXA database.

Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

This part of the expedition is supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopics 1, 2 and 3.

In all publications based on this expedition, the **Grant No. AWI_PS149_04** or, in case of multidisciplinary work, **AWI_PS149_00** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2017) Polar Research and Supply Vessel POLARSTERN Operated by the Alfred-Wegener-Institute. Journal of large-scale research facilities, 3, A119. <http://dx.doi.org/10.17815/jlsrf-3-163>.

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6. MEDIA

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Grant-No. AWI_PS149_00

6.1 Virtual reality (VR)

Outline

The CONTRASTS virtual reality education and outreach initiative (working title, Embodied Arctic Datascape) is a film series that aims to address three concerns with science communication: 1) conventional modes of science communication are distributed through channels with already well-established, science-seeking audiences; 2) the consequences of climate change are centered in the Arctic but the drivers are not; and 3) efforts to combat disinformation campaigns with fact-based science journalism and 2D documentary films have failed to create sustained behavioral and policy actions required to mitigate climate breakdown. Embodied Arctic Datascape argues that, beneath myriads of explanations, this is ultimately a result of a crisis of engagement with information. Building off studies that repeatedly show how information alone is not enough to lead to action—particularly when delivered through abstract representations—and that VR increases emotional and cognitive engagement with climate science topics, Embodied Arctic Datascape is designed to bypass the cultural echo chambers and algorithmic gatekeeping that prevent factual science stories from reaching broad audiences. Additionally, the project is designed to reach a public that is disproportionately contributing to climate change with depoliticized and anti-doomsday narratives and address a gap in VR education research that focuses on behavioral change.

Objectives

How can immersive storytelling transform climate data into a participatory encounter - one that fosters connection not through explanation but through felt experience? Embodied Arctic Datascape is a collision of art and science methodologies as a research practice to create science communication that fundamentally alters the way in which people relate to information. VR places participants inside 3D/360° live action films, offering human-centric experiences that provide a world of context where participants can find valuable connections to a topic based upon personal frames of reference. VR has been proven to create meaningful psychological experiences because of three primary technological affordances: presence, immersion, and embodiment. Placing participants inside the story and creating space for them to step into the role of the explorer collapses the space between landscape, data, and scientific concepts; this teaches participants to connect observations back to questions that iterate clarity on climate change. By dissolving boundaries between observer and participant, between data and poetry, between instrument and body, Embodied Arctic Datascape does not communicate climate science - it transforms our capacity to relate to it. This is climate communication not as information delivery, but as embodied reckoning.

Work at sea

The work at sea involved recording 40 TB of 3D/360° audio-visual footage. 15 TB of 11K time lapse videos were taken from the crow's nest during station work. 25 TB of 8K, 3D/360° live action footage was taken of the scientific work on the ship and on the ice. The work at sea centered on filming with two Insta360 Pro 2 cameras and four insta360 X5 cameras. A particular emphasis was placed on over-time time-lapses from the same locations on the ship during the transits and station work to document the contrasting ice regimes and summer melt processes. The emphasis on capturing time-lapse footage supported the key objective of helping audiences locate the numeric, scientific data in the visually experienced landscape. This approach also helps audiences connect their own perceptual observations of the Arctic with questions CONTRAST researchers are asking and the tools they use to answer them. Preliminary 2-hour interviews were also recorded on the ship.

Preliminary (expected) results

Three 7–10-minute VR films that build on a growing series of virtual reality experiences – the first VR series to focus on communicating Arctic research. Each film will be grounded in a different formal structure (time lapses, live action VR interviews, Arctic as place (versus process or time)). The current series of polar Arctic VR documentaries includes two published films: *Into the Polar Night* (2020) and *The Arctic Halocline* (2023). The science lesson in *Into the Polar Night* (2020) centers on system-wide feedback loops; the lesson in *The Arctic Halocline* (2023) focuses on ocean stratification. Embodied Arctic Dataspace is designed to teach audiences about sea ice and address commonly held myths concerning ice melt and growth processes. Arctic Melt will approach sea ice as a complex material that grows, moves, melts, and acts differently as a seasonal ice-cover in the marginal ice zone, year-round mixture of First-Year Ice (FYI) and multi-year ice (MYI) along the transpolar drift system, and year-round MYI in the Last Ice Area north of Greenland. Through a material lens, audiences will learn about system-wide energy budgets, the concept of cycles within cycles, and the relationship between satellite and field derived measurements.

Data management

The VR film(s) will be made publicly available to all CONTRASTS participants and affiliated institutions for education and outreach initiatives, conferences, and workshops.

6.2 Constructive climate journalism

Objectives

The climate crisis is one of the biggest crises ever, and our actions today will have an impact for centuries to come. The relevant facts and assessments have been known for decades, yet journalistic communication on global warming remains a major challenge. This cannot be tackled from behind a desk alone although journalistic analyses of the many climate studies are very important. That is why the CONTRASTS expedition provided a great opportunity to share the viewers and users about the contrasting regimes in the Arctic, a region where global warming is so visible. For this the many perspectives of the researchers were drawn, because voices and faces help people understand the changes in the Arctic and the consequences of those for the whole world.

Climate journalism is not only about figures and analyses but also about the emotions of people who are looking into the future of global warming and are already experiencing it now: they may feel fear, anger or uncertainty but also hope, courage, a sense of inspiration or their own self-efficacy. The latter is evident in the portrayal of largely young people who venture onto Arctic sea ice for the first time in cold and windy conditions to study ice thickness, melt ponds or the atmosphere.

No less important is the description of the complexity of changing ecosystems such as the Arctic (or the Great Barrier Reef): While narratives that ‘everything is already lost’ often prevail in the media, ecosystems such as the Arctic are also showing resilience despite visible consequences and distressing perspectives for the future. Animals and microorganisms are trying to adapt somehow if the ongoing global warming still gives them a chance prospectively. In this respect, the CONTRASTS media work sends ‘mixed signals’: it explains how much ice has already melted in recent decades in the Arctic and which consequences arise but also how the ecosystem is trying to withstand.

After all, in times of ever-shorter attention spans, journalism is increasingly about images, videos, graphics and other eye-catchers. By showing changing ice floes during the melting season and the massive ice formations and turquoise melting pools near Greenland that are gradually disappearing, the climate crisis becomes more visible and tangible.

Because the climate crisis is usually communicated in a negative context, it is also important to combine this content with touching observations and moments of wonder. This approach is particularly important for content aimed at children but also for adults. A trip to the Arctic on *Polarstern* is an adventure that will make not only children’s hearts beat faster.

Work at sea

During the expedition, the media team closely accompanied several research teams in order to gain insights into their work and, at the same time, into the inner lives of the researchers. In this respect the work focused in particular on three researchers from three different teams (ROV, atmosphere and ecology). The ROV team for example provided visually striking images, both of ice drilling and the diving robot and, as a result, with the underwater footage. At the same time, photos, videos and audio recordings were collected in the various ice regimes and engaged with the scientific background of the future of the Arctic. Content was produced for various formats of the German public broadcast station “Westdeutscher Rundfunk” for radio, the homepage, the news app and social media.

Published and further expected results

Several pieces of content have already been published during the expedition: On board I especially focused on the story “Die Arktis der Zukunft – Unterwegs mit dem Forschungsschiff

Polarstern” for the “WDR” homepage and the “WDR aktuell” news app, published on 16 August 2025 (Fig. 6.1). This is a so-called “pageflow”: Text is combined with large-format photos, videos and graphics in a visually appealing way. Three researchers from three different teams are leading through a story that is also shedding light on the future of the Arctic and is illustrated with visual material so that readers can imagine this future. At the same time, they should not be left alone with the rather unsettling perspectives about global warming so ideas on how we can find our way in an increasingly uncertain world are given: <https://reportage.wdr.de/wie-sieht-die-arktis-der-zukunft-aus-unterwegs-mit-einem-forschungsschiff>

In addition, an Instagram reel for the “WDR” children’s brand “Maus”, a radio report for “Maus” and two radio conversations for the “WDR” station “1LIVE” which aims at young adults as their target group were produced and published. Research content on board and the integration of this content into the wider framework of climate research were combined with atmospheric parts and moments ‘to amaze’. Three further videos are planned which will include answers to questions from users on social media and, in one case, communicate the drastic changes in the Arctic through an innovative shift of perspective.



Fig. 6.1: Picture of the multimedia story “Die Arktis der Zukunft”, published on the “WDR” homepage and in the “WDR aktuell” news app.

In parallel, the usual AWI communication channels were supported with posting almost daily follow-polarstern app contributions (60 in total), publishing weekly extended reports on Meereisportal.de, and providing additional photo, video and audio material to the (social) media teams of AWI.de and Meereisportal.de. Different participants were reporting regularly through their individual social media accounts from the expedition. Expedition and team leaders were frequently asked to report to various media formats, e.g. interviews, live feeds, and newspaper articles. A major article was published in Der Spiegel at the end of CONTRASTS (‘Polarforscher befürchten Ökokollaps im Eismeer’, 4 September 2025 online and 6 September 2025 print).

A CONTRASTS expedition home page was created and hosted at Meereisportal.de. (www.meereisportal.de/contrasts, Fig. 6.2). The web page was launched with the start of the expedition and updated regularly. It contained 1) live data from different buoys, including the live views from the 3 Regime floes and 2 cameras on *Polarstern*, 2) live positions of the floes and *Polarstern*, presented in maps and as data for download, 3) News and reports from the expedition with links to other sources of information, 4) direct comparisons of the different regimes. Beyond static pages on all these topics, an interactive map was available presenting the different types of information on one page.

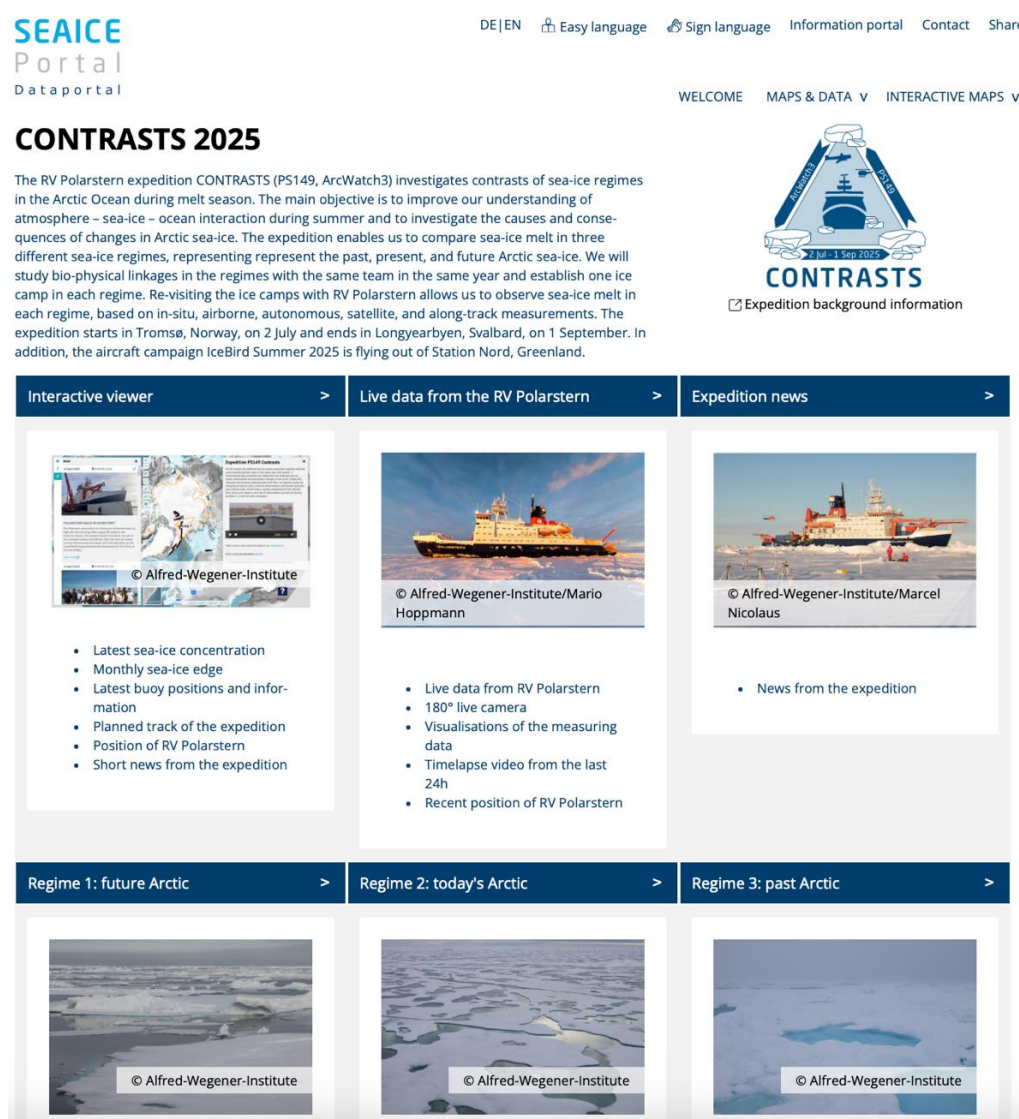


Fig. 6.2: Screenshot of the CONTRASTS project home page (front page). This page is available under www.meereisportal.de/contrasts.

APPENDIX

- A.1 Teilnehmende Institute / Participating institutes**
- A.2 Fahrtteilnehmer:innen / Cruise participants**
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- A.4 Stationsliste an Bord / Station list on board**
- A.5 Eisstationen Karten / Ice station maps**
- A.6 Eisstationen Wetter / Ice stations weather**
- A.7 Eisstationen Eventliste / Ice stations event list**

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

Affiliation	Address
On board	
CH.WSL	Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL-Institut für Schnee- und Lawinenforschung (SLF) Flüelstrasse 11 7260 Davos Dorf Switzerland
DE.AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
DE.DRF	Helicopter Service DRF Luftrettung gAG Laval Avenue E312 77863 Rheinmünster Germany
DE.DWD	Deutscher Wetterdienst Seewetteramt Bernhard Nocht Str. 76 20359 Hamburg Germany
DE.MARUM	MARUM – Zentrum für Marine Umweltwissenschaften der Universität Bremen Leobener Str. 8 28359 Bremen Germany
DE.NHC	Helicopter Service Northern HeliCopter GmbH Gorch-Fock-Str. 103 26721 Emden Germany
DE.UNI-Bayreuth	Universität Bayreuth Universitätsstraße 30 95447 Bayreuth Germany
DE.UNI-Bremen	Universität Bremen Bibliothekstraße 1 28359 Bremen Germany
DE.UNI-DUE	Universität Duisburg-Essen Universitätsstraße 2 45141 Essen Germany

Affiliation	Address
On board	
DE.UNI-Koeln	Universität zu Köln Albertus-Magnus-Platz 50923 Köln Germany
DE.UNI-Oldenburg	Carl von Ossietzky Universität Oldenburg Institut für Chemie und Biologie des Meeres (ICBM) Carl-von-Ossietzky-Strasse 9-13 26132 Oldenburg Germany
DE.WDR	Westdeutscher Rundfunk Äußere Kanalstr. 77 50827 Köln Germany
EDU.DARTMOUTH	Dartmouth College 14 Engineering Dr. Hanover NH 03755 United States
EDU.WHOI	Woods Hole Oceanographic Institution 266 Woods Hole Road Woods Hole MA 02543 United States
JP.HOKKAIDO	Hokkaido University Faculty of Fisheries Sciences 3-1-1 Minatocho Hokkaido 041-8611 Japan
JP.UTOKYO	The University of Tokyo 5-1-5, Kashiwa-no-ha Kashiwa 277-8564 Japan
NO.NPOLAR	Norsk Polarinstitutt Framsenteret Hjalmar Johansens gt. 14 9296 Tromsø Norway
NO.UIT	UiT – Norges arktiske universitet Postboks 6050 Langnes 9037 Tromsø Norway

Affiliation	Address
On board	
SE.SU	Stockholms Universitet Svante Arrhenius väg 16C 10691 Stockholm Sweden
TWN.NAMR	National Academy of Marine Research 11F., No. 25, Chenggong 2nd Rd. Qianzhen Dist. 806 Kaohsiung Taiwan
US.AL	Amy Lauren VR 7541 Parkdale Ave Apt 2W Saint Louis MO 63105 United States
US.APL-UW	University of Washington Applied Physics Laboratory 1013 NE 40th St Seattle WA 98105 United States

Affiliation	Address
Not on board	
EDU.CU	University of Colorado 216 UCB 80309 Boulder USA
FI.FMI	Finnish Meteorological Institute Erik Palmenin Aukio 1 100 Helsinki Finland
TWN.NSYSU	National Sun Yat-sen University 70 Linhai Road Gushan District Kaohsiung City 804 Taiwan

A.2 FAHRTTEILNEHMER:INNEN / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Ahrens	Katharina	DE.AWI	Technician	other geo sciences
Allerholt	Jacob	DE.AWI	Technician	Oceanography
Blei	Torben	DE.AWI	PhD student	other geo sciences
Brechtelsbauer	Stefanie	SE.SU	Student (Master)	Oceanography
Bryan	Natasha	DE.AWI	PhD student	Biology
Bühler	Linnu	DE.UNI-Köln	PhD student	Meteorology
Byron	Savannah	EDU.DARTMOUTH	PhD student	Engineering Sciences
Choi	Yeon	DE.AWI	PhD student	Oceanography
Cimoli	Emiliano	JP.HOKKAIDO	Scientist	Physics
Clemens-Sewall	David	EDU.WHOI	Scientist	Engineering Sciences
Dadic	Ruzica	CH.WSL	Scientist	Glaciology
Dahlke	Sandro	DE.AWI	Scientist	Meteorology
Divine	Dmitry	NO.NPOLAR	Scientist	Oceanography
Eggers	Sarah Lena	DE.AWI	Technician	Biology
Eisenhuth	Phillip	DE.AWI	PhD student	Physics
Elmaleh	Coralie	DE.AWI	Engineer	Physics
Fu	Ke-Hsien	TWN.NAMR	Scientist	Oceanography
Fuchs	Daniel	DE.DRF	Technician	Helicopter Service
Gebhardt	Florian	DE.AWI	PhD student	Meteorology
Gerstein	Johannes	DE.AWI	Student (Master)	Physics
Gischler	Michael	DE.NHC	Pilot	Helicopter Service
Greenwood	Nora	US.APL-UW	Student (Master)	Oceanography
Haines	Hannah Carolyn	DE.AWI	PhD student	Biology

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Harding	Jack	DE.NHC	Pilot	Helicopter Service
Haugeneder	Michael	CH.WSL	Scientist	Meteorology
Iversen	Morten Hvitfeldt	DE.AWI	Scientist	Biology
Jaggi	Matthias	CH.WSL	Engineer	Physics
Jörss	Anna-Marie	DE.AWI	Scientist	Meteorology
Kaphegyi	Insa	DE.UNI-Oldenburg	Student (Master)	Biology
Koenig	Zoe	NO.UiT	Scientist	Oceanography
Kraberg	Alexandra	DE.AWI	Scientist	Biology
Kruppen	Thomas	DE.AWI	Scientist	Physics
Lang	Sergej	DE.AWI	Student (Bachelor)	other geo sciences
Linck Rosenhaim	Ingrid	DE.AWI	Scientist	Data
Menke	Margret	DE.UNI-Bremen	PhD student	Biology
Miehe	Kai	DE.DRF	Technician	Helicopter Service
Müller	Sina	DE.AWI	PhD student	other geo sciences
Nicolaus	Marcel	DE.AWI	Scientist	Geophysics
Palm	Anna Charlotte	DE.WDR	Journalist	Public Outreach
Pamphile dos Santos	Julia	DE.UNI-Bremen	Student (Master)	other geo sciences
Regnery	Julia	DE.AWI	Scientist	Logistics
Reuter	Runa Turid	DE.MARUM	PhD student	Geology
Richman	Amy Lauren	US.AL	Other (e.g. freelancer or pupil)	Public Outreach
Ringel	Maximilian	DE.UNI-Bremen	PhD student	Physics
Salganik	Evgenii	DE.AWI	Scientist	Oceanography
Schiller	Martin	DE.AWI	Engineer	Physics
Son	Eun Yae	JP.UTOKYO	Scientist	Oceanography
Spakowski	Lars	DE.UNI-Bayreuth	Student (Bachelor)	Meteorology

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung/ Discipline
Spreen	Gunnar	DE.UNI-Bremen	Scientist	Physics
Takahashi	Keigo	JP.HOKKAIDO	Scientist	Biology
Tao	Ran	DE.AWI	Scientist	other geo sciences
Walbröl	Andreas	DE.UNI-Köln	Scientist	Meteorology
Webster	Melinda	US.APL-UW	Scientist	Geophysics
Welteke	Nahid	DE.UNI-DUE	Student (Master)	Chemistry
Wenzel	Anna Julia	DE.DWD	Scientist	Meteorology
Zhang	Linxin	DE.UNI-Bremen	PhD student	Geophysics
Zimmer	Florian	DE.AWI	PhD student	Geophysics

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

No	Dienstgrad	Rank	Nachname / Last name	Vorname / First name
1	Kapitän	Master	Schwarze	Stefan
2	1. Offizier	Chief Mate	Langhinrichs	Jacob
3	1. Offizier Ladung	Chief Mate Cargo	Janik	Michael
4	2. Offizier	2nd Mate	Hering	Igor
5	2. Offizier	2nd Mate	Rathke	Wulf Jannik
6	Schiffsärztin	Doctor	Gößmann- Lange	Petra
7	Leitender Ingenieur	Chief Engineer	Grafe	Jens
8	2. Ingenieur	2nd Engineer	Farysch	Tim
9	2. Ingenieur	2nd Engineer	Brose	Thomas Christian Gerhard
10	2. Ingenieur	2nd Engineer	Loske	Sven
11	Schiffselektrotechniker Maschine	Ship Electrotechnical Officer Engine	Zivanov	Stefan
12	Elektroniker Winden	Electrotechnical Engineer Winches	Jäger	Vladimir
13	Elektroniker Netzwerk/Brücke	Electrotechnical Engineer Network/Bridge	Müller	Andreas
14	Elektroniker Labor	Electrotechnical Engineer Labor	Hüttebräucker	Olaf
15	Elektroniker System	Electrotechnical Engineer System	Pliet	Johannes
16	Bootsmann	Bosun	Sedlak	Andreas
17	Zimmermann	Carpenter	Neisner	Winfried
18	Schiffsmechaniker Deck	Multi Purpose Rating Deck	Klee	Philipp
19	Schiffsmechaniker Deck	Multi Purpose Rating Deck	Burzan	Gerd-Ekkehard
20	Schiffsmechaniker Deck	Multi Purpose Rating Deck	Fischer	Sascha
21	Schiffsmechaniker Deck	Multi Purpose Rating Deck	Klähn	Anton
22	Schiffsmechaniker Deck	Multi Purpose Rating Deck	Kryszkiewicz	Maciej Waldemar
23	Schiffsmechaniker Deck	Multi Purpose Rating Deck	Koppenhöfer	Simon

No	Dienstgrad	Rank	Nachname / Last name	Vorname / First name
24	Schiffsmechaniker Deck	Multi Purpose Rating Deck	Bäcker	Andreas
25	Schiffsmechaniker Deck	Multi Purpose Rating Deck	Röth	Benedikt
26	Decksmann/Matrose	Able Seaman	Ackenhausen	Hendrik
27	Lagerhalter	Storekeeper	Preußner	Jörg
28	Schiffsmechaniker Maschine	Multi Purpose Rating Engine	Rolofs	Nils Christian Timo
29	Schiffsmechaniker Maschine	Multi Purpose Rating Engine	Hänert	Ove
30	Schiffsmechanikerin Maschine	Multi Purpose Rating Engine	Klinger	Dana
31	Schiffsmechaniker Maschine	Multi Purpose Rating Engine	Loew	Caspar
32	Schiffsmechaniker Maschine	Multi Purpose Rating Engine	Münzenberger	Börge
33	1. Koch	1st Cook	Hofmann	Werner
34	2. Köchin	2nd Cook	Hammelmann	Louisa
35	2. Köchin	2nd Cook	Dietrich	Emilia Felizitas Ilse Lieselotte
36	1. Stewardess	1st Stewardess	Brändli	Monika
37	2. Stewardess	2nd Stewardess	Naundorf	Katharina
38	2. Steward	2nd Steward	Dibenau	Torsten
39	2. Stewardess	2nd Stewardess	Möhle	Steffi
40	2. Stewardess / Krankenschwester	2nd Stewardess / Nurse	Schwantes	Andrea
41	2. Steward / Wäscherei	2nd Steward / Laundry	Arendt	Rene
42	2. Steward / Wäscherei	2nd Steward / Laundry	Cheng	Qi
43	2. Steward / Wäscherei	2nd Steward / Laundry	Chen	Dansheng

A.4 STATIONSLISTE / STATION LIST PS149

Station list of expedition PS149 from Tromsø – Longyearbyen; the list details the action log for all stations along the cruise track.

This list contains only stations taken onboard *Polarstern*. See <https://www.pangaea.de/expeditions/events/PS149> to display the entire station (event) list for expedition PS149 including all stations taken on and from the ice.

This version contains Uniform Resource Identifiers for all sensors listed under <https://sensor.awi.de>. See <https://www.awi.de/en/about-us/service/computing-centre/data-flow-framework.html> for further information about AWI's data flow framework from sensor observations to archives (O2A).

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149-track		2025-07-02T07:00:00	69.74732	19.14244		CT	Station start	Tromsø - Longyearbyen
PS149-track		2025-09-01T04:59:59	78.18557	14.25567		CT	Station end	Tromsø - Longyearbyen
PS149_0_Underway-1		2025-07-02T16:00:00	69.74732	19.14245	12.8	SWEAS	max depth	
PS149_0_Underway-2		2025-07-02T16:00:00	69.74732	19.14245	12.8	SNDVELPR	max depth	
PS149_0_Underway-3		2025-07-03T05:59:22	72.29445	18.26327	369.2	ADCP	Station start	
PS149_0_Underway-3		2025-08-31T14:14:48	78.96254	6.39844	1718.4	ADCP	Station end	
PS149_0_Underway-4		2025-07-03T07:05:51	72.51067	18.02388	353.6	TSG	Station start	
PS149_0_Underway-4		2025-08-31T12:26:23	79.13282	5.55683	1322.5	TSG	Station end	
PS149_0_Underway-5		2025-07-03T07:06:21	72.51229	18.02201	356.7	TSG	Station start	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_0_Underway-5		2025-08-31T12:26:06	79.13325	5.55460	1322.5	TSG	Station end	
PS149_0_Underway-6		2025-07-03T07:08:18	72.51868	18.01475	349.6	FBOX	Station start	
PS149_0_Underway-6		2025-08-31T14:14:11	78.96349	6.39367	1720.0	FBOX	Station end	
PS149_0_Underway-7		2025-07-03T07:09:07	72.52129	18.01192	354.3	pCO2	Station start	
PS149_0_Underway-7		2025-08-31T14:14:26	78.96308	6.39575	1719.0	pCO2	Station end	
PS149_1-1		2025-07-05T07:15:54	79.44275	9.05250	122.1	CTD-RO	max depth	EL31 47m
PS149_1-2		2025-07-05T07:33:47	79.44263	9.05348	122.1	HN	Station start	Mesh size 20
PS149_1-2		2025-07-05T07:36:44	79.44253	9.05348	122.3	HN	Station end	Mesh size 20
PS149_1-3		2025-07-05T07:36:45	79.44253	9.05349	122.3	MSN	Station start	AWI004 SL=50m
PS149_1-3		2025-07-05T08:12:15	79.44263	9.05500	122.1	MSN	Station end	AWI004 SL=50m
PS149_2-1	2025P344	2025-07-05T13:52:45	79.94693	9.00979	473.6	ISVP	Station start	
PS149_2-1	2025P344	2025-07-05T13:54:33	79.94758	9.00991	473.6	ISVP	Station end	
PS149_3-1		2025-07-06T03:13:40	81.59287	17.67484	1635.6	CTD-RO	max depth	EL31; 1618m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_3-2		2025-07-06T04:11:35	81.59140	17.69136	1607.2	FLOAT	max depth	
PS149_4-1		2025-07-06T04:16:07	81.59411	17.71413	1620.5	FLOAT	max depth	
PS149_5-1		2025-07-06T04:20:23	81.59735	17.72799	1673.4	FLOAT	Station start	
PS149_5-1		2025-07-06T04:20:25	81.59737	17.72810	1673.4	FLOAT	Station end	
PS149_6-1		2025-07-06T04:25:12	81.60113	17.74394	1776.4	FLOAT	Station start	
PS149_6-1		2025-07-06T04:25:14	81.60117	17.74408	1776.4	FLOAT	Station end	
PS149_7-1		2025-07-06T04:30:46	81.60596	17.76518	1829.6	FLOAT	Station start	
PS149_7-1		2025-07-06T04:30:48	81.60598	17.76528	1829.6	FLOAT	Station end	
PS149_8-1		2025-07-06T04:35:46	81.60939	17.77958	1915.7	FLOAT	Station start	
PS149_8-1		2025-07-06T04:35:48	81.60941	17.77967	1915.7	FLOAT	Station end	
PS149_9-1		2025-07-06T08:15:25	82.09657	19.89102	3663.6	FLOAT	Station start	
PS149_9-1		2025-07-06T08:30:24	82.10283	19.88860	3670.8	FLOAT	Station end	
PS149_9-2	2025P346	2025-07-06T08:15:44	82.09675	19.89085	3667.7	ISVP	Station start	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_9-2	2025P346	2025-07-06T08:30:30	82.10285	19.88885	3662.1	ISVP	Station end	
PS149_10-1	Tara Polar Station	2025-07-06T09:34:55	82.25177	20.15734	3746.4	MONS	Station start	Tara Polar Station; Problems with propeller
PS149_10-1	Tara Polar Station	2025-07-07T18:17:51	82.67355	20.09817	3974.2	MONS	Station end	Tara Polar Station; Problems with propeller
PS149_11-1	2025P343	2025-07-07T14:50:20	82.64108	20.12319	3961.9	ISVP	Station start	Deployed on the ice
PS149_11-1	2025P343	2025-07-07T14:54:00	82.64161	20.12189	3962.2	ISVP	Station end	Deployed on the ice
PS149_11-2	2025X17	2025-07-07T17:31:11	82.66673	20.08685	3970.2	BUOY	Station start	
PS149_11-2	2025X17	2025-07-07T17:41:21	82.66836	20.08833	3973.4	BUOY	Station end	
PS149_12-1	2025X18	2025-07-07T18:26:07	82.67504	20.10535	3974.6	BUOY	Station start	Two scientists brought on ice with Mummy Chair;
PS149_12-1	2025X18	2025-07-07T18:49:33	82.67805	20.11076	3975.6	BUOY	Station end	Two scientists brought on ice with Mummy Chair;
PS149_12-2		2025-07-07T20:27:13	82.68663	20.14065	3969.3	CTD-RO	max depth	SL: 1996m EL31
PS149_12-3		2025-07-07T21:27:38	82.68583	20.20335	3975.2	HN	Station start	
PS149_12-3		2025-07-07T21:33:38	82.68610	20.20351	3976.0	HN	Station end	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_12-4		2025-07-07T21:34:09	82.68612	20.20380	3976.2	MSN	Station start	1464 m, AWI 004
PS149_12-4		2025-07-07T23:39:59	82.68838	20.23257	3974.7	MSN	Station end	1464 m, AWI 004
PS149_13-1	Ice Station 1a	2025-07-09T06:32:22	83.80447	20.75359	4073.9	ICE	Station start	# Ice Station 1a; Sea ice 1.4m thick on Gangway
PS149_13-1	Ice Station 1a	2025-07-12T18:25:00	83.85695	24.25235	4071.5	ICE	Station end	# Ice Station 1a; Sea ice 1.4m thick on Gangway
PS149_13-10		2025-07-11T15:12:09	83.77495	22.55323	4070.7	MSC	max depth	45 m; AWI004
PS149_13-11		2025-07-11T16:17:45	83.77558	22.60966	4071.3	CTD-RO	max depth	97 m; EL31
PS149_13-12		2025-07-12T20:52:44	83.87044	24.41912	4070.9	TVMUC	max depth	SL 4032m; Free from the ground GE52.1 Max Tension 4.9t; No samples available
PS149_13-2		2025-07-09T11:37:09	83.78118	20.79669	4075.2	CTD-RO	max depth	4042 m; EL31; failure altimeter software
PS149_13-3		2025-07-09T14:30:09	83.76208	20.84044	4078.0	HN	Station start	
PS149_13-3		2025-07-09T14:35:09	83.76156	20.84247	4077.5	HN	Station end	
PS149_13-4		2025-07-09T15:04:22	83.75849	20.85580	4076.7	MSN	Station start	AWI004 1483m
PS149_13-4		2025-07-09T17:00:16	83.74586	20.93438	4076.9	MSN	Station end	AWI004 1483m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_13-5		2025-07-09T17:09:17	83.74482	20.94186	4074.4	MSN	Station start	AWI004; 1500m; problem with the battery; problem solved
PS149_13-5		2025-07-09T19:54:20	83.72732	21.11152	4076.1	MSN	Station end	AWI004; 1500m; problem with the battery; problem solved
PS149_13-6		2025-07-11T08:32:07	83.75563	22.21048	4070.6	ROSINA	Station start	2000m; EL31; It is set at 2000 m with 0.3 m
PS149_13-6		2025-07-11T13:04:27	83.77168	22.43460	4071.0	ROSINA	Station end	2000m; EL31; It is set at 2000 m with 0.3 m
PS149_13-7		2025-07-11T14:11:45	83.77383	22.49698	4070.9	CTD-RO	max depth	996 m; EL31
PS149_13-8		2025-07-11T13:42:27	83.77301	22.46974	4071.1	HN	Station start	
PS149_13-8		2025-07-11T13:47:36	83.77317	22.47451	4070.9	HN	Station end	
PS149_13-9		2025-07-11T14:55:45	83.77472	22.53833	4072.3	XCTD	Station start	1000 m
PS149_13-9		2025-07-11T15:05:09	83.77486	22.54689	4072.4	XCTD	Station end	1000 m
PS149_14-1	2025O29	2025-07-12T18:58:00	83.86501	24.25432	4071.3	ISVP	Station start	
PS149_14-1	2025O29	2025-07-12T19:47:32	83.86733	24.32842	4071.1	ISVP	Station end	
PS149_14-2	2025P348	2025-07-12T19:56:06	83.86776	24.34133	4071.2	ISVP	Station start	Deployed on the ice
PS149_14-2	2025P348	2025-07-12T19:56:42	83.86779	24.34222	4071.1	ISVP	Station end	Deployed on the ice

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_15-1		2025-07-13T15:19:09	84.66704	20.76445	4056.2	CTD-RO	max depth	2004 m; EL31
PS149_15-2		2025-07-13T14:39:09	84.66777	20.73574	4055.5	HN	Station start	
PS149_15-2		2025-07-13T14:43:18	84.66793	20.73213	4055.5	HN	Station end	
PS149_15-3		2025-07-13T16:43:31	84.66325	20.79035	4057.9	MSN	Station start	AWI004; 1466m
PS149_15-3		2025-07-13T18:43:46	84.65837	20.82618	4059.5	MSN	Station end	AWI004; 1466m
PS149_15-4		2025-07-13T20:38:23	84.65415	20.82954	4059.8	TVMUC	max depth	Winch failure; GE52.1 SL: 3996m; Max Rope Tension 5.4t
PS149_16-1	Ice Station 2a	2025-07-14T12:36:36	85.02274	13.51283	3065.2	ICE	Station start	# Ice station 2a
PS149_16-1	Ice Station 2a	2025-07-17T17:58:01	84.68662	13.94451	3612.9	ICE	Station end	# Ice station 2a
PS149_16-10		2025-07-17T19:34:31	84.69323	13.87611	3554.7	TVMUC	max depth	GE52.1; 3497m
PS149_16-11	2025X28	2025-07-17T18:24:50	84.69241	13.87896	3558.5	BUOY	Station start	Deployed on ice
PS149_16-11	2025X28	2025-07-17T19:07:22	84.69226	13.87133	3555.1	BUOY	Station end	Deployed on ice
PS149_16-2		2025-07-14T16:29:37	85.02428	13.60267	3065.6	CTD-RO	max depth	EL31; 2492m
PS149_16-3		2025-07-14T15:41:09	85.02292	13.59540	3048.4	HN	Station start	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_16-3		2025-07-14T15:45:45	85.02303	13.59601	3067.5	HN	Station end	
PS149_16-4		2025-07-14T17:43:11	85.02742	13.61616	3086.0	MSN	Station start	AWI004; 1467m
PS149_16-4		2025-07-14T19:42:27	85.03298	13.66691	2828.5	MSN	Station end	AWI004; 1467m
PS149_16-5		2025-07-14T19:44:00	85.03304	13.66787	2840.3	ROSINA	Station start	SL: 1500m
PS149_16-5		2025-07-14T22:18:49	85.03285	13.80709	2882.0	ROSINA	Station end	SL: 1500m
PS149_16-6		2025-07-15T08:43:38	84.99464	13.92946	3050.9	BONGO	Station start	SL: 100m
PS149_16-6		2025-07-15T08:59:01	84.99339	13.94760	2926.5	BONGO	Station end	SL: 100m
PS149_16-7		2025-07-15T09:17:10	84.99158	13.96844		MSC	max depth	SL: 45m
PS149_16-8		2025-07-15T09:26:32	84.99050	13.97846	2872.1	MSN	Station start	SL: 1548m; communication problems
PS149_16-8		2025-07-15T12:17:18	84.96016	14.10437	3182.2	MSN	Station end	SL: 1548m; communication problems
PS149_16-9		2025-07-15T12:54:27	84.95181	14.11336	3665.6	CTD-RO	max depth	267 m; EL31
PS149_17-1		2025-07-18T14:28:09	84.57858	-0.30062	3909.8	CTD-RO	max depth	1994 m; EL31
PS149_17-2		2025-07-18T13:46:09	84.57982	-0.30900	3821.0	HN	Station start	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_17-2		2025-07-18T13:52:22	84.57961	-0.30831	3808.3	HN	Station end	
PS149_17-3		2025-07-18T14:44:18	84.57824	-0.29675	3912.1	HN	Station start	
PS149_17-3		2025-07-18T14:53:45	84.57803	-0.29154	3920.6	HN	Station end	
PS149_17-4		2025-07-18T15:48:54	84.57815	-0.26481	3937.6	MSN	Station start	AWI004; 1466m
PS149_17-4		2025-07-18T18:16:00	84.58076	-0.27521	3915.3	MSN	Station end	AWI004; 1466m
PS149_18-1	Ice Station 3a	2025-07-19T17:45:41	84.48201	-17.87623	3392.7	ICE	Station start	# Ice Station 3a
PS149_18-1	Ice Station 3a	2025-07-22T18:00:00	84.34905	-17.88603	3407.1	ICE	Station end	# Ice Station 3a
PS149_18-10		2025-07-20T14:57:00	84.45616	-17.88031	3406.3	BONGO	Station start	100 m; AWI004
PS149_18-10		2025-07-20T15:13:27	84.45493	-17.88049	3406.8	BONGO	Station end	100 m; AWI004
PS149_18-11		2025-07-20T18:49:37	84.44233	-17.95078	3410.2	MSC	max depth	AWI004; 45m
PS149_18-12		2025-07-20T19:02:34	84.44203	-17.95684	3410.3	ROSINA	Station start	Max Depth: 1500m
PS149_18-12		2025-07-20T22:18:23	84.44249	-18.00031	3410.6	ROSINA	Station end	Max Depth: 1500m
PS149_18-13		2025-07-22T09:22:20	84.37179	-17.89405	3406.8	MSC	max depth	AWI004; SL: 45m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_18-14	2025O32	2025-07-22T18:15:03	84.35055	-17.76547	3402.1	ISVP	Station start	Deployed on ice
PS149_18-14	2025O32	2025-07-22T19:21:02	84.34830	-17.75995	3400.8	ISVP	Station end	Deployed on ice
PS149_18-2		2025-07-19T21:31:38	84.48528	-17.93815	3387.1	CTD-RO	max depth	EL31; SL: 2992m
PS149_18-3		2025-07-19T20:26:34	84.48321	-17.93182	3394.5	HN	Station start	
PS149_18-3		2025-07-19T20:43:35	84.48371	-17.93500	3393.5	HN	Station end	
PS149_18-4		2025-07-19T22:54:59	84.48748	-17.92535	3391.1	XCTD	Station start	
PS149_18-4		2025-07-19T23:02:54	84.48760	-17.92315	3391.3	XCTD	Station end	
PS149_18-5		2025-07-20T08:26:16	84.46650	-17.93685	3401.5	MSN	Station start	AWI004; SL: 1466m
PS149_18-5		2025-07-20T10:15:19	84.46681	-17.94353	3401.5	MSN	Station end	AWI004; SL: 1466m
PS149_18-6		2025-07-20T10:15:43	84.46681	-17.94348	3401.5	MSN	Station start	AWI004; SL 1463m; problem with the net; hoisted again from 175m
PS149_18-6		2025-07-20T12:58:27	84.46374	-17.90272	3402.9	MSN	Station end	AWI004; SL 1463m; problem with the net; hoisted again from 175m
PS149_18-7		2025-07-20T13:35:45	84.46175	-17.89189	3403.7	CTD-RO	max depth	402 m; EL31

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_18-8		2025-07-20T14:20:45	84.45882	-17.88313	3405.2	BONGO	Station start	103 m; AWI004
PS149_18-8		2025-07-20T14:37:27	84.45761	-17.88131	3405.7	BONGO	Station end	103 m; AWI004
PS149_18-9		2025-07-20T14:41:09	84.45734	-17.88103	3405.9	BONGO	Station start	100 m; AWI004
PS149_18-9		2025-07-20T14:54:27	84.45635	-17.88037	3406.2	BONGO	Station end	100 m; AWI004
PS149_19-1		2025-07-23T08:33:07	83.92748	-5.11712	3006.7	GOPRO	Station start	
PS149_19-1		2025-07-23T09:03:32	83.93386	-5.11940	3047.6	GOPRO	Station end	
PS149_20-1		2025-07-24T12:45:09	83.72545	11.14600	3544.7	TVMUC	max depth	3573 m; GE52.1
PS149_21-1	Ice Station 1b	2025-07-25T16:30:00	82.70097	27.11850	3972.5	ICE	Station start	# Ice Station 1b
PS149_21-1	Ice Station 1b	2025-07-28T16:40:09	82.48972	28.41798	3832.2	ICE	Station end	# Ice Station 1b
PS149_21-10		2025-07-26T15:22:09	82.61289	26.70351	3976.5	ROSINA	Station start	Max. depth = 1500m; AWI004
PS149_21-10		2025-07-26T18:07:20	82.59855	26.67387	3978.8	ROSINA	Station end	Max. depth = 1500m; AWI004
PS149_21-11		2025-07-26T17:36:21	82.60121	26.68060	3977.5	HN	Station start	
PS149_21-11		2025-07-26T17:40:45	82.60082	26.67965	3978.0	HN	Station end	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_21-12		2025-07-26T18:21:11	82.59741	26.67066	3978.6	MSC	max depth	AWI004; 35m
PS149_21-13		2025-07-27T09:35:05	82.54197	26.82966	3963.3	OTTER_USV	Station start	
PS149_21-13		2025-07-27T10:50:32	82.54079	26.86635	3961.8	OTTER_USV	Station end	
PS149_21-14		2025-07-28T10:35:31	82.48627	28.16876	3850.1	OTTER_USV	Station start	
PS149_21-14		2025-07-28T11:23:37	82.48584	28.18942	3848.2	OTTER_USV	Station end	
PS149_21-15		2025-07-28T18:15:47	82.49418	28.48711	3829.0	TVMUC	max depth	GE72.1; 3770m
PS149_21-2		2025-07-25T21:02:41	82.67038	27.03515	3964.9	CTD-RO	max depth	EL31; SL 2297m
PS149_21-3		2025-07-25T20:03:51	82.67626	27.06447	3965.9	HN	Station start	
PS149_21-3		2025-07-25T20:06:48	82.67595	27.06314	3965.9	HN	Station end	
PS149_21-4		2025-07-25T22:36:01	82.66297	26.98398	3966.8	XCTD	Station start	
PS149_21-4		2025-07-25T22:43:22	82.66248	26.98027	3967.5	XCTD	Station end	
PS149_21-5		2025-07-26T08:31:51	82.63180	26.78420	3977.2	MSN	Station start	AWI004; SL 1471m
PS149_21-5		2025-07-26T10:37:48	82.62896	26.73241	3978.4	MSN	Station end	AWI004; SL 1471m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_21-6		2025-07-26T13:23:09	82.62182	26.71427	3978.8	CTD-RO	max depth	362 m; EL 31
PS149_21-7		2025-07-26T14:09:45	82.61856	26.71046	3978.2	BONGO	Station start	100 m; AWI004
PS149_21-7		2025-07-26T14:26:36	82.61729	26.70895	3978.2	BONGO	Station end	100 m; AWI004
PS149_21-8		2025-07-26T14:29:45	82.61707	26.70873	3978.0	BONGO	Station start	100 m; AWI004
PS149_21-8		2025-07-26T14:43:09	82.61602	26.70749	3977.5	BONGO	Station end	100 m; AWI004
PS149_21-9		2025-07-26T14:45:45	82.61582	26.70724	3977.3	BONGO	Station start	100 m; AWI004
PS149_21-9		2025-07-26T15:00:45	82.61463	26.70584	3976.7	BONGO	Station end	100 m; AWI004
PS149_22-1		2025-07-29T08:30:04	83.24457	21.85258	4069.5	MSN	Station start	AWI004; SL: 1467m
PS149_22-1		2025-07-29T10:52:25	83.25108	21.88409	4069.6	MSN	Station end	AWI004; SL: 1467m
PS149_22-2		2025-07-29T08:54:51	83.24704	21.85571	4069.9	HN	Station start	
PS149_22-2		2025-07-29T09:04:40	83.24696	21.85661	4070.3	HN	Station end	
PS149_22-3		2025-07-29T11:50:14	83.25190	21.90905	4069.9	CTD-RO	max depth	EL31; SL 1995m
PS149_23-1		2025-07-29T13:05:09	83.25168	21.96120	4069.9	GOPRO	Station start	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_23-1		2025-07-29T13:13:36	83.25129	21.92655	4069.9	GOPRO	Station end	
PS149_24-1		2025-07-29T20:06:59	83.62139	17.61555	4070.0	XCTD	Station start	1000m
PS149_24-1		2025-07-29T20:14:50	83.62344	17.62185	4070.3	XCTD	Station end	1000m
PS149_24-2		2025-07-29T21:03:36	83.66979	16.99554	4072.6	XCTD	Station start	490m; Connection lost at 280m
PS149_24-2		2025-07-29T21:11:03	83.67039	16.98418	4072.6	XCTD	Station end	490m; Connection lost at 280m
PS149_24-3		2025-07-29T22:05:07	83.72659	16.47146	4067.7	XCTD	Station start	1000m
PS149_24-3		2025-07-29T22:12:11	83.72764	16.46598	4067.3	XCTD	Station end	1000m
PS149_24-4		2025-07-29T23:19:39	83.80218	16.76103	4070.9	XCTD	Station start	1100m
PS149_24-4		2025-07-29T23:25:26	83.80340	16.76442	4070.9	XCTD	Station end	1100m
PS149_24-5		2025-07-30T00:46:27	83.85166	16.07750	4069.0	XCTD	Station start	1100 m
PS149_24-5		2025-07-30T00:53:27	83.85129	16.07845	4069.2	XCTD	Station end	1100 m
PS149_24-6		2025-07-30T01:56:36	83.87126	15.39887	4070.7	XCTD	Station start	1100 m
PS149_24-6		2025-07-30T02:06:09	83.86895	15.40680	4069.7	XCTD	Station end	1100 m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_24-7		2025-07-30T03:21:45	83.80026	15.07183	4064.3	XCTD	Station start	1100 m
PS149_24-7		2025-07-30T03:28:09	83.79963	15.06865	4064.6	XCTD	Station end	1100 m
PS149_24-8		2025-07-30T04:17:42	83.74001	15.00169	4066.4	XCTD	Station start	
PS149_24-8		2025-07-30T04:24:12	83.73922	14.99132	4066.6	XCTD	Station end	
PS149_24-9		2025-07-30T05:47:34	83.69975	15.76361	4070.2	XCTD	Station start	
PS149_24-9		2025-07-30T05:58:06	83.69932	15.76079	4070.2	XCTD	Station end	
PS149_25-1	Ice Station 2b	2025-07-30T07:00:05	83.75746	15.80904	3939.7	ICE	Station start	# Ice Station 2b
PS149_25-1	Ice Station 2b	2025-08-01T17:31:26	83.73587	18.99135	4072.5	ICE	Station end	# Ice Station 2b
PS149_25-10		2025-07-31T09:02:43	83.70674	17.11253	4070.7	XCTD	Station start	
PS149_25-10		2025-07-31T09:12:37	83.70718	17.12184	4070.9	XCTD	Station end	
PS149_25-11		2025-07-31T11:42:14	83.71408	17.29320	4071.5	CTD-RO	max depth	EL31; SL: 3024m
PS149_25-12		2025-07-31T10:44:56	83.71113	17.21258	4071.1	HN	Station start	
PS149_25-12		2025-07-31T10:53:46	83.71156	17.22320	4071.1	HN	Station end	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_25-13		2025-07-31T13:15:45	83.71515	17.45466	4072.9	OTTER_USV	Station start	
PS149_25-13		2025-07-31T15:28:09	83.70736	17.68202	4072.7	OTTER_USV	Station end	
PS149_25-14		2025-08-01T19:15:04	83.74920	19.00526	4072.5	TVMUC	max depth	GE72.1; 4009m
PS149_25-2		2025-07-30T10:04:44	83.75786	15.83944	3941.9	MSN	Station start	AWI004; SL 1467m
PS149_25-2		2025-07-30T12:01:27	83.75577	15.92369	3951.4	MSN	Station end	AWI004; SL 1467m
PS149_25-3		2025-07-30T12:03:27	83.75567	15.92569	3951.7	MSN	Station start	1503 m; AWI004
PS149_25-3		2025-07-30T13:55:09	83.74716	16.05202	4046.3	MSN	Station end	1503 m; AWI004
PS149_25-4		2025-07-30T13:58:45	83.74676	16.05576	4046.7	BONGO	Station start	100 m; AWI004
PS149_25-4		2025-07-30T14:13:09	83.74510	16.06999	4049.8	BONGO	Station end	100 m; AWI004
PS149_25-5		2025-07-30T14:16:09	83.74478	16.07261	4049.5	BONGO	Station start	100 m; AWI004
PS149_25-5		2025-07-30T14:29:09	83.74322	16.08447	4045.9	BONGO	Station end	100 m; AWI004
PS149_25-6		2025-07-30T14:31:45	83.74290	16.08678	4044.2	BONGO	Station start	100 m; AWI004
PS149_25-6		2025-07-30T14:45:45	83.74115	16.09870	4035.5	BONGO	Station end	100 m; AWI004

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_25-7		2025-07-30T15:05:27	83.73859	16.11436	4019.3	MSC	max depth	35 m; AWI004
PS149_25-8		2025-07-30T15:57:56	83.73160	16.14799	3978.3	ROSINA	Station start	Max. depth = 1500m; AWI004
PS149_25-8		2025-07-30T18:25:57	83.71576	16.19201	4063.7	ROSINA	Station end	Max. depth = 1500m; AWI004
PS149_25-9		2025-07-31T08:29:42	83.70535	17.08206	4071.1	CTD-RO	max depth	EL31; 369m
PS149_26-1		2025-08-01T23:04:06	83.73231	17.37242	4072.5	XCTD	Station start	1000m
PS149_26-1		2025-08-01T23:11:21	83.73172	17.32908	4071.9	XCTD	Station end	1000m
PS149_26-2		2025-08-02T01:19:45	83.80023	15.86186	4028.5	XCTD	Station start	1000 m
PS149_26-2		2025-08-02T01:26:09	83.80405	15.85878	3827.5	XCTD	Station end	1000 m
PS149_27-1		2025-08-02T12:52:45	83.78934	6.99227	3747.9	GOPRO	Station start	
PS149_27-1		2025-08-02T12:56:16	83.79036	6.98535	3817.7	GOPRO	Station end	
PS149_28-1		2025-08-02T13:36:09	83.82014	6.78203	3846.3	MSN	Station start	1486 m; AWI004
PS149_28-1		2025-08-02T15:30:45	83.81883	6.89396	3857.8	MSN	Station end	1486 m; AWI004
PS149_28-2		2025-08-02T17:37:42	83.81601	6.92562	3860.0	CTD-RO	max depth	EL31; 1995m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_28-3		2025-08-02T16:46:36	83.81816	6.90840	3858.8	HN	Station start	
PS149_28-3		2025-08-02T16:52:23	83.81782	6.91058	3858.9	HN	Station end	
PS149_28-4		2025-08-02T16:52:07	83.81783	6.91049	3858.9	HN	Station start	
PS149_28-4		2025-08-02T16:55:59	83.81757	6.91169	3859.4	HN	Station end	
PS149_29-1		2025-08-03T16:07:49	83.61818	-11.85965	3974.7	XCTD	Station start	
PS149_29-1		2025-08-03T16:19:43	83.60467	-11.90155	3978.6	XCTD	Station end	
PS149_29-2		2025-08-03T17:05:00	83.54422	-12.04694	3714.9	XCTD	Station start	
PS149_29-2		2025-08-03T17:17:45	83.54419	-12.06295	3719.3	XCTD	Station end	
PS149_29-3		2025-08-03T18:50:48	83.51941	-12.67446	3686.4	XCTD	Station start	
PS149_29-3		2025-08-03T19:07:41	83.52460	-12.69728	3696.2	XCTD	Station end	
PS149_29-4		2025-08-03T19:47:15	83.52962	-13.08167	3594.7	XCTD	Station start	
PS149_29-4		2025-08-03T19:56:54	83.53183	-13.07837	3595.8	XCTD	Station end	
PS149_29-5		2025-08-03T22:10:21	83.59128	-13.11299	3609.1	XCTD	Station start	1000m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_29-5		2025-08-03T22:20:15	83.59252	-13.10249	3607.9	XCTD	Station end	1000m
PS149_29-6		2025-08-03T23:59:18	83.57387	-13.69023	3660.4	XCTD	Station start	1100 m, ripped-off
PS149_29-6		2025-08-04T00:24:09	83.57616	-13.66337	3664.4	XCTD	Station end	1100 m, ripped-off
PS149_29-7		2025-08-04T01:50:09	83.50762	-13.64476	3651.6	XCTD	Station start	900 m
PS149_29-7		2025-08-04T01:59:36	83.50832	-13.63425	3649.0	XCTD	Station end	900 m
PS149_29-8		2025-08-04T03:03:09	83.42847	-13.38129	3589.4	XCTD	Station start	1000 m
PS149_29-8		2025-08-04T03:09:54	83.42764	-13.34278	3571.3	XCTD	Station end	1000 m
PS149_29-9		2025-08-04T03:52:45	83.46090	-12.85480	3586.0	XCTD	Station start	1000m
PS149_29-9		2025-08-04T04:01:23	83.46762	-12.79931	3586.4	XCTD	Station end	1000m
PS149_30-1	Ice Station 3b	2025-08-04T07:28:09	83.58556	-12.56642	3922.9	ICE	Station start	# Ice Station 3b; Sea ice thickness: 1.70m and 2.00m
PS149_30-1	Ice Station 3b	2025-08-06T19:30:46	83.71856	-11.01244	3947.7	ICE	Station end	# Ice Station 3b; Sea ice thickness: 1.70m and 2.00m
PS149_30-10		2025-08-04T15:38:45	83.60886	-12.05544	3977.7	ROSINA	Station start	Problems with ROSINA
PS149_30-10		2025-08-04T16:59:58	83.61057	-11.99710	3977.2	ROSINA	Station end	Problems with ROSINA

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_30-11		2025-08-04T17:16:18	83.61087	-11.98504	3977.1	MSC	max depth	AWI004; 45m
PS149_30-12		2025-08-05T08:57:29	83.61831	-11.43859	3977.1	CTD-RO	max depth	EL31; SL: 480m
PS149_30-13		2025-08-05T12:24:27	83.62542	-11.36546	3873.4	CTD-RO	max depth	3292 m; EL31
PS149_30-14		2025-08-05T11:15:24	83.62344	-11.38892	3901.9	HN	Station start	
PS149_30-14		2025-08-05T11:27:12	83.62385	-11.38510	3805.4	HN	Station end	
PS149_30-15		2025-08-05T14:52:18	83.62630	-11.33389	3862.0	OTTER_USV	Station start	
PS149_30-15		2025-08-05T15:56:45	83.62635	-11.32617	3857.9	OTTER_USV	Station end	
PS149_30-16		2025-08-05T16:00:02	83.62636	-11.32582	3857.8	ROSINA	Station start	Problems with ROSINA
PS149_30-16		2025-08-05T17:04:19	83.62748	-11.32352	3874.8	ROSINA	Station end	Problems with ROSINA
PS149_30-17		2025-08-06T12:18:09	83.69803	-11.06778	3935.7	MUC	max depth	3872 m; GE72.1
PS149_30-2		2025-08-04T10:01:28	83.59928	-12.41056	3989.4	MSN	Station start	AWI004; SL: 1496m
PS149_30-2		2025-08-04T12:01:36	83.60548	-12.24174	3987.1	MSN	Station end	AWI004; SL: 1496m
PS149_30-3		2025-08-04T12:02:45	83.60551	-12.24036	3987.2	MSN	Station start	1465 m; AWI004

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_30-3		2025-08-04T13:53:45	83.60740	-12.13497	3978.0	MSN	Station end	1465 m; AWI004
PS149_30-4		2025-08-04T14:00:45	83.60752	-12.12953	3978.1	BONGO	Station start	65 m; AWI004
PS149_30-4		2025-08-04T14:10:09	83.60767	-12.12223	3977.9	BONGO	Station end	65 m; AWI004
PS149_30-5		2025-08-04T14:13:45	83.60773	-12.11944	3977.9	BONGO	Station start	65 m; AWI004
PS149_30-5		2025-08-04T14:21:45	83.60788	-12.11348	3977.8	BONGO	Station end	65 m; AWI004
PS149_30-6		2025-08-04T14:24:45	83.60793	-12.11124	3977.9	BONGO	Station start	65 m; AWI004
PS149_30-6		2025-08-04T14:33:18	83.60807	-12.10498	3977.8	BONGO	Station end	65 m; AWI004
PS149_30-7		2025-08-04T14:36:09	83.60811	-12.10290	3977.8	BONGO	Station start	65 m; AWI004
PS149_30-7		2025-08-04T14:45:27	83.60825	-12.09611	3977.7	BONGO	Station end	65 m; AWI004
PS149_30-8		2025-08-04T14:49:09	83.60830	-12.09336	3977.6	BONGO	Station start	65 m; AWI004
PS149_30-8		2025-08-04T14:58:09	83.60841	-12.08659	3977.7	BONGO	Station end	65 m; AWI004
PS149_30-9		2025-08-04T15:01:36	83.60845	-12.08398	3977.7	BONGO	Station start	65 m; AWI004
PS149_30-9		2025-08-04T15:09:27	83.60853	-12.07798	3977.7	BONGO	Station end	65 m; AWI004

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_31-1		2025-08-07T19:18:11	83.90499	8.79161	3808.8	GOPRO	Station start	
PS149_31-1		2025-08-07T19:40:46	83.91129	9.05266	3064.0	GOPRO	Station end	
PS149_32-1	Ice Station 1c	2025-08-09T08:00:12	83.30389	33.63752	3885.5	ICE	Station start	# Ice Station 1c
PS149_32-1	Ice Station 1c	2025-08-10T22:07:56	83.32688	34.14709	3872.4	ICE	Station end	# Ice Station 1c
PS149_32-10		2025-08-10T10:20:15	83.29170	33.94680	3867.1	CTD-RO	max depth	EL31; SL: 239m
PS149_32-11		2025-08-10T10:47:08	83.29403	33.95516	3868.4	HN	Station start	
PS149_32-11		2025-08-10T10:56:20	83.29479	33.95777	3868.7	HN	Station end	
PS149_32-12		2025-08-10T12:46:45	83.30373	33.99849	3865.0	CTD-RO	max depth	2998 m; EL31
PS149_32-13		2025-08-10T15:50:09	83.31437	34.07711	3865.1	ROSINA	Station start	Max. depth = 103m; AWI004
PS149_32-13		2025-08-10T16:19:48	83.31530	34.09164	3866.2	ROSINA	Station end	Max. depth = 103m; AWI004
PS149_32-14		2025-08-10T19:37:36	83.32035	34.13895	3870.4	MUC	max depth	GE72.1; 3810m
PS149_32-2		2025-08-09T14:09:09	83.22735	33.74634	3831.6	MSN	Station start	1461 m; AWI004
PS149_32-2		2025-08-09T16:13:14	83.22785	33.73192	3834.2	MSN	Station end	1461 m; AWI004

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_32-3		2025-08-09T16:12:57	83.22784	33.73196	3834.2	MSN	Station start	AWI004; 1463m
PS149_32-3		2025-08-09T18:06:00	83.23092	33.72422	3832.4	MSN	Station end	AWI004; 1463m
PS149_32-4		2025-08-09T18:08:15	83.23103	33.72404	3832.6	BONGO	Station start	AWI004; 80m
PS149_32-4		2025-08-09T18:18:06	83.23155	33.72362	3832.6	BONGO	Station end	AWI004; 80m
PS149_32-5		2025-08-09T18:20:08	83.23166	33.72350	3832.8	BONGO	Station start	AWI004; 80m
PS149_32-5		2025-08-09T18:30:53	83.23229	33.72295	3832.5	BONGO	Station end	AWI004; 80m
PS149_32-6		2025-08-09T18:34:45	83.23253	33.72274	3832.8	BONGO	Station start	AWI004; 80m
PS149_32-6		2025-08-09T18:47:25	83.23332	33.72210	3833.3	BONGO	Station end	AWI004; 80m
PS149_32-7		2025-08-10T08:24:19	83.28095	33.91856	3864.0	CTD-RO	max depth	EL31; SL 347m
PS149_32-8		2025-08-10T08:48:50	83.28326	33.92447	3865.6	XCTD	Station start	SL 1000m
PS149_32-8		2025-08-10T09:07:27	83.28502	33.92890	3867.3	XCTD	Station end	SL 1000m
PS149_32-9		2025-08-10T09:21:17	83.28633	33.93224	3867.8	MSC	max depth	AWI004; SL40m
PS149_33-1		2025-08-11T08:04:54	83.66172	27.83141	4061	MSN	Station start	AWI004; SL 1471m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_33-1		2025-08-11T09:57:04	83.66711	27.86427	4060.4	MSN	Station end	AWI004; SL 1471m
PS149_33-2		2025-08-11T11:07:22	83.67150	27.88139	4060.7	CTD-RO	max depth	EL31; SL 1994m
PS149_33-3		2025-08-11T10:40:28	83.67001	27.87642	4060.5	HN	Station start	
PS149_33-3		2025-08-11T10:47:43	83.67026	27.87784	4060.4	HN	Station end	
PS149_34-1		2025-08-11T12:12:27	83.67427	27.88428	4060.8	GOPRO	Station start	
PS149_34-1		2025-08-11T12:47:09	83.65024	27.65819	4061.2	GOPRO	Station end	
PS149_35-1		2025-08-11T21:00:21	84.33333	22.75894	4063.5	XCTD	Station start	920m
PS149_35-1		2025-08-11T21:07:56	84.33326	22.75937	4063.1	XCTD	Station end	920m
PS149_35-10		2025-08-12T06:28:46	84.45611	22.04224	4063.5	XCTD	Station start	
PS149_35-10		2025-08-12T06:41:18	84.46425	22.17254	4063.1	XCTD	Station end	
PS149_35-2		2025-08-11T22:06:34	84.34010	21.91151	4063.8	XCTD	Station start	SL: 1000m
PS149_35-2		2025-08-11T22:13:11	84.34030	21.90723	4063.9	XCTD	Station end	SL: 1000m
PS149_35-3		2025-08-11T23:10:12	84.40936	21.78238	4065.0	XCTD	Station start	SL: 1000m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_35-3		2025-08-11T23:20:34	84.41209	21.80481	4065.0	XCTD	Station end	SL: 1000m
PS149_35-4		2025-08-11T23:57:58	84.41252	22.45973	4064.3	XCTD	Station start	1000 m
PS149_35-4		2025-08-12T00:04:09	84.41174	22.48709	4064.3	XCTD	Station end	1000 m
PS149_35-5		2025-08-12T00:47:45	84.41880	23.21379	4064.2	XCTD	Station start	1000 m
PS149_35-5		2025-08-12T00:54:36	84.42297	23.21495	4063.5	XCTD	Station end	1000 m
PS149_35-6		2025-08-12T01:37:16	84.48335	22.83570	4063.8	XCTD	Station start	1000 m
PS149_35-6		2025-08-12T01:43:45	84.48688	22.80731	4063.5	XCTD	Station end	1000 m
PS149_35-7		2025-08-12T02:39:45	84.51762	22.47490	4061.6	XCTD	Station start	1000 m
PS149_35-7		2025-08-12T02:48:27	84.51556	22.48925	4061.5	XCTD	Station end	1000 m
PS149_35-8		2025-08-12T03:59:36	84.48309	21.54243	4063.0	XCTD	Station start	
PS149_35-8		2025-08-12T04:09:59	84.48486	21.51272	4062.8	XCTD	Station end	
PS149_35-9		2025-08-12T06:34:44	84.46142	22.13306	4063.0	XCTD	Station start	
PS149_35-9			84.40218	20.94925	4064.9	XCTD	Station end	

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_36-1	Ice Station 2c	2025-08-12T06:52:05	84.47367	22.17154	4061.7	ICE	Station start	# Ice Station 2c; Min. ice thickness: 1.50m to 1.60m; end date/time missing
PS149_36-1	Ice Station 2c	2025-08-14T17:22:33	84.61276	21.57467	4059.8	ICE	Station end	# Ice Station 2c; Min. ice thickness: 1.50m to 1.60m; end date/time missing
PS149_36-10		2025-08-13T09:19:08	84.50638	22.11443	4061.9	MSC	max depth	AWI004; SL:80m
PS149_36-11		2025-08-13T15:09:09	84.51300	21.85526	4063.7	OTTER_USV	Station start	
PS149_36-11		2025-08-13T16:18:42	84.52157	21.82711	4064.0	OTTER_USV	Station end	
PS149_36-12		2025-08-13T20:11:06	84.54349	21.81724	4063.7	XCTD	Station start	SL: 1000m
PS149_36-12		2025-08-13T20:20:51	84.54403	21.81654	4063.6	XCTD	Station end	SL: 1000m
PS149_36-13		2025-08-14T14:09:45	84.60138	21.57099	4059.0	TVMUC	max depth	3994 m; GE72.1
PS149_36-2		2025-08-12T09:58:12	84.47691	22.14426	4061.9	MSN	Station start	AWI004; SL: 1464m
PS149_36-2		2025-08-12T11:47:02	84.47788	22.05565	4061.7	MSN	Station end	AWI004; SL: 1464m
PS149_36-3		2025-08-12T12:29:09	84.47986	22.01224	4061.6	MSN	Station start	1480m; AWI004
PS149_36-3		2025-08-12T14:24:24	84.48963	21.92149	4061.4	MSN	Station end	1480m; AWI004

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_36-4		2025-08-12T14:25:18	84.48972	21.92109	4061.3	BONGO	Station start	80 m; AWI004
PS149_36-4		2025-08-12T14:35:18	84.49076	21.91726	4061.5	BONGO	Station end	80 m; AWI004
PS149_36-5		2025-08-12T14:37:18	84.49096	21.91656	4061.3	BONGO	Station start	80 m; AWI004
PS149_36-5		2025-08-12T14:47:45	84.49206	21.91355	4061.5	BONGO	Station end	80 m; AWI004
PS149_36-6		2025-08-12T14:49:45	84.49227	21.91308	4061.5	BONGO	Station start	80 m; AWI004
PS149_36-6		2025-08-12T14:59:09	84.49326	21.91121	4061.6	BONGO	Station end	80 m; AWI004
PS149_36-7		2025-08-12T21:19:38	84.50216	22.10938	4061.9	CTD-RO	max depth	EL31; SL 2992m; correction of a display error
PS149_36-8		2025-08-12T20:45:49	84.50389	22.10444	4062.0	HN	Station start	
PS149_36-8		2025-08-12T20:56:32	84.50335	22.10697	4062.0	HN	Station end	
PS149_36-9		2025-08-13T08:26:31	84.50800	22.11471	4061.8	CTD-RO	max depth	EL31; SL: 284m
PS149_37-1		2025-08-15T18:00:50	84.18385	-1.40174	3011.6	MSN	Station start	AWI004; 1492m
PS149_37-1		2025-08-15T19:58:36	84.17217	-1.43914	3922.9	MSN	Station end	AWI004; 1492m
PS149_37-2		2025-08-15T20:01:03	84.17055	-1.43613	3262.6	XCTD	Station start	SL: 594m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_37-2		2025-08-15T20:10:43	84.16858	-1.43890		XCTD	Station end	SL: 594m
PS149_37-3		2025-08-15T20:59:27	84.16384	-1.46207	3017.3	CTD-RO	max depth	SL: 96m; does not work properly
PS149_37-4		2025-08-15T21:17:50	84.16306	-1.46949	3011.6	HN	Station start	
PS149_37-4		2025-08-15T21:34:17	84.16100	-1.48512	3060.7	HN	Station end	
PS149_38-1		2025-08-15T21:46:59	84.15865	-1.49661	3025.2	GOPRO	Station start	
PS149_38-1		2025-08-15T22:07:52	84.13542	-1.38527	3485.6	GOPRO	Station end	
PS149_39-1		2025-08-16T00:07:09	84.04780	-2.94610	3357.1	XCTD	Station start	1000 m
PS149_39-1		2025-08-16T00:17:27	84.04340	-3.03089	3011.6	XCTD	Station end	1000 m
PS149_39-10		2025-08-16T07:06:22	83.83697	-7.09591	3088.7	XCTD	Station start	1000m
PS149_39-10		2025-08-16T07:14:13	83.83594	-7.14891	3111.4	XCTD	Station end	1000m
PS149_39-11		2025-08-16T08:05:19	83.79815	-7.54877	3289.8	XCTD	Station start	SL:1000m
PS149_39-11		2025-08-16T08:11:19	83.79411	-7.60048	3264.0	XCTD	Station end	SL:1000m
PS149_39-12		2025-08-16T08:41:43	83.76377	-7.89123	3226.9	XCTD	Station start	1000m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_39-12		2025-08-16T08:47:56	83.76242	-7.96739	3258.8	XCTD	Station end	1000m
PS149_39-13		2025-08-16T09:26:02	83.73533	-8.32652	3409.1	XCTD	Station start	SL: 1000m
PS149_39-13		2025-08-16T09:31:36	83.72597	-8.37515	3408.9	XCTD	Station end	SL: 1000m
PS149_39-14		2025-08-16T09:51:01	83.70287	-8.72407	3407.2	XCTD	Station start	SL: 1000m
PS149_39-14		2025-08-16T09:56:51	83.69255	-8.78336	3406.8	XCTD	Station end	SL: 1000m
PS149_39-15		2025-08-16T10:28:44	83.63503	-9.01731	3343.6	XCTD	Station start	SL: 1000m
PS149_39-15		2025-08-16T10:36:51	83.62678	-9.10919	3369.7	XCTD	Station end	SL: 1000m
PS149_39-16		2025-08-16T11:03:42	83.59134	-9.34409	3301.5	XCTD	Station start	SL: 1000m
PS149_39-16		2025-08-16T11:11:43	83.58570	-9.44148	3380.4	XCTD	Station end	SL: 1000m
PS149_39-17		2025-08-16T11:46:23	83.57651	-9.93127	3269.3	XCTD	Station start	SL: 1000m
PS149_39-17		2025-08-16T11:57:13	83.57404	-10.06863	3352.0	XCTD	Station end	SL: 1000m
PS149_39-18		2025-08-16T12:19:09	83.54858	-10.30636	3424.2	XCTD	Station start	1000 m
PS149_39-18		2025-08-16T12:26:27	83.54418	-10.37829	3389.2	XCTD	Station end	1000 m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_39-19		2025-08-16T13:15:09	83.52591	-10.83086	3059.2	XCTD	Station start	1000 m
PS149_39-19		2025-08-16T13:20:54	83.52401	-10.92709	3096.2	XCTD	Station end	1000 m
PS149_39-2		2025-08-16T00:47:45	84.01812	-3.44487	3254.3	XCTD	Station start	1000 m
PS149_39-2		2025-08-16T00:55:09	84.01287	-3.47330	3170.4	XCTD	Station end	1000 m
PS149_39-3		2025-08-16T01:38:18	83.98556	-3.88048	3226.6	XCTD	Station start	1000 m
PS149_39-3		2025-08-16T01:45:45	83.98547	-3.93570	3171.1	XCTD	Station end	1000 m
PS149_39-4		2025-08-16T02:43:18	83.97931	-4.33685	3014.6	XCTD	Station start	1000 m
PS149_39-4		2025-08-16T02:50:54	83.97746	-4.37322	3062.6	XCTD	Station end	1000 m
PS149_39-5		2025-08-16T03:24:27	83.96391	-4.77448	3187.2	XCTD	Station start	1000 m
PS149_39-5		2025-08-16T03:33:54	83.96138	-4.81475	3936.5	XCTD	Station end	1000 m
PS149_39-6		2025-08-16T04:13:11	83.92821	-5.15979	3060.7	XCTD	Station start	1000m
PS149_39-6		2025-08-16T04:20:04	83.92905	-5.17403	3067.2	XCTD	Station end	1000m
PS149_39-7		2025-08-16T05:00:20	83.90402	-5.62167		XCTD	Station start	1000m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_39-7		2025-08-16T05:06:49	83.89916	-5.63074	3367.7	XCTD	Station end	1000m
PS149_39-8		2025-08-16T05:20:26	83.88840	-5.80125	3011.6	XCTD	Station start	1000m
PS149_39-8		2025-08-16T05:43:13	83.88701	-6.08334	3117.6	XCTD	Station end	1000m
PS149_39-9		2025-08-16T06:24:27	83.85543	-6.55997	3036.9	XCTD	Station start	1000m
PS149_39-9		2025-08-16T06:30:57	83.85725	-6.62251	3089.8	XCTD	Station end	1000m
PS149_40-1		2025-08-16T12:41:27	83.54109	-10.41342	3337.5	CTD-RO	max depth	98 m; EL31
PS149_41-1	Ice Station 3c	2025-08-16T19:55:00	83.07948	-12.94787	3407.7	ICE	Station start	# Ice Station 3c; Min. ice thickness 1.5m
PS149_41-1	Ice Station 3c	2025-08-18T22:30:07	82.72068	-12.85279	3011.6	ICE	Station end	# Ice Station 3c; Min. ice thickness 1.5m
PS149_41-10		2025-08-17T13:21:45	82.93512	-12.80414	3160.6	MSN	Station start	1505 m; AWI004
PS149_41-10		2025-08-17T15:20:27	82.91634	-12.80457	3150.7	MSN	Station end	1505 m; AWI004
PS149_41-11		2025-08-18T11:00:58	82.77337	-12.83373	3263.4	OTTER_USV	Station start	
PS149_41-11		2025-08-18T11:51:00	82.77015	-12.83257	3341.3	OTTER_USV	Station end	
PS149_41-12		2025-08-18T14:21:09	82.75949	-12.82985	3011.7	TVMUC	max depth	2849 m; GE72.1

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_41-2		2025-08-16T22:26:12	83.05706	-12.93536	3374.4	CTD-RO	max depth	EL31; SL:3000m
PS149_41-3		2025-08-16T21:31:30	83.06405	-12.94040	3383.3	HN	Station start	
PS149_41-3		2025-08-16T21:42:23	83.06260	-12.93942	3381.5	HN	Station end	
PS149_41-4		2025-08-17T08:00:24	82.97515	-12.81435	3242.5	MSN	Station start	AWI004; SL 1484m
PS149_41-4		2025-08-17T09:59:05	82.96096	-12.81855	3210.4	MSN	Station end	AWI004; SL 1484m
PS149_41-5		2025-08-17T10:08:16	82.95982	-12.81886	3206.2	BONGO	Station start	AWI004; 80m
PS149_41-5		2025-08-17T10:21:18	82.95823	-12.81906	3199.4	BONGO	Station end	AWI004; 80m
PS149_41-6		2025-08-17T10:22:20	82.95811	-12.81908	3199.4	BONGO	Station start	AWI004; 80m
PS149_41-6		2025-08-17T10:35:45	82.95652	-12.81926	3196.0	BONGO	Station end	AWI004; 80m
PS149_41-7		2025-08-17T10:37:17	82.95633	-12.81925	3194.5	BONGO	Station start	AWI004; SL: 80m
PS149_41-7		2025-08-17T10:48:57	82.95495	-12.81922	3194.5	BONGO	Station end	AWI004; SL: 80m
PS149_41-8		2025-08-17T11:18:55	82.95138	-12.81805	3187.8	MSC	max depth	AWI004; SL: 51m
PS149_41-9		2025-08-17T12:50:27	82.93971	-12.80790	3162.4	CTD-RO	max depth	368 m; EL31

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_42-1		2025-08-19T01:51:27	82.72388	-11.30912	3161.5	XCTD	Station start	1000 m
PS149_42-1		2025-08-19T02:02:09	82.73370	-11.22824	3179.1	XCTD	Station end	1000 m
PS149_42-10		2025-08-19T07:14:10	82.95613	-7.91686	3179.5	XCTD	Station start	1000m
PS149_42-10		2025-08-19T07:21:01	82.96439	-7.83325	3117.1	XCTD	Station end	1000m
PS149_42-11		2025-08-19T07:51:08	83.00780	-7.69436	3143.5	XCTD	Station start	1000m
PS149_42-11		2025-08-19T07:57:21	83.01599	-7.62910	3011.6	XCTD	Station end	1000m
PS149_42-12		2025-08-19T08:16:29	83.04024	-7.37026	3011.7	XCTD	Station start	1000m
PS149_42-12		2025-08-19T08:22:32	83.05155	-7.31652	3011.7	XCTD	Station end	1000m
PS149_42-13		2025-08-19T08:36:35	83.07421	-7.15281	3011.6	XCTD	Station start	SL: 1000m
PS149_42-13		2025-08-19T08:46:35	83.08960	-7.10018	3016.2	XCTD	Station end	SL: 1000m
PS149_42-14		2025-08-19T09:06:56	83.11867	-6.94192	3011.7	XCTD	Station start	SL: 1000m
PS149_42-14		2025-08-19T09:16:08	83.13052	-6.83675	3214.3	XCTD	Station end	SL: 1000m
PS149_42-15		2025-08-19T09:35:18	83.15139	-6.58528	3143.9	XCTD	Station start	SL: 1000m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_42-15		2025-08-19T09:42:50	83.15414	-6.43802	3110.3	XCTD	Station end	SL: 1000m
PS149_42-16		2025-08-19T09:59:19	83.17535	-6.20547	3610.8	XCTD	Station start	SL: 700m
PS149_42-16		2025-08-19T10:07:12	83.18518	-6.12440	3913.2	XCTD	Station end	SL: 700m
PS149_42-17		2025-08-19T10:32:38	83.22779	-6.10912	3134.1	XCTD	Station start	SL: 1000m
PS149_42-17		2025-08-19T10:41:00	83.24117	-6.10454	3510.6	XCTD	Station end	SL: 1000m
PS149_42-18		2025-08-19T11:06:04	83.27015	-5.92198	3386.2	XCTD	Station start	SL: 1850m
PS149_42-18		2025-08-19T11:17:16	83.28301	-5.80211	3436.5	XCTD	Station end	SL: 1850m
PS149_42-19		2025-08-19T11:34:28	83.30995	-5.61668	3694.4	XCTD	Station start	SL: 1850m
PS149_42-19		2025-08-19T11:47:26	83.33016	-5.58804	3288.3	XCTD	Station end	SL: 1850m
PS149_42-2		2025-08-19T02:42:45	82.75364	-10.75143	3214.2	XCTD	Station start	1000 m
PS149_42-2		2025-08-19T02:52:27	82.75865	-10.68080	3175.6	XCTD	Station end	1000 m
PS149_42-20		2025-08-19T12:08:27	83.35298	-5.39151	3304.1	XCTD	Station start	1700 m
PS149_42-20		2025-08-19T12:18:09	83.34372	-5.26405	3227.8	XCTD	Station end	1700 m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_42-21		2025-08-19T12:39:36	83.33343	-4.98640	3118.6	XCTD	Station start	2000 m
PS149_42-21		2025-08-19T12:50:09	83.33876	-4.87152	3517.0	XCTD	Station end	2000 m
PS149_42-22		2025-08-19T13:11:45	83.35187	-4.52157		XCTD	Station start	1400 m
PS149_42-22		2025-08-19T13:19:45	83.36195	-4.38533		XCTD	Station end	1400 m
PS149_42-23		2025-08-19T13:35:45	83.37698	-4.08846	3511.7	XCTD	Station start	2000 m
PS149_42-23		2025-08-19T13:46:27	83.39172	-4.02388	3767.6	XCTD	Station end	2000 m
PS149_42-24		2025-08-19T14:02:09	83.42093	-3.96074	3797.1	XCTD	Station start	1850 m
PS149_42-24		2025-08-19T14:12:18	83.43740	-4.02557	3806.5	XCTD	Station end	1850 m
PS149_42-25		2025-08-19T14:32:27	83.46709	-4.16227	3379.7	XCTD	Station start	490 m
PS149_42-25		2025-08-19T14:40:09	83.46633	-4.16779	3354.8	XCTD	Station end	490 m
PS149_42-26		2025-08-19T15:43:54	83.51659	-4.13785	3805.8	XCTD	Station start	1850 m
PS149_42-26		2025-08-19T15:53:45	83.53078	-4.15919	3886.7	XCTD	Station end	1850 m
PS149_42-27		2025-08-19T16:30:01	83.54382	-3.67057	4003.9	XCTD	Station start	1970m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_42-27		2025-08-19T16:40:14	83.55580	-3.56277	3963.8	XCTD	Station end	1970m
PS149_42-28		2025-08-19T17:08:00	83.55853	-3.18798	3580.1	XCTD	Station start	2000m
PS149_42-28		2025-08-19T17:18:21	83.55786	-3.13095	3491.7	XCTD	Station end	2000m
PS149_42-3		2025-08-19T03:38:27	82.74777	-10.13341	3224.9	XCTD	Station start	1000 m
PS149_42-3		2025-08-19T03:45:09	82.74466	-10.04158	3229.5	XCTD	Station end	1000 m
PS149_42-4		2025-08-19T04:05:13	82.76459	-9.72336	3251.7	XCTD	Station start	890m
PS149_42-4		2025-08-19T04:12:34	82.76684	-9.66895	3238.8	XCTD	Station end	890m
PS149_42-5		2025-08-19T04:35:39	82.79149	-9.39880	3253.6	XCTD	Station start	1000m
PS149_42-5		2025-08-19T04:42:42	82.80279	-9.36048	3261.4	XCTD	Station end	1000m
PS149_42-6		2025-08-19T05:03:37	82.83931	-9.30753	3322.2	XCTD	Station start	1000m
PS149_42-6		2025-08-19T05:10:03	82.84506	-9.24957	3323.6	XCTD	Station end	1000m
PS149_42-7		2025-08-19T05:42:57	82.86615	-8.91542	3287.0	XCTD	Station start	1000m
PS149_42-7		2025-08-19T05:48:57	82.86480	-8.83264	3266.5	XCTD	Station end	1000m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_42-8		2025-08-19T06:15:29	82.88536	-8.50848	3324.9	XCTD	Station start	1000m
PS149_42-8		2025-08-19T06:21:27	82.88810	-8.41953	3321.9	XCTD	Station end	1000m
PS149_42-9		2025-08-19T06:44:03	82.91657	-8.18943	3304.7	XCTD	Station start	1100m
PS149_42-9		2025-08-19T06:50:23	82.92251	-8.10533	3288.8	XCTD	Station end	1100m
PS149_43-1		2025-08-20T17:57:48	83.70687	15.65391	4069.4	MSN	Station start	AWI004; 1495m
PS149_43-1		2025-08-20T19:52:27	83.69716	15.61106	4070.4	MSN	Station end	AWI004; 1495m
PS149_43-2		2025-08-20T20:52:49	83.69428	15.52776	4071.4	CTD-RO	max depth	EL31; SL: 2008m
PS149_43-3		2025-08-20T20:12:06	83.69465	15.58609	4071.4	HN	Station start	
PS149_43-3		2025-08-20T20:23:30	83.69418	15.57182	4070.9	HN	Station end	
PS149_43-4		2025-08-20T22:18:57	83.69729	15.41608	4070.0	XCTD	Station start	SL: 2000m
PS149_43-4		2025-08-20T22:31:40	83.69861	15.41052	4070.2	XCTD	Station end	SL: 2000m
PS149_44-1	Ice Station 1d	2025-08-21T16:15:44	83.18752	30.22622	3968.0	ICE	Station start	# Ice Station 1d; 2025P325; recovery camera bouy
PS149_44-1	Ice Station 1d	2025-08-21T16:50:06	83.18380	30.16109	3968.6	ICE	Station end	# Ice Station 1d; 2025P325; recovery camera bouy

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_44-2	Ice Station 1d	2025-08-21T17:58:04	83.21563	31.08544	3949.5	ICE	Station start	Recovery - 2025P328, ADCP
PS149_44-2	Ice Station 1d	2025-08-21T18:14:00	83.21875	31.21011	3939.4	ICE	Station end	Recovery - 2025P328, ADCP
PS149_44-3	Ice Station 1d	2025-08-21T18:37:47	83.24153	31.41555	3933.9	ICE	Station start	recovery -2025P324; met tower; buoy +100m line; recovery - 2025O30, 2025O30, and 2025O30
PS149_44-3	Ice Station 1d	2025-08-21T21:17:31	83.23710	31.53182	3927.7	ICE	Station end	recovery -2025P324; met tower; buoy +100m line; recovery - 2025O30, 2025O30, and 2025O30
PS149_45-1		2025-08-21T23:00:37	83.24847	33.26341	3848.8	DTOP	Station start	Recovery of iAOOS 1
PS149_45-1		2025-08-22T01:00:45	83.24583	33.25274	3846.6	DTOP	Station end	Recovery of iAOOS 1
PS149_46-1	Ice Station 2d	2025-08-23T06:51:59	84.20130	18.14983	4059.8	ICE	Station start	# Ice Station 2d
PS149_46-1	Ice Station 2d	2025-08-24T18:32:02	84.21307	17.32458	3910.0	ICE	Station end	# Ice Station 2d
PS149_46-2		2025-08-23T12:56:18	84.19440	18.13697	3754.4	CTD-RO	max depth	331 m; EL31
PS149_46-3		2025-08-23T13:39:36	84.19322	18.14600	3732.9	BONGO	Station start	80 m; SAWI004
PS149_46-3		2025-08-23T13:50:36	84.19282	18.14793	3728.7	BONGO	Station end	80 m; SAWI004

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_46-4		2025-08-23T13:53:09	84.19272	18.14838	3723.4	BONGO	Station start	80 m; AWI004
PS149_46-4		2025-08-23T14:02:09	84.19235	18.14987	3716.6	BONGO	Station end	80 m; AWI004
PS149_46-5		2025-08-23T14:05:09	84.19222	18.15039	3720.8	BONGO	Station start	80 m; AWI004
PS149_46-5		2025-08-23T14:16:09	84.19171	18.15203	3701.9	BONGO	Station end	80 m; AWI004
PS149_46-6		2025-08-23T16:06:57	84.18575	18.14353	3734.0	CTD-RO	max depth	EL31; 2992m
PS149_46-7		2025-08-23T15:06:36	84.18896	18.15384	3648.9	HN	Station start	
PS149_46-7		2025-08-23T15:17:45	84.18832	18.15269	3753.3	HN	Station end	
PS149_46-8		2025-08-23T17:37:18	84.18291	18.11620	3702.9	MSN	Station start	AWI004; 1465m
PS149_46-8		2025-08-23T19:37:29	84.18254	18.06662	4060.9	MSN	Station end	AWI004; 1465m
PS149_46-9		2025-08-23T19:45:45	84.18263	18.06362	4062.4	MSC	max depth	AWI004; 70m
PS149_47-1	Ice Station 3d	2025-08-26T07:10:51	82.42406	-6.16341	3268.2	ICE	Station start	# Ice Station 3d; Min. ice thickness: 1.60m - 1.80m
PS149_47-1	Ice Station 3d	2025-08-27T20:15:46	82.33896	-4.65722	3502.6	ICE	Station end	# Ice Station 3d; Min. ice thickness: 1.60m - 1.80m
PS149_47-2		2025-08-26T11:23:09	82.45442	-5.82578	4693.8	CTD-RO	max depth	EL31; SL: 3036m

Event label	Optional label	Date/Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment *
PS149_47-3		2025-08-26T10:24:45	82.44921	-5.90286	4626.2	HN	Station start	
PS149_47-3		2025-08-26T10:37:21	82.45034	-5.88616	4625.8	HN	Station end	
PS149_47-4		2025-08-26T13:18:09	82.46040	-5.67678	4769.5	MSC	max depth	42 m; AWI004
PS149_47-5		2025-08-26T14:10:45	82.46123	-5.61893	4762.9	CTD-RO	max depth	346 m; EL31
PS149_47-6		2025-08-26T14:36:27	82.46157	-5.59298	4761.8	MSN	Station start	1481 m; AWI004
PS149_47-6		2025-08-26T16:37:44	82.46260	-5.49955	4369.4	MSN	Station end	1481 m; AWI004
PS149_48-1		2025-08-28T13:57:45	81.88220	-10.06882	2348.4	CTD-RO	max depth	2264 m; EL31

*Comments are limited to 130 characters. See <https://www.pangaea.de/expeditions/events/PS149> to show full comments in conjunction with the station (event) list for expedition PS149.

Abbreviation	Method/Device
ADCP	Acoustic Doppler Current Profiler
BONGO	Bongo net
BUOY	Buoy
CT	Underway cruise track measurements
CTD-RO	CTD/Rosette
DTOP	Buoy, Drift Towing Ocean Profiler
FBOX	FerryBox
FLOAT	Floater
GOPRO	Digital Camera, GoPro
HN	Hand net
ICE	Ice station
ISVP	Surface velocity profiler
MONS	Monitoring station
MSC	Marine snow catcher
MSN	Multiple opening/closing net
MUC	MultiCorer
OTTER_USV	Otter Uncrewed Surface Vessel
pCO2	pCO2 sensor
ROSINA	Remotely ObServing INsitu camera for Aggregates
SNDVELPR	Sound velocity probe
SWEAS	Ship Weather Station
TSG	Thermosalinograph
TVMUC	Multicorer with television
XCTD	Expendable CTD

A.5 EISSTATIONEN KARTEN / ICE STATION MAPS

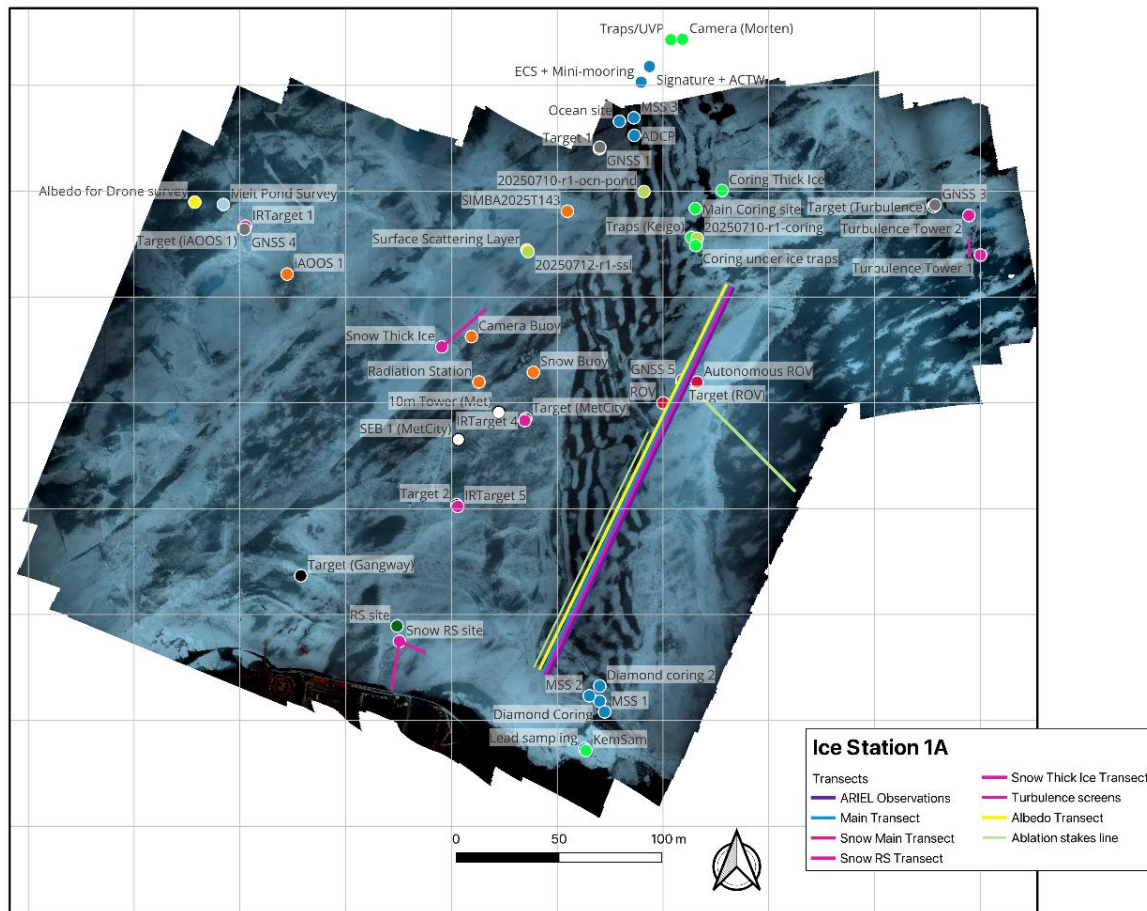


Abb. A5.1: Karte der Eisstation 1A (PS149_13-1) vom 09. Juli bis 12. Juli 2025. Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 11. Juli 2025. Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis. Das Gitter markiert Abstände von 50 m.

Fig. A5.1: Map of Ice Station 1A (PS149_13-1) from 09 July to 12 July 2025. The background map is a photo mosaic from drone flights on 11 July 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

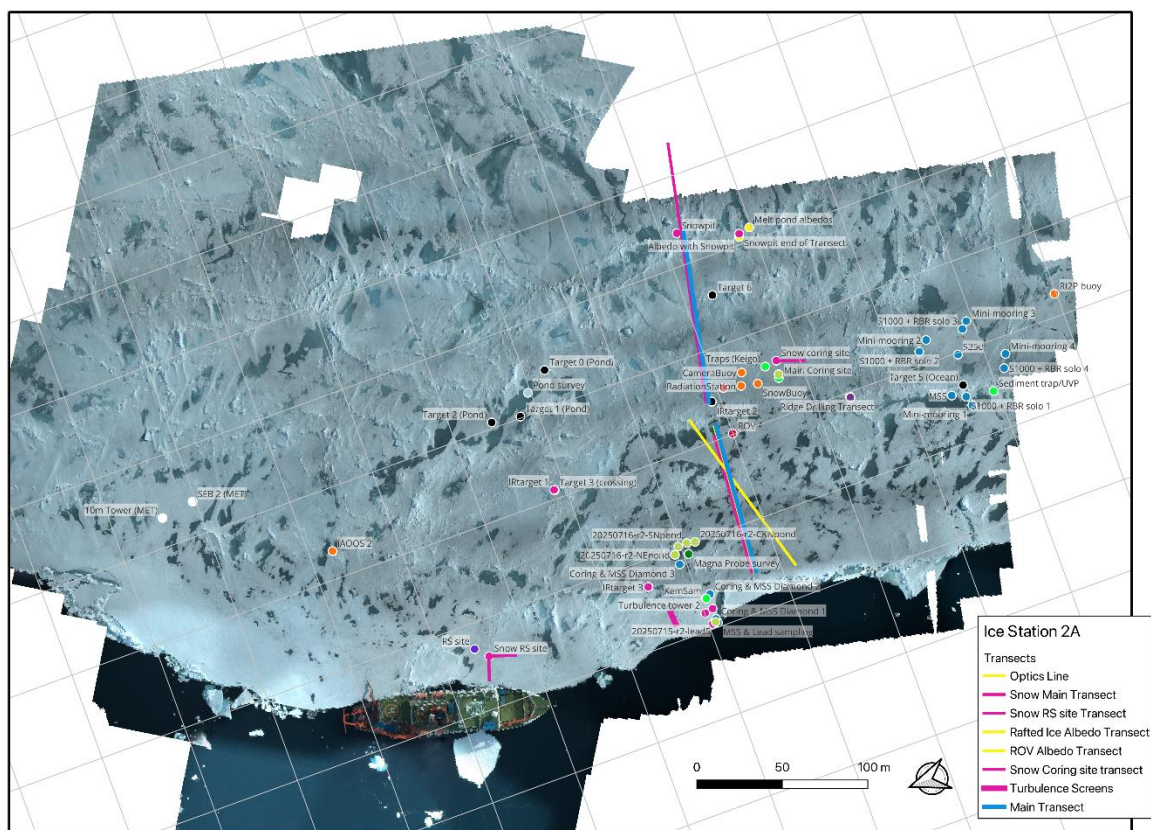


Abb. A5.2: Karte der Eisstation 2A (PS149_16-1) vom 14. Juli bis 17. Juli 2025. Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 14. Juli 2025. Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis. Das Gitter markiert Abstände von 50 m.

Fig. A5.2: Map of Ice Station 2A (PS149_16-1) from 14 July to 17 July 2025. The background map is a photo mosaic from drone flights on 14 July 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

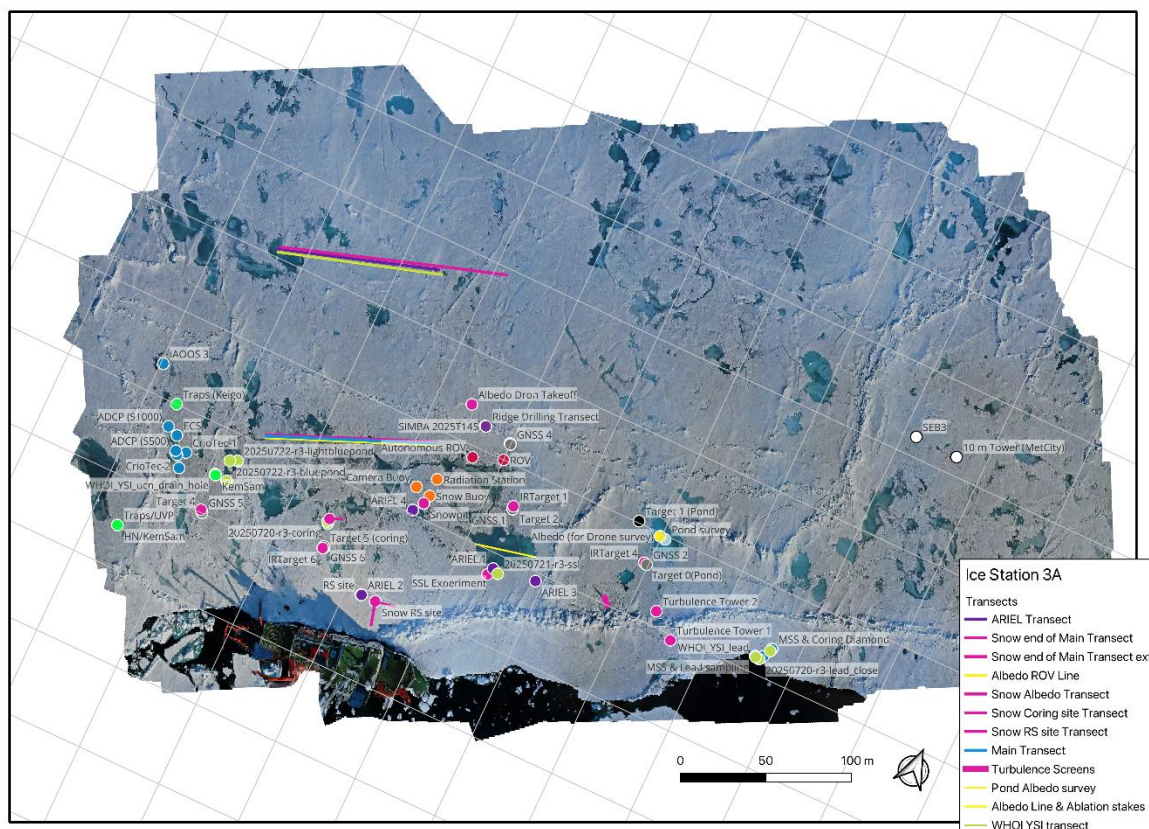


Abb. A5.3: Karte der Eisstation 3A (PS149_18-1) vom 19. Juli bis 22. Juli 2025. Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 19. Juli 2025. Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis. Das Gitter markiert Abstände von 50 m.

Fig. A5.3: Map of Ice Station 3A (PS149_18-1) from 19 July to 22 July 2025. The background map is a photo mosaic from drone flights on 19 July 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

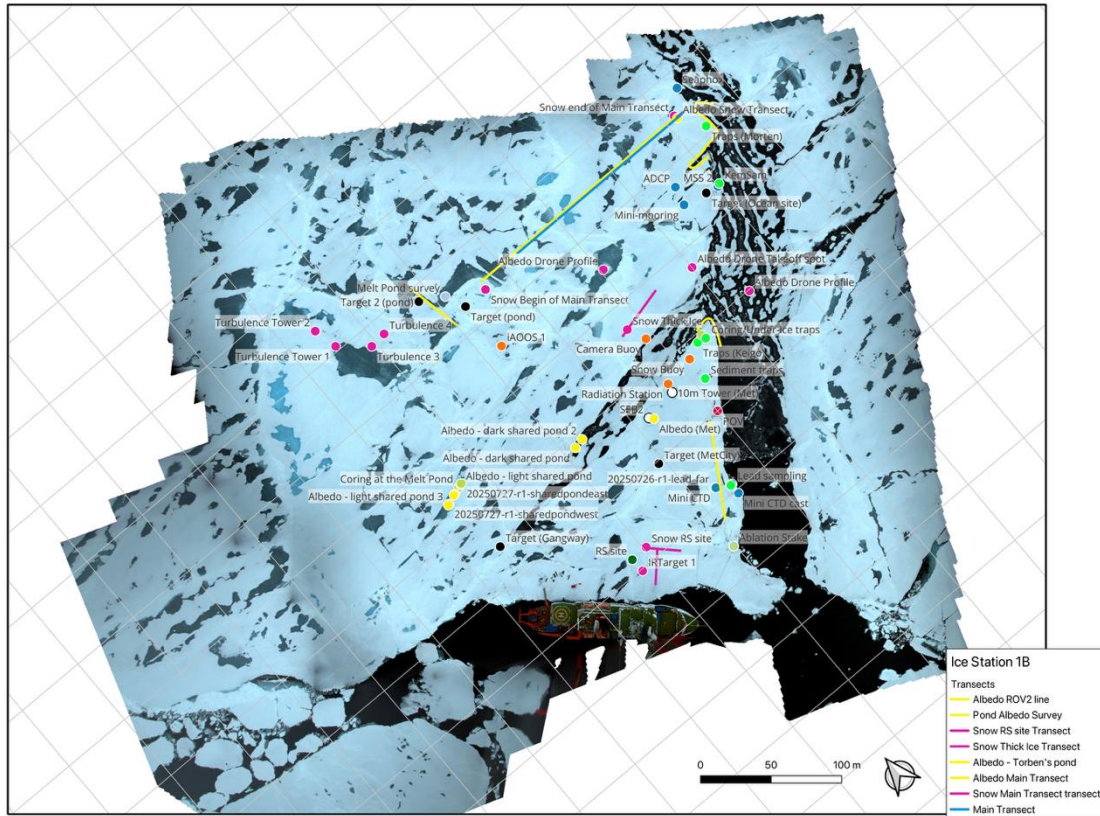


Abb. A5.4: Karte der Eisstation 1B (PS149_21-1) vom 25. Juli bis 28. Juli 2025. Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 25. Juli 2025. Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis. Das Gitter markiert Abstände von 50 m.

Fig. A5.4: Map of Ice Station 1B (PS149_21-1) from 25 July to 28 July 2025. The background map is a photo mosaic from drone flights on 25 July 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

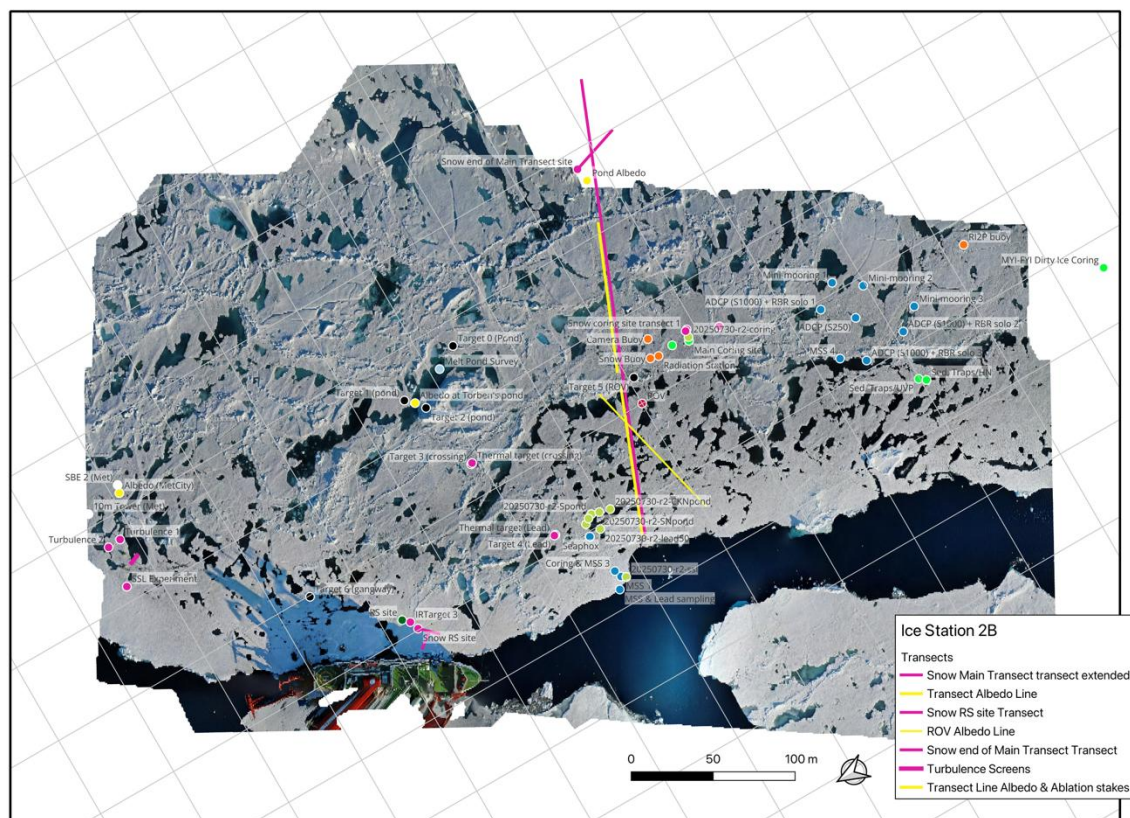


Abb. A5.5: Karte der Eisstation 2B (PS149_25-1) vom 30. Juli bis 01. August 2025.
Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 30. Juli 2025.
Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis.
Das Gitter markiert Abstände von 50 m.

Fig. A5.5: Map of Ice Station 2B (PS149_25-1) from 30 July to 01 August 2025. The background map is a photo mosaic from drone flights on 30 July 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

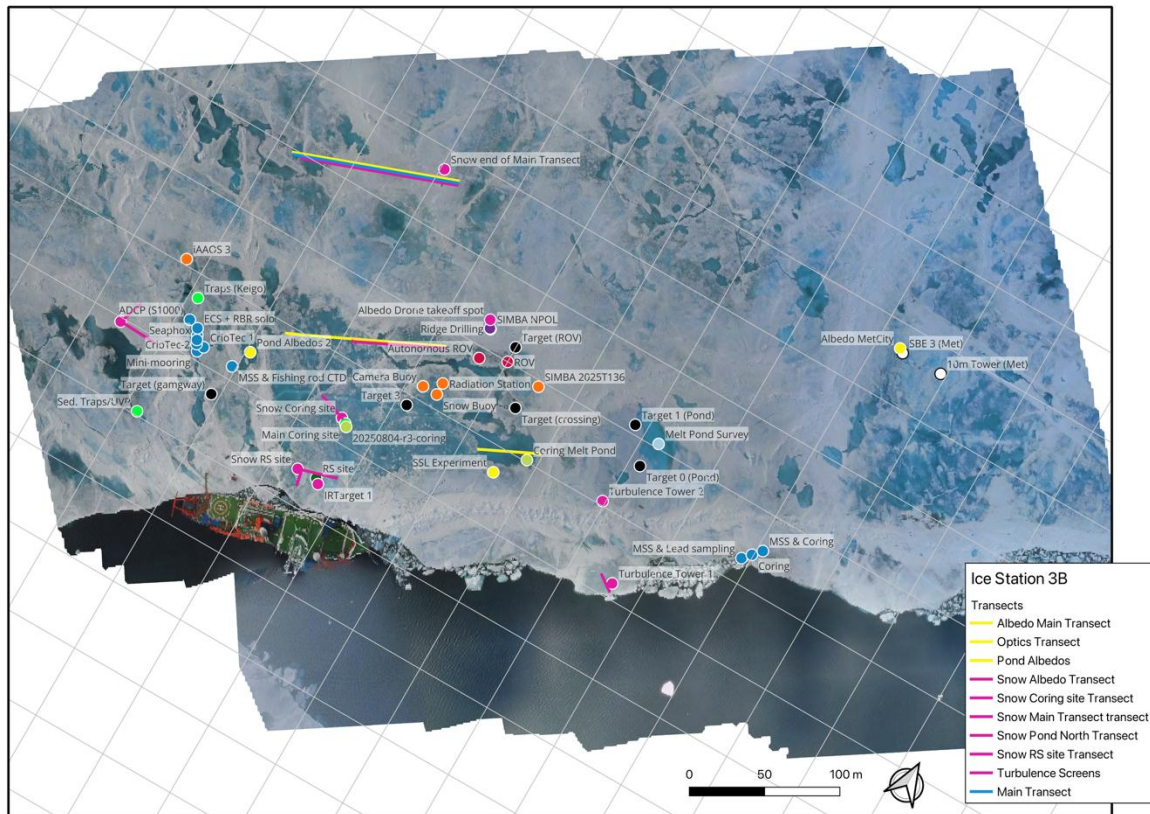


Abb. A5.6: Karte der Eisstation 3B (PS149_30-1) vom 04. August bis 06. August 2025.
 Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 04. August 2025.
 Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis.
 Das Gitter markiert Abstände von 50 m.

Fig. A5.6: Map of Ice Station 3B (PS149_30-1) from 04 August to 06 August 2025. The background map is a photo mosaic from drone flights on 04 August 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

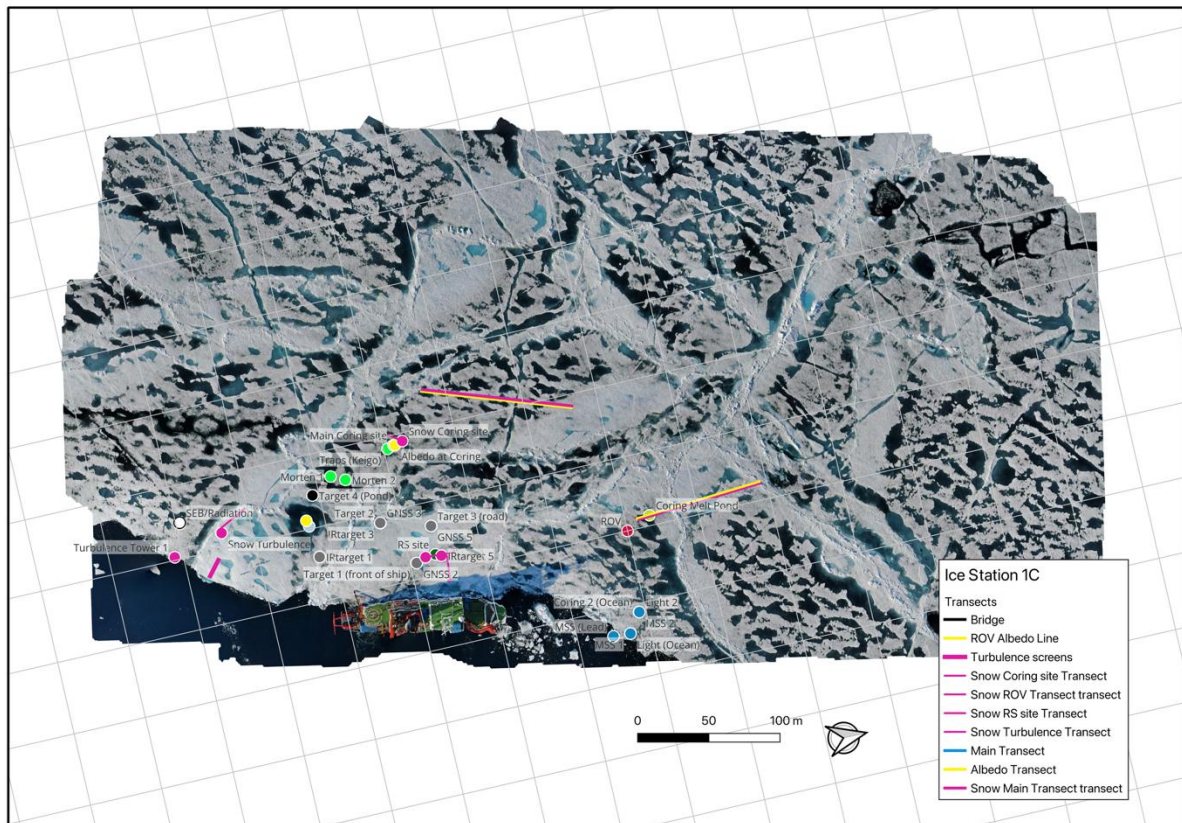


Abb. A5.7: Karte der Eisstation 1C (PS149_32-1) vom 09. August bis 10. August 2025.
 Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 09. August 2025.
 Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis.
 Das Gitter markiert Abstände von 50 m.

Fig. A5.7: Map of Ice Station 1C (PS149_32-1) from 09 August to 10 August 2025. The background map is a photo mosaic from drone flights on 09 August 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

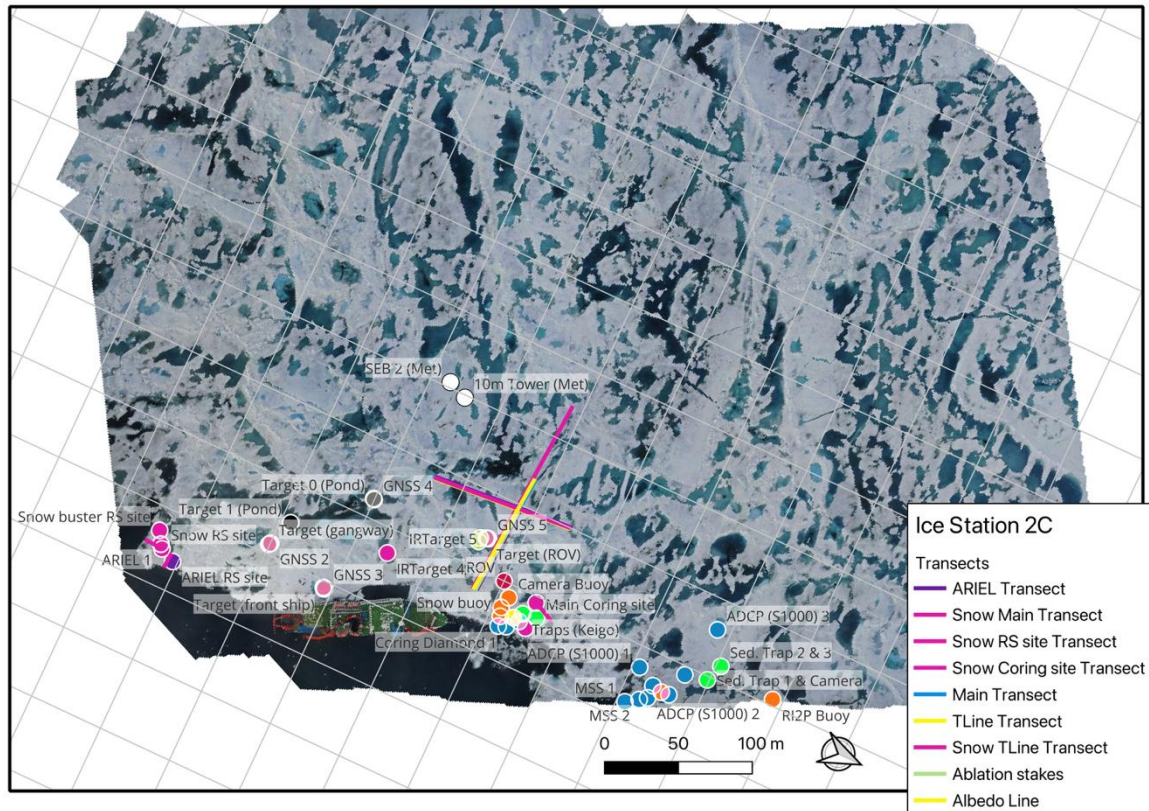


Abb. A5.8: Karte der Eisstation 2C (PS149_36-1) vom 12. August bis 14. August 2025.
 Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 13. August 2025.
 Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis.
 Das Gitter markiert Abstände von 50 m.

Fig. A5.8: Map of Ice Station 2C (PS149_36-1) from 12 August to 14 August 2025. The background map is a photo mosaic from drone flights on 13 August 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

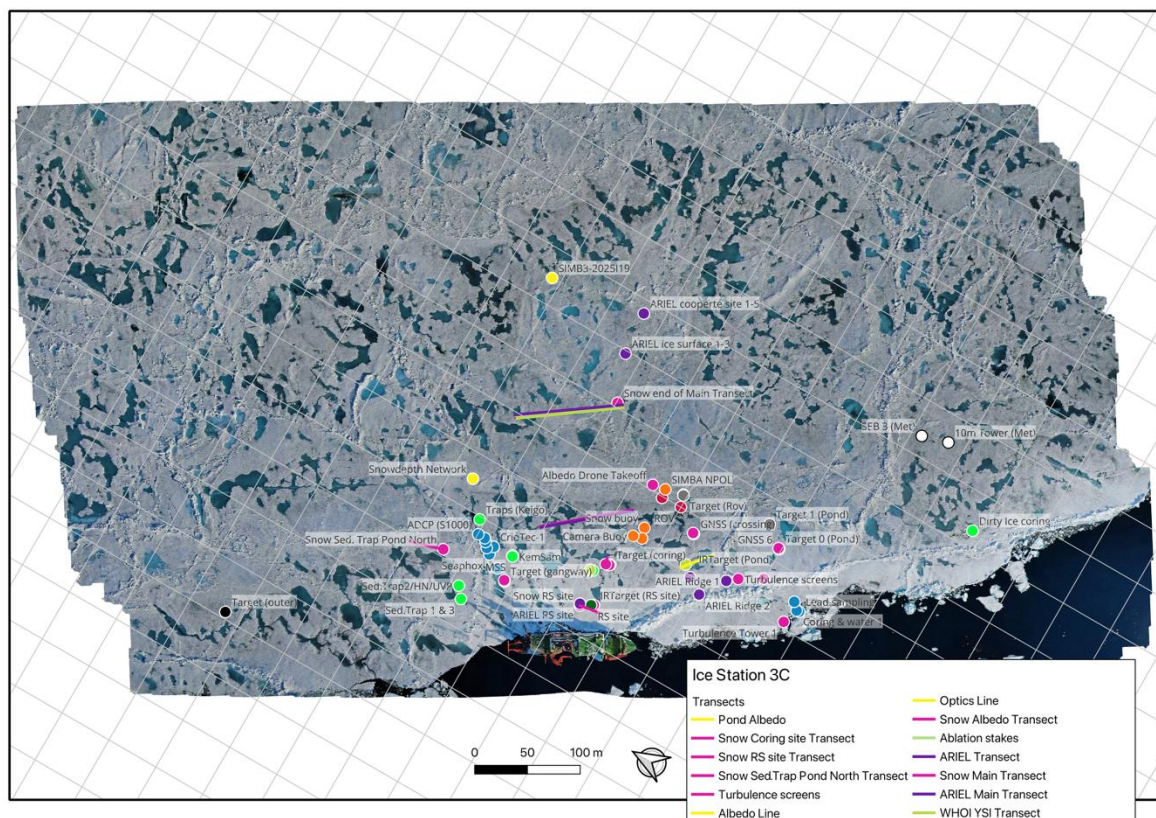


Abb. A5.9: Karte der Eisstation 3C (PS149_41-1) vom 16. August bis 18. August 2025.
 Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 18. August 2025.
 Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis.
 Das Gitter markiert Abstände von 50 m.

Fig. A5.9: Map of Ice Station 3C (PS149_41-1) from 16 August to 18 August 2025. The background map is a photo mosaic from drone flights on 18 August 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

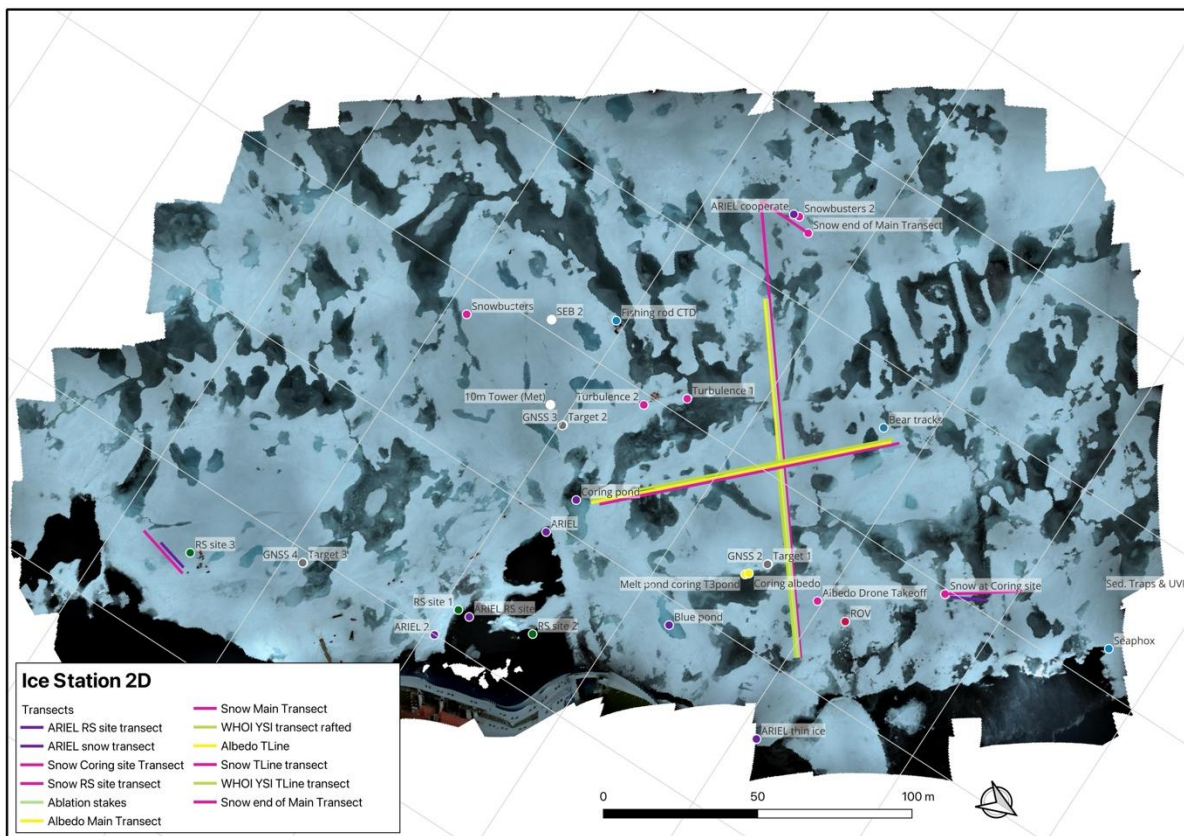


Abb. A5.10: Karte der Eisstation 2D (PS149_46-1) vom 23. August bis 24. August 2025.

Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 24. August 2025.

Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis.

Das Gitter markiert Abstände von 50 m.

Fig. A5.10: Map of Ice Station 2D (PS149_46-1) from 23 August to 24 August 2025. The background map is a photo mosaic from drone flights on 24 August 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

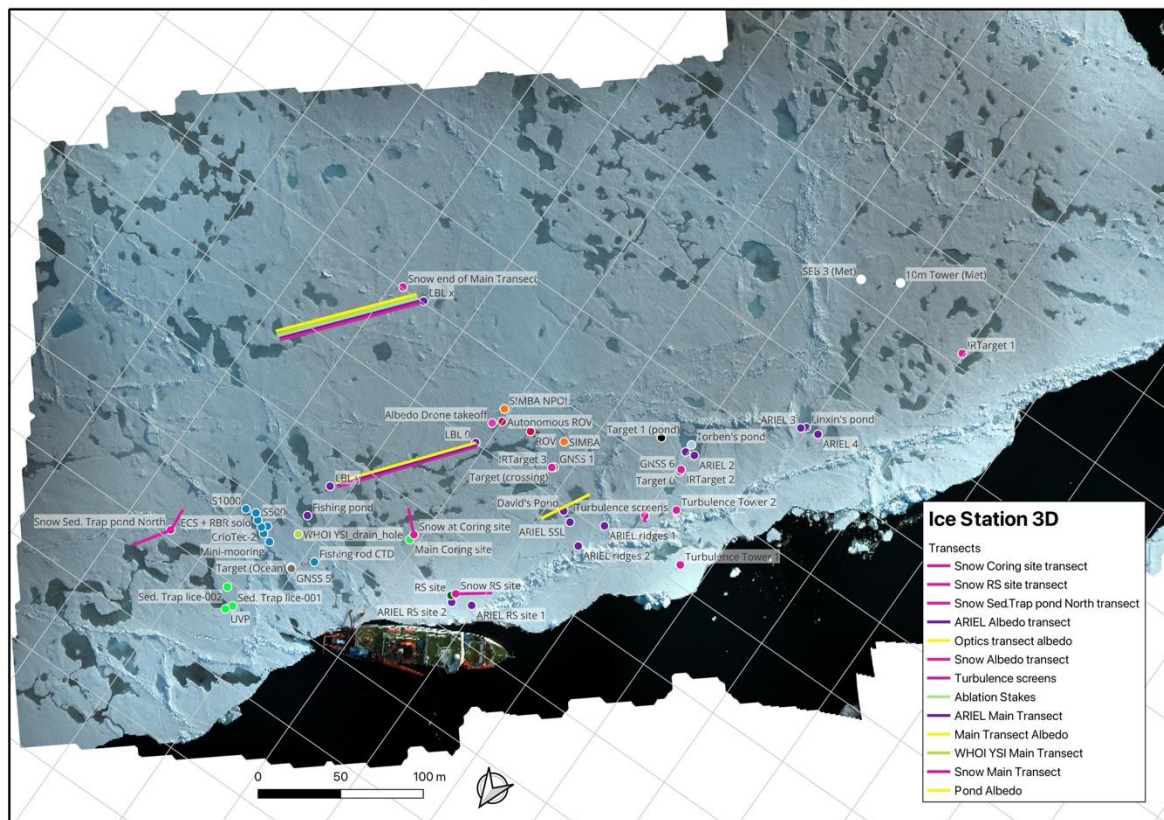


Abb. A5.11: Karte der Eisstation 3D (PS149_47-1) vom 26. August bis 27. August 2025.

Die Hintergrundkarte ist ein Fotomosaik aus Drohnenflügen vom 27. August 2025.

Die farbigen Markierungen zeigen die Positionen der einzelnen Events auf dem Eis.

Das Gitter markiert Abstände von 50 m

Fig. A5.11: Map of Ice Station 3D (PS149_47-1) from 26 August to 27 August 2025. The background map is a photo mosaic from drone flights on 27 August 2025. The colored markers show the positions of the individual events on the ice. The grid marks distances of 50 m.

A.6 EISSTATIONEN WETTER / ICE STATIONS WEATHER

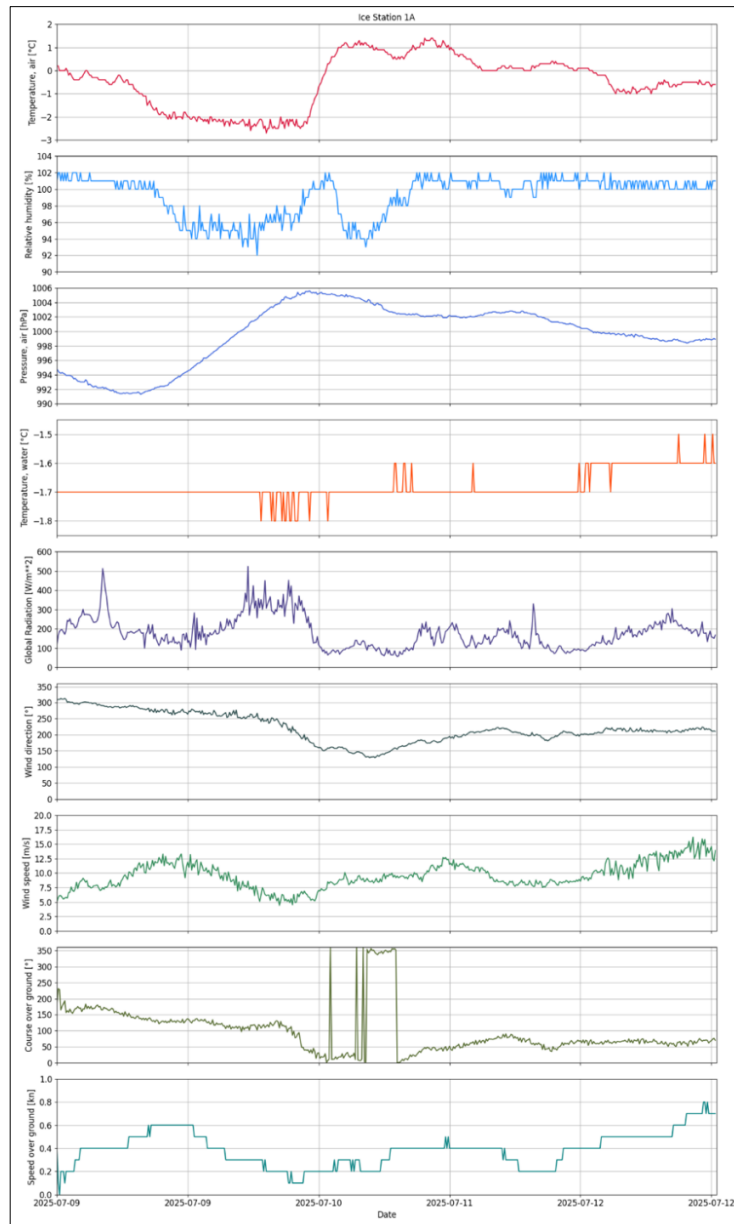


Abb. A6.1a: Wetterbedingungen während Eisstation 1A (PS149_13-1) vom 09. Juli bis 12. Juli 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.1a: Weather conditions during ice station 1A (PS149_13-1) from 09 July to 12 July 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

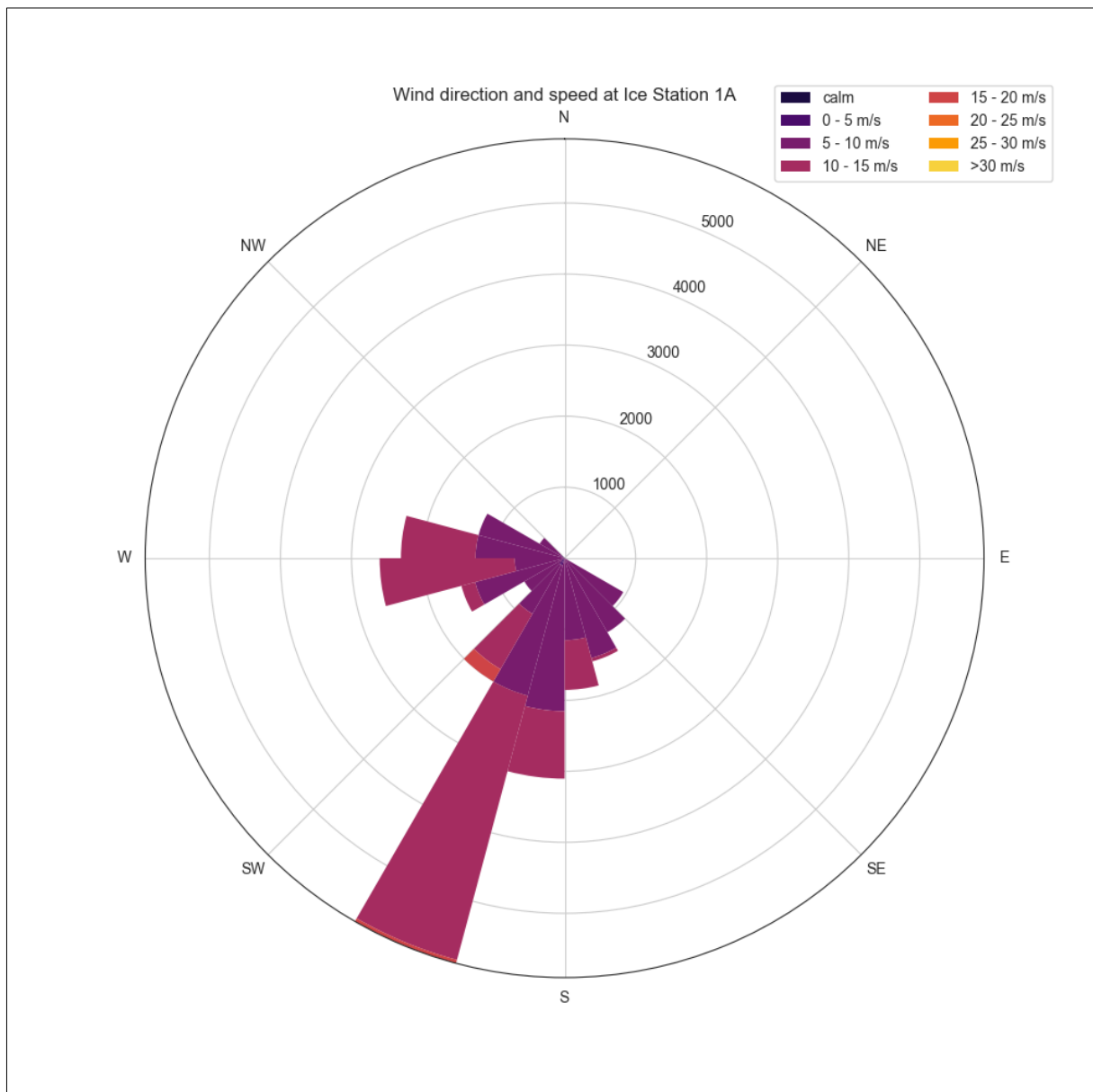


Abb. A6.1b: Winddiagramm während Eisstation 1A (PS149_13-1) vom 09. Juli bis 12. Juli 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.1b: Wind diagram during ice station 1A (PS149_13-1) from 09 July to 12 July 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

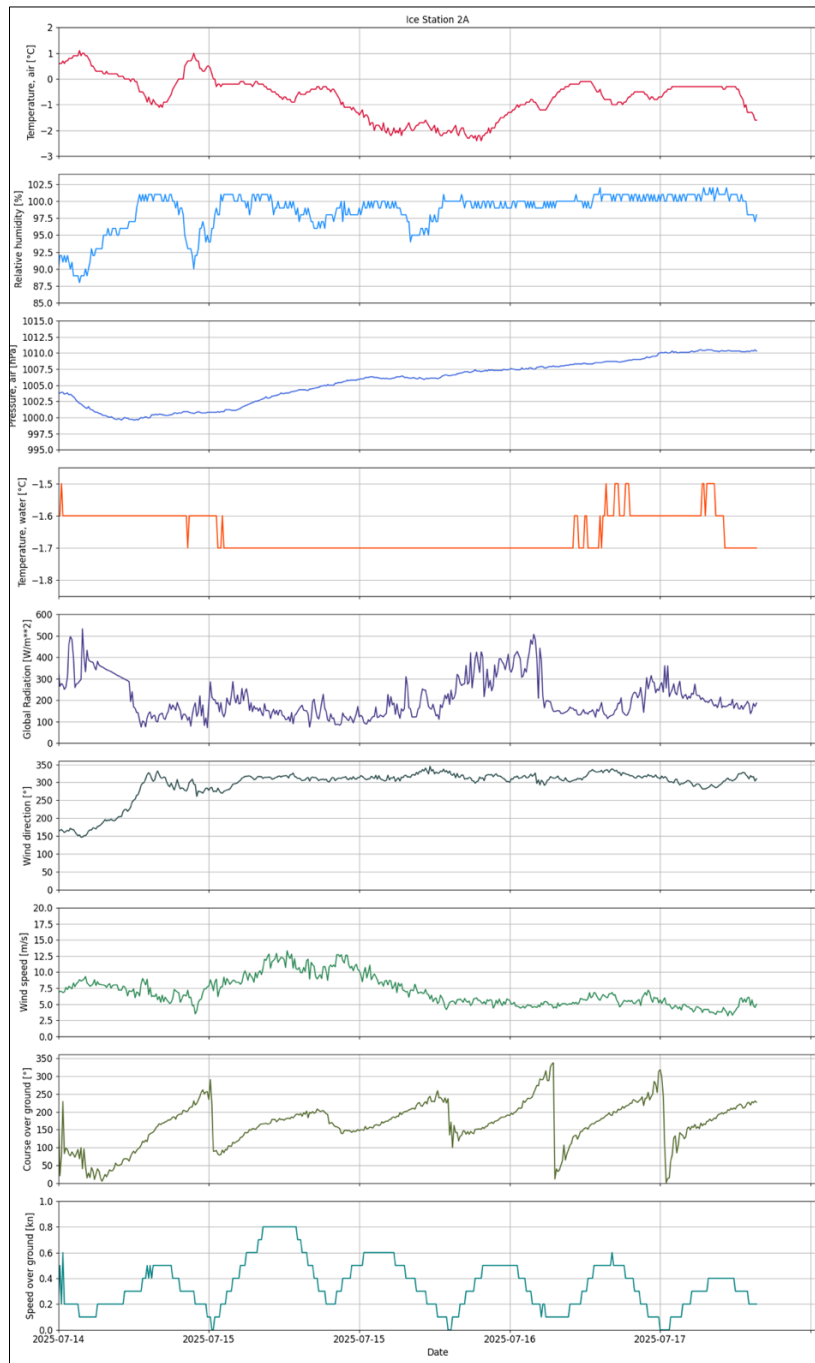


Abb. A6.2a: Wetterbedingungen während Eisstation 2A (PS149_16-1) vom 14. Juli bis 17. Juli 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.2a: Weather conditions during ice station 2A (PS149_16-1) from 14 July to 17 July 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

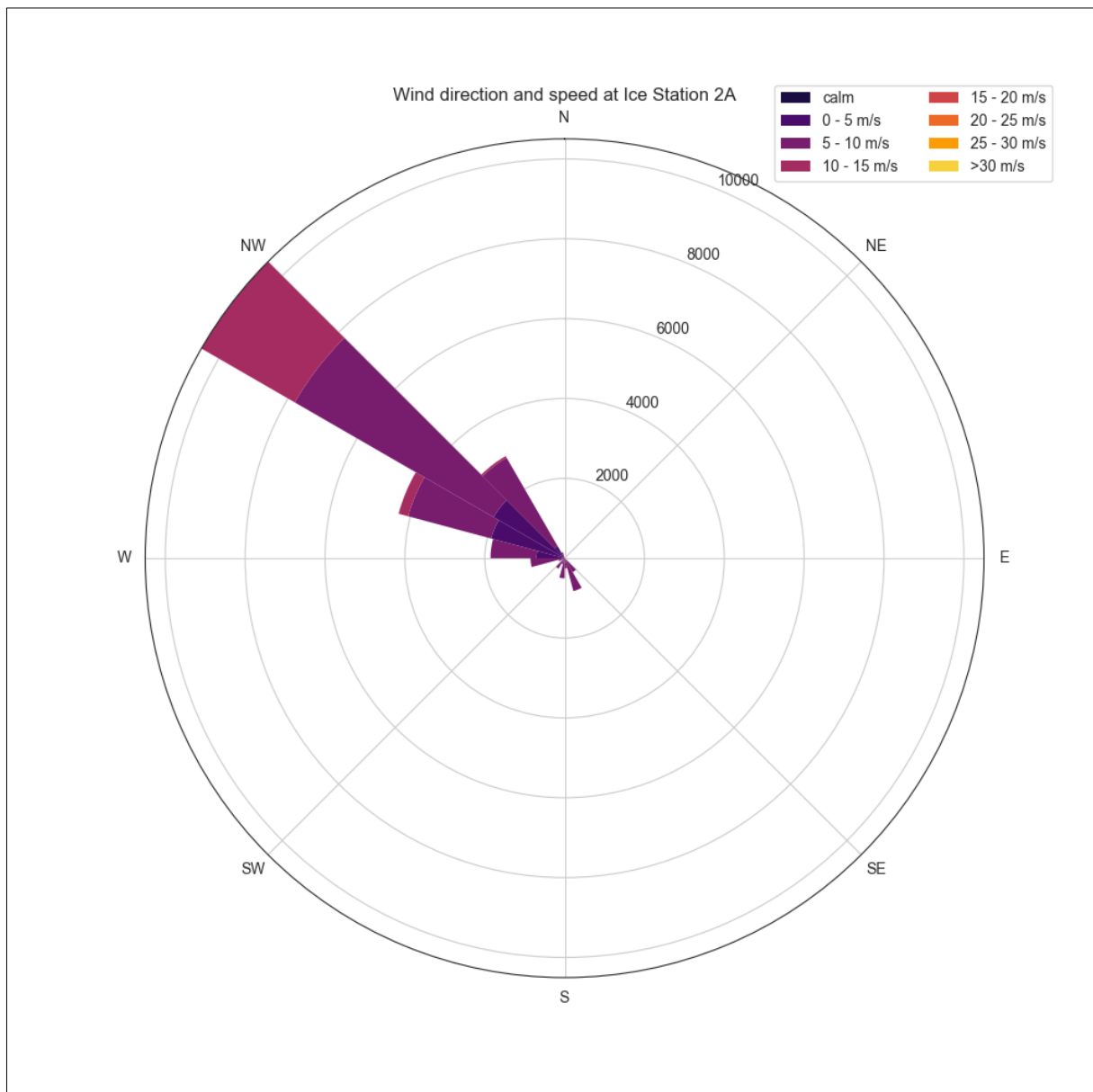


Abb. A6.2b: Winddiagramm während Eisstation 2A (PS149_16-1) vom 14. Juli bis 17. July 2025.
Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.2b: Wind diagram during ice station 2A (PS149_16-1) from 14 July to 17 July 2025.
The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

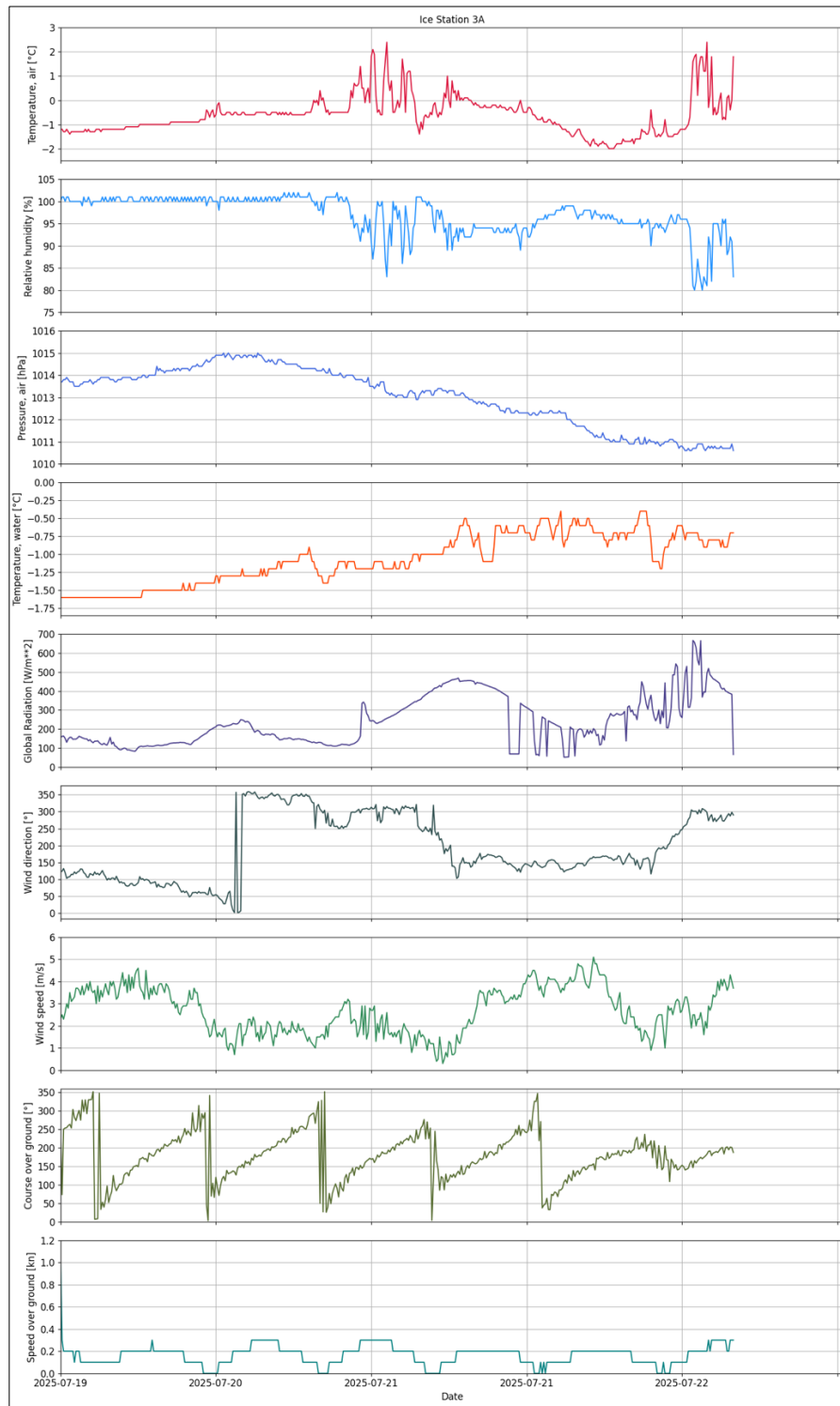


Abb. A6.3a: Wetterbedingungen während Eisstation 3A (PS149_18-1) vom 19. Juli bis 22. Juli 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.3a Weather conditions during ice station 3A (PS149_18-1) from 19 July to 22 July 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.



Abb. A6.3b: Winddiagramm während Eisstation 3A (PS149_18-1) vom 19. Juli bis 22. Juli 2025.
Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.3b: Wind diagram during ice station 3A (PS149_18-1) from 19 July to 22 July 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

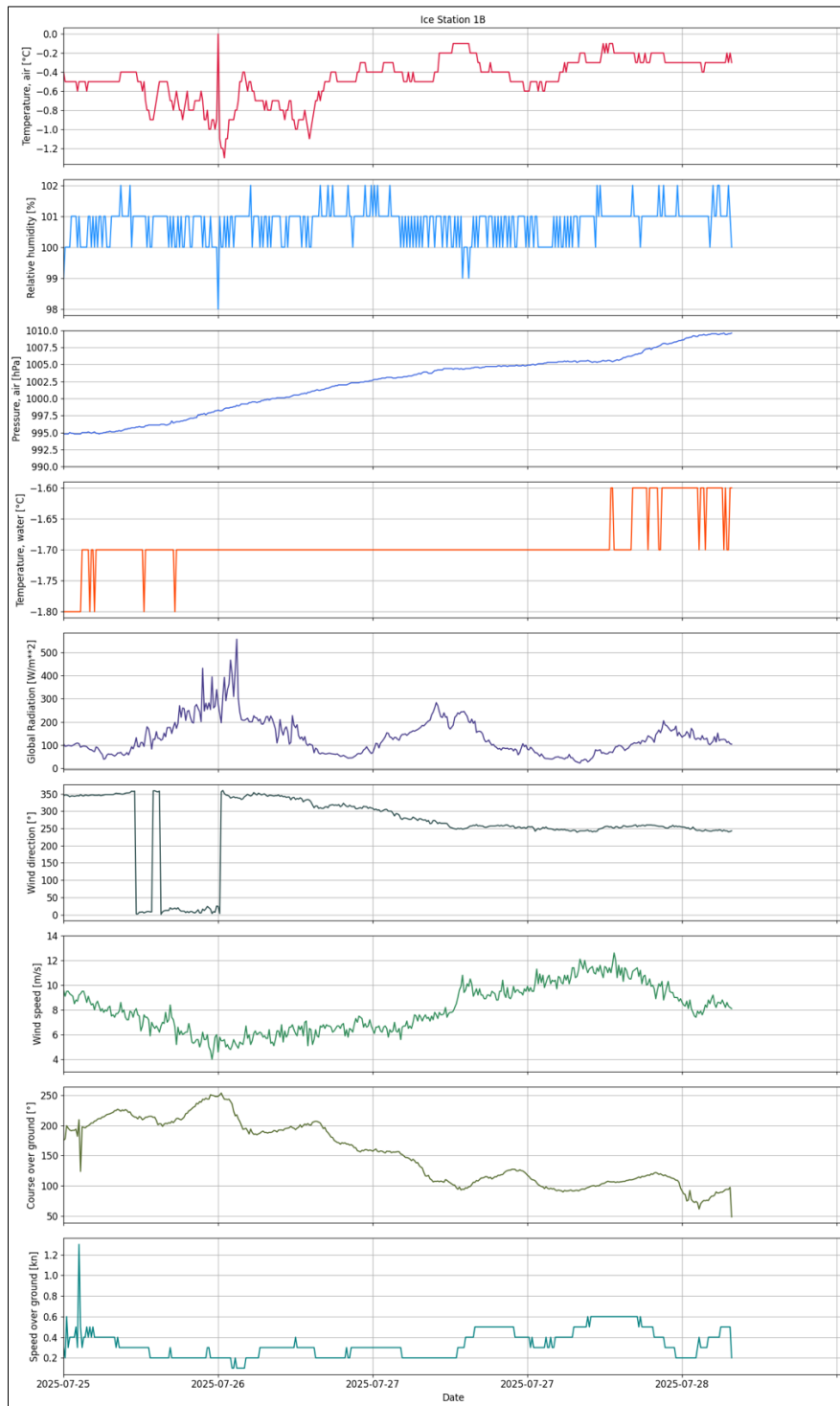


Abb. A6.4a: Wetterbedingungen während Eisstation 1B (PS149_21-1) vom 25. Juli bis 28. Juli 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.4a: Weather conditions during ice station 1B (PS149_21-1) from 25 July to 28 July 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

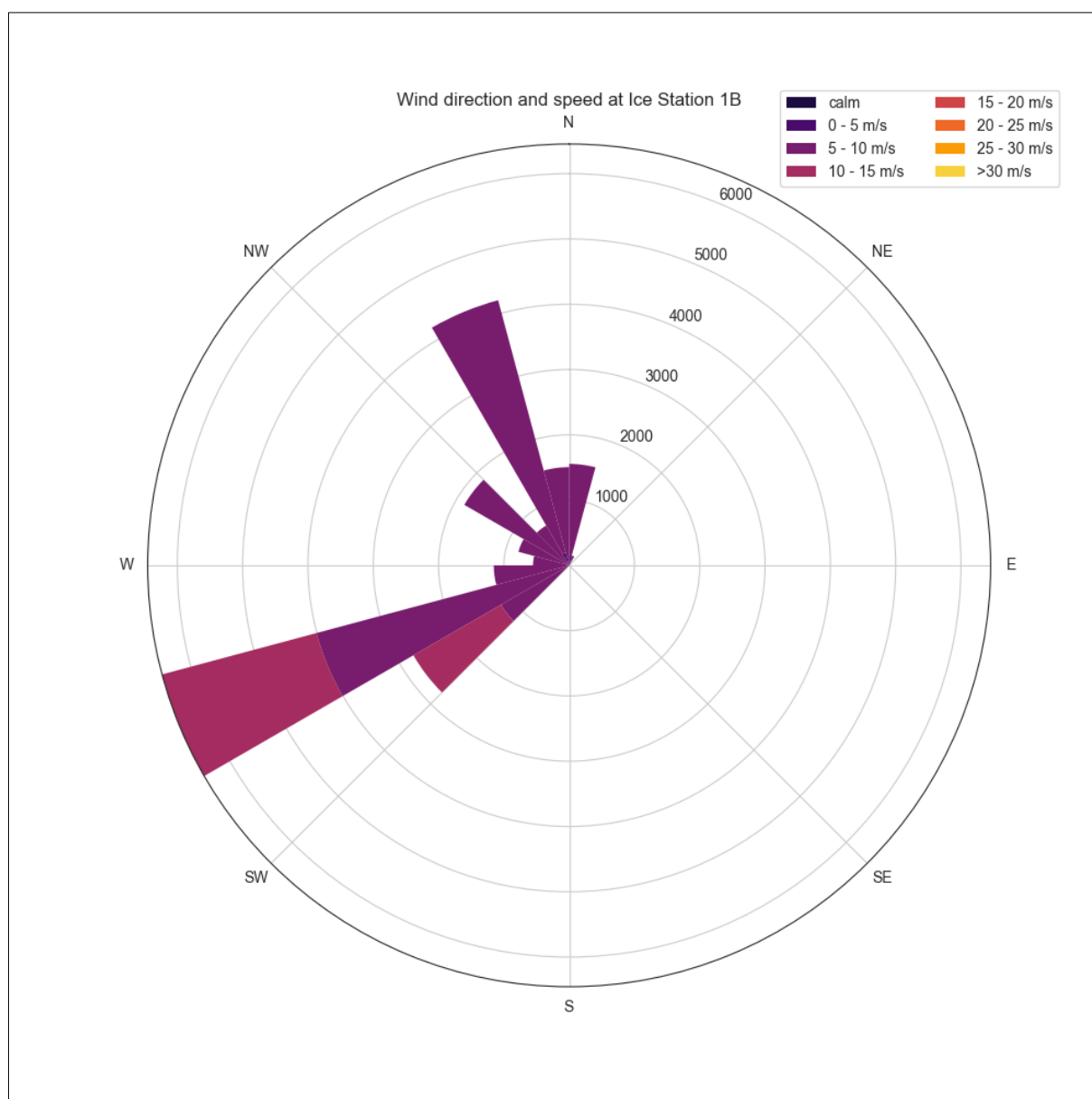


Abb. 6.4b: Winddiagramm während Eisstation 1B (PS149_21-1) vom 25. Juli bis 28. Juli 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. 6.4b: Wind diagram during ice station 1B (PS149_21-1) from 25 July to 28 July 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

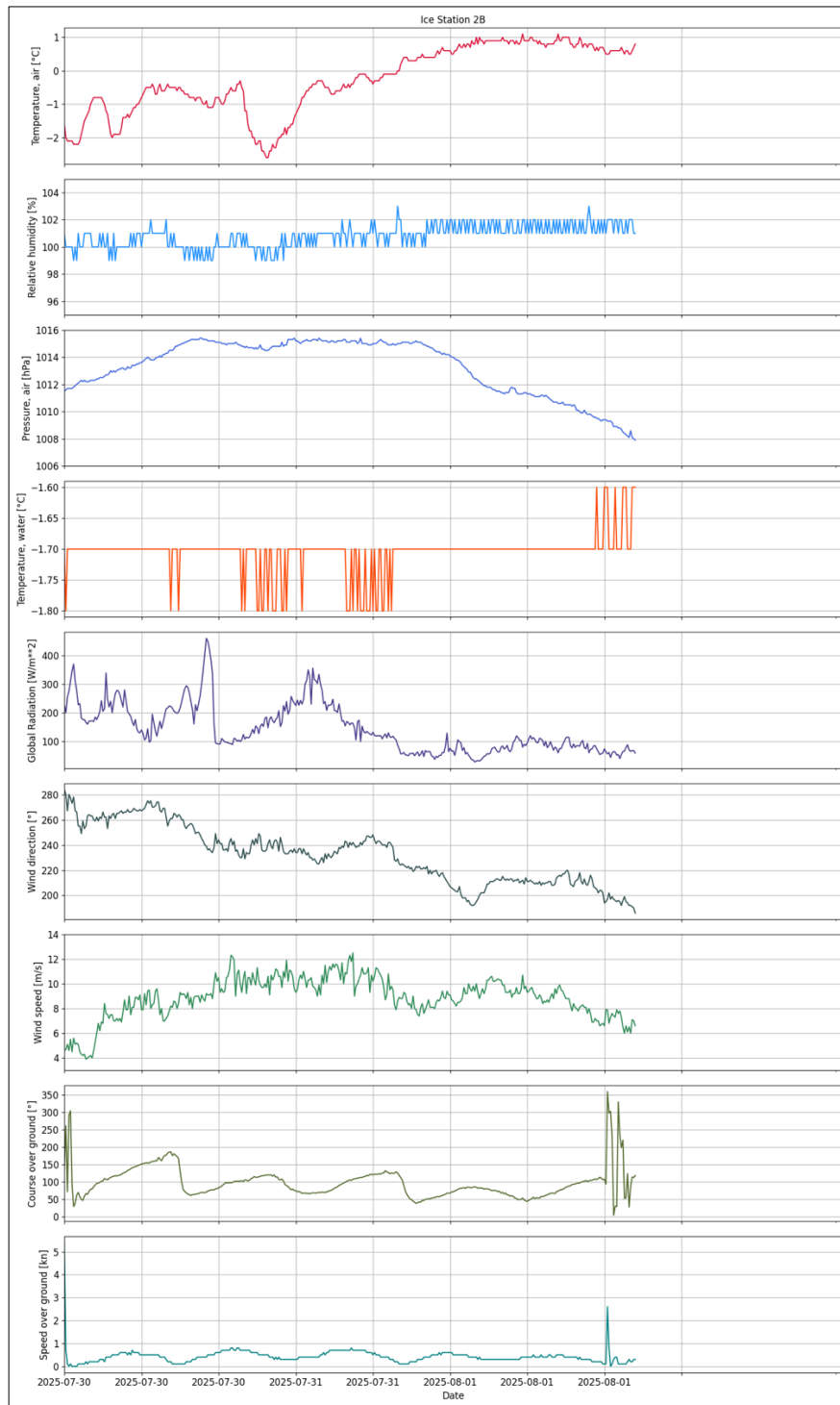


Abb. A6.5a: Wetterbedingungen während Eisstation 2B (PS149_25-1) vom 30. Juli bis 01. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.5a: Weather conditions during ice station 2B (PS149_25-1) from 30 July to 01 August 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

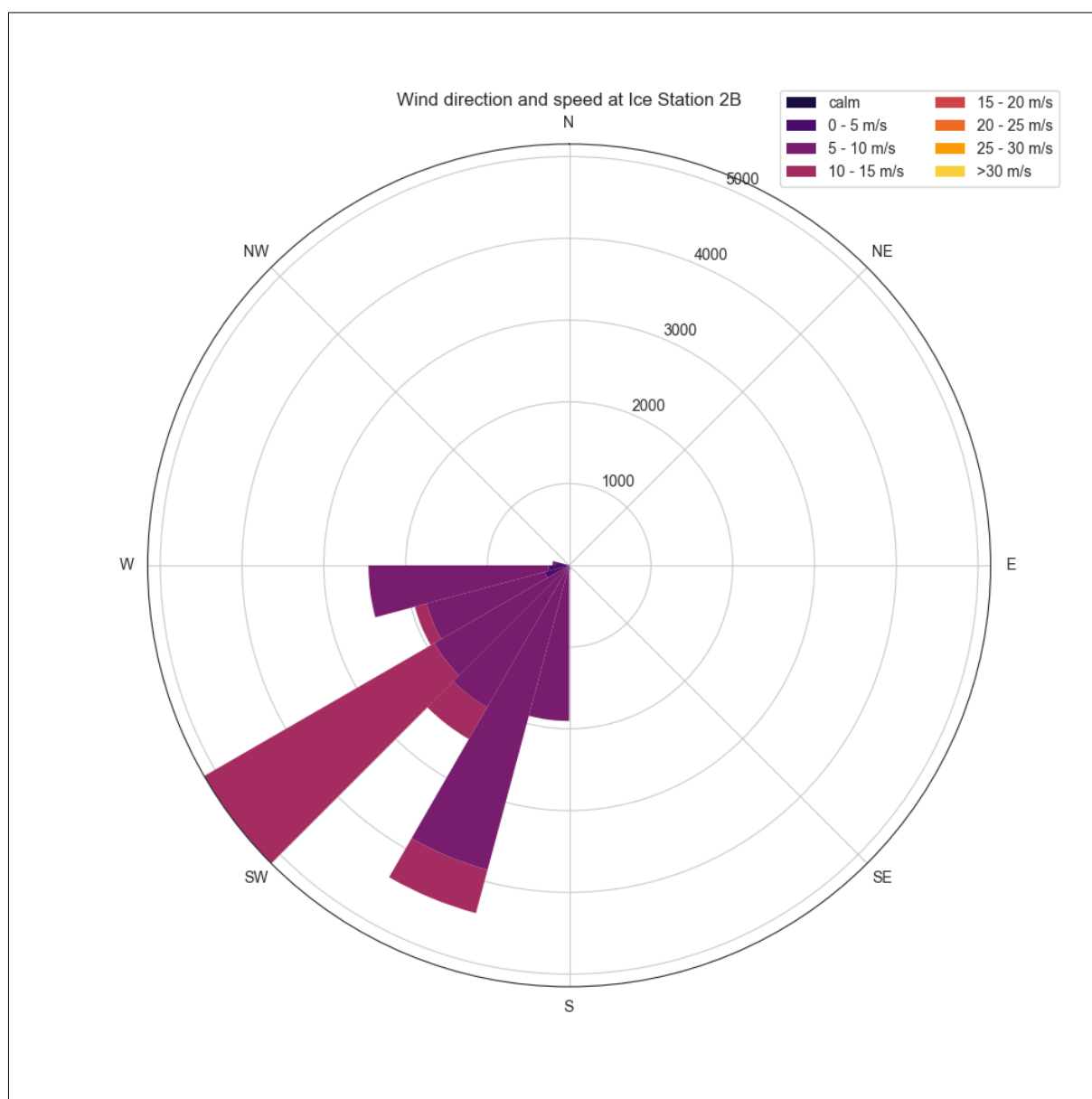


Abb. 6.5b: Winddiagramm während Eisstation 2B (PS149_25-1) vom 30. Juli bis 01. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. 6.5b: Wind diagram during ice station 2B (PS149_25-1) from 30 July to 01 August 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

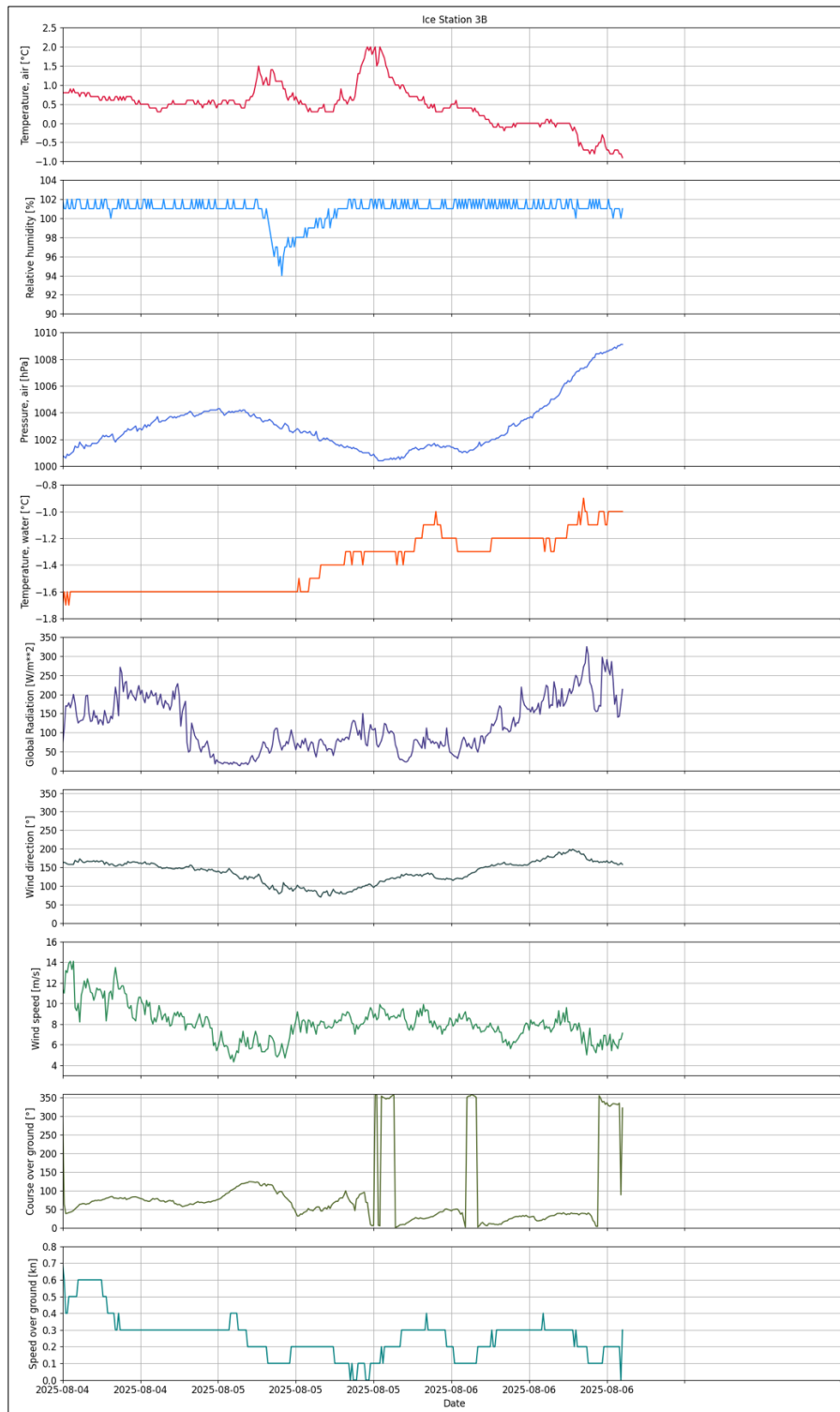


Abb. A6.6a: Wetterbedingungen während Eisstation 3B (PS149_30-1) vom 04. August bis 06. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.6a: Weather conditions during ice station 3B (PS149_30-1) from 04 August to 06 August 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

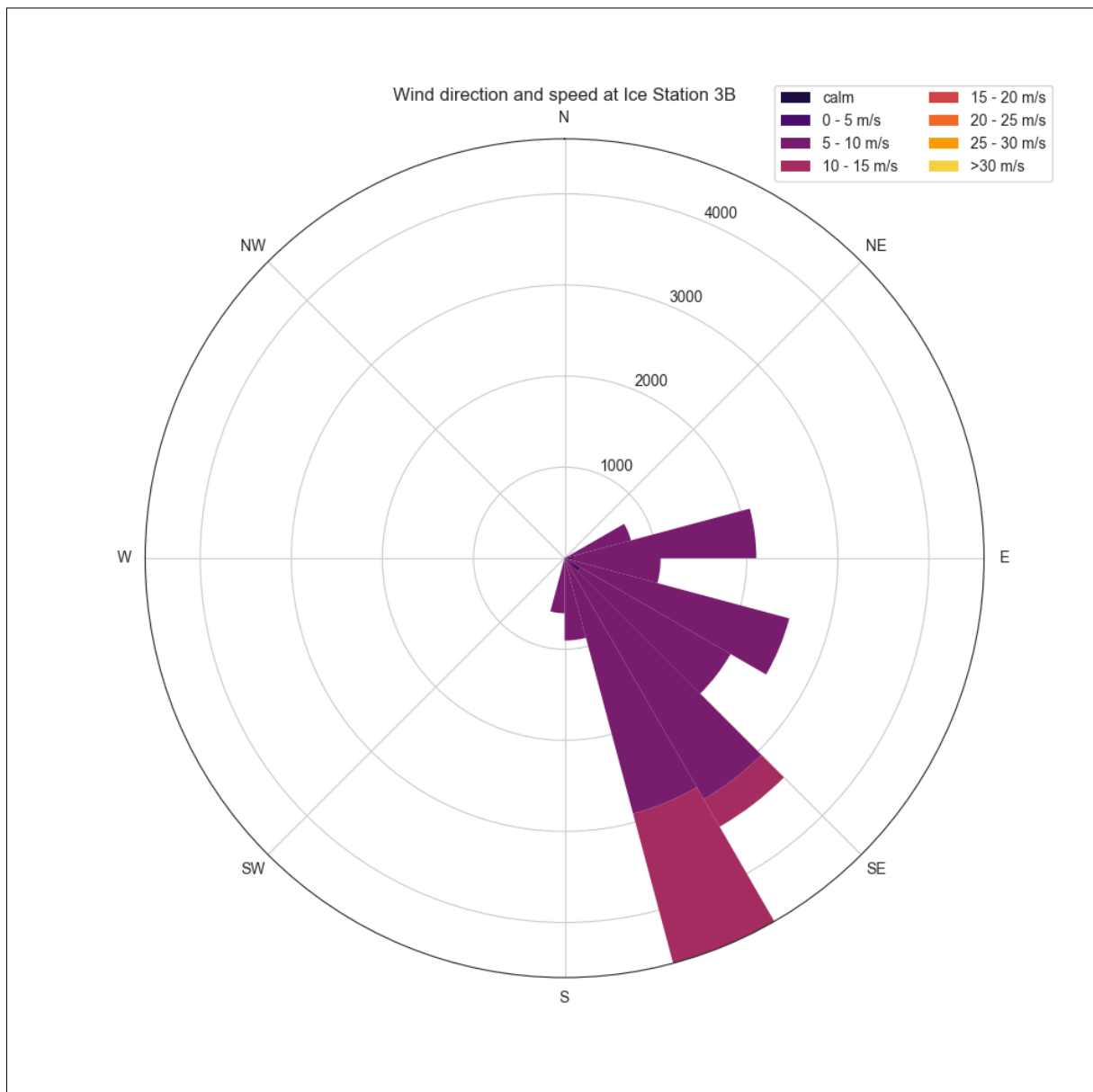


Abb. A6.6b: Winddiagramm während Eisstation 3B (PS149_30-1) vom 04. August bis 06. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.6b: Wind diagram during ice station 3B (PS149_30-1) from 04 August to 06 August 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

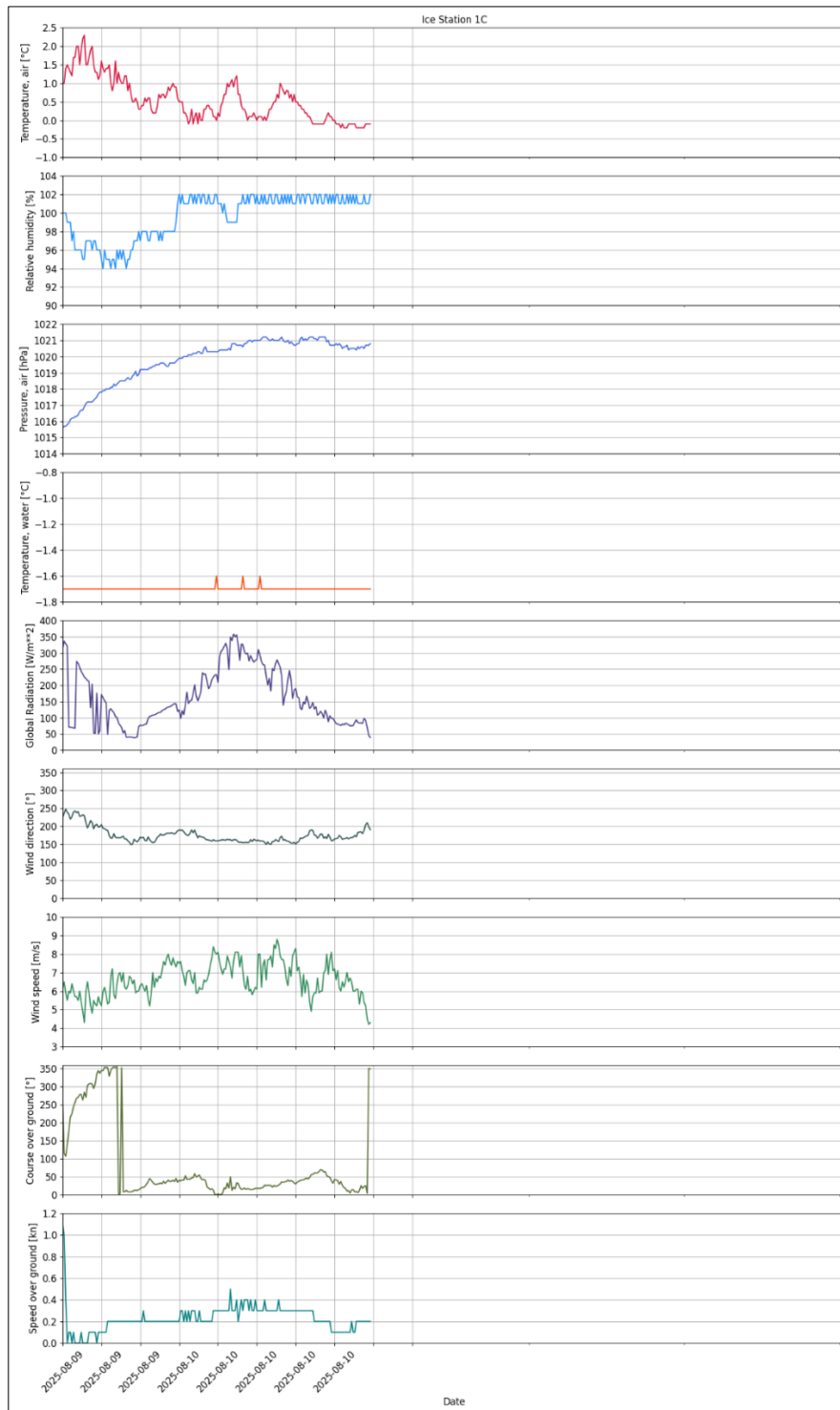


Abb. A6.7a: Wetterbedingungen während Eisstation 1C (PS149_32-1) vom 09. August bis 10. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.7a: Weather conditions during ice station 1C (PS149_32-1) from 09 August to 10 August 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

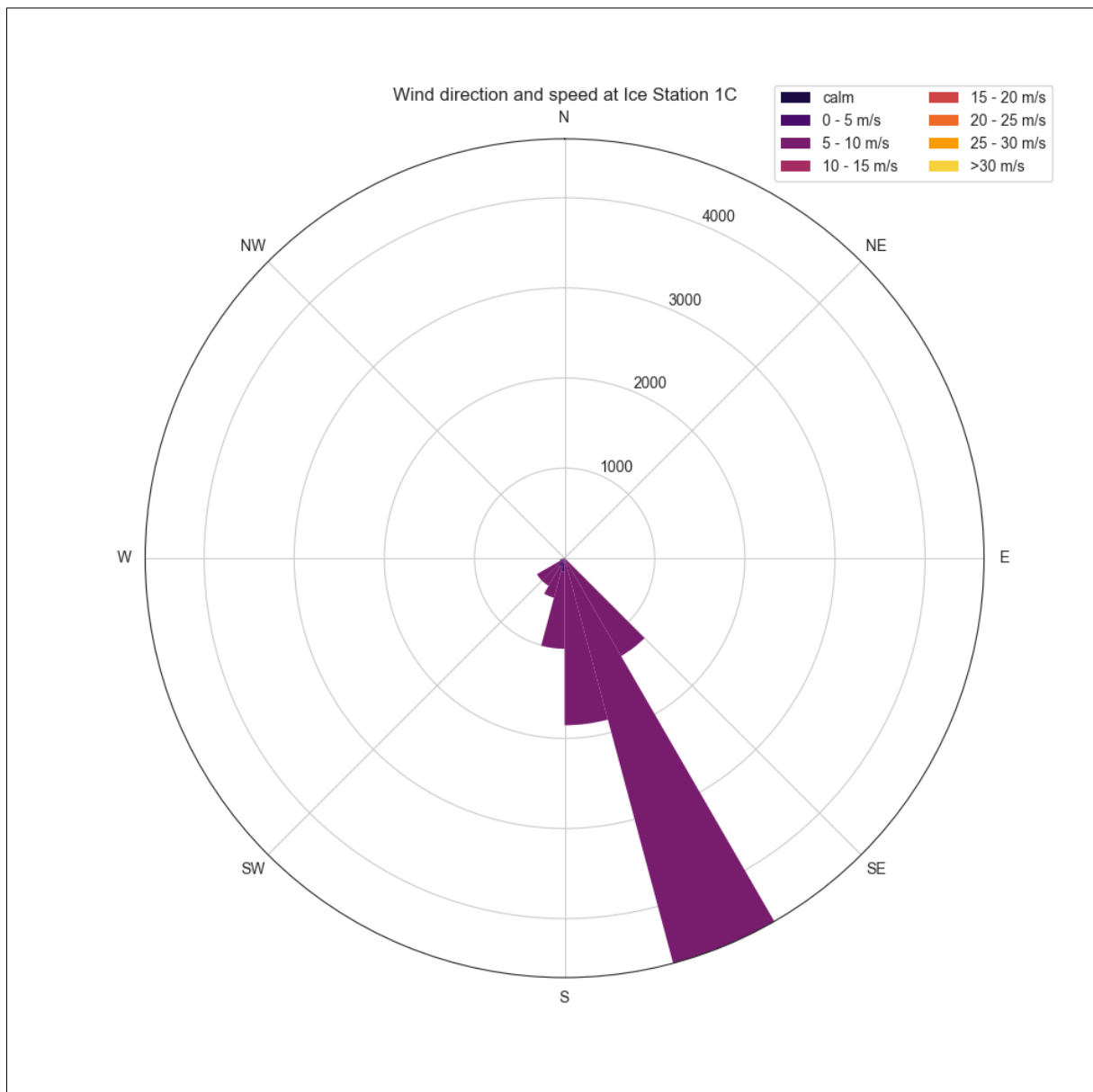


Abb. A6.7b: Winddiagramm während Eisstation 1C (PS149_32-1) vom 09. August bis 10. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.7b: Wind diagram during ice station 1C (PS149_32-1) from 09 August to 10 August 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

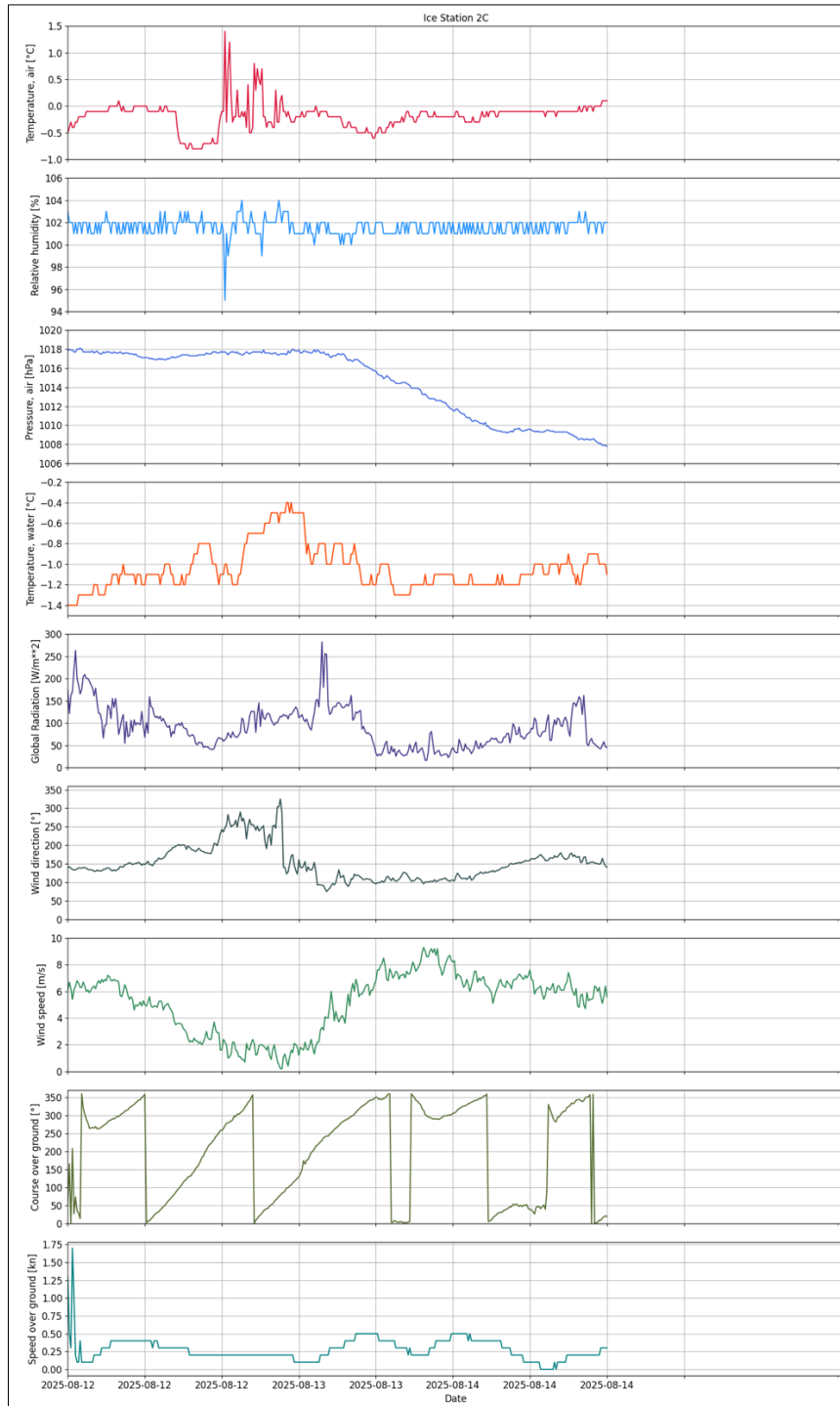


Abb. A6.8a: Wetterbedingungen während Eisstation 2C (PS149_36-1) vom 12. August bis 14. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.8a: Weather conditions during ice station 2C (PS149_36-1) from 12 August to 14 August 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

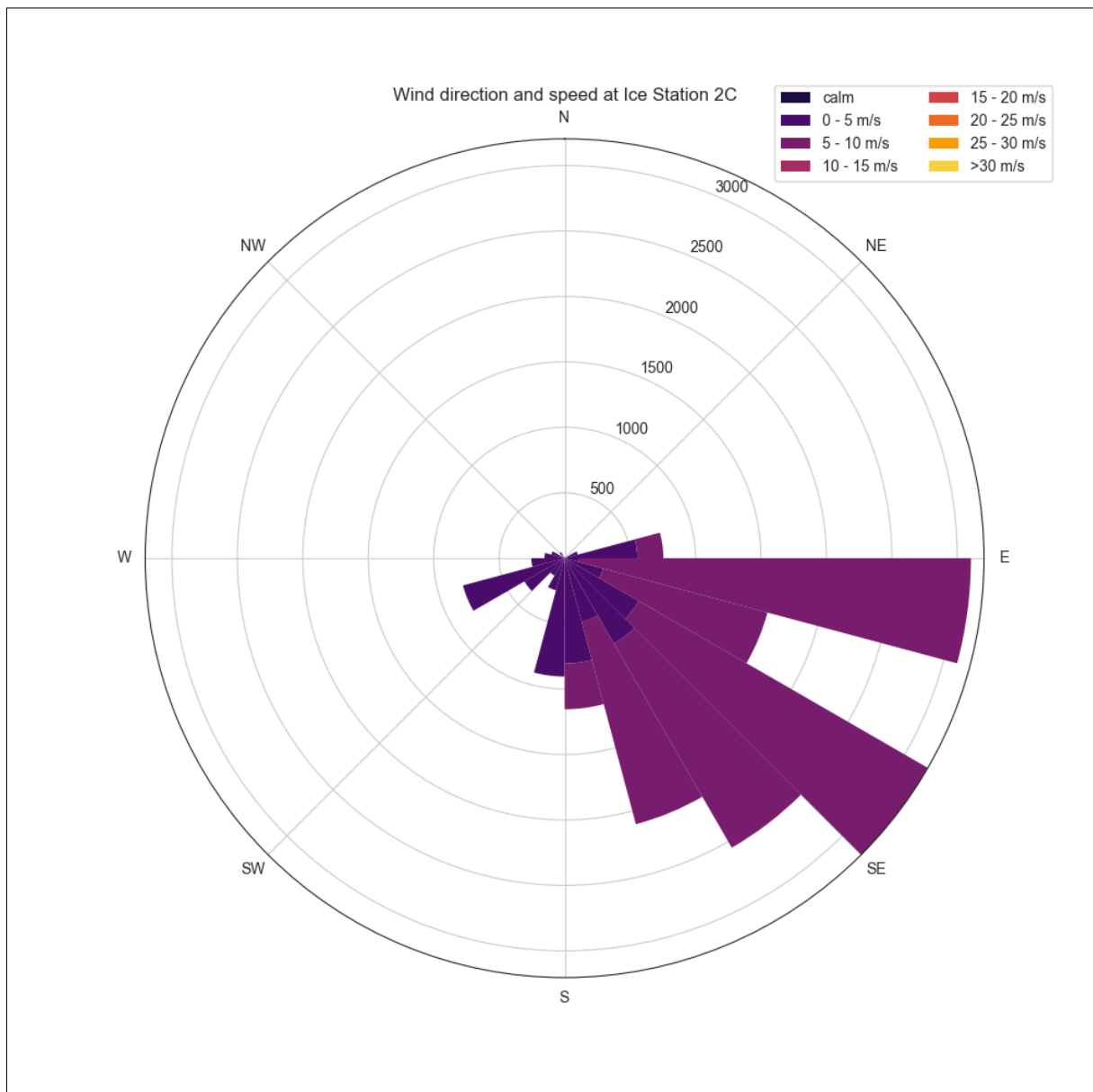


Abb. A6.8b: Winddiagramm während Eisstation 2C (PS149_36-1) vom 12. August bis 14. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.8b: Wind diagram during ice station 2C (PS149_36-1) from 12 August to 14 August 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

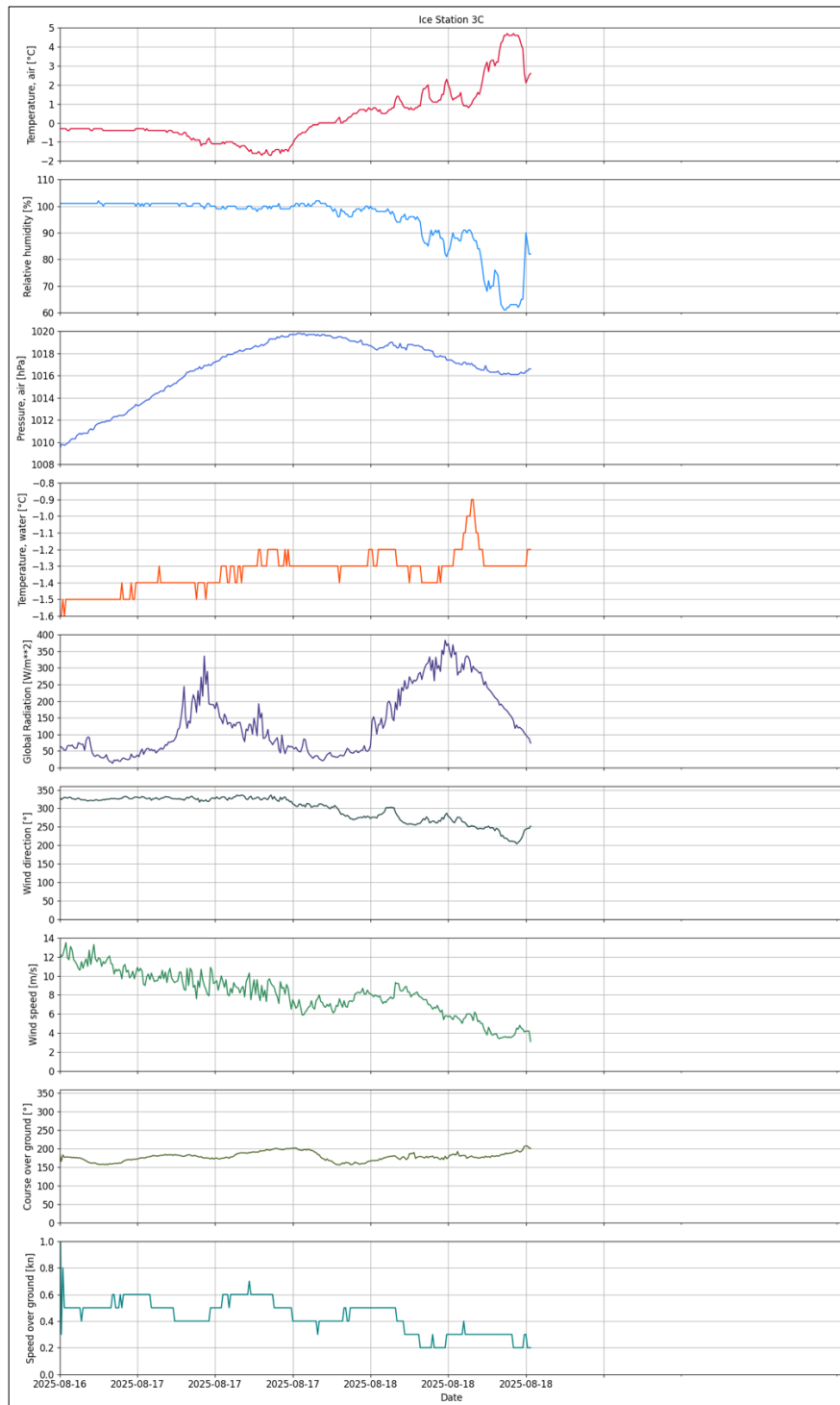


Abb. A6.9a: Wetterbedingungen während Eisstation 3C (PS149_41-1) vom 16. August bis 18. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.9a: Weather conditions during ice station 3C (PS149_41-1) from 16 August to 18 August 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

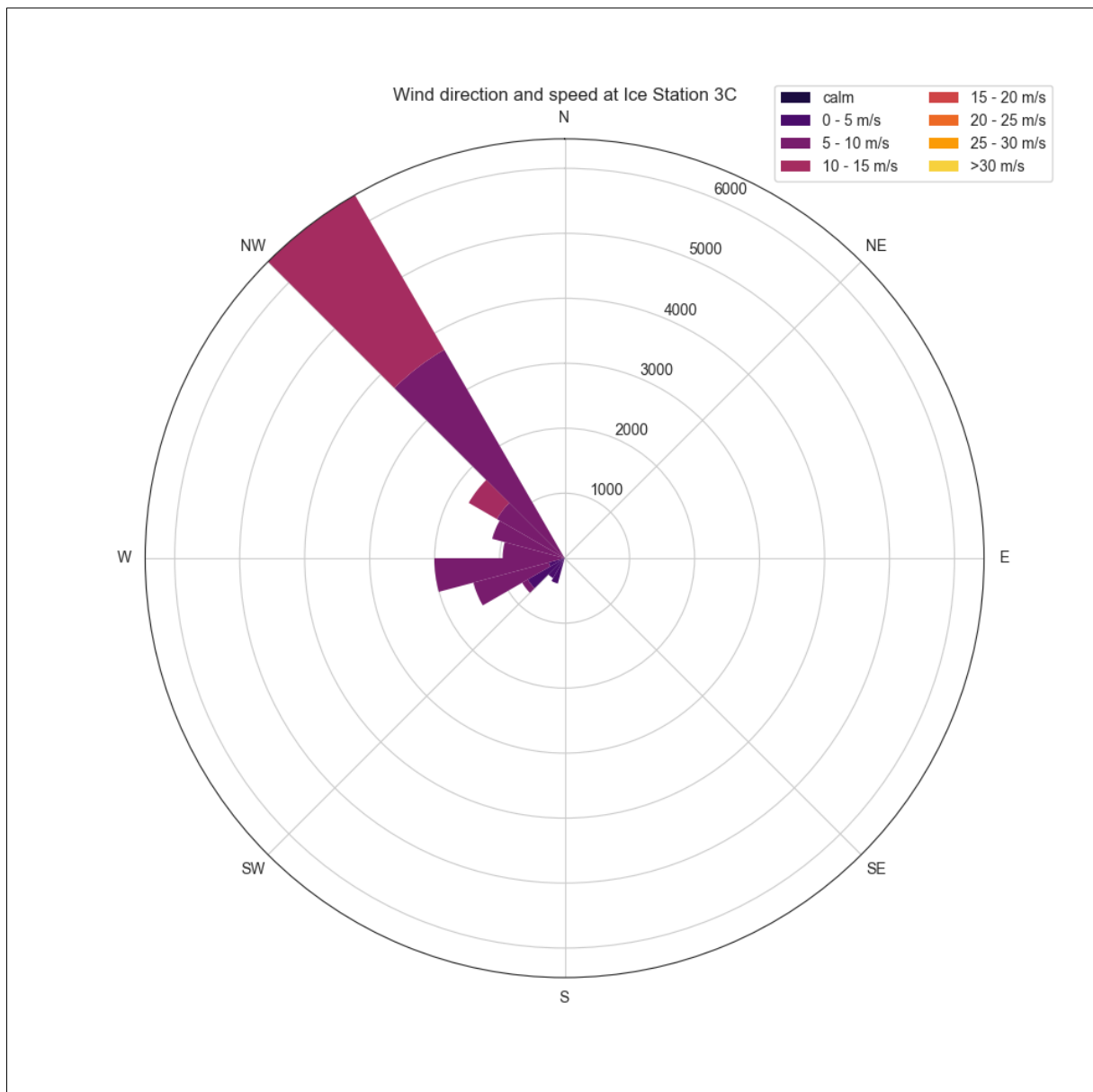


Abb. A6.9b: Winddiagramm während Eisstation 3C (PS149_41-1) vom 16. August bis 18. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.9b: Wind diagram during ice station 3C (PS149_41-1) from 16 August to 18 August 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

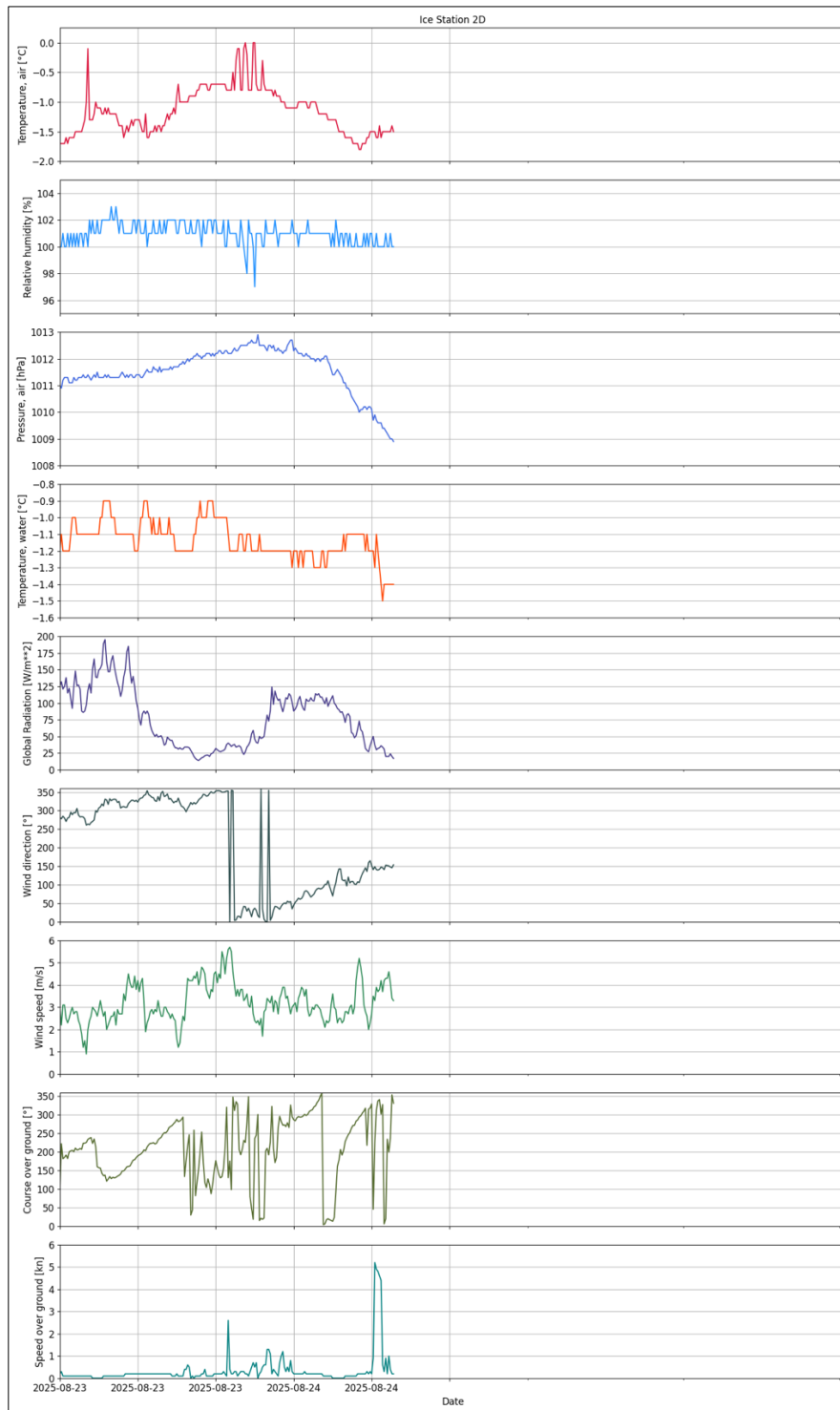
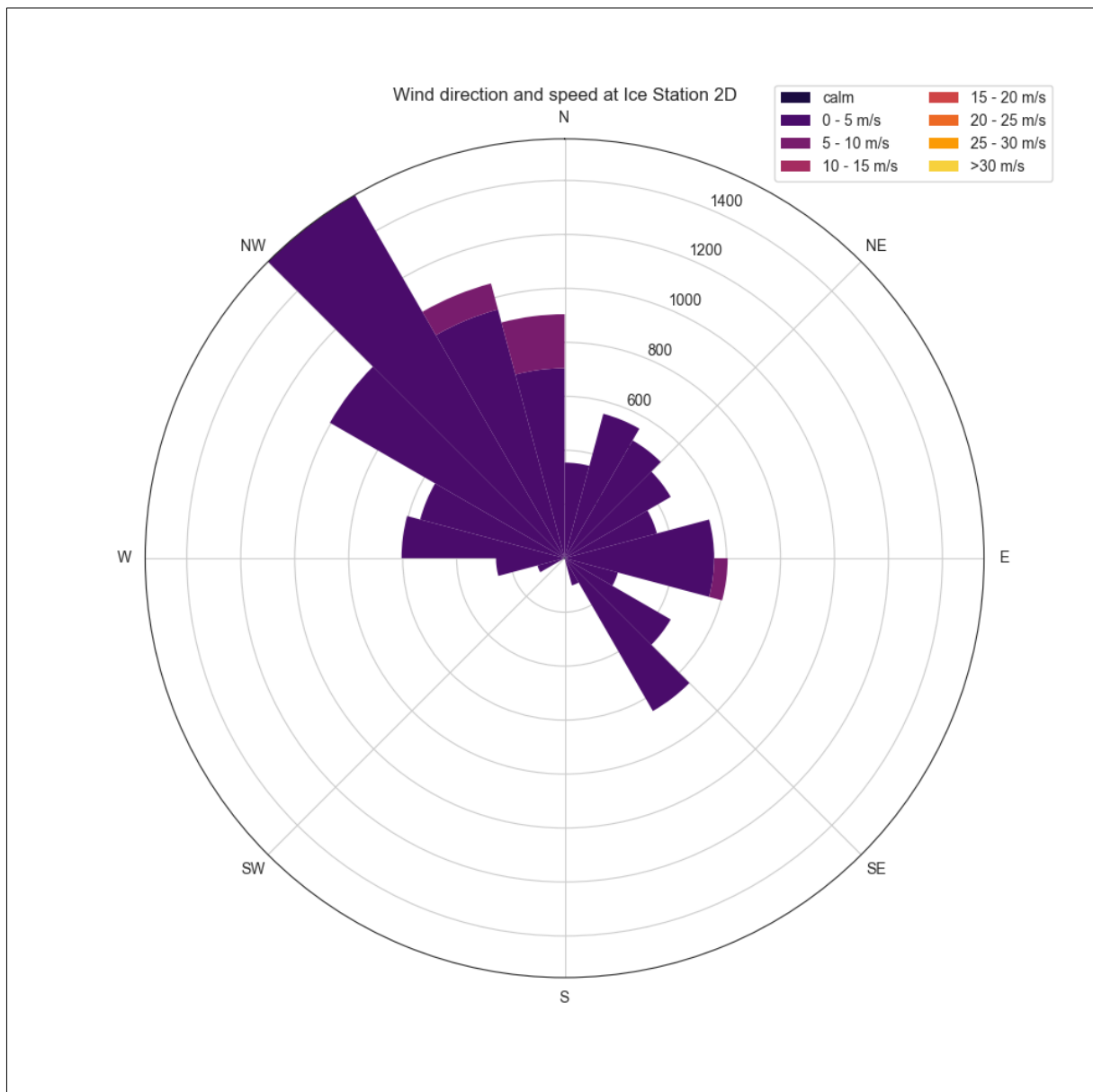


Abb. A6.10a: Wetterbedingungen während Eisstation 2D (PS149_46-1) vom 23. August bis 24. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.10a: Weather conditions during ice station 2D (PS149_46-1) from 23 August to 24 August 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.



Abb, A6.10b: Winddiagramm während Eisstation 2D (PS149_46-1) vom 23. August bis 24. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.10b: Wind diagram during ice station 2D (PS149_46-1) from 23 August to 24 August 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

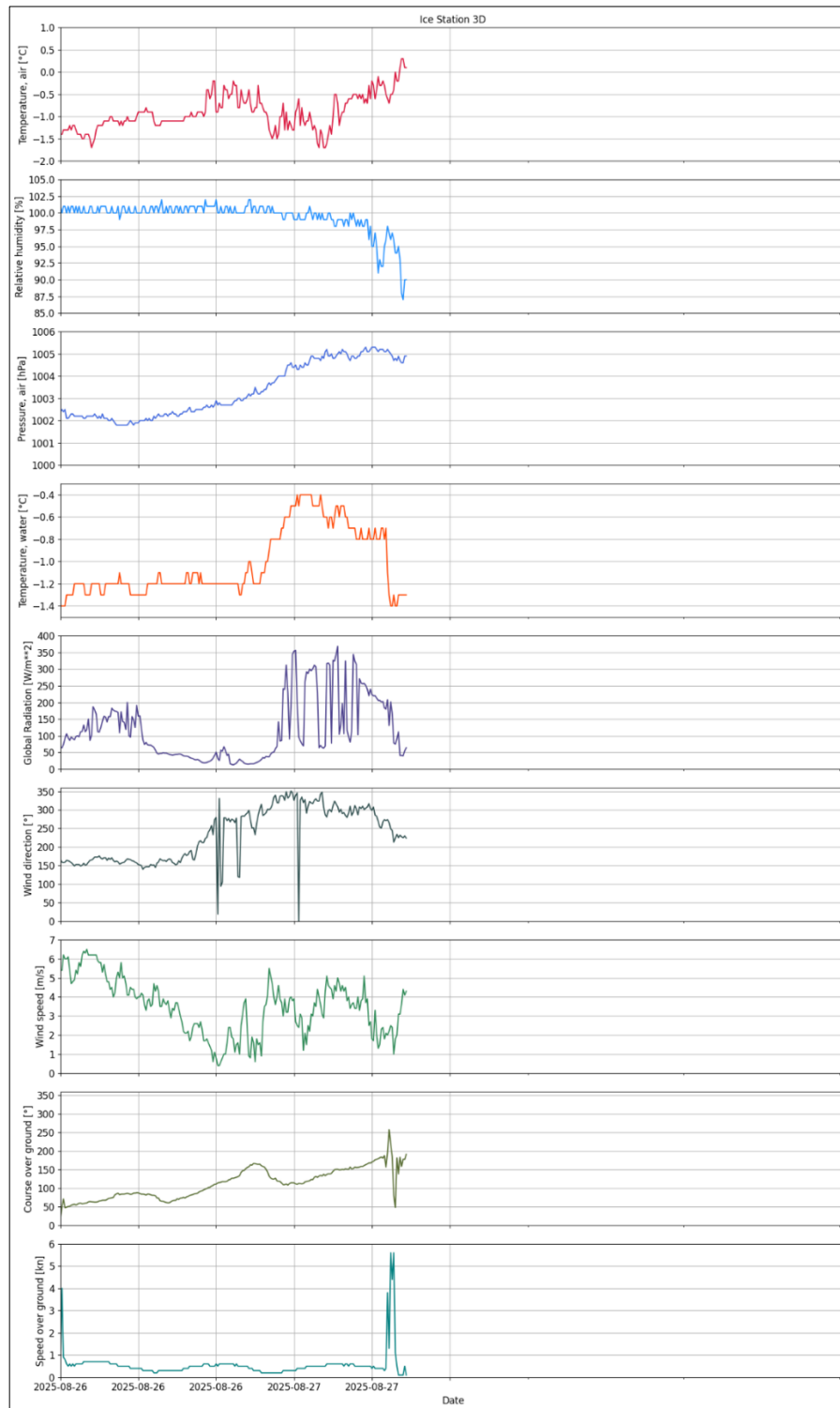


Abb. A6.11a: Wetterbedingungen während Eisstation 3D (PS149_47-1) vom 26. August bis 27. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert. Die Zeitachse ist für alle Eisstationen gleich skaliert.

Fig. A6.11a: Weather conditions during ice station 3D (PS149_47-1) from 26 August to 27 August 2025. The data (10-minute values) were obtained from sensors on board the Polarstern and exported from D-SHIP. The time axis is scaled identically for all ice stations.

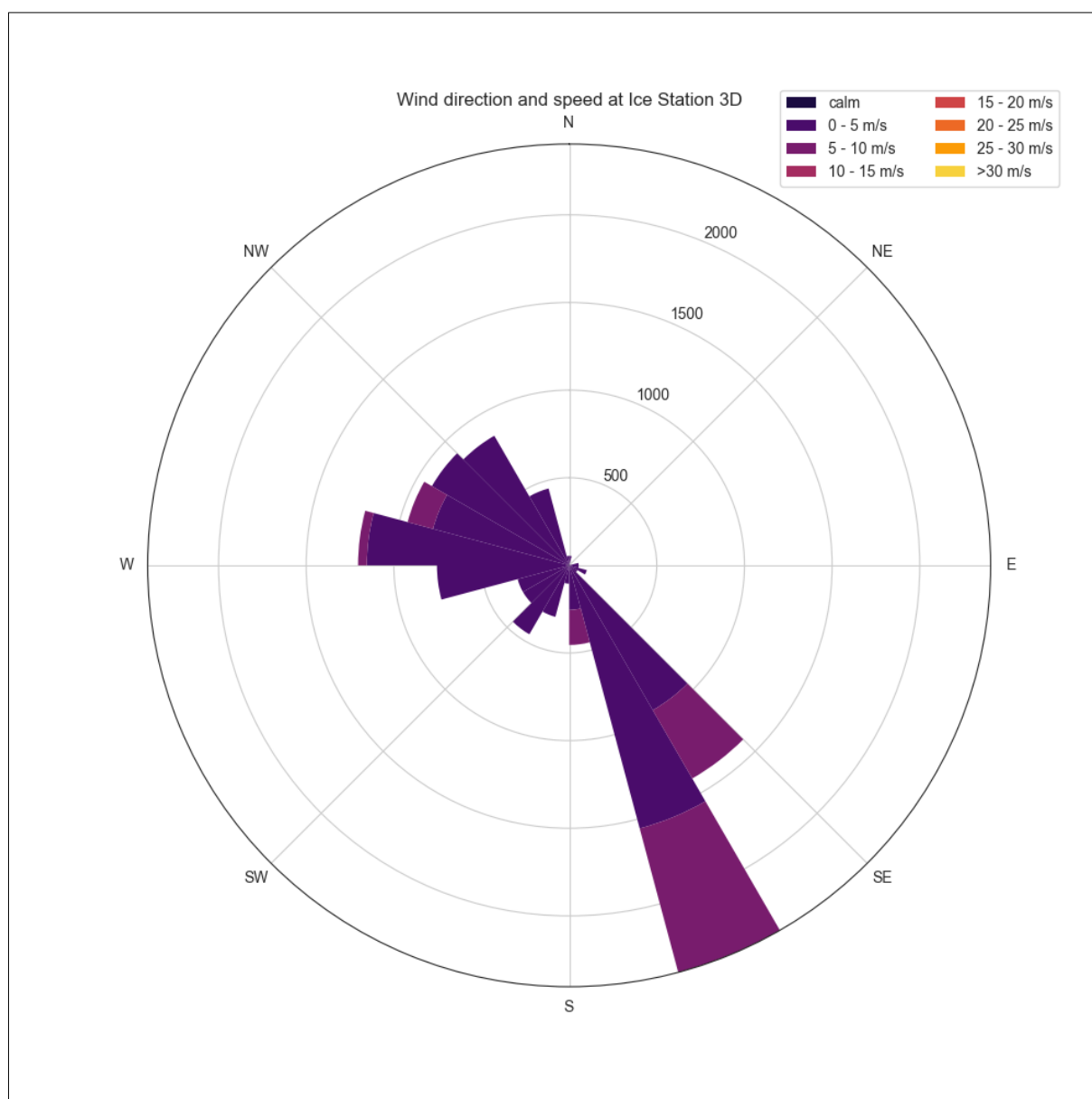


Abb. A6.11b: Winddiagramm während Eisstation 3D (PS149_47-1) vom 26. August bis 27. August 2025. Die Daten (10-min Werte) stammen von Sensoren an Bord von Polarstern und wurden aus D-SHIP exportiert.

Fig. A6.11b: Wind diagram during ice station 3D (PS149_47-1) from 26 August to 27 August 2025. The data (10-minute values) originate from sensors on board Polarstern and were exported from D-SHIP.

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