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Expeditions to Antarctica: ANT-Land 2023/24 NEUMAYER STATION III, Kohnen Station and Field Campaigns

Edited by

Julia Regnery, Tim Heitland and
Christine Wesche
with contributions of the participants

HELMHOLTZ

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(Foto: Tim Heitland, AWI)

Cover: Iceberg in the Atka Bay
(Photo: Tim Heitland, AWI)

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ANT-Land 2023/24

8 November 2023 – 1 March 2024

***Neumayer Station III*, *Kohnen Station* and Other Field Campaigns in Antarctica**

Field Operation Manager *Neumayer Station III*
Tim Heitland and Christine Wesche

Scientific Coordinator
Julia Regnery

Logistical Coordinator
Christine Wesche

Contents

1. ÜBERBLICK UND EXPEDITIONSVERLAUF

Christine Wesche, Tim Heitland DE.AWI

In der Saison 2023/2024 traten die Einschränkungen durch die Coronavirus-Pandemie in den Hintergrund. Dennoch wurden Vorsichtsmaßnahmen getroffen, um zu verhindern, dass das Virus an die Station gelangt und sich ausbreitet. Der gesamte Flugbetrieb fand in enger Zusammenarbeit mit dem Norwegischen Polarinstitut (NPI) und White Desert statt. Insbesondere auf den Interkontinentalflügen des NPI wurden besondere Vorsichtsmaßnahmen für den Fall getroffen, dass Mitreisende an CoV-2 erkranken. Generell hatte die Pandemie nur einen minimalen Einfluss auf die Planung und Durchführung der Saison an der *Neumayer-Station III* und der *Kohnen-Station*, und glücklicherweise blieb die *Neumayer-Station III* erneut frei von SARS Co-V 2.

Die Sommersaison begann mit leichter Verspätung am 8. November 2023 mit der Ankunft der ersten Sommergäste aufgrund von wetterbedingten und technischen Einschränkungen im interkontinentalen Flugverkehr. Die wissenschaftlichen und technischen Arbeiten begannen sofort. Die erste Stationserhöhung musste vorbereitet und durchgeführt werden, und die Traverse zur *Kohnen-Station* musste vorbereitet werden. Die wissenschaftlichen Projekte MARE, SPOT und SIBEAT begannen mit ihren Messungen. Außerdem wurde mit dem Bau eines neuen Grabens für das Magnetikobservatorium begonnen, das Teil des Geophysikobservatoriums ist. Die wissenschaftlichen und technischen Arbeiten wurden während dieses sehr erfolgreichen Zeitraums in vollem Umfang durchgeführt. Die Saison endete am 1. März 2024 mit der Abreise der letzten Sommergäste und stellt somit offiziell den Beginn der 44. Überwinterung dar.

Auch die *Kohnen-Station* wurde in dieser Saison wieder geöffnet, da technische Arbeiten erforderlich waren so wie auch für wissenschaftliche Projekte Arbeiten beantragt worden waren. Nach einer zweiwöchigen Vorbereitungszeit machte sich das Team auf die 750 km lange Reise von der *Neumayer-Station III* zur *Kohnen-Station*. Nach einer 10-tägigen Reise wurde die *Kohnen-Station* am 3. Dezember 2023 erreicht und sofort mit den Vorbereitungen für die wissenschaftlichen Arbeiten begonnen. Während der 10-tägigen Traverse führten zwei mitreisende Wissenschaftler Messungen der Schneeakkumulation entlang der Route durch. Das 6-köpfige wissenschaftliche Team an der *Kohnen-Station* wurde am 19. Dezember 2023 mit der Ankunft des wissenschaftlichen PIs komplettiert. Nach einer erfolgreichen Saison wurde die *Kohnen-Station* am 20. Januar 2024 winterfest gemacht und das Traversenteam machte sich auf den Rückweg zur *Neumayer-Station III*, wo es am 25. Januar 2024 eintraf.

Die *Neumayer-Station III* wurde in dieser Saison von einem Charterschiff in enger Zusammenarbeit mit dem British Antarctic Survey (BAS) versorgt. Im Dezember und Januar fanden insgesamt zwei Schiffsbesuche statt.

SUMMARY AND ITINERARY

During the season 2023/2024, the restrictions imposed by the coronavirus pandemic were only in the background, but precautionary measures were still taken to prevent the virus from entering the station and spreading within it. The entire flight operation took place in close cooperation with the Norwegian Polar Institute (NPI) and White Desert. On NPI intercontinental flights in particular, special precautions were taken in the event of fellow travellers suffering from CoV-2. In general, the pandemic had only minimal impact on the planning and realisation of the season at *Neumayer Station III* and *Kohnen Station*, and fortunately *Neumayer Station III* once again remained free of SARS Co-V 2.

The season started with a slight delay on 8 November 2023 with the arrival of the first summer guests due to weather and technical restrictions on intercontinental air traffic. Scientific and technical work began immediately. The first station elevation had to be prepared and carried out, and the traverse to *Kohnen Station* had to be prepared. The scientific projects MARE, SPOT and SIBEAT began their measurements. Work also began on the construction of a new trench for the magnetics observatory, which is part of the geophysics observatory. The scientific and technical work was carried out in full during this very successful period. The 44th wintering officially began on 1 March 2024 with the departure of the last summer guests.

The *Kohnen Station* was also reopened during this season, as technical work was required and scientific projects had requested work. After a two-week preparation period, the team set off on the 750 km journey from *Neumayer Station III* to *Kohnen Station*. After a 10-day journey, the *Kohnen Station* was reached on 3 December 2023 and preparations for the scientific work began immediately. During the 10-day traverse, two scientists travelling with the team carried out measurements of snow accumulation along the traverse route. The 6-person scientific team at *Kohnen Station* was completed on 19 December 2023 with the arrival of the scientific PI. After a successful season, the *Kohnen Station* was left winterised on 20 January 2024 and the traverse team set off on the return journey to *Neumayer Station III*, where they arrived on 25 January 2024.

This season, *Neumayer Station III* was supplied by a charter vessel in close cooperation with the British Antarctic Survey (BAS). A total of two ship calls took place in December and January.

2. WEATHER CONDITIONS DURING ANT-LAND 2023/24 AT *NEUMAYER STATION III*

Pablo Conrat Fuentes DE.AWI

The weather situation at *Neumayer Station III* during ANT-Land 2023/24 (Fig. 2.1) showed some deviations from the climatology in terms of the basic meteorological parameters listed in Table 2.1. Temperatures were above average, whiteout occurrence below average, and wind speeds below or close to average.

In November the mean temperature of -4.2 °C was substantially above the long-term average and wind speeds were lower than usual despite three (short) storms. Air pressure was within the typical range. The above average temperatures can be attributed to the period of high temperatures and low diurnal variability mid of the month. The end of the month displayed the typical diurnal variability with night time temperatures of -25 °C. The storm around 13 November 2023 led to the first snow accumulation event of the season with almost 20 cm accumulated. December 2023 was also warmer than the climatology with a mean temperature of -2.3 °C. The wind was measured close to its long-term average at 7.3 m/s. Two storms at the beginning and mid of the month influenced this greatly. The occurrence of white-out was still below average but within the ±1 standard deviation range. January was marked by mostly calm conditions with occasional brief storms in the second half of the month. Temperatures remained above average with a monthly mean of -2.4 °C. Weather was more variable in February with several storms and snowfall events. This led to snow accumulation in the second half of the month. Temperature-wise the month laid well above the climatological average with -2.6 °C compared to -8.1 ± 1.5 °C. This came with an unusually late onset of sea ice formation.

Statistically, the parameters shown in Table 2.1 during ANT-Land 2023/24 are partly well outside of the one standard deviation range around their long term mean values. The pressure in November, the wind speeds in December and February, and white-out occurrence in November, December and February are close to the long-term averages.

Concerning snow accumulation (Fig. 2.1) there were two substantial and persistent snow accumulation events during ANT-Land 2023/24 in mid-November and the second half of February. There was a major technical issue with the snow height sensor which was resolved in the first half of November and a short interruption beginning of February due to maintenance work. The last valid reading before the longer outage was taken on 30 October 2023 reading 10.2 m. This is almost identical to the first reading after reactivation on 10 November 2023. Overall snow accumulation in 2023 was among the highest recorded at the site (1.27 m). The ongoing year started off with a below average accumulation record.

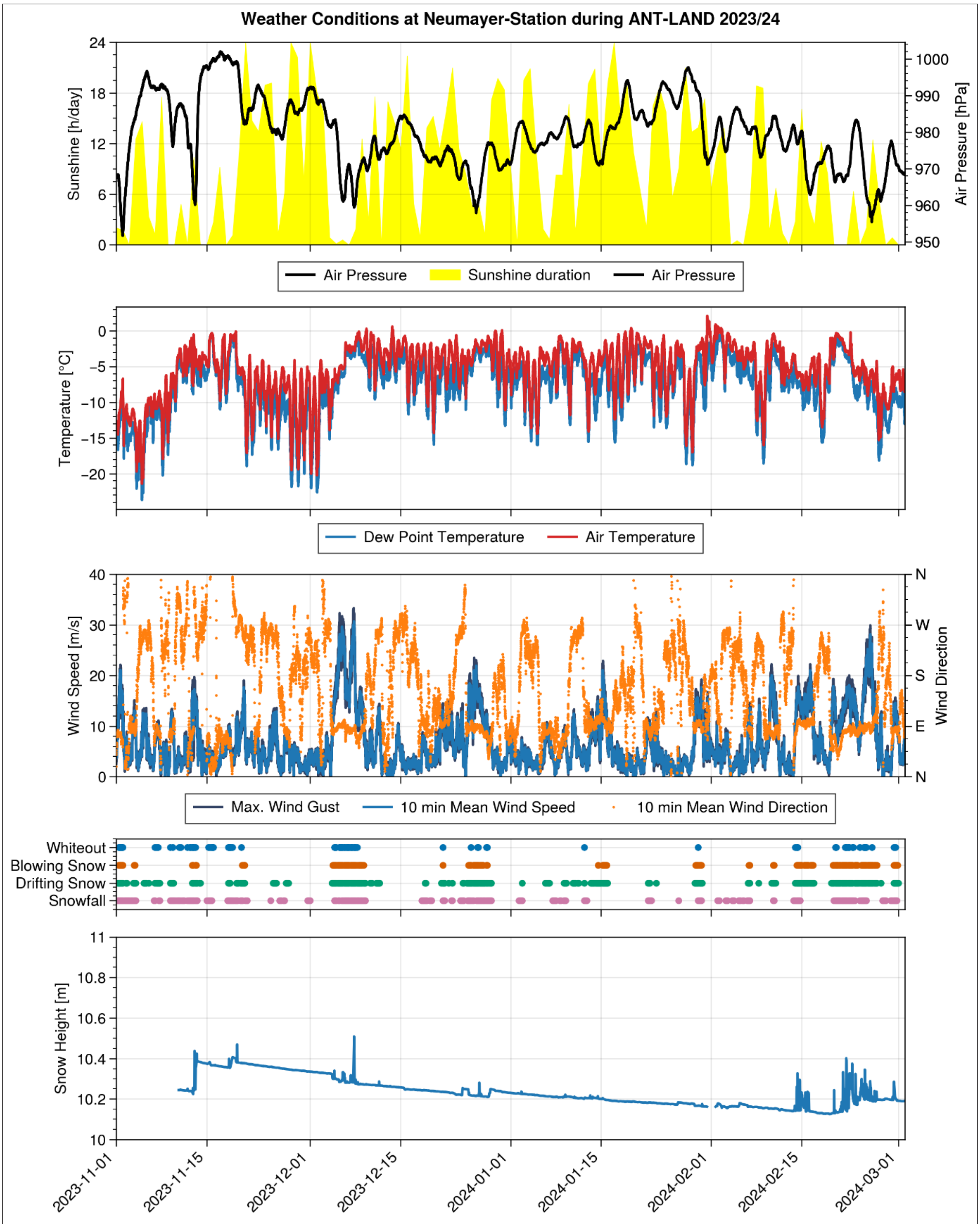

Fig. 2.1: Weather conditions at Neumayer Station III during ANT-Land 2023/24

Tab. 2.1: Monthly averages of meteorological parameters at *Neumayer Station III*. In parentheses are the long-term mean values for the time from 1981 (1992 for White-Out) to 2022, together with the standard deviation. All values are calculated from the 3 hourly synoptic observations. Note that at 3 UTC white-out was not observed, which biases the frequency of occurrence to too low values.

	Temperature	**Pressure**	**Wind Speed**	**White-out**
November 2023	-4.2 °C (-9.8 ± 1.4) °C	986.4 hPa (984.3 ± 4.6) hPa	5.2 m/s (9.4 ± 1.6) m/s	12,9% (23 ± 12) %
December 2023	-2.3 °C (-4.8 ± 0.8) °C	974.1 hPa (987.1 ± 5.7) hPa	7.4 m/s (7.3 ± 1.4) m/s	10.9% (17 ± 10) %
January 2024	-2.4 °C (-4.1 ± 1.0) °C	982.2 hPa (989.0 ± 4.2) hPa	4.8 m/s (6.6 ± 1.2) m/s	0.8% (12 ± 8) %
February 2024	-2.6 °C (-8.1 ± 1.5) °C	974.3 hPa (987.0 ± 3.6) hPa	7.8 m/s (7.6 ± 1.5) m/s	8,6% (14 ± 9) %

3. STATION OPERATIONS

Christine Wesche, Tim Heitland DE.AWI

The season started on 8 November 2023 with the arrival of the technical team and the first scientists. The weather was sufficiently good for work to begin immediately. As in every season, work began with the first station elevation, which was completed on schedule. Between the second station elevation, further necessary outdoor work was carried out and scientific projects were supported to the best of our ability.

The traverse to *Kohnen Station* was quickly prepared and started on 23 November 2023, with two scientists on board who carried out the snow accumulation measurements as part of the Kottaspegel project.

Due to the necessary renovation of the magnetic observatory, a 50-metre-long balloon trench was built this season to house the geophysical measuring instruments in future. The construction work took place to the south of the existing trench and was completed with the departure of the technicians. In the second half of the season, the remaining work and the installation of the measuring equipment were carried out.

The 43rd wintering team officially handed over the station tasks to the 44th wintering team on 13 January 2024. This consists of 12 team members, as a three-person media team will be filming the nearby emperor penguin colony.

After completing the work at *Kohnen Station*, the traverse team made their way back to *Neumayer Station III* on 20 January 2024, which they reached on 25 January 2024.

Neumayer Station III celebrated its 15th birthday on 20 February 2024.

The season ended successfully with the departure of the last summer guests on 1 March 2024.

3.1 Technical Operations at *Neumayer Station III*

Thomas Matz and Peter Köhler (Logistics) DE.AWI

All preparatory work necessary for the start of the season was carried out by the wintering team in October. This concerns the preparation of the 1,500 m long snow runway for the Basler and Twin Otter ski-equipped aircraft, but also the provision of storage and functional containers that were transported from the winter storage to the station for the summer operation.

After the technical team also arrived at *Neumayer Station III* works started immediately. Like every season two station elevations were successfully completed as well as many of the planned maintenance tasks. The outer platforms were routinely raised.

The technical summer staff was heavily involved in all ship discharge operations and performed the container stowage work. They assisted with cargo transports of the aircraft and in the scientific area. Various service works to enable the scientific programs were done by the technical team.

As part of the medium-term energy modernisation of the station's technical equipment and installations, the installation of the photovoltaic system was fully completed, the operating conditions of the wind turbine under ice-forming ambient conditions were examined and the installation conditions for the future battery storage system were assessed.

A grid analyser was installed to support the current planning for the battery storage system. This device is analysed constantly throughout the year remotely by an expert in measurement technology. As a result, statements can be made about the condition of the stations electrical grid and possible grid filter systems can be designed to eliminate existing and future deviations from the standard.

Station maintenance works and repairs

In the months of November and December two station elevations could be carried out as planned and without complications. The 30th station elevation started on 10 November 2023 and was finished after twelve days. As the station was lifted twice, the 31st station elevation started on 2 December 2023 and was completed on 18 December 2023. In total, the *Neumayer Station III* was lifted nearly 2.3 m (without settling in the snow), to compensate for the annual snow accumulation around the station.

Extensive maintenance work was carried out as planned. A diesel engine in the energy center was replaced for maintenance in Germany. Furthermore, a power generator was replaced for the first time, which is also being serviced. The vibration dampers of the motors and generators were replaced in all combined heat and power units.

A new grating floor was installed in the tween deck in the northern area. In future, heavy-duty racks are to be installed in this area for the electrical components of other wind turbines. Furthermore, a grating floor was installed in the northern area on deck U1, on which large cable mounts were installed. The cable lengths of all the wind turbine cables and future systems required for the station elevation are stored on these mountings.

After years of use, a start was made on renovating the corridors and bedrooms. In the second half of the season, extensive painting work was carried out in these warm areas by an external company.

Further measuring equipment from the meteorological observatory was installed on the roof of the station in the southern area, including a heavy cloud height radar. The technical team carried this out with the help of the telescopic crane. A roof hatch was replaced with a new one with a window. A lidar was installed underneath in the warm area of the station. The electrical supply and communication lines were installed as previously planned. The measuring systems for weather observation were put into operation.

A small section of the wooden flooring on deck 0 of the station was renewed. There are plans to replace further areas of the worn wooden flooring for the coming summer season.

In the storage area on deck U1, the storage of technical material for the station and vehicles has begun to be revised. New storage cabinets with drawers were installed. Inventories were carried out. Further areas are to be expanded in the coming summer season using a drawer system. This will improve the storage and overview.

The elevator of the station was serviced and repaired by a mechanic of the manufacturing company at the beginning of the season.

The test PV system was fully connected to the grid with the extent of the PV modules now installed on the east-, north- and west side of the station building. The sensors for evaluating the mechanical loads on the PV modules and the energetic yield have been fully installed. Remote evaluation of data in Germany is made possible. Three different types of PV-modules have been mounted including solid ones as well as flexible ones.

A grid analyser was installed to support the current planning for the battery storage system. This device is analysed constantly throughout the year remotely by an expert in measurement technology. As a result, statements can be made about the condition of the stations electrical grid and possible grid filter systems can be designed to eliminate existing and future deviations from the standard.

Regular inspection of the operational safety of the station

The two-yearly inspection of all technical equipment in the station and the partial inspection of the station structure by an external DNV inspector took place on a regular basis. No serious defects were found.

Actions in the terrain, airfield and routes

Grounds maintenance work was carried out around the station throughout the summer season. Snowdrifts on the outer facilities were removed.

Several times during the season, the 1,500 m long airfield and the taxiway were groomed. The routes to the surrounding scientific measurement facilities such as the Single Penguin Observation and Tracking (SPOT) observatory and the Perennial Acoustic Observatory in the Antarctic Ocean (PALAOA) as well as to the winter storage facility were prepared.

Scientific/technical outdoor facilities

The air chemistry observatory, the platform of the TROPOS (Leibniz Institute for Tropospheric Research) laboratory container and the Radom (satellite link) had to be elevated.

The TROPOS project with the one laboratory container on the platform was completed. The container was dismantled and loaded onto sleds for a return shipment to Germany by ship.

The measuring fields of the infrasound array could also be elevated by the technical team and maintained by the personnel of the Federal Institute for Geosciences and Natural Resources (BGR).

The New Magnetic Observatory

After the test trench, built years ago for testing purposes, was closed at the beginning of the current season, a new observatory building was erected next to the Old Magnetic Observatory.

The New Magnetic Observatory is now housed in a 60-metre-long ice vault 7 metres below the snow surface. The structure was built by external snow construction experts and completed, ready for use, by the *Neumayer Station III* technical team.

The New Vertical Axis Wind Turbine (VAWT)

The new F144-50 wind turbine was tested intensively during the last winter. At the end of the wintering period, a generator damage occurred that could not be repaired either remotely or by the manufacturer’s experts at the station. The turbine was dismantled from the mast and sent to the manufacturer in Belgium.

In preparation for the installation of the repaired turbine, the mast of the F144-50 was raised to the new snow height using an elevation module, as planned in the design.

Number and size of storage facilities at *Neumayer Station III*

An inventory was carried out of all storage containers in order to reassess the stock of technical and scientific materials and to return items that are no longer required. These are to be returned in the coming season.

At the end of the summer season, all storage containers were moved to winter storage. This camp has now been moved further west, away from the ice edge. The heavy tank containers in particular were placed on snow hills to make them easier to tow by the Pistenbullies.

IT and communication

The satellite system for data communication and telephony to Germany has already been in use for many years and is to be replaced by modern technology in the coming years.

During the summer season, 2 new STARLINK systems were initially only tested for Wi-Fi. Transfer rates of up to 250 Mbit were reached. A significant improvement on the old system.

The STARLINK system is to be integrated into the IT station network in the coming summer season to replace the old system in future.

Extensive routine work was carried out in the station's IT and communications area.

Vehicle engineering

For the Pistenbully vehicles, again a mechanic from the manufacturer Kässbohrer was at *Neumayer Station III* during the entire season. The 18 vehicles of the type "300 Polar" were extensively maintained with the support of the technical team. Various modifications and conversions were carried out on the vehicles and cranes. The crane on the PB35 was replaced with one that can also accommodate a man basket. The station vehicle with crane is also intended as a reserve for the cherry picker if it should break down. One vehicle, the PB25, which was damaged heavily in the hydraulic system in season 2022/23, was transported by ship to Germany as planned in order to have it repaired by the manufacturer. The PB28 had an engine failure towards the end of the summer season, so it had to be replaced with a spare engine. The vehicle is ready to drive again.

Repair and maintenance work was carried out on the defective Arctic Truck vehicles by a mechanic from the Islandic Manufacturer early in the season. As part of the maintenance work, a central tyre pressure management system was installed. This enables significantly improved traction control and improves the grip in difficult snow conditions. Both vehicles were ready for use again for upcoming scientific campaigns.

Several components of the car sledge, intended to improve the utility value and range of the Arctic Truck vehicles, was modified by the manufacturer beforehand the season and installed at the station. The sledge is now available for future field campaigns.

All heavy-duty 20 ft sleds were maintained and repaired where necessary.

The snow mobiles were serviced according to the specifications of the manufacturer, and repairs were performed.

Various repairs, especially smaller wood and welding works, were performed at the sledges for the snow mobiles to keep them ready for use, as already happened in the past season. In case of extensive damages, the sledges will be exchanged.

3.2 Technical Operations at *Kohnen Station*

Christine Wesche, Hendrik Klawitter DE.AWI

After the arrival of the supply traverse on 3 December 2023, the station was opened and put into operation according to protocol. Planned technical work was carried out during the season.

Clearing out and closing the trench

Due to a shortage of empty containers, re-stowing work was necessary at *Kohnen Station* to generate space for the items from the Trench. Parts of the scientific equipment stored in the trench were prepared for return transport in the 2024/25 season. For the next season, it must be ensured that sufficient empty containers are available to completely clear out the trench.

Extension of the borehole

The extension of the borehole to the surface had to be postponed due to the lack of storage space for the items from the trench. Access to the Locj is no longer possible without protection.

Work carried out in the trench

- Shelves in the scientific trench were dismantled and, after consultation, partially transported to *Neumayer Station III* for further use
- Parts of the scientific equipment were removed from both the scientific trench and the intermediate trench (second level of the trench) and stowed in the available containers.
- The borehole cell was dismantled and is also located in this container. The additional thermal cell has not yet been removed
- The borehole has been extended into the scientific trench
- A product group inventory of the food stored at *Kohnen Station* was carried out.
- A pre-sorting of the cargoes that are to remain at *Kohnen Station* and possibly then be stored in a container in the winter storage facility there

Further logistics work at *Kohnen Station*

- Replacement of the water system with copper pipes
- Carrying out the inventory of the winter storage facility at the *Kohnen Station*
- Repair of the aeronautical radio system at *Kohnen Station*
- Moving the station clear, as it was not necessary to raise the station and was also not possible due to the lack of a replacement hydraulic cylinder
- Raising the winter storage facility
- Repair of the station generator after fault analysis

- Airfield work over the entire season
- Raising the masts for the power distributors outside the station

3.3 General Flight Operations

Christine Wesche DE.AWI

In the 2023/24 season, the NPI's intercontinental flights to *Troll Station* were mainly used. A major advantage here is that some personnel and freight can be carried from Bremen. In total, six of the seven flights offered to *Troll Station* were used to transport 83 people to Antarctica and 74 people from Antarctica. In addition, a small number of participants were transported on the intercontinental flights between Cape Town and Wolfs Fang operated by White Desert.

The feeder flights between *Troll Station* and Wolfs Fang Runway were operated by White Desert. In addition to the feeder flights to the stations, logistics flights were operated between *Neumayer Station III* and *Kohnen Station* to transport personnel and freight.

3.4 Ship Operations

Christine Wesche DE.AWI

Due to *Polarstern's* cruise planning and the resulting cancellation of a ship call in Atka Bay, *Neumayer Station III* was supplied by a Royal Arctic Lines charter vessel in the 2023/24 season. The ship *Malik Arctica* was used for the complete supply and disposal in close cooperation with BAS.

Malik Arctica reached the Atka Bay region on 20 December 2023. The unloading operation started on 21 December 2023. On 22 December 2023, the last cargo containers were taken over and some of the fuel was bunkered. On the afternoon of 22 December 2023, the ship set off for the British *Halley VI station* to carry out the supply and disposal operations there. The operation at the *Halley VI station* lasted from 28 December 2023 to 5 January 2024. *Malik Arctica* was back in the Atka Bay region on 10 January 2024 and the loading work began on 11 January 2024. After loading the ship, all the remaining empty tank containers were loaded in order to bunker them on board. This took 1.5 days and the tank containers were unloaded again on 13 January 2024 and the supply of *Neumayer Station III* was completed.

4. *NEUMAYER STATION III*

4.1 Yearly Maintenance of the Meteorological Observatory *Neumayer*

Sebastian Berger, Holger Schmithüsen, Jürgen Gräser, Markus Rex, Lukas Muser, Pablo Conrat Fuentes

DE.AWI

Grant-No. AWI_ANT_1

Outline

The Meteorological Observatory *Neumayer* is an ongoing project that is dedicated to climate monitoring. The observatory is permanently attended by a meteorologist that changes with the station's crew every year. During austral summer major maintenance work is performed.

Objectives

The Meteorological Observatory *Neumayer* is dedicated to monitor essential climate variables in high quality. The station is part of various international networks, such as the Baseline Surface Radiation Network (BSRN), the Network for the Detection of Atmospheric Composition Change (NDACC) and the GCOS Reference Upper Air Network (GRUAN). In order to guarantee high quality time series, the observatory is normally serviced once per year by permanent staff. All instrumentation and operating procedures are checked, and the yearly changing new staff is trained on site.

Fieldwork

In the field season 2023/24 instrumentation and operating procedures of the following atmospheric observations were handed over from one meteorologist to the next:

- 3-hourly synoptic observations
- daily upper-air soundings
- weekly ozone soundings
- continuous surface radiation and meteorological mast measurements
- single column precipitation radar

During this season all planned maintenance tasks were carried out. Three new remote sensing instruments were installed on the station roof: a wind lidar, a cloud radar, and a micro pulse cloud- and aerosol lidar. The foundations for the new meteorological measurement field to be constructed in ANT-Land 2024/25 were laid.

Concerning automatic weather stations (AWS) the following was carried out:

- AWS Søråsen: serviced as planned
- AWS Halfvarryggen: serviced as planned
- AWS Kohnen: serviced as planned
- AWS Filchner: station was dismantled by BAS

Within DROMLAN, the forecasting support of the Meteorological Observatory of the *Neumayer Station III* changed due to the change of DROMLAN forecasting provider from the German Weather Service to StormGeo. General weather observations and if needed landing weather observations at *Neumayer Station III* for the DROMLAN community were provided as usual.

Preliminary (expected) results

The long-term monitoring of climate variables is to be continued for another year. The existing measurements are complemented with those from three new remote sensing instruments. This is expected to improve the understanding of Antarctic clouds and aerosols.

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. Furthermore, data is supplied to various international networks, mainly those organised within the World Meteorological Organisation (WMO).

This expedition was supported by the Helmholtz Research Programme "Changing Earth–Sustaining our Future" Topic 1, Subtopic 1 and 2; Topic 2, Subtopic 1, 2, and 3.

In all publications based on this expedition, the **Grant No. AWI_ANT_1** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

4.2 Long-term Air Chemistry Observations at *Neumayer Station III*

Rolf Weller (not in the field), Zsófia Juranyi, Olaf Eisen, Tim Bösch, Nellie Wullenwebe — DE.AWI

Grant-No. AWI_ANT_2

Objectives

The atmosphere above Antarctica is the cleanest part of the Earth's troposphere and can be employed as a large clean air laboratory to study natural conditions comparable to atmospheric processes prevailed elsewhere in preindustrial times. Therefore, Antarctica offers an outstanding place to study the background composition and the natural biogeochemical cycling of aerosol. Nowadays, minor anthropogenic emissions arising from fossil fuel combustion during research and tourism activities may be considered as well.

The main task of the Neumayer air chemistry observatory is to provide continuous, year-round data records for important gaseous and particulate trace components of the coastal Antarctic troposphere. Such long-term atmospheric observations are mandatory to understand the present Southern Ocean climate system and identify its major drivers. Another aspect of studying atmospheric chemistry in Antarctica is the need to interpret records of archived trace compounds in ice cores and their relation to environmental conditions. Provided the present atmospheric chemistry and the physical-chemical processes of air to snow transfer are well characterized, we can use such records to derive information about climate, composition and chemistry of the paleo-atmosphere. The Neumayer air chemistry observatory is one of only very few comparable clean air laboratories operated in Antarctica partly established since 1983. There is a strong scientific cooperation with the meteorological observatory. Both observatories are part of the GAW (Global Atmosphere Watch) global station network. On site, one of the nine over-winterer, usually an air-chemist or meteorologist is responsible for the observatory.

Part I Atmospheric measurements: Aerosol and trace gases

Fieldwork

We completed all necessary work to run the observatory for another year without cutback. Concerning technical issues, we send back the MAX-DOAS controller (IUP-Heidelberg, PI: Udo Frieß) and our Laser Aerosol Spectrometer LAS 3340 for repair and maintenance. In addition, we exchanged a broken CF-card at the aethalometer AE33. In December 2023, the Air Chemistry Observatory was jacked up. This procedure and the set-up of the new Geophysical Observatory 150 m south-west to the Air Chemistry Observatory entailed occasional interruptions of all measurements for several hours. Finally, the operation of the observatory was taken over by the new air chemistry over-winterer Tim Bösch, arriving at *Neumayer Station III* on 20 December 2023. Tim took on the responsibility for the Air Chemistry Observatory on-site thanks to the competent and dedicated instruction by Nellie Wullenweber. Due to upcoming retirement, Zsófia Juranyi succeeded Rolf Weller in managing the Air Chemistry Observatory. She arrived in February at *Neumayer Station III* assisting Tim Bösch in maintenance and calibration work.

The project **VACCINE** (*Variation in Antarctic cloud condensation nuclei (CCN) and ice nucleating particle (INP) concentrations at NEumayer Station III*) managed by the Institute for Tropospheric Research (TROPOS, Leipzig. PI: Silvia Henning) in cooperation with the AWI started in December 2019 and will be continued for another over wintering period. We will link these data with regional meteorology and the chemical composition of the sampled aerosol particles for identifying sources of INP and CCN. The scientific background of this project addresses the fact that Polar Regions have a strong global impact on climate conditions but the crucial aerosol – cloud – climate interaction is poorly understood, especially in the Southern Ocean realm. For further information and first, preliminary results, see separate contribution by Silvia Henning (Chapter 4.14). VACCINE strongly supported the TROPOS **COALA** project (*Continuous Observations of Aerosol-cLoud interaction in Antarctica*, PI: Ronny Engelmann, project over-winterer: Martin Radenz). The scientific focus of COALA was on profiling observations of water vapor, aerosol, clouds, and precipitation (see separate contribution by Martin Radenz, Chapter 4.20).

Preliminary (expected) results

Meanwhile, we completed an in-depth evaluation and validation of the established long-term observations (LTO). Like in previous years, the outcome of the completed analysis revealed the high quality of the measured time series comprising

- condensation particle (CP) concentration
- aerosol size distribution
- black carbon (BC) concentration
- aerosol scattering coefficients
- surface ozone concentration

with generally negligible data gaps, occasionally caused by short temporary instrumental problems or routine service operations. The following graphs show exemplarily the obtained validated time series of these parameters for the year 2023. Further information on metadata can be found in data sets archived in PANGAEA (e.g.: https://doi.pangaea.de/10.1594/PANGAEA.945533)

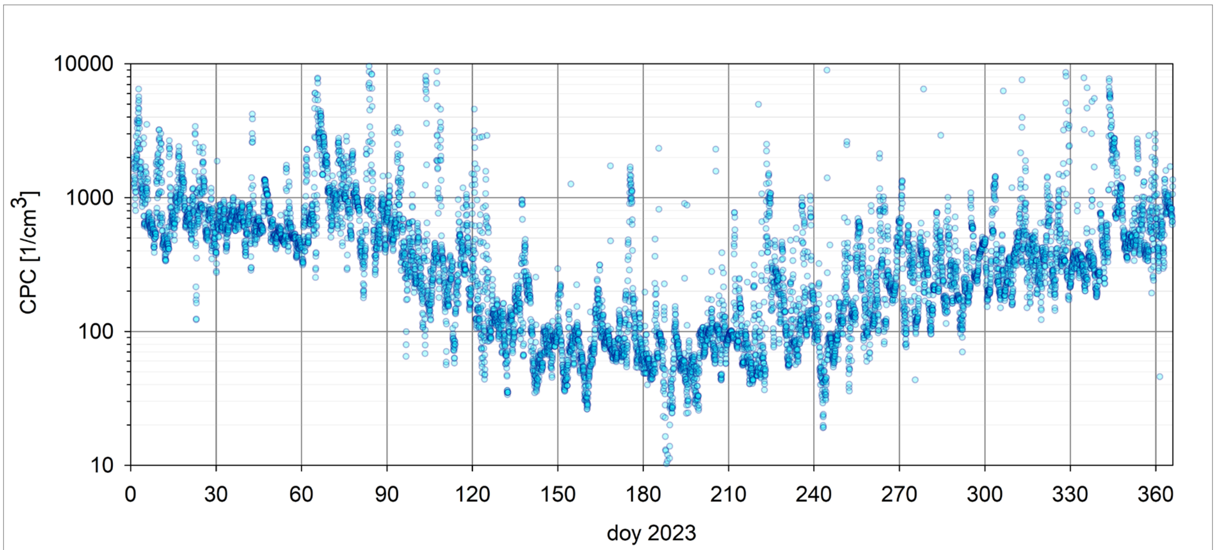

Fig. 4.2.1: Time series of the CP concentrations for the year 2023 measured with a TSI type CPC 3775 condensation particle counter. This instrument detects all particles above the lower 50% cut-off diameter of 4 nm (doy 2023 = day of the year 2023).

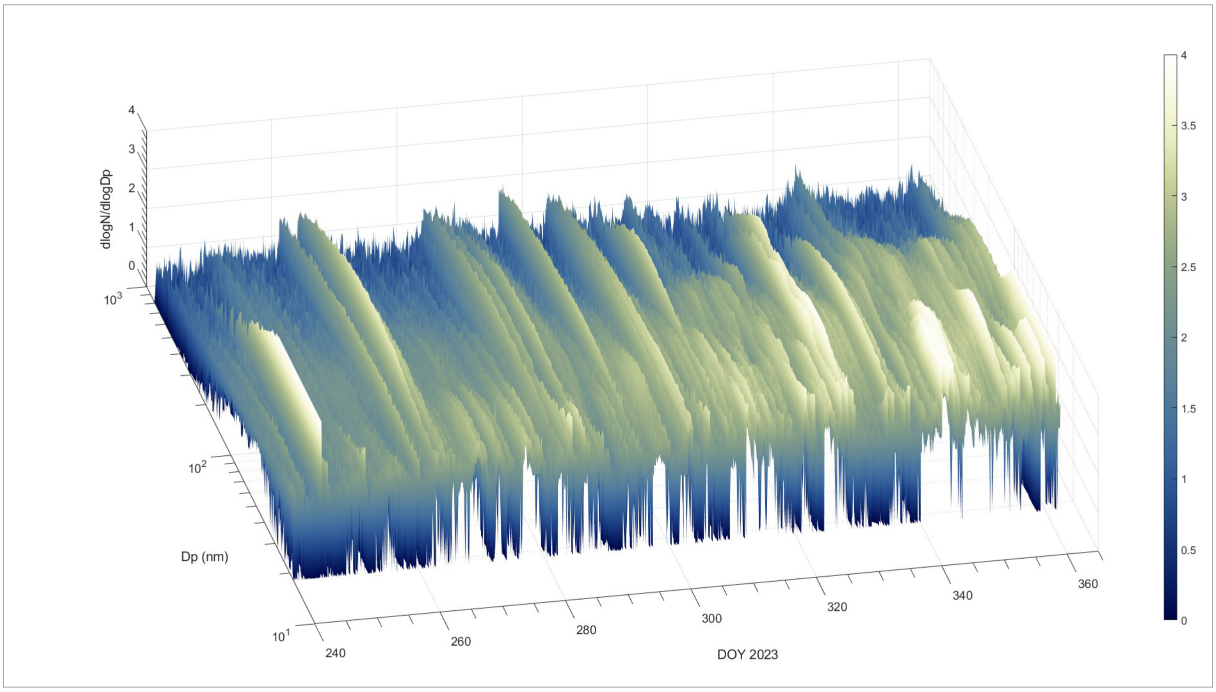

Fig. 4.2.2: 3D contour plot of the particle size distribution dN/dlogD_p (cm^{-3}) with a dlogN/dlogDp (cm^{-3}) scale as z-axis (logarithmic colour scale to the right; D_p = particle diameter). The plot shows the size distribution between 16 nm and 820 nm measured by a Scanning Mobility Particle Sizer (SMPS Model 3936, TSI). Presented data are one-hour averages based on the originally size distribution spectra taken in 10-minute intervals.

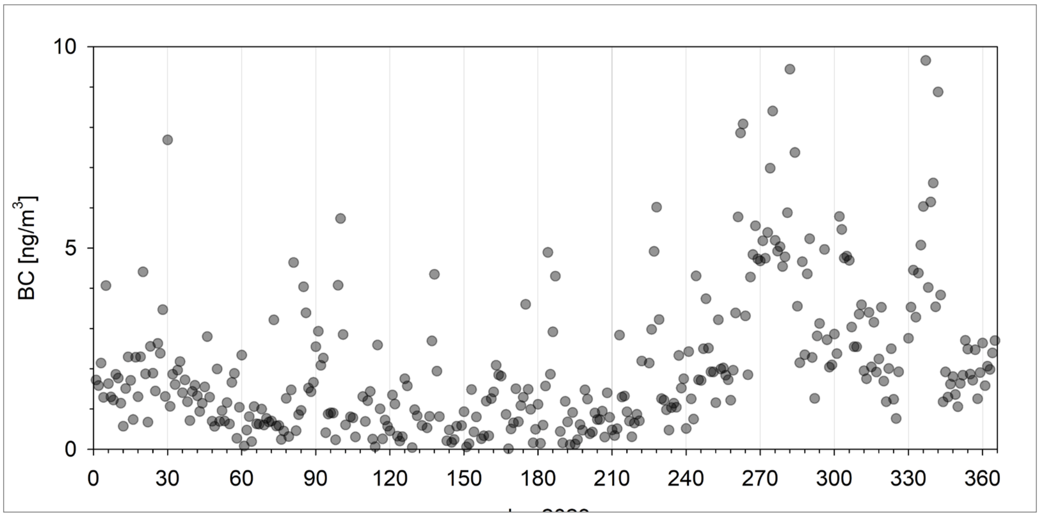

Fig. 4.2.3: Time series of BC concentrations measured at Neumayer with a so-called Multi Angle Absorption Photometer (MAAP, Thermo). Note that the BC data shown were rigorously cleaned from local contamination, which is feasible considering wind direction and particle concentrations. Here, the presented data are daily means based on the originally data taken in 1-minute intervals.

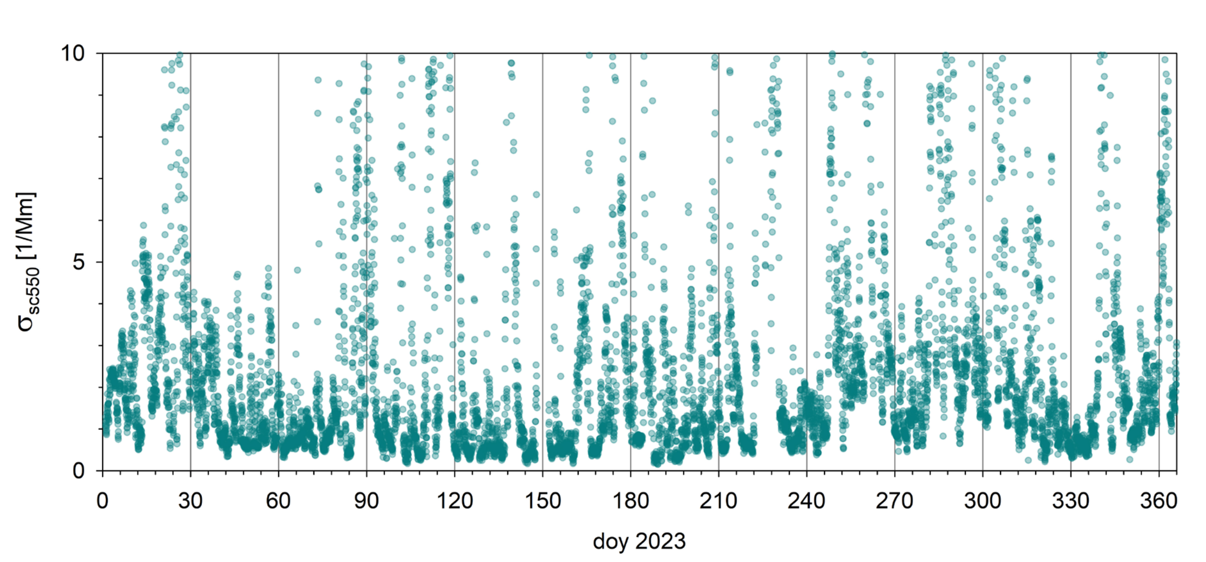

Fig. 4.2.4: Time series of aerosol scattering coefficient at 550 nm, $\sigma_{sp}(550)$, measured with an integrating nephelometer (TSI Model 3563). Presented data are one-hour averages based on originally one-minute data.

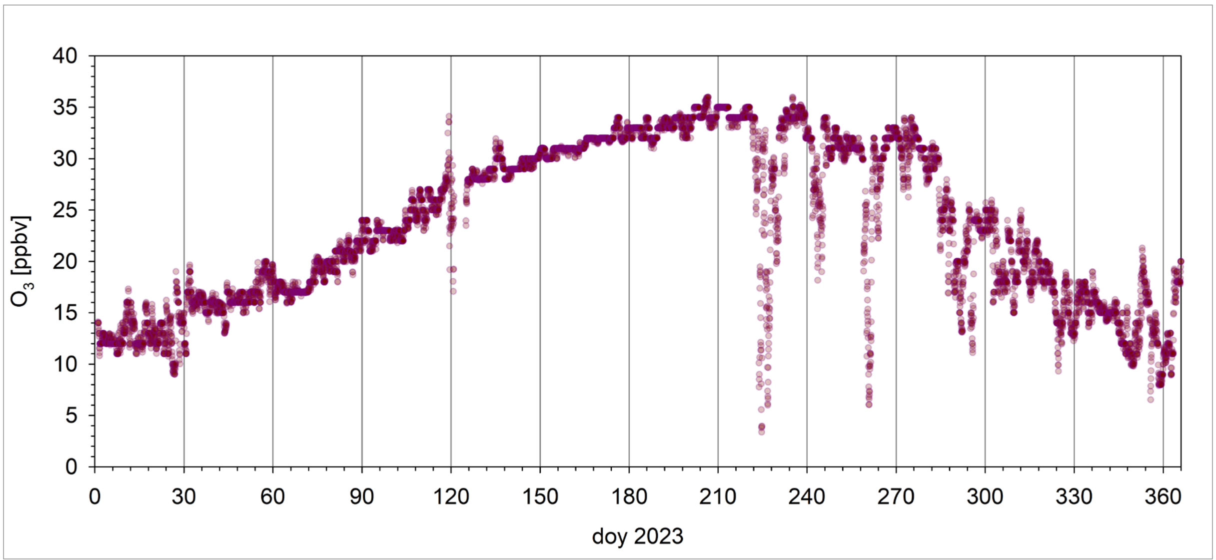

Fig. 4.2.5: Measured surface ozone time series (ppbv: parts per billion by volume) at Neumayer for the year 2023 (measured with an UV photometer O3 41M, Environnement). Presented data are one-hour averages based on originally one-minute data.

Part II Snow accumulation and glaciological studies

Fieldwork

In order to put impurity content retrieved in snow, firn and ice cores into the glaciological context, it is important to have a reliable record of the surface mass balance. To this end the long-time observation of snow accumulation measurement at stake fields were continued and conducted bi-weekly at the Pegelfeld Süd and weekly at the Pegelfeld Spuso III. In addition, monthly measurements of density in snow pits were performed near the SpusoIII.

Preliminary (expected) results

With the completion of the year 2023 the snow surface accumulation measurements at the Pegelfeld Süd completed 32 years of measurement. After the two years 2020 and 2021 with considerably higher than normal snow accumulation at the surface, and the rather average year 2022 with an accumulation of roughly 1 m/a, 2023 showed again high a record year with a total of 164 cm of annual accumulation at the Pegelfeld Süd and 156 cm at Pegelfeld Spuso, the second highest accumulation value in the recorded history (Fig. 4.2.6 accumulation). Currently, a MSc thesis is in progress to evaluate the whole record in terms of interannual variations, seasonal shifts and relation to large-scale circulation and climate change.

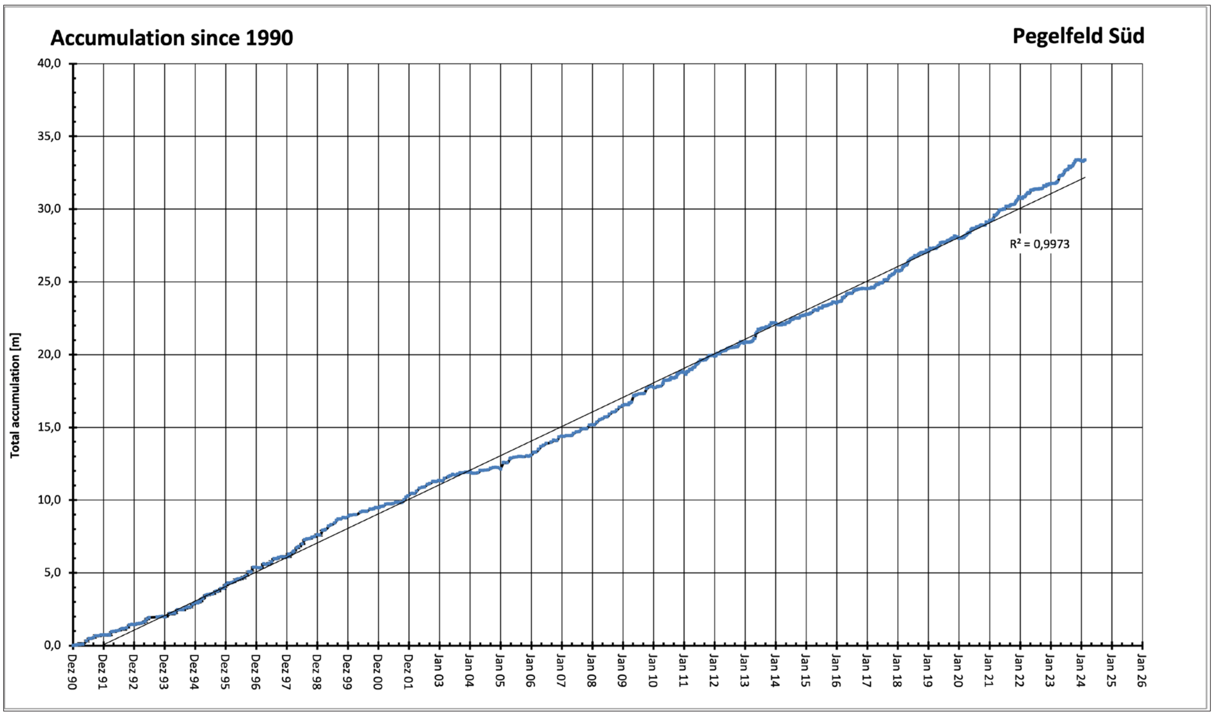

Fig. 4.2.6: Total accumulation values at Pegelfeld Süd (mean value of stake farm)

Data management

Part I Atmospheric measurements: Aerosol and trace gases

In the meanwhile, we archived the long-term observations after thorough evaluation in the respecting repositories.

- PANGAEA: The submitted data are available under:
  https://doi.pangaea.de/10.1594/PANGAEA.961235,
  https://doi.pangaea.de/10.1594/PANGAEA.965553,
  https://doi.pangaea.de/10.1594/PANGAEA.965481,
  https://doi.pangaea.de/10.1594/PANGAEA.965502,
  https://doi.pangaea.de/10.1594/PANGAEA.965468,
  https://doi.pangaea.de/10.1594/PANGAEA.965466.
- GAW: The submitted data are available at NILU/EBAS under:
  https://ebas-data.nilu.no/Default.aspx (note: accept policies, select "Germany" – "Neumayer" and desired data).

Part II Snow accumulation and glaciological studies

The semi-automatic workflow has been implemented to incorporate the metadata of newly acquired density measurements directly into registry.o2a-data.de (formerly sensor.awi.de).

To homogenize the data accessibility for the glaciological measurements, a Jupyter notebook based on Python has been developed to make the data easily readable (i.e. convert from the xls format to ASCII), formatted in the same way and include standard graphic displays. The notebook is currently being extended to included also the accumulation values before publication on github and HGF's gitlab.

The data will be managed in the same way as was done for other data sets: after data processing and quality checking, the corrected data and derived products will be made available to the community via PANGAEA:

- Raw glaciological observations from AWI's quasi-long-term observatory glaciology have already partly been stored in PANGAEA
- The surface snow density record in PANGEA 10.1594/PANGAEA.963323 has been extended and is currently being updated with the 2023 values.

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 1, Subtopic 2 and Topic 2, Subtopic 3.

In all publications based on this expedition, the **Grant No. AWI_ANT_2** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

4.3 The Geophysical Observatory

Jölund Asseng[1], Tanja Fromm[1] (not in the field), Nora Schoeder[1], Felix Strobel[1], Amelie Nüsse[1], Andrey Jakovlev[1], Vera Schlindwein[1] (not in the field), Jürgen Matzka[2] (not in the field)

[1]DE.AWI
[2]DE.GFZ

Grant-No. AWI_ANT_3

Objectives

The Geophysical Observatory at *Neumayer Station III* allows long term observations with different geophysical instruments and contributes to worldwide networks collecting geophysical data for the scientific community. Due to its location at the coast line of Antarctica, the observatory provides valuable data points for geophysical networks with sparse data coverage in the southern hemisphere where the spacing between data points easily becomes hundreds or thousands of kilometers. The closest stations with winter capacities are *SANAE IV* (230 km), *TROLL* (420 km) and *Novolazarevskaya* (750 km). In contrast to datasets acquired as part of short-term projects, the observatory provides continuous, long-term time series that allow revealing slow and small changes otherwise undetectable.

The observatory operates instruments for the following disciplines or tasks: a) seismology (Fromm et al. 2018; Eckstaller et al. 2006), b) geomagnetism (GFZ 2016) and c) GNSS recordings.

a) Seismology

The primary objective of the seismographic observations at *Neumayer Station III* is to complement the worldwide network of seismographic monitoring stations in the southern hemisphere. Within Antarctica only eleven broad-band seismometers provide data in real time, three of them are operated by AWI. A focus of the AWI network is the detection of local and regional earthquakes within Antarctica. Recently, interest in seismological data from ice covered regions has drastically increased, as seismometers also record cryogenic events giving information about processes of ice dynamics (e.g. Aster et al. 2018).

The local seismographic network at *Neumayer Station III* comprises the station VNA1 near *Neumayer Station III* itself and two remote stations VNA2 and VNA3 on the ice rises Halvfarryggen and Søråsen, respectively. In addition, the seismic broad-band station VNA2 is part of a small aperture array with 15 vertical seismometers placed on three concentric rings in a total diameter of almost 2 km. Other unattended seismographic broadband stations (KOHN, WEI, SVEA, UPST, DS4, NVL) record data at logistically feasible locations (see Fig. 4.3.1).

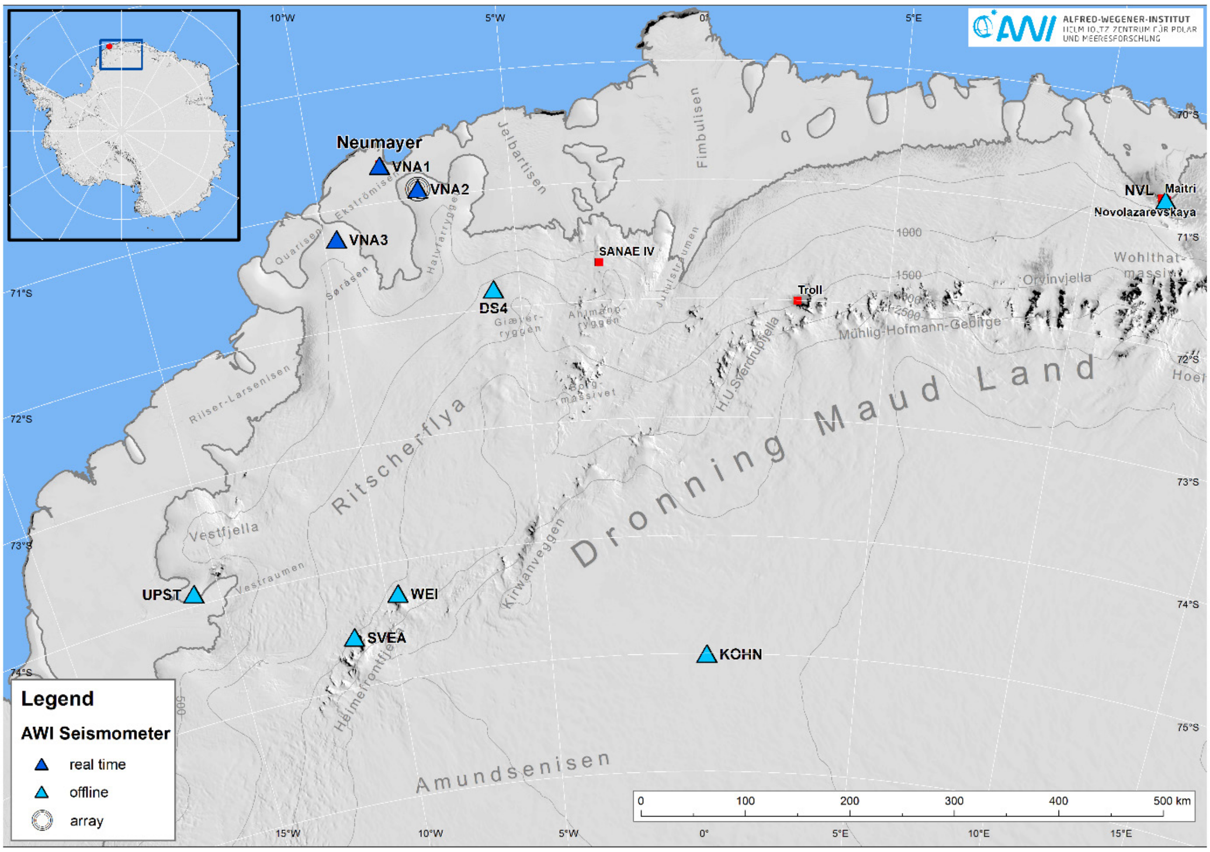

Fig. 4.3.1: Map showing the active seismometer stations in Dronning Maud Land of the AWI network during 2023

b) Geomagnetism

The Geomagnetic Observatory at *Neumayer Station III* was built in 2009 and currently hosts a GSM-19 Overhauser proton-magnetometer which records the earth magnetic field's total intensity, a 3-component fluxgate sensor recording directional changes (FGE) and high frequency induction coils for ionosphere research (MICA-S, see Chapter 4.21). Every 3-4 days, declination and inclination of the geomagnetic field is measured manually using a non-magnetic theodolite with a single-axis fluxgate sensor mounted on the telescope. For declination measurements, the knowledge of the geographic north direction is necessary. Since there is no stable reference for geographic north it has to be determined periodically by a gyro compass. Since 2014 the observatory is a certified member of the INTERMAGNET organisation guaranteeing quality and standard specifications for measuring, recording and exchanging data. It is one of only five INTERMAGNET observatories in Antarctica and the only one on an ice shelf.

c) GNSS recordings

We continuously record GNSS data since the beginning of July 2012 with a dual-band receiver situated on the roof of *Neumayer Station III*. At first, we used an Ashtech Z-12 receiver until June 2020. Since February 2020, a Novatel PwrPak7 is installed in combination with the VP6235 VeraPhase dual band GNSS antenna. GNSS data provides valuable information for higher atmospheric research and reveal characteristics of the Ekström Ice Shelf dynamics. During the winter of 2021 we increased the sample rate of the receiver to 50 Hz and added support for GLONASS, Galileo and Beidou.

Fieldwork

In summer season 2023/24 AWI seismometer stations VNA2, VNA3, DS4, WEI and *Kohn* were visited for maintenance and data collection. At *Kohn Station*, the sensor has been moved from the former drilling trench to a separate snow pit. The seismographic station NVL at the Russian station *Novolazarevskaya* is currently not accessible.

The geomagnetic fieldwork consisted of taking manual theodolite measurements of the declination and inclination of the magnetic field every three days and gyro measurements for the determination of geographic North on a monthly basis.

Furthermore, a completely new magnetic observatory has been built and equipped during the season and started operation at the end of the season. It will run this year parallel to the old observatory. It is planned to stop operation and dismantle the old observatory in the coming summer season. The destruction of the roof by a big snow load in nearly 20 m depth and some technical changes made the new construction unavoidable.

Similar to the old magnetic observatory, the new observatory hosts a GSM-90 Overhauser proton-magnetometer, a 3-component fluxgate sensor (FGE) and a non-magnetic theodolite with a single-axis fluxgate sensor mounted on the telescope. The geographic north reference will be determined periodically by a new gyro compass. Additionally, a second 3-component fluxgate sensor (GEOMAG 02) is installed. The length of the observatory trench is 62 m. This enables a greater distance between sensors and magnetic parts and thus guarantees a high quality of magnetic measurements and angle determinations for declination measurements.

The available space in the trench was also used to install two 3-component broad-band seismometers to substitute the seismometer in the old observatory in the future.

At the snow pit of MICAS-S station the entrance was raised to maintain accessibility.

1. A total of 6,932 earthquakes were located in the year 2023. 2,173 of these earthquakes were associated with earthquakes listed in international catalogues. In addition, 4,759 earthquakes were located by AWI (Fig. 4.3.2).

2. 4,173 earthquakes have been detected in and around Antarctica (Fig. 4.3.3). 3,164 of these earthquakes were recorded in the South Sandwich region.

3. During the entire year, there was a high focus on local earthquakes and icequakes since these can only be detected by local seismometers due to their lower magnitude. Nevertheless, they can teach us a lot about ice dynamics of the Ekström Ice Shelf. In 2023, 571 ice- and earthquakes have been recorded by the *Neumayer* Observatory. Figure 4.3.4 shows the amount of Antarctic quakes over the last 5 years.

4. During 2023, *Neumayer Station III* moved 155.9 meters from 70°39’41.73”S, 8°17’0.54”W to 70°39’36.79”S, 8°17’3.44”W.

5. The total magnetic field intensity decreased by 55.74 nT from a mean of 38000.78 nT at 1 January 2023 to a mean of 37945.04 nT at 31 January 2023. This decrease is the net effect of the regional weakening of the Earth magnetic field in the South Atlantic Magnetic Anomaly and the change of the remanent crustal magnetic field, due to *Neumayer Station III* moving with the ice shelf (Fig. 4.2.5).

Preliminary results

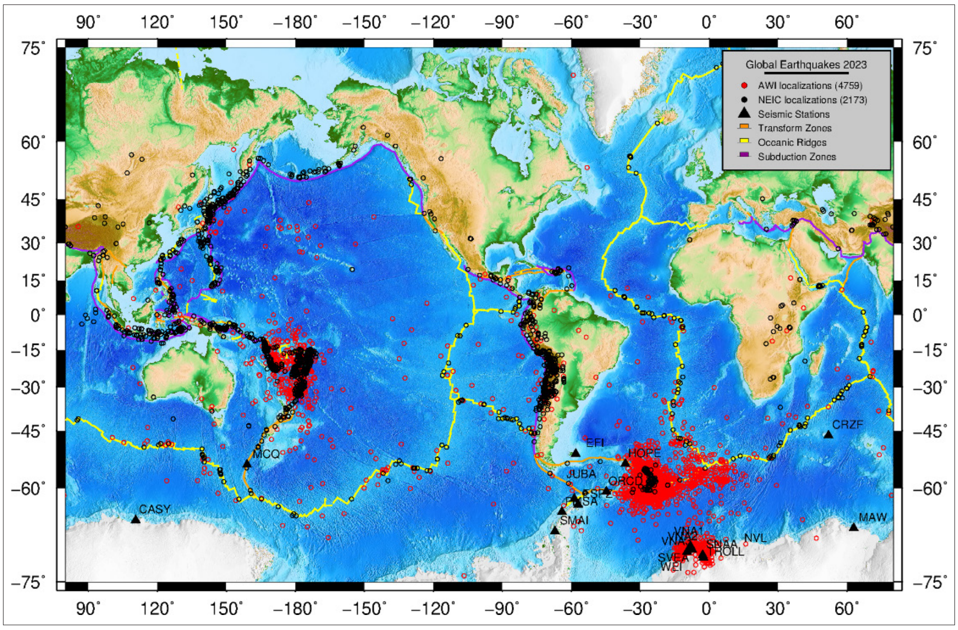

Fig. 4.3.2: Map showing seismic events recorded by the AWI network in 2023

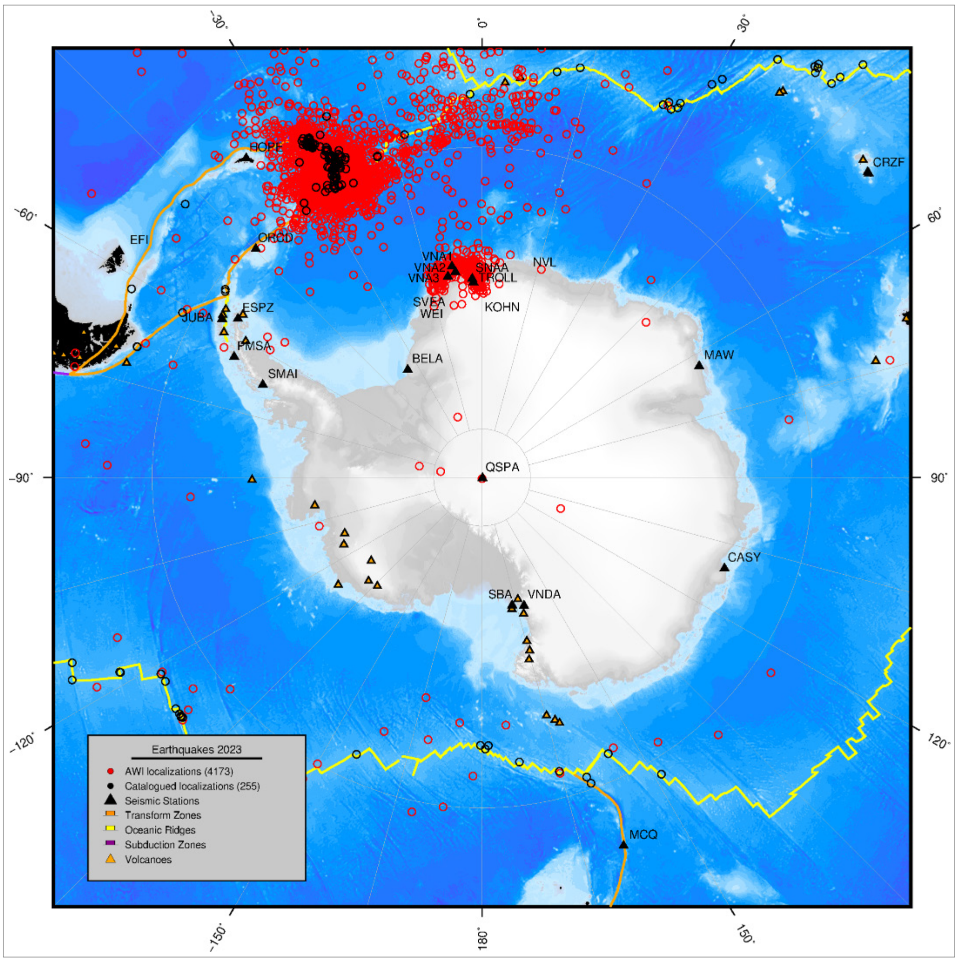

Fig. 4.3.3: Regional earthquakes in 2023

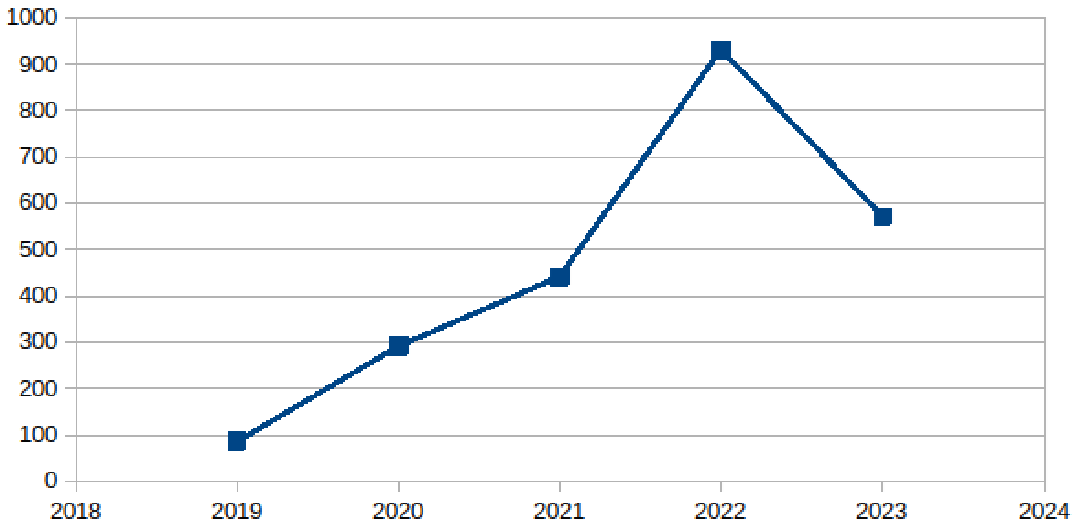

Fig. 4.3.4: Antarctic ice- and earthquakes

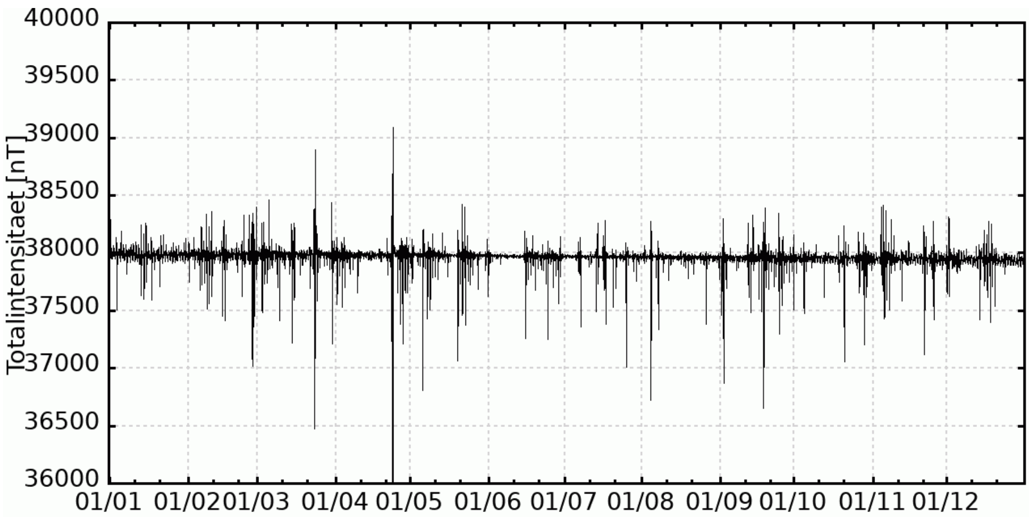

Fig. 4.3.5: Total Intensity of the geomagnetic field at Neumayer Station III, recorded by the Overhauser GSM-19 in 2023.

Data management

- Seismological waveform data can be accessed via Geofon (https://geofon.gfz-potsdam.de/doi/network/AW). Information about arrivals and events can be retrieved from ISC (http://www.isc.ac.uk).
- Data from the geomagnetic observatory can be accessed via INTERMAGNET (https://intermagnet.github.io) and SuperMAG (http://supermag.jhuapl.edu)
- GPS data in Rinex format are available on request.

This expedition was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 2, Subtopic 3.

In all publications based on this expedition, the **Grant No. AWI_ANT_3** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2016a). *Neumayer III* and *Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.4 CTBTO – IS27 Infrasound Station

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Nora Schröder[2], Felix Strobel[2],
Amelie Nüsse[2], Andrey Jakovlev[2]

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[2]DE.AWI

Grant-No. AWI_ANT_4

Objectives

In accordance with the Comprehensive Nuclear Test Ban Treaty (CTBT), the IS27 infrasound station is operated at the German *Neumayer Station III* Antarctic Research Base as one of 60 global distributed elements of the infrasound network of the International Monitoring System (IMS). Infrasound stations measure micropressure fluctuations in the atmosphere, and thus are primarily focused on the monitoring of compliance with the CTBT with respect to atmospheric nuclear explosions. The proximity of the VNA seismic array enables seismo-acoustic studies. The IS27 array is situated approximately 3 km southwest of the *Neumayer Station III* (Fig. 4.4.1). It comprises nine elements (Fig. 4.4.2), each equipped with a microbarometer and a data acquisition system. (Fig. 4.4.3) The array is arranged on a spiral at regularly increasing radii from the centre point. The aperture of this array is approximately 2 km. The central array control system is installed in the *Neumayer Station III*. IS27 commenced operations in 2003.

Fieldwork

IS27 must be operated continuously with a minimum of 98% data availability within a year. This is a prerequisite for an IMS station. Routine maintenance of the array is essential to ensure high reliability and is typically carried out annually during the Austral summer, between December and February. The condition of the equipment must be checked, hardware and software upgrades must be installed, and any necessary repairs must be carried out. The nine elements were successfully raised to the surface without incident, notably thanks to the efforts of the AWI Bauteam.

Preliminary (expected) results

Data availability and quality for year 2023 met the requirement set by the CTBTO. All data were qualified for data processing at CTBTO.

Waveform data from IS27 contributed to several recently conducted atmospheric research studies (please refer to references list below).

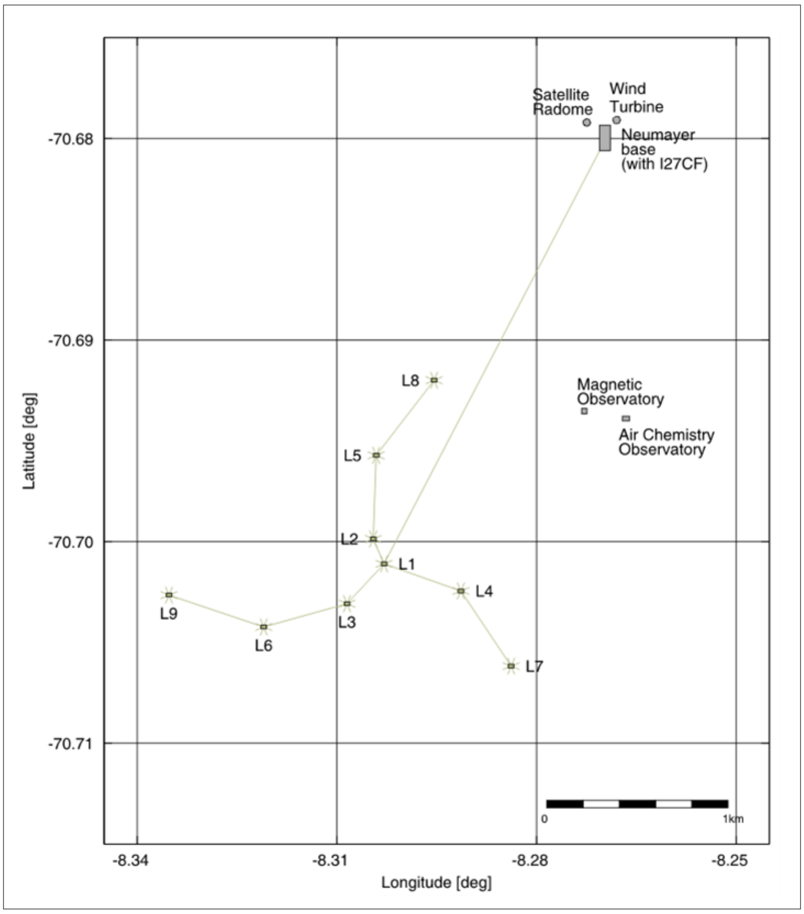

Fig. 4.4.1: Map showing the location and layout of the Infrasound Array IS27 with reference to Neumayer Station III.

Fig. 4.4.2: One of the nine infrasound elements after recovering from snow. Flagpoles mark the outer positions of the air-pressure inlet-tubes which are part of the wind-noise-reduction-system. In the center, a field-box is buried in the snow. A WiFi-link connects each element with the Neumayer Station III.

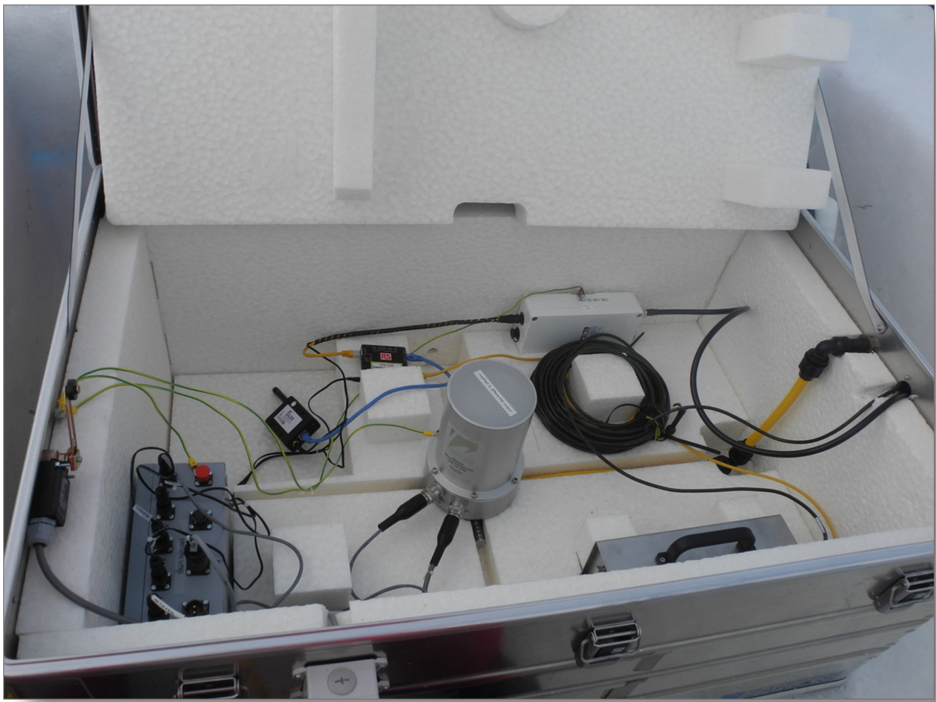

Fig. 4.4.3: The insulated field-box contains the microbarometer (in the middle), data acquisition system as well as the power supply and a communication unit.

Data management

Archived data, as well as real-time infrasound waveform data and associated metadata, are publicly available. Such data can be accessed via the BGR FDSN Webservice (https://eida.bgr.de/info).

In all publications based on this expedition, the **Grant No. AWI_ANT_4** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2016a). *Neumayer III* and *Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.5 AFIN – Antarctic Fast Ice Network

Lukas Ole Muser[1], Martin Radenz[2], Nellie Wullenweber[1], Mara Neudert[1], Stefanie Arndt[1], Christian Haas[1] (not in the field), Markus Janout[1] (not in the field)

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Grant-No. AWI_ANT_5

Objectives

Sea ice fastened to coasts, icebergs and ice shelves (fast ice) is of crucial importance for climate and ecosystems. At the same time, it is not represented in climate models and many processes affecting its energy- and mass balance are currently only poorly understood. Near Antarctic ice shelves, this fast ice exhibits two unique characteristics that distinguish it from most other sea ice:

1. Ice platelets form and grow in super cooled water masses, which originate from cavities below the ice shelves. These crystals rise to the surface, where they accumulate beneath the solid sea ice cover. Through freezing of interstitial water, they are incorporated into the sea ice fabric as platelet ice.
2. A thick and highly stratified snow cover accumulates on the fast ice, altering the response of the surface to remote sensing and affecting sea ice energy and mass balance.

At the same time, fast ice is ideal to monitor sea ice and its seasonal evolution, because it may be accessed from nearby stations. In order to improve our understanding of sea ice processes and mass balance, we perform a continuous measurement program on the fast ice of Atka Bay, Antarctica. This work contributes to the international Antarctic Fast Ice Network (AFIN), which was initiated as legacy project under the International Polar Year (IPY) and is set out to establish an international network of fast-ice monitoring stations around the Antarctic coastline. The monitoring programme at *Neumayer Station III* started in 2010 (Arndt et al. 2020).

Fieldwork

Sea ice conditions

First sea ice, platelet ice, and snow thickness measurements were carried out on 26 May 2023. Since then, the entire transect was sampled once per month (Tab. 4.5.1).

On 31 December, the last sea ice measurements of the season were conducted. Due to crack widening and increased potential for instability in the bay, the bay was closed on 1 January 2024.

AFIN2023 / SIBEAT

For the 2023 season, the fast ice programme in Atka Bay can be divided into two phases. The first phase covers the wintering period until the end of October and from mid to late December (AFIN2023). During this time, manual measurements of snow, ice, and sub-ice platelet layer thickness in drill holes were conducted. Additionally, the ground-based electromagnetic induction system (GEM-2) was used to determine the total ice thickness and sub-ice platelet layer thickness across Atka Bay. In addition, conductivity-temperature-depth profiles (CTDs) were sampled in the vertical water column at specific locations throughout the bay. At the beginning of the season, two sea ice buoys and the autonomous electromagnetic induction sounding system (autoEM) were deployed on the ice.

The second phase, from the beginning of November to mid-December, involved the sea ice biology and physics program SIBEAT, led by Ilka Peeken (see Chapter 4.16). During this phase, the AFIN programme was continued and expanded, particularly in terms of spatial coverage of ice thickness and CTD measurements across the bay. In addition, ice cores were collected.

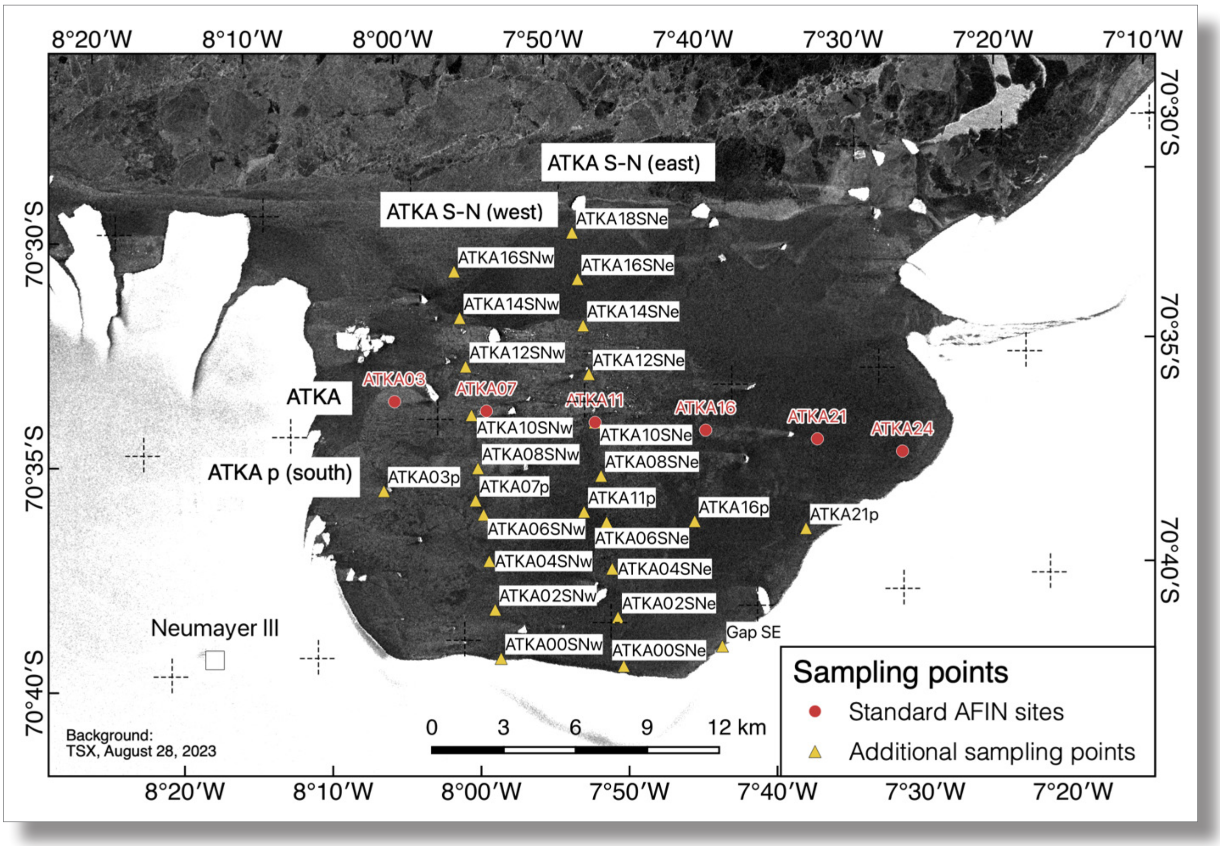

Fig. 4.5.1: Overview of all measurement sites in Atka Bay for the season 2023. ATKA03-24 denotes the routine measurement sites of AFIN, referred to as "ATKA." The numbers (03-24) indicate the distance from the western shelf ice edge. Additional points for the CTD measurements, as well as transects with the GEM device along ATKA S-N (east and west), ATKA P (south), and the Gap SE, are marked with yellow triangles. Background: TerraSAR-X image recorded on 28 August 2023

Conducted measurement principles

Manual measurements of sea ice and snow thickness

Manual measurements of sea ice and sub-ice platelet layer thickness, freeboard, and snow depth (drillings and stake measurements) were conducted across Atka Bay. As in previous years, six fixed sampling sites along a 25-km-long transect across Atka Bay have been revisited monthly between annual formation and end of October (Fig. 4.5.1).

All conducted drill hole measurements within the AFIN work are summarized in Table 4.5.1.

Continues sea ice thickness transects by means of an electromagnetic induction sounding system (EM)

In addition to the manual sea ice and snow thickness measurements, a ground-based electromagnetic induction sounding device GEM-2 (Geonics Limited, Mississauga, Ontario, Canada) was operated from which we can derive total sea ice thickness (sea ice thickness plus snow depth) as well as the sub-ice platelet layer thickness. The measurements were always carried out together with the drill hole measurements as well as the CTD measurements. In addition, extensive additional E-W and N-S transects (Fig. 4.5.1A) were defined and surveyed in order to obtain a comprehensive description of the thickness of the sub-ice platelet layer and consolidated fast ice for the whole bay.

All conducted GEM-2 measurements are summarized in Table 4.5.1.

Deployment of autonomous ice tethered platforms (buoys)

To measure sea ice and snow thickness throughout the seasonal cycle on an hourly basis, two autonomous ice-tethered platforms (buoys) were deployed on the fast ice in Atka Bay near ATKA11 (see Fig. 4.5.1) on 1 and 2 June 2023. One Snow Buoy (2023S111) measured snow accumulation, while one Ice Mass Balance buoy (IMB, 2023T89) recorded sea ice growth over the course of the year.

Due to significant snow accumulation near ATKA11, the Snow Buoy was lifted on 29 November 2023. The IMB stopped transmitting data on 28 December 2023, for reasons that remain unclear. Subsequently, during the breakup of the northern edge of the bay, the area containing the buoys broke off on 2 January 2024, causing both buoys to drift with the ice within the Antarctic Coastal Current towards the Weddell Sea. Due to the small size of the ice floe, it did not survive the summer melt, leading to the Snow Buoy ceasing data transmission on 15 January 2024.

In addition, snow accumulation measurements with the Snow Buoy next to the Air Chemistry Observatory near *Neumayer Station III* continued at the same location since January 2013. However, with the battery depleting again on 13 March 2023, it was decided to conclude the time series after 10 years and recover the buoy.

Autonomous electromagnetic induction sounding system (autoEM)

An autonomous electromagnetic induction sounding system (autoEM) was developed to continuously determine the sub-ice platelet layer thickness at a certain location over a longer period of time. Therefore, an electromagnetic induction system device, EM31, was installed in a kayak and which transmits its data to *Neumayer Station III* via the newly established LoRa system at the station. The complete data set is stored on the system and has to be downloaded regularly. During this season, the autoEM system was installed on the ice for the first time on 1 June 2023, at ATKA11 in the immediate vicinity of the other autonomous measurement systems. However, due to some technical issues, the system had to be dismounted again and adjusted accordingly. Finally, on 19 June the autoEM was successfully re-installed at ATKA11 (see Tab. 4.5.1). Due to high snow accumulation and subsequent flooding of the measurement site, the system was recovered on 4 November 2023.

CTD profiling

To describe the water mass properties in the vertical water column, a Conductivity-Temperature-Depth (CTD) sensor suit was lowered from the ice bottom down to the ocean floor. The CTD was either deployed through an existing gap in the southeastern part edge of Atka Bay or a hole was drilled in the ice with the ice core drill for each CTD (Fig. 4.5.1).

All CTD measurements are summarized in Table 4.5.1.

Tab. 4.5.1: Overview of all conducted measurements within the framework of AFIN. The sampling sites/transects are marked in Figure 4.5.1.

Date	Drilling	GEM	CTD	autoEM	buoys
26 May 2023	ATKA03-24	Along whole trip			
28 May 2023	ATKA03	Along whole trip			
01 Jun 2023	ATKA11			Deployment at ATKA11	Deployment of Snow Buoy at ATKA11
02 Jun 2023				Recovery for repairs	Deployment IMB at ATKA11
19 Jun 2023	ATKA03-24			Re-deployment at ATKA11	
11 Jul 2023		Along whole trip	ATKA11, ATKA08SNw		
15 Jul 2023		Whole ATKASNe to ATKA00SNw to ATKA07p to ATKA0p	ATKA11, Gap SE		
26 Jul 2023	ATKA03-24		ATKA11, ATKA24		
05 Aug 2023		Whole ATKAp and along southern ice edge			
15 Aug 2023		Whole ATKAp and along whole trip	ATKA11, ATKA00SNe, Gap SE		
20 Aug 2023		Along whole trip	ATKA18SNe, ATKA11		
23 Aug 2023	ATKA03-24	Along whole trip			
30 Aug 2023		Along whole trip	ATKA00SNe, Gap SE		
07 Sep 2023		Whole ATKAp and along southern ice edge	ATKA00SNe, ATKA11		
18 Sep 2023		Along whole trip	ATKA11, ATKA16SNe		
27 Sep 2023	ATKA03-24	Along whole trip	ATKA03, ATKA11, ATKA24		
30 Sep to 01 Oct 2023		Some GEM transects along the south-eastern shelf ice edge	15-hours CTD with 11 casts (approx. hourly) at ATKA11		
18 Oct 2023	ATKA03-24	Along whole trip	ATKA03, ATKA11, ATKA24		
19 Oct 2023		Whole ATKAp and along southern ice edge	ATKA00SNe, Gap SE		

Date	Drilling	GEM	CTD	autoEM	buoys
25 to 26 Oct 2023		Some GEM transects along the south-eastern shelf ice edge	14-hours CTD with 11 casts (approx. hourly) at Gap SE		
04 Nov 2023				Recovery	
10 Nov – 17 Dec 2023	AFIN work conducted as integrated part of SIBEAT project by Peeken et al.				
23 Dec 2023	ATKA18SNe, ATKA14SNe, ATKA12SNe, ATKA11	Along whole trip	ATKA12SNe		
31 Dec 2023	ATKA08SNe, ATKA06SNe, ATKA04SNe, ATKA02SNe, ATKA00SNe	Along whole trip	ATKA08SNe, ATKA04SNe, ATKA00SNe		

Preliminary (expected) results

Fast ice, sub-ice platelet ice and snow thickness

Figure 4.5.2 summarizes all measurements of snow, sea ice, and sub-ice platelet layer thickness, as well as the observed freeboard throughout the season. The snow layer reached annual maximum thickness values of 0.48 m in the east at ATKA24 and 1.18 m at ATKA21 and ATKA11, which are located in close proximity to icebergs. These results highlight the exceptionally high snow deposition, a trend observed throughout the *Neumayer Station III* region in 2023. The mean annual maximum thickness of the fast ice is 1.99 ± 0.22 m, with an average annual platelet ice accumulation of 6.17 ± 0.41 m. The latter value is notably high compared to previous years, likely due to the presence of numerous icebergs in the bay that may inhibit the northward venting of platelets caused by tidal movements. In contrast, the average maximum thickness of the fast ice remains consistent with measurements from previous years.

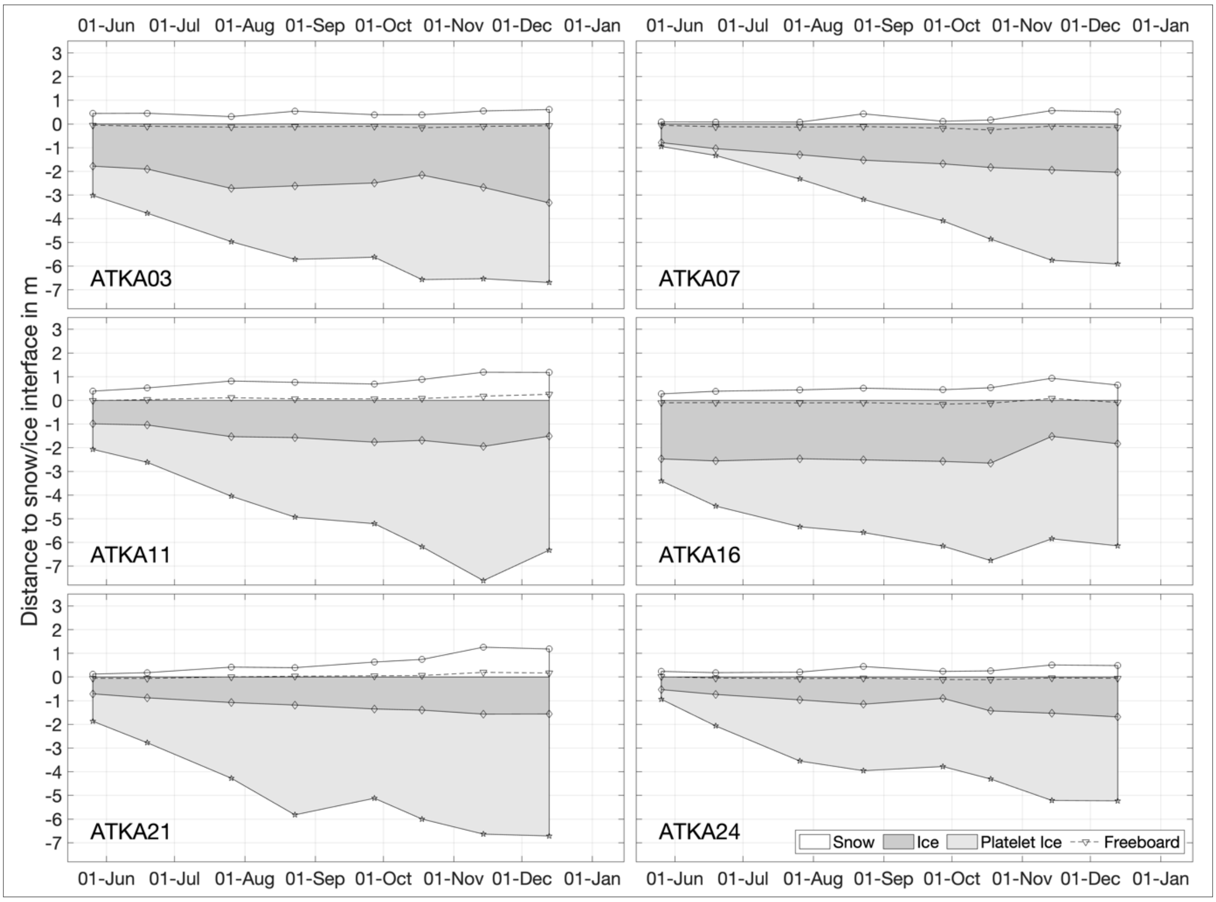

Fig. 4.5.2: Overview of all manual snow depth, sea ice and sub-ice platelet layer thickness as well as freeboard measurements for the six sampling sites along the standard AFIN transect (Fig. 4.5.1A) in 2023.

Figure 4.5.3 depicts the snow accumulation recorded by the Snow Buoy 2022S111 (at ATKA11) from 2 June 2023, to 15 January 2024. At the end of June, a strong storm resulted in an initial accumulation of 50 cm of new snow. This was followed by a gradual, steady increase until another significant wind event added an additional 30 cm of snow at the buoy location. Subsequent storms until early September appeared to redistribute the snow without significantly altering the overall snow budget. Snow accumulation remained relatively constant until early December, when another storm contributed approximately 20 cm of snow. With the break-up of the northern edge of Atka Bay and the subsequent drift of the buoys at ATKA11 with the ice in the Antarctic Coastal Current towards the Weddell Sea, coupled with temperatures around the freezing point, the snow surface experienced a significant loss of 20 cm in snow mass during January. This loss occurred before the buoy either sank or flipped due to summer sea ice melt or the decay of ice in the ice edge zone on 15 January 2024.

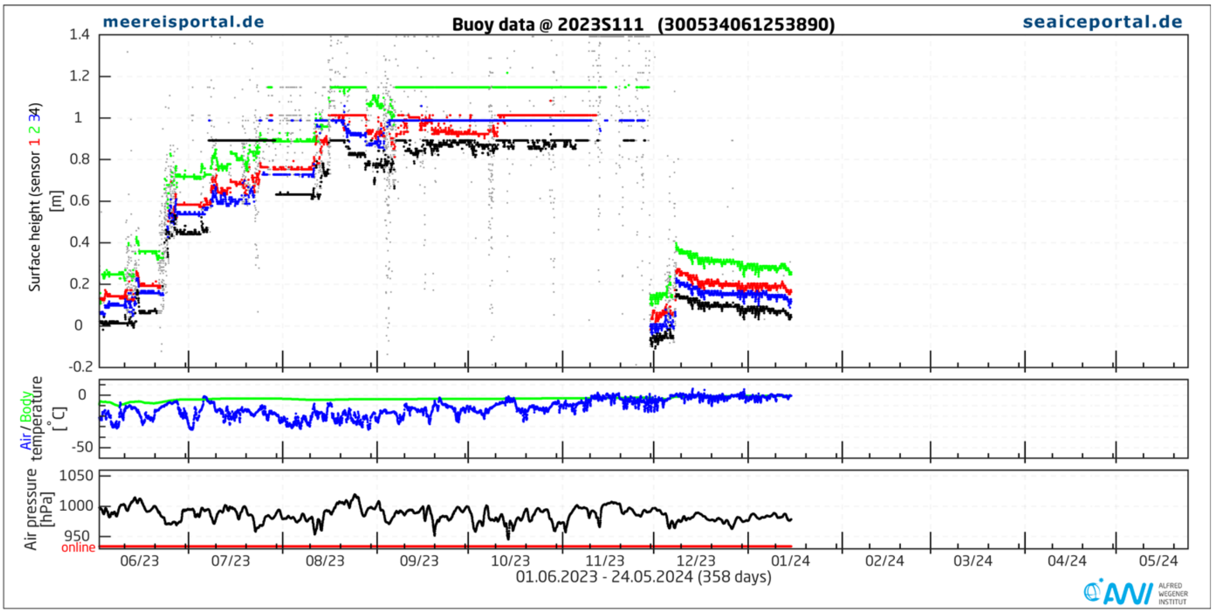

Fig. 4.5.3: Time series of snow accumulation along with the respective meteorological conditions for Snow Buoy 2022S111, deployed on 2 June 2023 at ATKA11 (Fig. 4.5.1, data. meereisportal.de). The buoy was lifted on 29 November 2023, which causes the step in the plotted data.

CTD Profiles

A total of 58 CTD casts were conducted at various locations across Atka Bay (Fig. 4.5.1), including two day-long hourly sampling series comprising 11 and 14 casts each. Figure 4.5.4 illustrates the series of 11 upcasts and downcasts of the CTD on 25/26 October at the GAP SE location. For detailed analysis, only the downcast data is utilized because the water mass stratification is already altered and mixed during the lowering of the CTD, leading to relatively constant salinity profiles over the entire water column in the upcast data.

While the salinity profile appears relatively constant over time, the temperature profile exhibits a slight diurnal cycle throughout the sampling period. Specifically, undercooled water plumes were observed between 18:00 and 00:00 UTC, with the strongest signal at 23:30, diminishing thereafter, and slightly reoccurring at 08:00 UTC. These observations are likely related to tidal movements and the associated transport of undercooled water masses from the shelf towards the north.

Future work will focus on elaborating the detailed relationships between the seasonal and regional platelet ice distribution and the water mass distribution beneath the fast ice in Atka Bay.

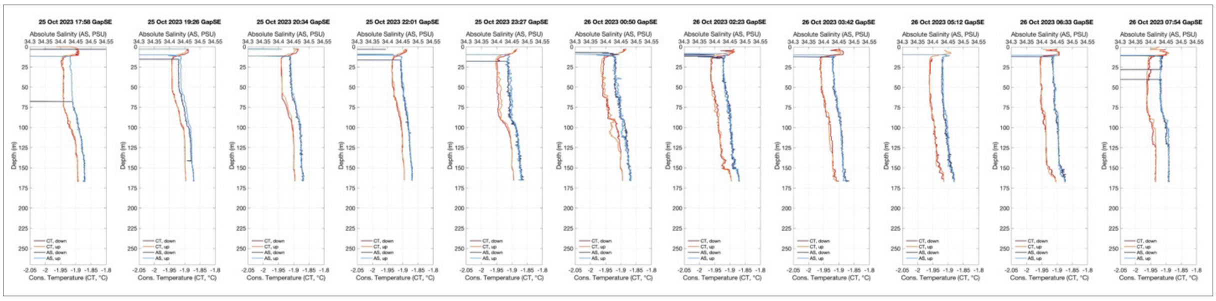

Fig. 4.5.4: Profiles of absolute salinity and conservative temperature for the downcast (dark blue/red) and upcast (light blue/orange) at the GAP SE location during the 24-hour sampling on 25/26 October.

Data management

All manual drilling measurements are already post-processed and will be published in PANGAEA within one year. By default, the CC-BY license will be applied.

All sea ice thickness data from electromagnetic induction sounding as well as CTD data will be released following its analysis in the home laboratories after the expedition or depending on the completion of competing obligations (e.g. PhD projects), upon publication as soon as the data are available and quality-assessed. Data submission will be to the PANGAEA database. By default, the CC-BY license will be applied.

All buoy positions and raw data are available in near real time through the sea ice portal www.meereisportal.de. At the end of their lifetime (end of transmission of data), all data will be finally processed and made available in PANGAEA. The Snow Buoys report their position and atmospheric pressure directly into the Global Telecommunication System (GTS). Furthermore, all data are exchanged with international partners through the International Program for Antarctic Buoys (IPAB).

This expedition was 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_ANT_5** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.6 CHOICE@Neumayer – Consequences of Longterm-Confinement and Hypobaric Hypoxia on Immunity in the Antarctic Environment at *Concordia Station* and *Neumayer Station III*

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Dominique Moser (not in the field)

Grant-No. AWI_ANT_6

Objectives

The overarching goal of the field study, CHOICE@Neumayer, is to explore the dynamic relationship between stress and the immune system and its ramifications on the well-being of the wintering crews stationed at *Neumayer Station III* in Antarctica. This research endeavor is intricately connected to prior and ongoing scientific inquiries conducted in Antarctica (Concordia, known as CHOICE_III) and in space (International Space Station (ISS), referred to as IMMUNO and IMMUNO_2). Led by the Hospital of the Ludwig Maximilian University of Munich, “Laboratory of Translational Research Stress and Immunity” an international research team endeavors to delve into the following aspects at *Neumayer Station III*:

a) Scrutinizing how the immune system intereacts to prolonged periods of isolation and confinement, elucidating potential stress-induced, neuroendocrine, and metabolic alterations.

b) Assessing the consequential impact of these changes on the overall health of the participants in field

Fieldwork

For the winterover-season 2023, after a baseline data collection in the fall of 2022, the examinations of all nine subjects started on the station in February 2023 to run the CHOICE@ Neumayer observation in a monthly period over the winter. The study has been completed by 6 subjects and ended by the last time point in March 2024 for the post-collection in Berlin (joint activity and kindly organized by Prof. Dr. Alexander Stahn). Blood, saliva, urine, hair and stool samples were collected and also questionnaires were filled in.

Preliminary (expected) results

The ongoing investigations conducted in the extreme exposome of the Antarctic environment elicits distinctive stress and immune responses. These studies aim to deepen our understanding and strengthen the statistical significance of any significant environmental and sex-specific differences observed. Notably, gender disparities have been identified as independent of heightened psychological stress, with potential links to environmental factors. However, the origins and implications of these gender differences require further elucidation, and efforts to investigate them are currently underway, necessitating a large sample size. The present analyses of samples collected from the recent and previous overwintering seasons focus on evaluating the impact of fresh food on the immune system at both the transcriptional and functional levels, as well as on the microbiome profile. Findings regarding the latter indicate a dynamic shift in microbiome diversity during missions, which subsequently recovers upon return to Europe and that seem differentially changed as a function of oxygen tension / altitude. Further immune functional phenomics analyses are currently in progress with these data collected in the winterover 2023.

Data management

All samples and documentation which have been collected along the study time-points are considered confidential as they are considered “medical research data” that is subject to data protection regulation and has to follow the rules and regulations of the institutional ethical board (Ethikkommission an der Medizinischen Fakultät der LMU). Once the samples are analyzed and anonymized, data batches can be made available upon request and reconsideration of the topics of interest if covered by the ethical approval (a re-iteration the ethical board might be necessary).

Molecular data (viral DNA and transcriptome/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).

In all publications based on this expedition, the **Grant No. AWI_ANT_6** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III* and *Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

4.7 Neuromayer – Neurophysiological Changes in Human Subjects During Long-Duration Over-Wintering Stays at *Neumayer Station III* in Antarctica

Alexander Stahn[1] (not in the field), Anika Friedl-Werner[1] (not in the field), Katharina Brauns[1] (not in the field), Poppy Barsby[1] (not in the field), Stefan Hetzer[2] (not in the field), Simone Kühn[3] (not in the field), Bernhard Riecke[4] (not in the field), Tom Hartley[5] (not in the field)

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Grant-No. AWI_ANT_11

Outline

The project will help to find predictive indicators and biomarkers for resilience and adaptation in individuals and teams, and to aid in selection and individualized countermeasure development with the goal to maintain and optimize performance capability and behavioral health during long-duration missions. The project is based on a close cooperation between Charité Universitätsmedizin Berlin the Polar Institute for Polar and Marine Research. The study is voluntary, approved by the Charité Ethics Committee, and all subjects provide written informed consent prior to their participation. All data collection is performed in accordance with the Declaration of Helsinki and GDPR.

Objectives

The overarching objective of the project is to investigate the effect of long-duration Antarctic stays on crew health and behavior. To this aim we have optimized a set of measures combining cutting-edge imaging technologies, molecular markers and behavioral and operational measures. Our primary outcome are structural and functional brain changes assessed by MRI before and after the winter-over. In addition, we also assess behavior and cognitive performance with sensitive but unobtrusive state-of-the-art cognitive and psychosocial measurement tools. These measures will be performed before, after and during the winter-over. The test battery is based on a number of well-validated paradigms and specifically targets spatial cognition, i.e., the ability to process information of our location in spatial environments. We also draw and subsequently freeze blood samples from the crew members before, during and after the campaign, which will later allow for the identification and time course of biological markers of vulnerability to the effects of prolonged exposure to Antarctic overwintering. To parse out the effects of reduced sensory stimulation from other stressors during long duration space missions such as social isolation, crew conflicts, sleep and circadian disorders, and reduced physical activity levels we will administer various surveys to capture individual responses the expedition.

Fieldwork

Data has been collected in crew members at *Neumayer Station III* since ANT-Land 2018/19. Data collections in field are optimized to limit crew burden and maximize scientific return.

Preliminary (expected) results

It is expected that the multiple stressors associated with long-duration overwintering lead to neurobehavioral changes as assessed by structural and functional brain imaging, key neurotrophins and behavior (e.g., mood and cognitive performance). We also expect that resilience will reflect inter-individual differences in sensitivity to the stressors associated with prolonged Antarctic missions. We recently published data on the neurobehavioral effects of overwintering on *Neumayer Station III* in the *New England Journal of Medicine* (Impact Factor: 70.67) (Stahn et al. 2019). These data revealed considerable changes in brain structure, cognitive performance, and neurotrophins that are key to learning, memory formation, and brain plasticity.

Data management

Data will be analyzed at the PI's laboratory at Charité and his partners. Data will be pseudonymized and stored on a central server that is backed up and managed by the universities' IT programmes. Results will be publicly disclosed by submission to peer-reviewed journals with authorships that accurately reflects the contributions of those involved. De-identified data will be made available as long as all personl information can be protected. We will carefully attend to any characteristic that might make the data fields identifiable (e.g., campaign, analog, mission length and/or sex).

In all publications based on this expedition, the **Grant No. AWI_ANT_11** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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Stahn A C, Gunga H C, Kohlberg E, Gallinat J, Dinges D and Kühn S (2019) Brain changes in response to long Antarctic expeditions. New England Journal of Medicine 381(23):2273–2275. https://doi.org/10.1056/NEJMc1904905

4.8 Glaciology@NM – Quasi-Long-Term Observatory

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Grant-No. AWI_ANT_8

Outline

This project provides long-term time series of glaciological observables at *Neumayer Station III* and its hinterland. In consists of three sub-projects, which will be described in the following order in chapters Objectives and Fieldwork:

The sub-project "MIMO-EIS (Monitoring melt where Ice Meets Ocean – Continuous observation of ice-shelf basal melt on Ekström Ice Shelf, Antarctica)" monitors the temporal variation of the basal melt in the centre of the Ekströmisen on sub-daily times scales. In addition, it investigates spatial variations of annually averaged basal melt rates.

In the sub-project "NM surface mass balance", surface accumulation and surface layer density were regularly observed at the two stake farms Pegelfeld Süd and Pegelfeld Spuso as part of the airchemistry observatory or the *Neumayer Station III*. Results are described in Chapter 4.2 Part II of this volume.

As part of the conventional density observations, the sub-project "GNSS–RR (Global Navigation Satellite System – Reflecto/Refractometry)" aims at developing a methodology deriving automated and continuous specific surface mass balance time series for fast moving parts of ice sheets and shelves (>10m/a).

The sub-project "Kottaspegel" investigates the spatio-temporal variation of the snow accumulation along the traverse route between *Neumayer Station III* and Kottas camp, if possible, also to *Kohnen Station*, as done in 2023/24. Snow accumulation is determined from reading of snow height at bamboo stakes in annual to bi-annual intervals, which is relevant to provide ground-truth measurement for satellite and regional climate modelling approaches.

Objectives

Antarctic mass balance is mainly controlled at the surface and the edges, where the interaction of ice shelves with the ocean water underneath is one of the key processes for the future development. Especially for the Antarctic ice sheet, mass loss through ice shelves is the dominant component of loss in the mass budget. The quasi-longterm observatory Glaciology@ NM provides continuous monitoring system of surface mass balance and basal melting of the Ekström Ice Shelf (EIS) as well as its inflowing part of the grounded ice sheet.

Regarding the ice–ocean interaction of EIS we determine the interannual and seasonal variability of basal melt rates to improve our understanding of the processes of ice-ocean interaction along the DML coast. To this end, an Autonomous phase-sensitive Radio-Echo Sounding (ApRES) was deployed in the center of EIS in 2020, at the flank of the main bathymetric trough, as part of the sub-project MIMO-EIS. Data is retrieved annually and is used as validating constraints in numerical ocean-modelling runs as well as satellite-based analyses. The project will extend a chain of already available and ongoing ApRES observations on other ice shelves in the Dronning Maud Land Region, like Roi Baudouin and Fimbul, and thus increase our observational and potentially monitoring capabilities in this region. The continuous system has been extended with discrete repeat measurements as well as a second pilot system next to the grounding line of EIS.

The second component concerns the surface mass balance. Apart from weekly and bi-weekly snow height readings at several stake farms since 1990, providing a temporally resolved variation on snow accumulation, a continuous line with a distance of 500 m or 1000 m has been operated on an annual to tri-annual basis along the traverse route to the Kottas mountains and further to *Kohnen Station* (Kottaspegel). Those readings provide the spatial variation of multi-annual surface accumulation.

The third component concerns the determination of density, required to convert snow accumulation to mass. While conventional measurements in snow pits are carried out at *Neumayer Station III* as well as along the Kottaspegel traverse route, the implementation of a GNSS-RR near *Neumayer Station III* enables us to obtain a continuous time series of density. After a successful initial two-year pilot study (Steiner et al., 2023), the system is now in operational use as part of the Neumayer Meteorological Observatory (chapter 4.1 of this volume).

All components together provide an essential understanding of the processes determining the basal and surface mass balance around EIS and towards the polar plateau. These provide unique ground-truthing observations to calibrate, e.g., regional climate models, as well as observations derived from satellite remote sensing. At the same time the time series capture the changing climate conditions in this part of Antarctica, as continuous observations serve as an early warning system (compare Part II of chapter 4.2 of this volume).

Fieldwork

After arrival at *Neumayer Station III* on 8 November 2023 the traverse equipment for Kottaspegel and maintenance of MIMO-EIS was prepared.

MIMO-EIS

The autonomous pRES (ApRES) system at the site MIMO-EIS-8 was dug out by a team of four people (Hameed Moqadam and Fyntan Shaw, assisted by Nora Schoeder, Felix Strobel) over five hours and dismounted on 16 November 2023 and data downloaded. The station was raised to the new level of the surface redeployed by a team of four persons (Hameed Moqadam and Fyntan Shaw, assisted by Holger Zahlauer and Matthias Brehm) and put in operation in the autonomous (ApRES) mode on 21 November 2023 with an antenna separation of 10 m. The system records measurements every hour with data storage in joint files about every 4 h (5 MB limit for file size). Additional pRES re-measurements with different antennae polarizations were performed on 17 November 2023 and 21 November 2023 at seven locations: MIMO-EIS-4 to MIMO-EIS-8 (Fig. 4.8.1), MIMO-EIS-A (formerly also known as site6), MIMO-EIS-B (formerly also known as site7) and at a new position MIMO-EIS-C, which was initialized in November 2021 (Tab. 4.8.1). All polarimetric pRES sites, initially marked with two bamboo poles, were re-marked with two new poles, as the exact positioning of the antennas is key for obtaining useful data (Fig. 4.8.2).

Measurements at all stations were conducted using snowmobiles as vehicles. At the site MIMO-EIS-C the battery short circuited, damaging the interior cables and packaging, which needed to be replaced. The battery remained functional, but the clean-up and repairs delayed work by a couple days.

The ApRES system at the site MIMO-EIS-D (referred to as cApRES_GL in Drews et al., 2022) was serviced as part of the traverse to *Kohnen Station*. It was dug out by a team of four persons (Hameed Moqadam and Fyntan Shaw, assisted by Keno Wind and Bernd Buehler) over five hours and dismounted on 24 November 2023, during the Kottaspegel traverse, and data downloaded. The station was raised to the new level of the surface redeployed by the same team of four persons and put in operation in the autonomous mode on 24 November 2023 with an antenna separation of 10 m. A few days later it was noticed that the initial evaluation of the performance of the station was wrong and that the station was not in operation. It was therefore redeployed by the traverse from *Kohnen Station* on their way back to *Neumayer Station III*.

After repair the system was again deployed on 22 April 2024 at the new site MIMO-EIS-E (position in Tab. 4.8.2). Transfer to and from the site was accomplished using two Hilux vehicle with four people from the overwintering team and took 10 hours in total (transit outbound 3h, deployment 3h, transit inbound 4h). The system has been working since then and regularly sends state of health messages.

Kottaspegel

First density measurements were conducted in the vicinity of *Neumayer Station III*. After a delay caused by bad weather for about a week the measurements along the traverse commenced on 23 November, reaching *Kohnen Station* on 3 December. Measurements along the traverse were performed with the standard setup, i.e., a two-person team on a snowmachine with two Nansen sleds accompanying the traverse train. On some days assistance was provided by the logistic team, Aurelia Hölzer and Matthias Brehm, allowing half-day two-person shifts, with teams swapping over after the lunch break. Aurelia and Matthias helped on 26 and 27November and 1 and 2 December. Aurelia also briefly helped on 30 November. In total, 1,435 stakes readings were obtained at 1,124 locations and 396 new stakes newly deployed. The first South of and including the Kottas mountains, poles were renewed every 1 km, whereas on the plateau (after the Kottas mountains up to *Kohnen Station*) poles were renewed only every 3 km.

At the end of each day, a snow core was drilled to obtain snow density (Tab. 4.8.2). The snow core (diameter: 9 cm, Kovacs ice drill) was weighed with a spring scale. Together with the additionally measured core hole depth, the snow and/or ice density is determined. Snow density is calculated from sample volume and in-field weight measurement using a portable electronic scale.

GNSS-RR

No particular tasks for the sub-project GNSS-RR were carried out in the 2023/24 field season. Any maintenance of the snow height measurement mast (SHM), as part of the meteorological are described in chapter 4.1 of this volume.

Tab. 4.8.1: Position of pRES measurements on Ekströmisen and preliminary values for the long-term average basal melt rates ab. Station MIMO-EIS-D was initialized by the project ReMeltRadar in January 2022 (Drews et al., 2022) and damaged during maintenance. It was thus discontinued and deployed at a new position on 22 April 2024, the new site MIMO-EIS-E.

Station	Latitude 2022/23 °	Longitude 2022/23 °	Latitude 2023/24 °	Longitude 2023/24 °	ab m/a	Comments
MIMO-EIS-4	-70.64662	-8.20719	-70.64553	-8.20752	2.63	
MIMO-EIS-5	-70.74422	-8.82184	-70.74210	-8.82374	0.33	
MIMO-EIS-6	-70.80771	-8.62620	-70.80622	-8.62781	0.44	
MIMO-EIS-7	-70.83056	-8.72028	-70.82906	-8.72208	0.44	
MIMO-EIS-8	-70.82139	-8.74583	-70.82006	-8.74226	0.40	
MIMO-EIS-A	-70.76293	-8.87127	-70.76142	-8.87338	0.40	
MIMO-EIS-B	-70.87500	-8.88083	-70.87354	-8.88296	0.57	
MIMO-EIS-C	-70.68314	-8.45211	-70.68173	-8.45302	0.43	
MIMO-EIS-D	-71.6146	-8.4311	-71.6135	-8.4296		Failed after maintenance – discontinued
MIMO-EIS-E	n.a.	n.a.	-71.4264	-8.3302		New site, initialized 22 April 2024 (traverse point KP180)

Tab. 4.8.2: Location of density measurements performed with the snow corer

Date	CoreID	Lat °	Lon °	mean density kg/m³	max. depth cm
22.11.2023		-70.66245	-8.32215	399.80	100
23.11.2023		-71.26076439	-8.40004138	409.98	50
24.11.2023		-71.61093006	-8.4358887	396.85	77
25.11.2023		-72.13255439	-8.83585128	305.58	100
26.11.2023		-73.27866711	-9.69720645	331.04	100
27.11.2023		-74.20532982	-9.75260101	321.34	105
29.11.2023		-74.50067003	-9.21964576	353.83	95
30.11.2023		-74.87010898	-8.30308722	351.15	95
01.12.2023		-75.00219417	-5.25978335	341.76	95
02.12.2023		-75.01531066	-2.1626343	391.26	96
03.12.2023		-75.00833418	-0.02421095	380.59	92

Preliminary (expected) results

MIMO-EIS

Preliminary analysis of the repeated pRES measurement, matching pairs measured at different seasons, and taking into account strain thinning and firn compaction, yield average basal melt rates (Table 4.8.1). Please note that the individual results at each site are a result of multiple measurements at different polarisations. The order of magnitude of tentative results as published in Eisen et al. (2020) can be confirmed by our preliminary analysis of the re-measurements in previous season.

Since its deployment, the ApRES system operating in unattended mode at MIMO-EIS-8 has been sending state-of-health messages regularly via an Iridium link in its Eulerian frame of reference. Analysis of the continuous ApRES data is ongoing. First results indicate that the temporal variability is very similar in all years 2020 to 2023. It is strongest in month August to November, with melt rate peaks equivalent to up to 2.5 m/a and periodicity of roughly two weeks. Minimum melt rates are always higher than ~0.5 m/a September through November. From December to August, maximum melt rates are below an equivalent of 1 m/a and partly even no melting occurred or was below the detection limit, according to our analysis. A peer-reviewed manuscript is currently in preparation to publish these findings (Zeising et al., in prep.).

As the objectives of MIMO-EIS are strongly overlapping with the those of the project ReMeltRadar, field operations and expertise were joined as much as possible. For instance, the polarimetric ApRES near the grounding line of Ekströmisen as part of ReMeltRadar (Drews et al., 2022) continued the operation as a longer-term station as site MIMO-EIS-D, which was now relocated to MIMO-EIS-E. The added value of such joint operation was already evident during the season: first time series analysis indicates coherence of stronger melting events during winter 2022.

Given our experience from now the several winters of ApRES measurements on Ekströmisen, the operation of the system with a 105 Ah Pb battery, securely stored in a Zarges box, and two 16 GB SD cards (one being the mirror of the other) are sufficient to allow more than one year of unattended operation at 1 h measurement intervals.

Kottaspegel

The compilation and analysis of data regarding actual snow accumulation at each of the measured points has not been completed as of the writing of this report. Table 4.8.2 summarizes the calculated snow core densities along the traverse.

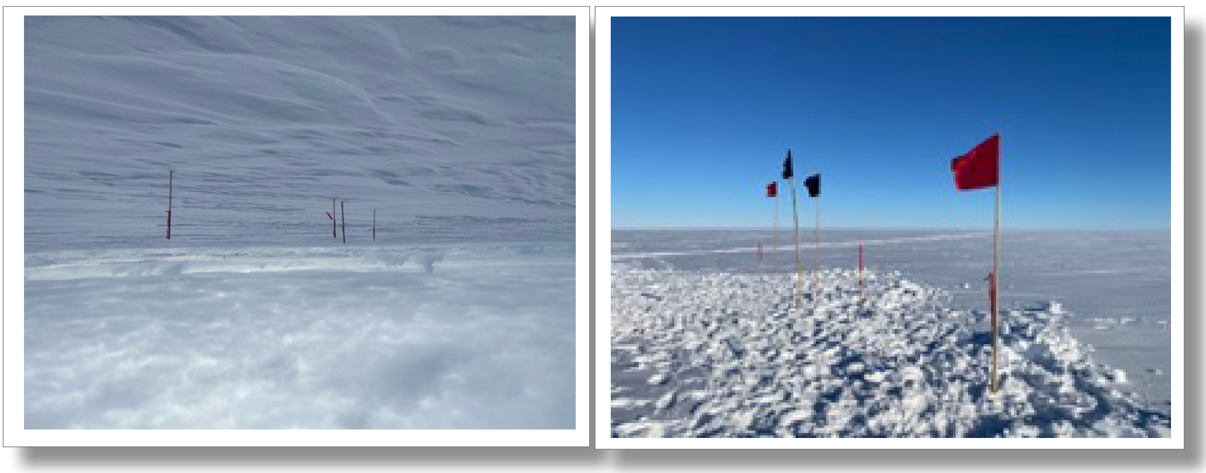

Fig. 4.8.1: Left (a): Photograph of MIMO-EIS-8 before maintenance on 16 November 2023. Right (b): photograph of station MIMO-EIS-8 after deployment on 21 November 2023

Fig. 4.8.2: Accumulation stake measurements: Left (a): Setup of snowmachine train. Right (b): measuring the height of a bamboo stake higher than 2 m with an extension and a wireline device, which automatically records GPS positions.

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. Metadata for MIMO-EIS are already available in registry.o2a-data.de (ID 8403, item: Phase-sensitive Radio Echo Sounding System, event labels NMEIS?_23). Previous results from MIMO-EIS are available in at https://doi.org/10.1594/PANGAEA.962778.

Metadata for density measurement performed during the Kottaspegel traverse and at *Neumayer Station III* for the 2023/24 season are already available in registry.o2a-data.de under IDs 8363 (AWI single tube snowpack sampler) and 5065 (Ice Corer Kovacs Mark II). The already quality checked density data is available in at https://doi.org/10.1594/PANGAEA.963323 .

For the GNSS-RR sub-project, the Python code for preprocessing, processing, analyzing, and visualizing the GNSS-RR data is provided on GitHub https://github.com/lasteine/GNSS_RR.git and archived in Zenodo under https://doi.org/10.5281/zenodo.10135417. Collected and analyzed multifrequency and multisystem GNSS data have been made publicly available at PANGAEA (https://doi.org/10.1594/PANGAEA.958973, Steiner et al., 2023).

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.

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In all publications based on this expedition, the **Grant No. AWI_ANT_8** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III* and *Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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Eisen O, Zeising O, Steinhage D, Berger S, Hattermann T, Pattyn F, Trumpik N, Wehner I, Korger E, and Stakemann J (2020) MIMO-EIS – Monitoring melt where Ice Meets Ocean – Continuous observation of ice-shelf basal melt on Ekström Ice Shelf, Antarctica. In: Fromm T, Oberdieck C, Matz T, and Wesche, C. (eds) Expeditions to Antarctica: ANT-Land 2019/20 Neumayer Station III, Kohnen Station, Flight Operations and Field Campaigns. Berichte zur Polar- und Meeresforschung = Reports on polar and marine research, Bremerhaven, Alfred Wegener Institute for Polar and Marine Research 745, 118 p. https://doi.org/10.2312/BzPM_0745_2020

Steiner L, Schmithüsen H, Wickert J, and Eisen O (2023) Combined GNSS reflectometry–refractometry for automated and continuous *in situ* surface mass balance estimation on an Antarctic ice shelf The Cryosphere 17:4903–4916. https://doi.org/10.5194/tc-17-4903-2023

4.9 PALAOA 3 – Longterm Observations Perennial Acoustic Observatory in the Antarctic Ocean

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Grant-No. AWI_ANT_12

Outline

In December 2005, the Alfred Wegener Institute for Polar and Marine Research (AWI), Germany, established an autonomous listening station named PALAOA (**P**erenni**AL** **A**coustic **O**bservatory in the **A**ntarctic Ocean, Boebel et al. 2006) in the eastern Weddell Sea close to the German Antarctic research base *Neumayer Station III*. The technical project goals were to develop an autonomously operating passive acoustic observatory which records the Antarctic underwater soundscape year-round and continuously, covering a frequency range between 10 Hz and 96 kHz, i.e. the full range of marine mammal vocalizations in that area. The collected data are used to study the acoustic ecology of marine mammals as well as the natural background noise levels in this pristine environment, i.e. as reference for anthropogenically ensonified ocean regions (e.g., Van Opzeeland et al. 2010; Roca et al. 2023). To shield the hydrophone from damage by passing ice bergs, it was deployed through a borehole in the app. 100 m thick protrusion of the Ekström Ice Shelf, which advances ~150 m per year on average. The current project arose from the need for drilling new holes following the break off event of the ice shelf with the old boreholes (drilled in 2005) in February 2022. Redrilling in 2023/24 warrants continuation of the long term data series of the LTO PALAOA.

Objectives

This seasons‘ objective was the re-installation of 3 new hydrophones on the Ekström Ice Shelf approx. 18 km north of *Neumayer Station III* for the continuation of the long-term data acquisition. New hydrophone positions were aimed to be 1 km, 2 km and 3 km off the shelf-ice edge where the former PALAOA recorder unit was situated. Using the AWI's hot-water drill, three holes were to be drilled through the app. 100 m thick ice shelf, through which the hydrophones are deployed. As back-up option, we also, as in 2022/23, explored the option to use the holes drilled by the melting probe from the project "TripleIceCraft" (see description of project "TripleIceCraft"). The TripleIceCraft holes however turned out not to exhibit sufficient width and depth for hydrophone deployment. All field work was planned to be realized during the stay at *Neumayer Station III* from End of January until the end of the summer season in the beginning of March 2024.

Fieldwork

On 17 January 2024 at 20:00, drilling of the first hole (PALAOA North) was initiated using the AWI hot water drilling (HWD) system. The system works by pumping water from a water basin through 6 WAPs which create hot (~90℃) and pressurized water. Hot water is delivered both back to the water basin, to melt snow and also to the drill hose. The drill hose ends in a cupper lance that delivers the water down the drill hole, melting the ice as it is lowered. Two different lances were used to create the holes for hydrophone deployment: Lance 1 (60 mm diameter) and Lance 2 (120 mm diameter). Each lance must penetrate the full thickness of the ice shelf to allow the hydrophones to be deployed. At the first hole (1 km from the shelf edge, Fig. 4.9.1), the ice shelf was penetrated at 83 m after which the lance was retrieved and the the procedure was repeated with the second lance. After retrieving the second lance, the hydrophone (Teledyne Reson TC4032-1) on a 200 m cable could be deployed using a flow weight of 13 kg. The flow weight was tied tot he hydrophone with corrosion links, so the weight would come off within hours after deployment in sea water. Twenty metres of cable were retained on the surface to have sufficient length to connect to the recording unit. Hydrophone functioning was verified upon deployment. The borehole was filled with snow and the recording unit installed in a snow shaft next to it. The snow shaft was covered with wood plates and snow and marked with flags.

On 24 January 2024 and 25 January 2024 the second (PALAOA Central) and third (PALAOA South) boreholes were drilled at respectively 2 and 3 km from the shelf ice edge (Fig. 4.9.1) following the same procedure. Table 4.9.1 lists the details for each drilling.

Hydrophones installed at PALAOA Central and South were installed without recorder and function as back up sensors to revert to when the position of PALAOA North has advanced too far towards the ice shelf edge. Hydrophone cables at these two positions were fixed to and shielded by wood plates which were covered with snow and position-marked with flags.

Tab. 4.9.1: Deployment details PALAOA North, Central and South

Position	Date	Start drilling (60mm)	End drilling (60mm)	Total lance deployment depth	Start drilling (120mm)	End drilling (120mm)	Estimated local shelf ice thickness	Hydrophone deployment
PALAOA North **S 70,507110°, W 008,211135**	17.01.2024	20:00	22:00	120m	22:15	18.01.2024 01:00	83m	18:01.2024 02:00
PALAOA Central **S 70,514494°, W 008,226845°**	24.01.2024	15:15	17:00	135m	17:30	19:20	110m	24.01.2024 20:00
PALAOA South **S 70,521668°, W 008,234009°**	25.01.2024	15:00	16:30	130m	16:45	18:00	120m	25.01.2024 19:30

Preliminary (expected) results

All hydrophones were successfully installed and functioning. Multiple test recordings at all three locations were carried out to fine tune recording settings (NB modification in gain settings: recording with gain 4). Late February, a first break-off of the ice shelf occurred, removing 200 m from the shelf edge. Further later break-offs reduced this distance further and also reduced the distance to the shelf edge on the western side of the ice shelf finger on which our hydrophones were installed. During most of March, the recorder was retrieved to await the unstable situation. Early May 2024, the recorder was installed again at PALAOA-Central. First data have been verified and data collection will be continued at this site for now. With the continuation of the PALAOA LTO data collection, we anticipate to be able to:

- Continue monitoring marine mammal occurrence patterns and acoustic behaviour in relation to annual as well as seasonal fluctuations and anomalies in sea ice conditions
- Understand soundscape and acoustic community composition and functioning in (virtually) pristine acoustic environments
- Investigate species-specific acoustic ecology in relation to species-specific (changing) sea ice habitats
- Monitor patterns in acoustic (species) diversity and build acoustic libraries for AI-based detection tooling as well as outreach purposes

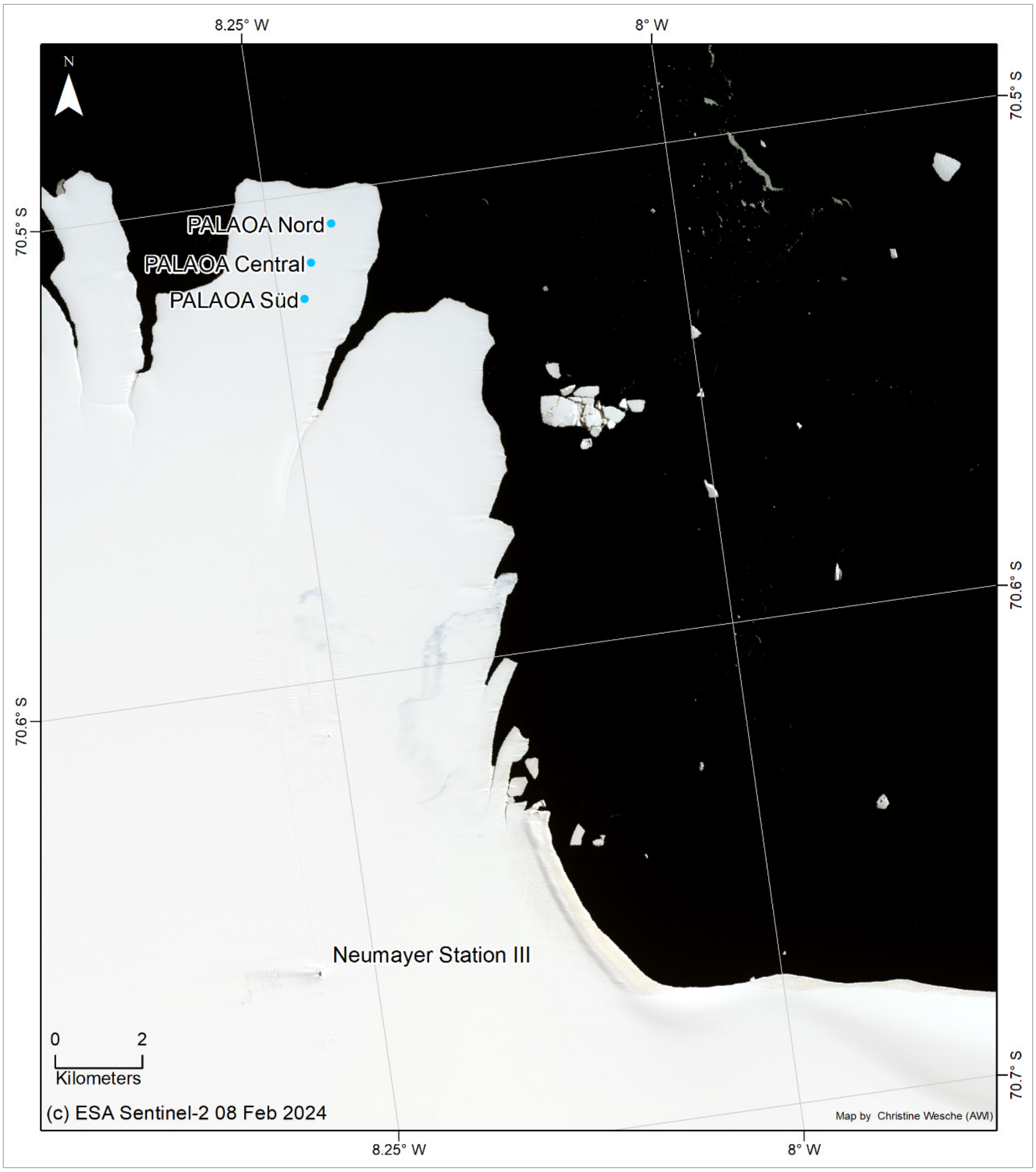

Fig. 4.9.1: Map of the Eckström Ice Shelf on which PALAOA North, Central and South were installed.

Data management

Our data management of passive acoustic data involves:

1. Data preparation and standardization procedures to transfer Level 0 audio 'raw' data to standardized Level 2 audio data, including the generation of machine-readable metadata files and data processing reports for each data set.
2. Data processing and quality control via the Open Portal to Underwater Soundscapes (OPUS, www.opus.aq) to obtain quality-controlled Level 2+ and Level 3+ audio data and data products (i.e., standardized spectrograms).
3. Data publication of Level 1+ audio data and all relevant metadata according to FAIR principles via PANGAEA on a CC-BY4.0 license, after quality control. Additionally, Level 2+ and Level 3+ will be made openly accessible on OPUS.

Further relevant software, workflows or code generated during the project will be published in the respective manuscripts or at other suitable platforms (e.g., zenodo for further standard operating procedure documents).

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 6, Subtopic 4.

In all publications based on this expedition, the **Grant No. AWI_ANT_12** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III* and *Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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Roca I T, Kaleschke L, Van Opzeeland I (2023) Sea-ice anomalies affect the acoustic presence of Antarctic pinnipeds in breeding areas. Frontiers in Ecology and the Environment 21(5):227-233.

Van Opzeeland I, Van Parijs S, Bornemann H, Frickenhaus S, Kindermann L, Klinck H, ... and Boebel O (2010) Acoustic ecology of Antarctic pinnipeds. Marine Ecology Progress Series 414:267–291.

4.10 SPOT – Single Penguin Observation and Tracking

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Grant-No. AWI_ANT_13

Objectives

SPOT is a long-term remote controlled observatory to monitor emperor penguins continuously throughout the year for biophysical, ecological and behavioural studies.

Continuous data collection over prolonged time periods is the cornerstone of behavioural and ecological studies. Such data can be used to analyze a large scale of behavioral and ecological problems, from an individual animal to population trends. Time lapse imaging has gained significant interest within the last decade and is now a standard tool due to the large availability of low-cost digital cameras (Kucera & Barrett 1993; Newbery & Southwell 2009; Lynch, Alderman & Hobday 2015) as well as the steadily increasing capability of image processing software (Dell et al. 2014; Gerum et al. 2016). However, in remote and climatically harsh locations such as Antarctica, data acquisition and physical access to the observation system can be challenging. We implemented a remote-controlled and energetically self-sufficient observatory (SPOT, Fig. 4.10.1) specifically designed to operate in Antarctic conditions.

The observatory is designed with the aim to investigate the population and behavioral ecology of emperor penguins (Zitterbart et al. 2011, 2014; Gerum et al. 2013). The challenges in observing emperor penguin colonies are that those are poorly accessible, and their mating and breeding behaviour can only be observed during the coldest and darkest months, with wind speeds up to 150 km/h and temperatures as low as -50°C. Therefore, the observatory needs to be, autonomous and remotely controllable, as well as require little maintenance. As emperor penguins do not build nests, and incubate their single egg on their feet, the whole colony can move within an area of several km^2. To observe such a large area, we installed 7 stationary wide-angle cameras for panoramic overview images, and a steerable 29 megapixel camera mounted on a pan-and-tilt unit as well as a long wave thermal imaging camera. Both, the thermal and the colour camera, are equipped with a telephoto lens for either high-resolution images, stitched panoramic images, or video recordings of the colony.

SPOT was deployed in the Austral summer season 2012/13 at Atka Bay (70°37.0'S, 8°9.4'W), approximately 8 km north of *Neumayer Station III*, on the Ekström Ice Shelf (Richter et al. 2018). Since 2013, we have been collecting wide-angle overview images at a rate of 1 frame per minute to determine the colony position, and when visibility conditions permit daily panoramic images stitched from high-resolution images to count penguins, and on-demand high-resolution video recordings of the colony at 5 frames per second (fps).

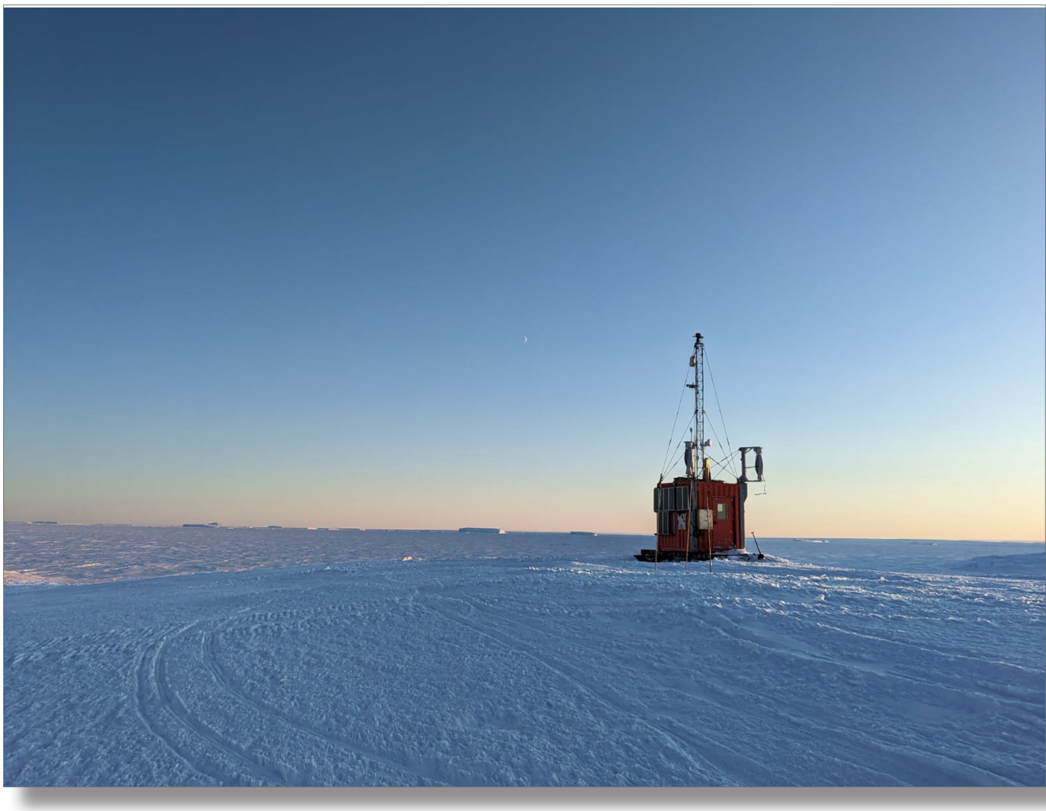

Fig. 4.10.1: SPOT penguin observatory

Fieldwork

Data collection throughout the winter 2023 went without major problems.

Unfortunately, during most of the 2023 breeding season, the Penguin colony did not settle at their usual spot right in front of the penguin observatory, but approximately 1-2 km north, behind an ice ridge, and were not observable during this time. This situation was very similar to 2022, and we speculate that the large iceberg in front of Atka Bay is causing this change in breeding site location. The situation did not change until the end of the breeding season. We did not choose to move the observatory, because moving SPOT during winter with very cold temperatures might lead to significant damage to the cables.

During the summer field season (ANT-Land 2023/24), a major electronic overhaul of SPOT was conducted. We replaced the “brains” of spot and moved from a Barix based microcontroller to a Raspberry PI based controller board for increased flexibility. We furthermore replaced the entire control electronics of the overview cameras to allow for data storage during periods when the WIFI connection between SPOT and *Neumayer Station III* is turned off to save power. Now, SPOT collects an overview image every 10 minutes if in sleep mode.

Preliminary (expected) results

We have been operating SPOT now for 12 breeding seasons with increasing success, which is reflected in annual operation time and data collected. Whilst during the first 2 years we had hardware failure of different components, this has not occurred since the winter of 2015. The operation is conducted completely remotely with support from the Overwinters in case it is needed.

In a recent publication (Winterl et al., 2024) we used 3 years of abundance data derived from SPOT to develop a method with which we can precisely calculate emperor penguin abundance and breeding success across Antarctica from as little as 6 satellite pictures collected during spring (Fig. 4.10.2). The capacity of SPOT to produce abundance estimates as a calibration was critical for this new method.

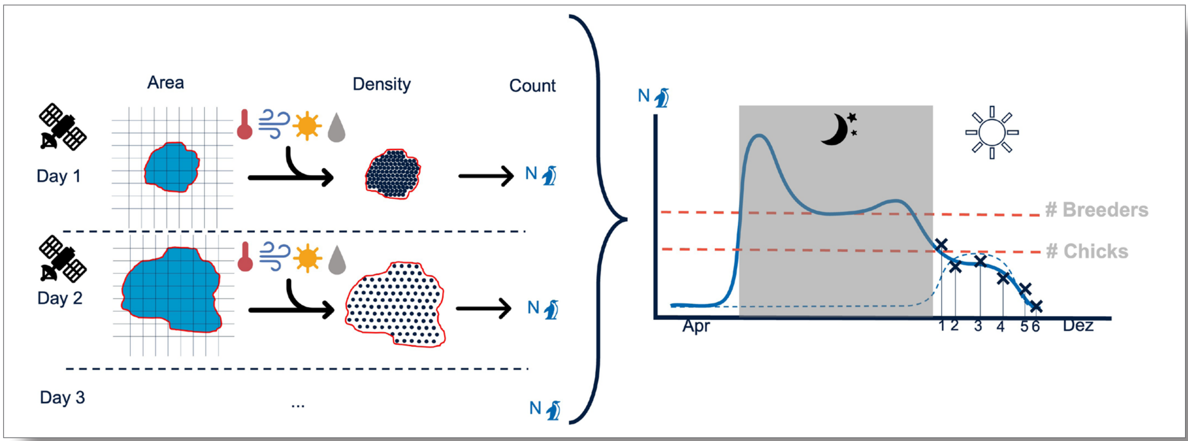

Fig. 4.10.2: Overview of Method to derive breeding success from low-resolution satellite data

Data management

All data recorded by SPOT is transferred annually to the AWI Pangea Data storage repository and stored in the long-term archive.

In all publications based on this expedition, the **Grant No. AWI_ANT_13** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.11 MARE – Monitor the Health of the Antarctic using the Emperor Penguin as a Sentinel

Gaël Bardon[1,2], Johannes Bartl[3], Lauren Stanley[4], Ben Fabry[3], Céline Le Bohec[1,2] (not in the field), Daniel P. Zitterbart[3,4] (not in the field)

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Grant-No. AWI_ANT_14

Objectives

Operation of a long-term emperor Penguin Life Observatory in Atka Bay (on land and at sea) to evaluate the dynamics and trends of this population, and, ultimately, the amplitude of the adaptive capacities of the species.

The main goal of MARE is to assess the vulnerability of Antarctic ecosystems using a sentinel species of Polar Regions: the emperor penguin (*Aptenodytes forsteri*), which stands at the forefront of the impacts of climate warming. Until 2017, the general biology of the entire species (e.g. all the breeding, life-history, and demographic parameters) was based on the monitoring of a single colony (*Pointe Géologie* in *Terre Adélie*, colony that our team is also monitoring electronically and through camera systems within the framework of the IPEV 137 project). Yet, to evaluate the overall trend of a species and the amplitude of its adaptive capacities, it is crucial to monitor over the long-term more than one population breeding in different ecosystems. This is especially true considering that the species is at high risk of extinction in a very near future according to climatic scenario (Trathan et al. 2020). In that context, this second worldwide Life Observatory of emperor penguins (started in 2017 in Atka Bay; that aim to be embedded in an Integrated East Antarctic Marine Research (IEAMaR) Observatory, Gutt et al. 2022) aims to measure the species' adaptive potential to climate change and associated fluctuations in prey abundance and distribution.

WP1

Since 2017, each year and over several decades, 300 five-month-old emperor penguin chicks from Atka Bay colony (out of the approx. 7'000 chicks present each year at the end of the breeding cycle) are marked with small Passive Integrated Transponders (PIT) in order to monitor birds of known-age and -history throughout their life. Microtagged individuals are detected and identified, year after year, with Mobile Identification Systems (MIS), i.e. Radio-Frequency Identification (RFID)-antenna-sledges temporarily deployed on access passageways to birds' breeding sites and RFID-antenna mounted on ECHO-Rover.

WP2

Gathering knowledge on the distribution at sea of the upper-level species is fundamental to help us to define and map marine biological 'hotspots' and/or Marine Protected Areas (MPA). Since 2017, emperor penguins from Atka Bay colony are equipped, over regular intervals and at different stages of their life cycle, with miniaturized multi-sensor biologgers to understand how this species uses the space at sea during the breeding/wintering season, their migration, and their wintering at-sea habitats, and to explore their foraging strategies (communication and collective foraging behaviour, collaboration with Drs. A. Thiebault and I. Charrier University of Paris-Saclay).

In addition, through yearly collection of biological samples we aim at monitoring the diet and trophic level (and their yearly variability) on which emperor penguins are foraging. Gastroliths collected in dead chicks (stomach contents of dead birds) aim to improve the geologic characterization of the foraging grounds and thus the glacial-geologic history of the Ekströmisen region (collaboration with Prof. O. Eisen AWI and Dr. N. Koglin BGR). Moreover, prevalence and yearly variability of microplastics and contaminants is monitored through the analyses of these biological samples (collaborations with Dr. G. Gerdts AWI, Prof. G. Seralini University of Caen, Drs. F. Descroix-Comanducci, P. Bersuder, J. Friedrich, C. Alonso-Hernandez IAEA).

Fieldwork

The ANT-Land 2023/24 summer season for MARE programme ran from 8 November 2023 to 19 January 2024 on the Atka Bay emperor penguin colony.

300 five-month-old emperor penguin chicks from the colony of Atka Bay were microtagged. Each of these chicks were also measured (flippers and beak), blood sampled, weighted, and temporary marked before release (for not recapturing them another time). 50 feces samples were collected during manipulation.

3 RFID-antenna-sledges (Fig. 4.11.1) have been deployed on different access passageways of the emperor penguins from the sea to their breeding colony and/or have been placed so that the colony passes over them during its natural movements due to wind. These antennas allowed to identify microtagged birds in order to collect longitudinal capture-mark-recapture data for our population dynamic modelling.

Fig.4.11.1: Deployment of a RFID-antenna-sledge on an access passageway used by emperor penguins between the colony and the sea.

New tests were conducted with the ECHO rover (Fig. 4.11.2) to approach groups of breeding penguins from the colony using autonomous driving. The rover has been demonstrated to be capable of successfully recognizing and tracking penguins, and it can engage in a slow approach to scan the RFID tag.

Fig.4.11.2: ECHO-Rover tested near the emperor penguin colony.

Colony census (every two weeks) and classical phenological/breeding parameters, chick mortality, and major constraints were monitored over the course of the season. A total of 80 dead emperor penguin chicks were found dead and collected for biometry. 30 of them in good condition were dissected and their stomach was collected.

Acoustic recorders (*AudioMoth*, Fig. 4.11.3) were deployed around the colony as part of preliminary tests that aim 1) to create a database of calls for acoustic capture-mark-recapture analysis and 2) to locate individuals from calls by triangulation. 10 recorders were deployed several times, for a period of one week each time.

Fig.4.11.3: Acoustic recorders deployed at the emperor penguin colony.

Preliminary (expected) results

The first “on-land” objective of MARE Programme, which aims to model the population dynamics/trends of Atka Bay colony thanks to the yearly microtagging of fledging chicks and identification through MIS (use of RFID-antenna-sledges and ECHO-Rover) started season 2021-2022), is based on a long-term data collection (capture-mark-recapture method): age-specific vital traits (survival and breeding success rates) necessary to feed the population models will be available after a minimum of 10 years of electronic monitoring (note that to our knowledge in *Pointe Géologie* colony, emperor penguins start to reproduce in average at 5-year old). After the first detections during the season 2022/23, this season 2023/24 (November to mid-January), we detected 40 different previously PIT-tagged emperor penguins (Tab. 4.11.1). The high detection rate is promising for robust survival analyses, and the next step is to double the number of detection systems on site throughout the breeding season (April to January).

Tab. 4.11.1: Proportion of birds detected during the season 2023/24 from the different groups of marking.

Year of marking	**2017/2018**	**2018/2019**	**2019/2020**	**2020/2021**	**2021/2022**	**2022/2023**	**2023/2024**
Marked as juvenile	19/300	15/300	3/300	0/0	0/300	0/300	106/300
Marked as adult	0/25	2/20	0/0	0/0	1/24	0/1	0/0

Regarding the phenology/census of Atka Bay emperor penguin colony of this season 2023/24: as last year, the colony was and remained mainly on the ice shelf, divided in several sub-colonies. The main group was located near the Meereisrampe in November but moved to and beyond Pingirampe in January. A large group stayed close to the Winter storage area. A small group with a few dozens of chicks remains on the sea ice over the course of the breeding season. Groups of penguins (chicks and adults, from a couple of individuals to several dozens) ventured to and around *Neumayer Station III* during the season. A maximum number of chicks was counted in mid-December with almost 7,700 individuals, which represents a good breeding year for Atka Bay emperor penguin colony.

Data management

Phenology data, Capture-Mark-Recapture, the composition of stomach contents and the mineralogical composition of the gastroliths will be published in AWI’s PANGAEA repository after analyses completion of the analysis, as it was previously done for the at-sea objectives published in 2022 (e.g. https://doi.pangaea.de/10.1594/PANGAEA.913447; https://www.movebank.org/cms/panel_embedded_movebank_webapp?gwt_fragment=page=studies,path=study1322558986).

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.

In all publications based on this expedition, the **Grant No. AWI_ANT_14** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.12 NODEMPICE-NM 2023 – Environmental Seismology for Emperor Penguin Behaviour and Population Monitoring

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Grant-No. AWI_ANT_17

Objectives

Current climate change projections indicate that rising temperatures and changing wind patterns will have a negative impact on sea ice (Meehl et al. 2019; Alkama et al. 2020) on which emperor penguins breed. In this context of habitat loss for the species, some studies indicate that emperor penguin populations will decline by more than 50% during the current century (see the synthesis by Trathan et al. 2020, of which two members of the project are part). NODEMPICE is part of the recent development of "environmental seismology", which provides new observables and proxies for the monitoring of environmental processes in the context of climate change (e.g., Larose et al. 2015). We want to employ related seismic techniques to identify sea-ice characteristics which also might be felt by penguins. For First, icequakes from cracks display a characteristic frequency in the 10 s to 100 s or Hz range, which depends on the ice thickness. Second, lower-frequency modes of elastic sea ice motion might also depend on ice thickness and potentially be felt by the animals. Key questions are: what is the distribution of the mechanical properties of ice (sea and land)? How do they change both spatially and over time? How do animal colonies respond (finely – behavioral responses of an individual, a group of penguins called a "huddle", and the colony) to these characteristics and their variations? Are there any particular characteristics of sea ice (which may be related to site configuration, e.g., anchorage to islands, mainland, ice shelf rifts, icebergs) that are critical to the selection of emperor penguin breeding sites (e.g., compromise between sea ice stability, protection from prevailing winds, distance to feeding sites)?

The NODEMPICE project can be broken down into two operational phases in the field at *Neumayer Station III*. In Phase I we will deploy a network of miniaturized "Node" seismometers over several weeks, on a few sites around and on the nesting sites (note that the penguin colonies are mobile, that is, they can move several meters or even hundreds of meters during a day) to investigate feasibility. In Phase II we plan to repeat the operation, with the same design, over a three-year period at both *Dumont d'Urville Station* and *Neumayer Station III* sites, in order to integrate interannual seasonal environmental variability in our models and to detect interannual changes and local trends in the physical and biological properties of our systems. Deployment will be on winter sea ice in May/June and retrieval in December/January before break-up.

The field work described in this report is a contribution to Phase I at *Neumayer Station III*.

Fieldwork

The recording systems consisting of a 3-component geophone, a DataCube (data acquisition including GPS antenna) with external power supplies and accessory cables were deployed at the locations indicated in Table 4.12.1.

Tab. 4.12.1: Station number, deployment position and deployment date.

Station	Position	Date
PS00	-70° 35.9456‘ -8° 08.3096‘	2023-06-09
PS04	-70° 35.8158‘ -8° 07.8154‘	2023-06-09
PS08	-70° 35.6800‘ -8°07.2421‘	2023-06-09
PS12	-70° 35.5744‘ -8° 06.7225‘	2023-06-16
PS20	-70° 35.3234‘ -8° 05.6567‘	2023-06-16
PS36	-70° 34.8351‘ -8° 03.5165‘	2023-06-16

On 18 September 2023, the stations were checked. The batteries of five stations were in working condition, the sixth was flooded and the battery box was subsequently frozen, so it could not be checked.

The recovery took place in October by a six-person team, after waiting for a period of bad weather. On 4 and 6 October 2023, all stations were removed without residue, with two exceptions:

- At one station, a power cable had frozen into the sea ice and could not be retrieved. The cable was therefore left behind.
- At a second station, the box containing the battery was flooded by a high layer of snow (the top of the sea ice is pushed below the level of the sea water). This led to corrosion of one of the battery’s connections and the formation of verdigris. The contaminated water in the battery box was disposed of at the *Neumayer Station III* in accordance with regulations.

A total of four stations were flooded.

Preliminary (expected) results

Since the start of the NODEMPICE project, we performed three deployments at *Dumont d’Urville Station* (DDU). The first two experiments occurred in 2022 and 2022 were design to test the instruments and the protocols of installation along with the best parametrization for the seismic instruments. The actual sciences experiments started in 2023 with a deployment of 3 antennas of 5 nodes each deployed three different locations near DDU.

As we are writing this report only preliminary spectrogram analysis have been performed on the recorded data (Fig. 4.12.1). The initial results show many high frequency impulsive sources that could be used to access the thickness of sea ice from the time-frequency dispersion of the bending wave emitted by those impulsive sources. In addition, seismic noise is also recorded and should allow us to apply the inversion methodology proposed by Moreau et al. (2020) to estimate the elastic properties (Young’s modulus, Poisson’s ratio, etc.) of sea ice from the interferometry of ambient seismic noise. More analysis needs to be conducted to confirm those perspectives, which will then also be applied to the NM data set.

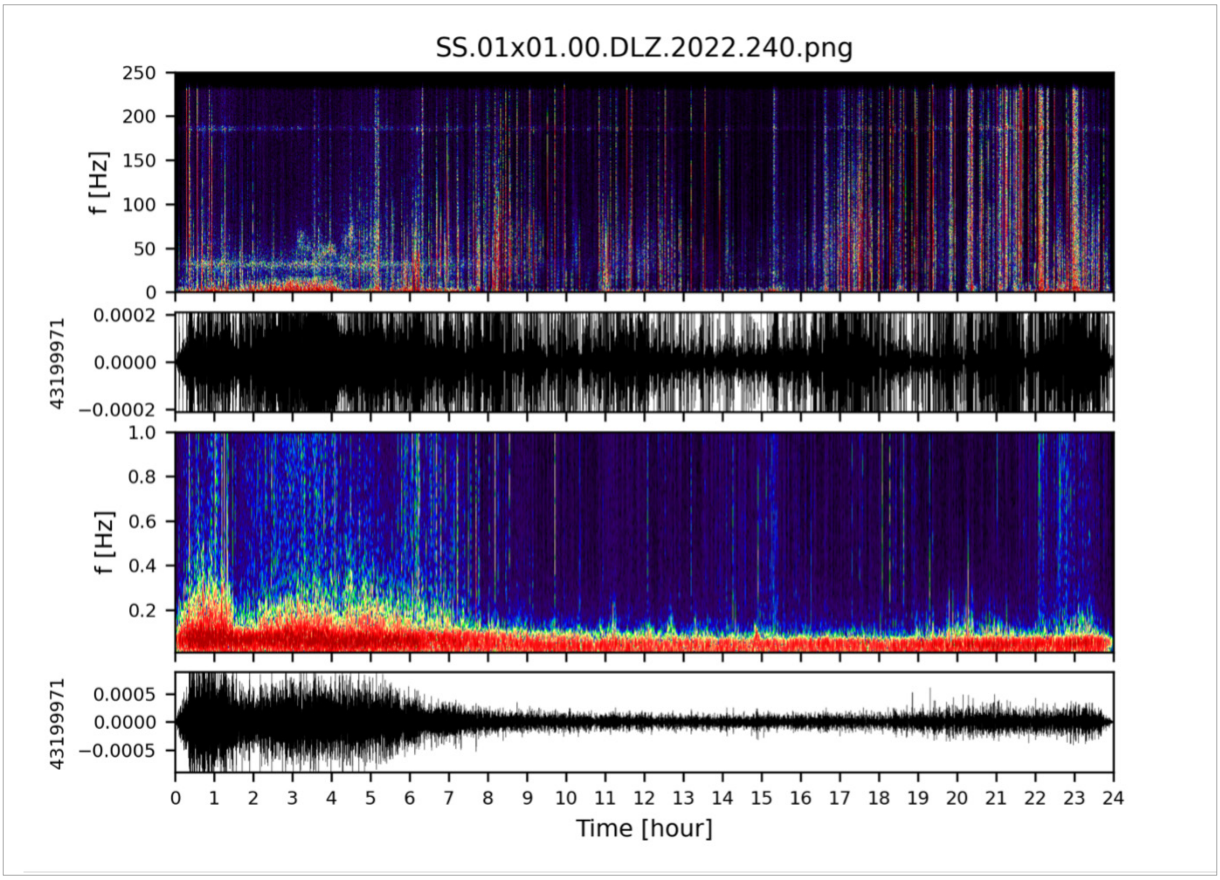

Fig. 4.12.1: Time series and spectrogram to two periods recorded at DDU.

Data management

The raw measurements are currently quality checked and will be 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.

This expedition was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopics 1, 2 and 4.

In all publications based on this expedition, the **Grant No. AWI_ANT_17** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

References

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Larose et al. (2015) Environmental seismology: What can we learn on earth surface processes with ambient noise? Journal of Applied Geophysics 116:62–74.

Meehl et al. (2019) Sustained ocean changes contributed to sudden Antarctic sea ice retreat in late 2016. Nature Communications 10:14.

4.13 WSPR RADIO Beacon at *Neumayer Station III* – Evaluation of Southern Hemisphere Radio Propagation

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Grant-No. AWI_ANT_15

Objectives

The objective of this project is to gain more knowledge about the propagation of radio waves in the ionosphere at Antarctic latitudes and at frequencies between 100 kHz and 50 MHz. This is achieved by about 2000 amateur radio stations (also called “ham radio”) spread over the globe. These stations transmit beacon signals or/and receive them from other stations, generating so-called “spots”. These spots are reported into an open web-based database system, also known as “WSPR-Net”. The beacon messages use a standardized format called “propagation reporter protocol”, which has been developed and introduced in 2008 by Joe Taylor, amateur radio call sign K1JT, physicist and Nobel Laureate. Because seasonal propagation situations south of the tropic were scarce to date, a WSPR (Weak Signal Propagation Reporter) beacon station was installed at *Neumayer Station III* in 2018.

The project was initially intended to last for one year, but extended to a full 11-year sunspot cycle until 2030. These years of high activities of the sunspot shows interesting changes of the propagation over the Ionosphere.

The project is funded by the investigating institution as well as by DARC (German Amateur Radio Club) and supported by several private individuals highly dedicated to amateur radio and to research projects. The receivers at *Neumayer Station III* / SPUSO are operating autonomously with special decoder programs reporting the mean of the relative signal-to-noise ratio (SNR) during receiving intervals.

Fieldwork

Both, the transmitter and the receivers are operated remote and by self-controlling. If there occurs a deviation from the expected results, first the remote-control operator tries to solve the reason for the missing results and second, in an excellent cooperation with the winter team the evaluation *in situ* could give some more information about the possible technical defect.

The enhancement of technical equipment is prepared in Germany and shipped with *Polarstern*. The summer technical team exchanges the prepared equipment, if needed.

Receiver of WSPR Spots

The receiving system at Spuso consists of three receivers that can be used as remotely configured. Two receivers are permanently set to continuously monitor 8 amateur radio bands in the range 1.8-14 MHz and 7-50 MHz. The receivers also decode all received transmissions and send them to the database at wsprnet.org. From there, the information can be analyzed according to various aspects in a special evaluation tool at wspr.live.

It became apparent that after several years of operation, the large triangular wire loops for reception of worldwide spots with their antenna wire were torn several times and therefore required more maintenance work during the year. The wire had to be mended several times. Unfortunately, there was not enough aerial wire at *Neumayer Station III*. New wire had to be delivered with the supply run. The large loop was therefore no longer maintained due to the lack of aerial wire.

Low spot numbers revealed that one of the two isolating amplifiers, applied for the large loop had become defective. The attempt to find and eliminate the fault with the overwintering team did not lead to any results. The large loop was therefore connected directly without the isolating amplifier to the receivers.

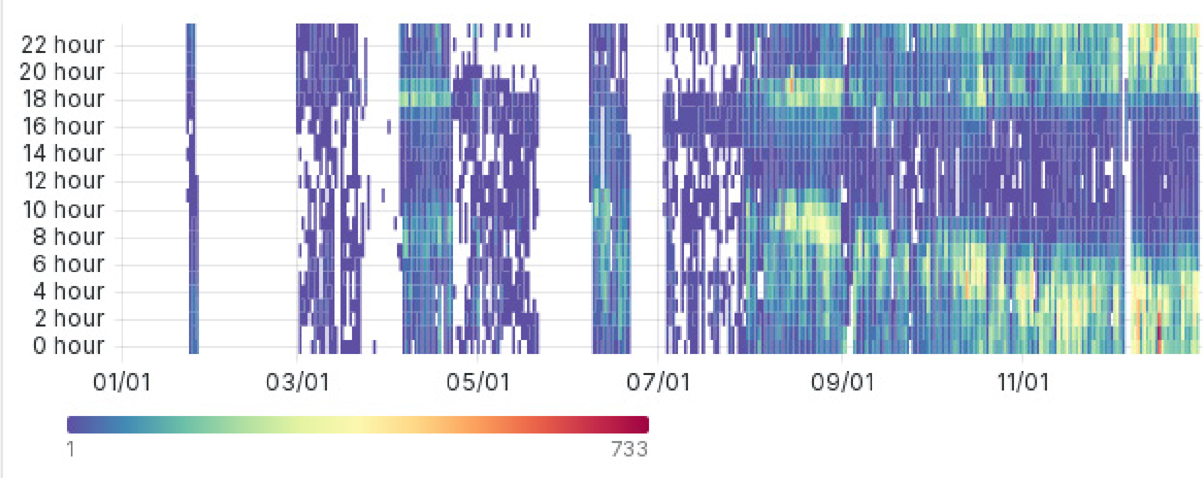

Fig. 4.13.1: Distribution of the spot numbers per hour received over date and hour of day with the defective large loop and defective isolating amplifier on all bands.

Figure 4.13.1 shows the distribution of 338779 spots over the date and over the hour of the day received with the large loop. The number of spots per hour is shown in the color. Very few spots were registered in the first half of the year. The defective condition of the preamplifier became apparent in the middle of the year. At the beginning of August, the defective isolating amplifier was bypassed and the large antenna for the low frequencies was connected directly.

The highest number of spots will be received on the large antenna in August between hour 9 and 11 and between hour 18 and 20. (colored light yellow blocks) This time shifts in December to the time from hour 20 to 6.

In December, practically only a few spots are received between hour 8 and 17.

To remember: A transmission of a spot lasts 112 seconds. A new transmission is carried out every 2 minutes. Around 1,500 ham radio stations are involved worldwide, spread across the globe mainly in the northern hemisphere. From January 1 to December 31, there are 262,800 2-minute slots in which reception or transmission is possible.

Preliminary (expected) results

From 1 January to 31 December 2023, 497,000 spots were received. All spots received by the two receivers at the same time are only counted once. Figure 4.13.2 shows the distribution and the absolute number of spots of the receiving system. In total there have been collected 1,492.774 spots. The 7 MHz band collected up the largest share with 400,000 spots. With 10 % fewer spots, the 14 MHz band is followed by the 10 MHz band. These three bands are received simultaneously by both receivers. The reception numbers are therefore relatively high.

Due to the sunspot cycle and the strong influence on the ionosphere, the upper frequency bands for amateur radio up to 30 MHz may also be significantly more ionized in 2023 compared to years during sunspot minimum. This is most evident in the increasing number of spots on 28 MHz.

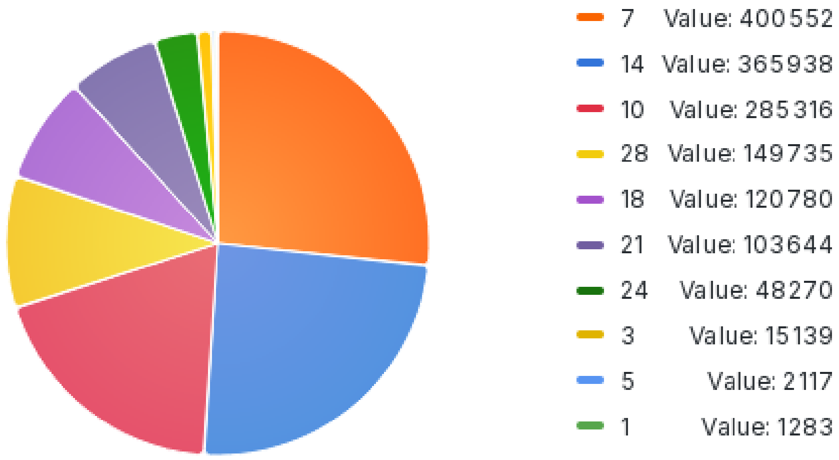

Fig. 4.13.2: Distribution of the received unique spots 1 January to 31 December 2023 on all receivers at SPUSO.

Figure 4.13.2 clearly shows that almost two thirds of all spots occur on the frequencies 7, 14 and 10 MHz. This is followed by 28 MHz.

During operation, it also became apparent that one of the three Redpitaya receivers was unstable. The third receiver was therefore operated in parallel with the uncertain receiver. However, the results also show that the sensitivity may also be different in the two receivers operated in parallel. Around 15 % more spots were recorded in the additional receiver. The cause of these differences has not yet been determined.

WSP-Receiver for the lower bands

The low band receivers are configured for the frequency bands from 1,8 to 14 MHz

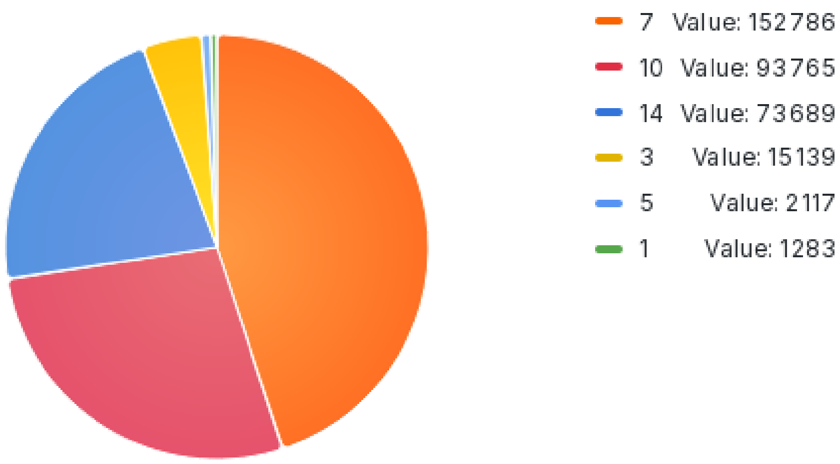

Fig. 4.13.3: Distribution of Spots received with the low band receiver on the large loop. Absolute number: 338,779 spots.

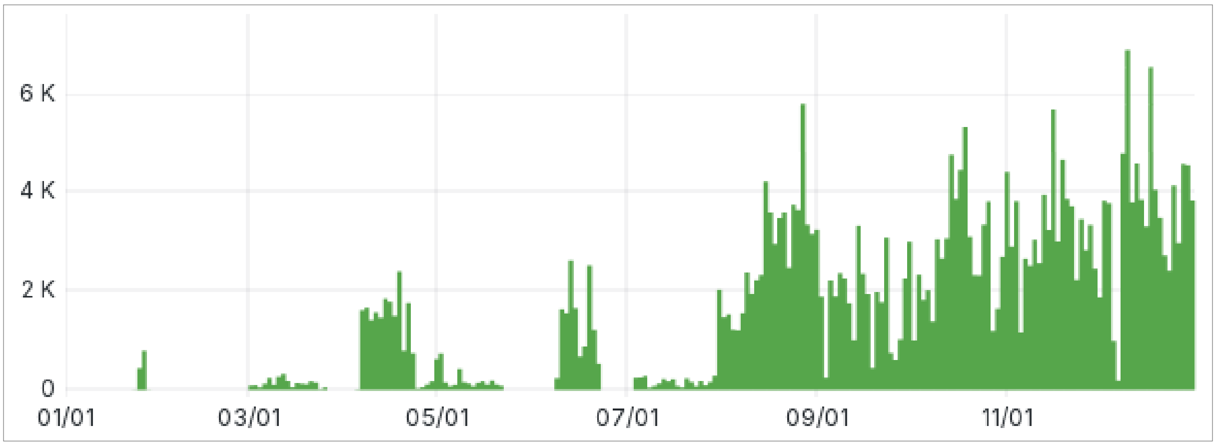

Fig. 4.13.4: Number of Spots per day received on all bands with the large loop.

Figure 4.13.4 shows the number of spots received daily on the large loop. Up to 7,000 spots are received at the beginning of December on all frequencies from 1.8-14 MHz. The selected frequency range was chosen based on the size of the large loop. Figure 4.13.1 corresponds to Figure 4.13.4 and shows the distribution of the spots received on the large loop over date and time of day.

In August, a particularly large number of spots are received during the hours 8-10 and 17-19. This period shifts and widens in December from 6 p.m. to 6 a.m. continuously.

To clarify the question of how many of the spots are received on the higher bands and at what times, the 14 MHz band was selected here.

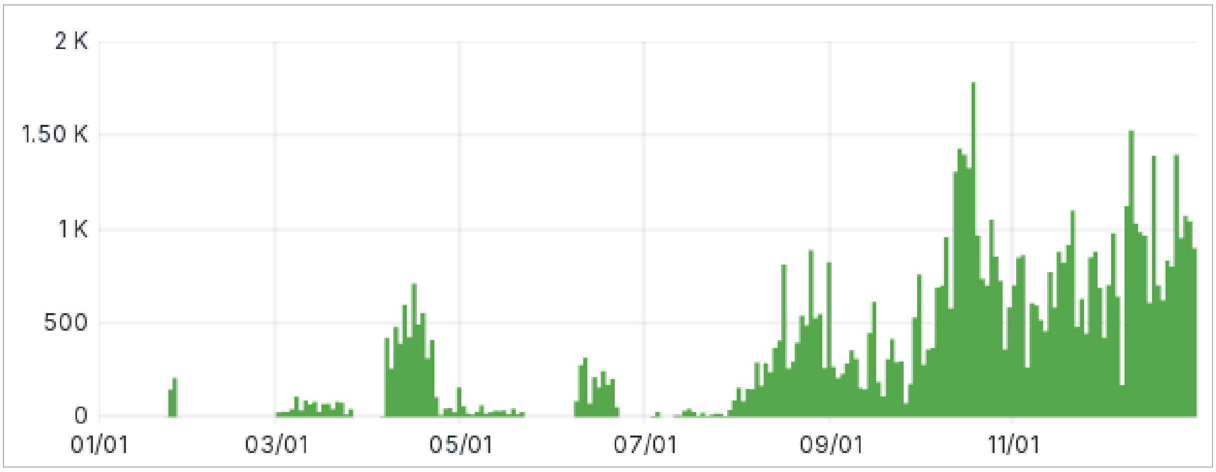

Fig. 4.13.5: Number of spots received on 14 MHz with the large loop.

Figure 4.13.5 shows the number of spots received daily with the large loop on 14 MHz. Figure 4.13.6 also shows the distribution over the times of day.

From August to November inclusive, a particularly large number of spots are received from 18:00 to 19:00. The morning maximum between 4:00 and 6:00 a.m. is much less prominent and only starts to develop in October. There was practically no reception recorded in the months before that.

In July and August, the sun is still relatively low in the sky. There are fewer hours with daylight than nighttime. The ionosphere can only be ionized to a lesser extent, so that practically no radio transmission on 14 MHz is possible over long distances.

From the beginning of October, day and night are the same during the day. The ionosphere can therefore be ionized much better. In December, the sun is above the horizon for 24 hours, so that transmission is also possible during the night hours without interruption. During the hours when the sun is high in the sky, the deeper layers of the ionosphere are ionized, resulting in strong attenuation and less radio transmission.

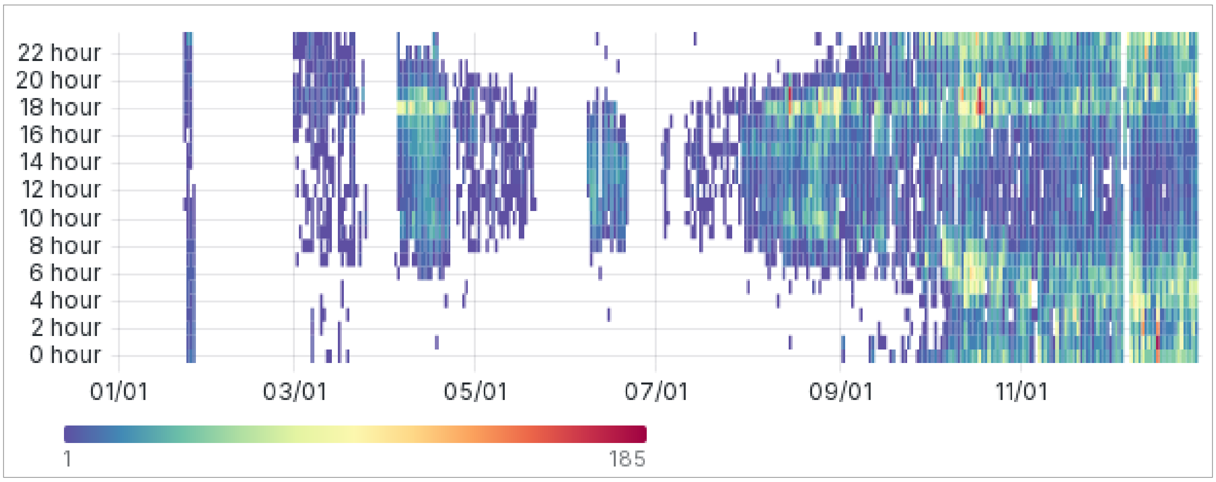

Fig. 4.13.6: Distribution over Date and hour of the day of spots received on 14 MHz with the large loop.

During the hours when the sun is high, the deeper layers of the ionosphere are ionized, resulting in strong attenuation and also making less radio transmission possible.

WSPR-Receiver for the higher bands

Due to the strong ionization of the sun, frequencies up to over 30 MHz can be used for long-distance transmission. For this reason, reception on the smaller loop with a circumference of 60 m for frequencies from 7 MHz to 28 MHz is shown and described below for comparison.

The higher absolute number of received spots (618,014) on the smaller loop can be explained, among other things, by the fact that this loop is broken less frequently than the large loop. Furthermore, the isolation amplifier for this antenna was intact without interruption.

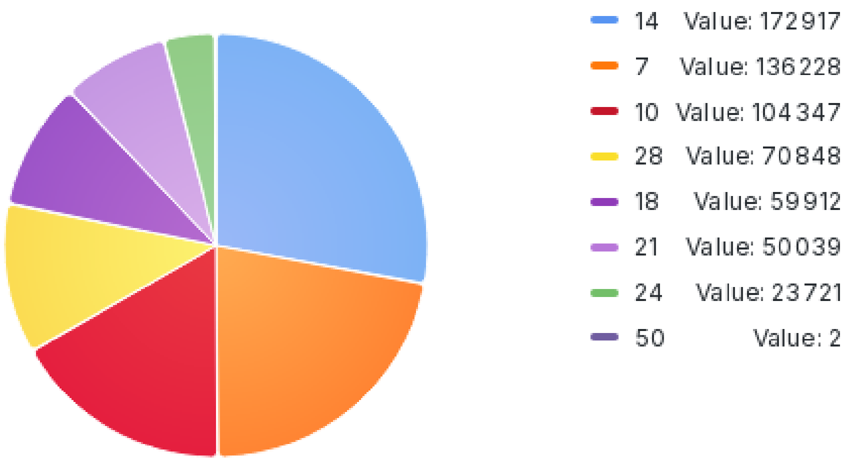

Fig. 4.13.7: Distribution of Spots received with the high band receiver on the small loop. Absolute number: 618.014.

Figure 4.13.7 shows the distribution of the spots on the received frequency bands. At 14 MHz, practically two and a half times as many spots were received with this antenna system as with the large loop.

It is also noticeable that significantly more spots are received on 28 MHz than on the 18-24 MHz frequency bands. Long-distance transmission in this higher frequency range is characterized by significantly lower attenuation in the lower layers of the ionosphere, so that transmission is more likely to be possible.

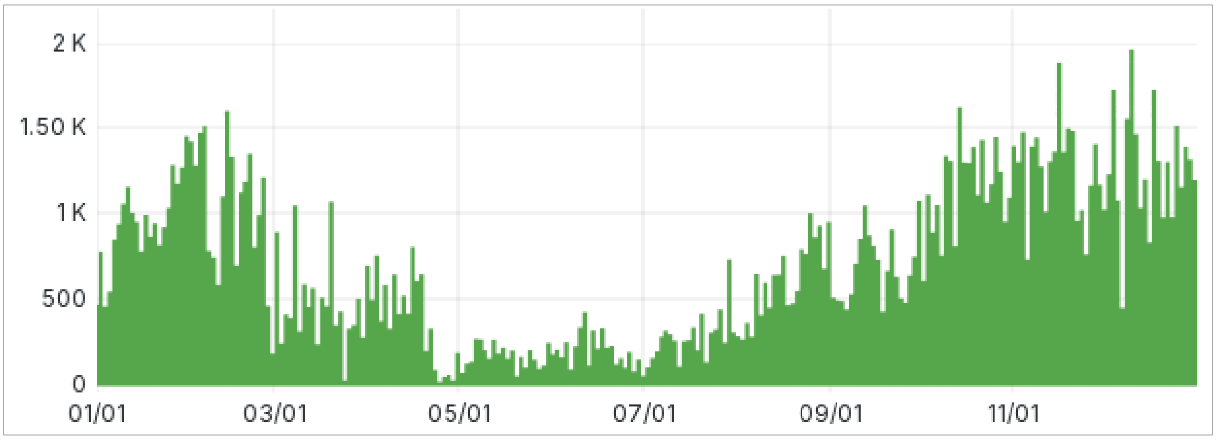

Fig. 4.13.8: Number of spots received on 14 MHz with the small loop.

Figure 4.13.8 shows the number of spots received daily at 14 MHz on the small loop. This makes a comparison with Figure 4.13.5 possible. Slightly higher numbers of spots per day are received on the antenna better suited to the high frequencies (Fig. 4.15.8). However, peak values of up to 2000 only occur in November and December.

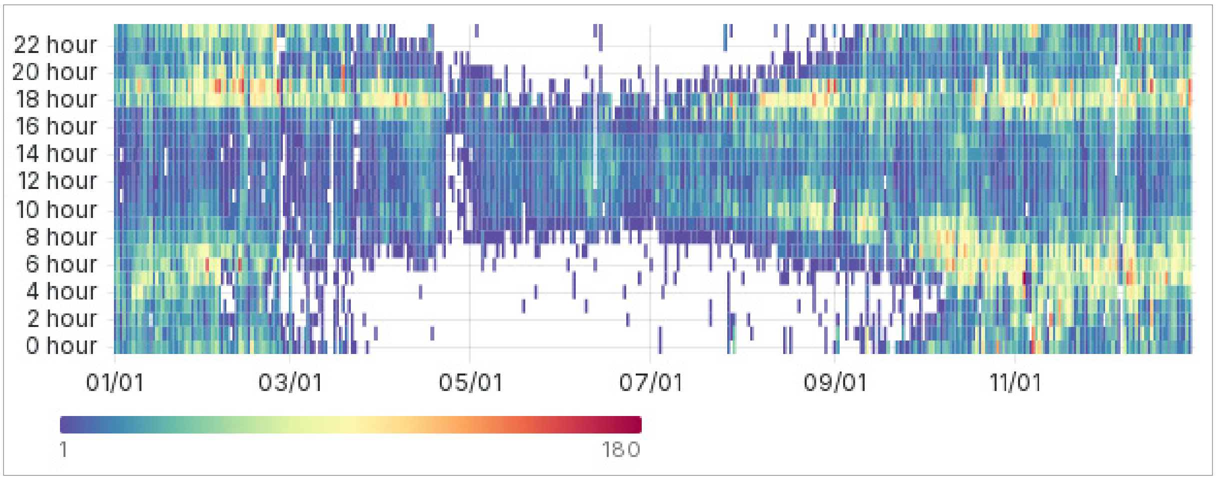

Fig. 4.13.9: Distribution over Date and hour of the day of spots received on 14 MHz with the small loop.

Figure 4.13.9 shows the distribution of spots received on 14 MHz over date and time of day. The increased number from 18:00 to 19:00 is clearly visible. The morning maximum from 9:00 to 10:00 a.m. in August and September shifts to 6:00 a.m. at the beginning of October and is distributed throughout the night in November.

The clearly visible white areas without reception from March to October are related to the position of the sun. In June, transmissions are possible on 14 MHz from 10:00 to 16:00 despite the polar night.

By comparing this period from 10:00 to 16:00 in June and December, however, it also becomes clear that the number of spots received in December decreases compared to June due to the higher daytime attenuation of the deeper ionosphere layers.

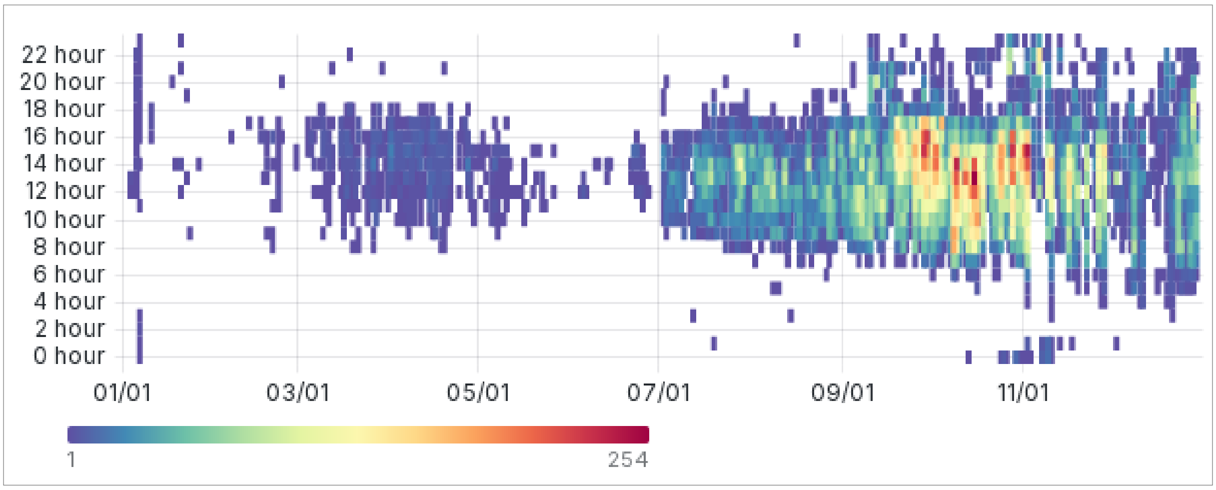

Fig. 4.13.10: Distribution over Date and hour of the day of spots received on 28 MHz with the small loop. Absolute number: 74,868 spots.

Figure 4.13.10 only shows the received spots on 28 MHz as a distribution over the hour of day and date. Starting in July, spots are received during the daytime. The increased number of spots in October is particularly remarkable. If we assume that transmission on 28 MHz is largely possible in daylight with the increased ionization, a larger number of transmitting beacons can only be reached in the northern hemisphere during the months with equal day and night periods. During the winter in the northern hemisphere, the sun is very low in the sky and the daytime is relatively short. This hinders the strong ionization that would be required for transmission on 28 MHz. Accordingly, the numbers of spots received on 28 MHz fall back during these months.

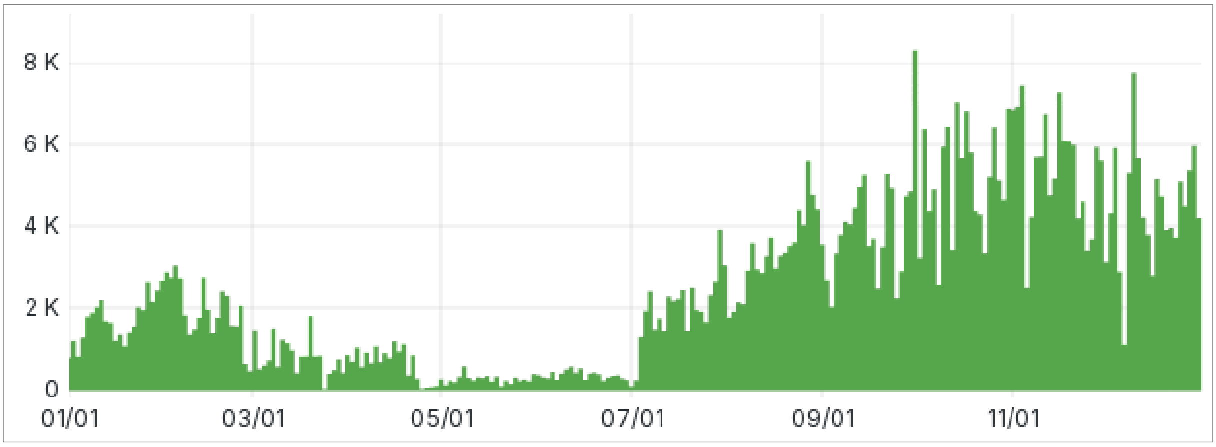

Fig. 4.13.11: Number of spots received on all higher bands with the small loop.

Figure 4.13.11 shows the number of spots received daily for all bands between 7 and 28 MHz on the small loop. It is clearly visible that more than 8000 spots are received on at least one day in October. A comparison with Figure 4.13.8 shows that basically only the second half of the year can be analyzed. In the first half of the year, major difficulties with the antennas and the isolating amplifiers had not been resolved for some time.

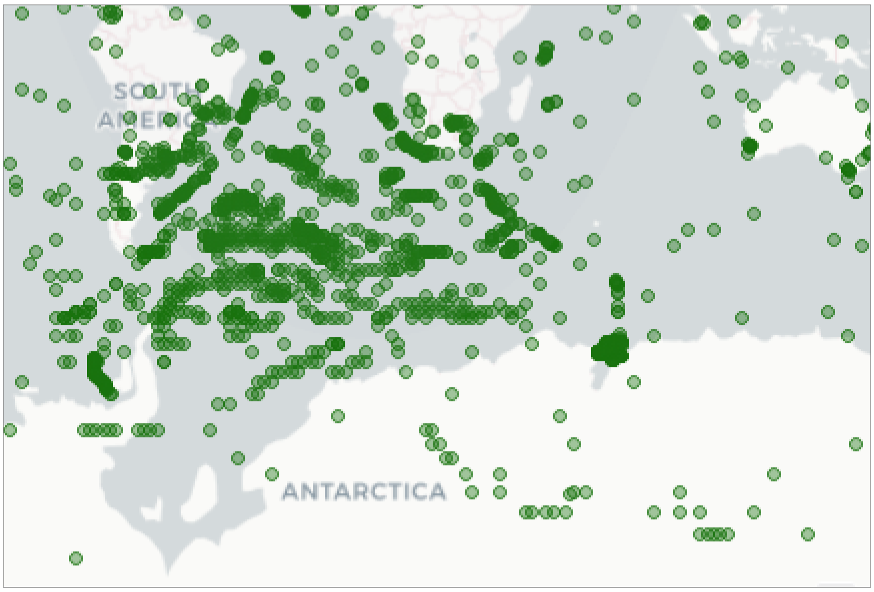

Fig. 4.13.12: Southern Hemisphere with tracks of ballones and Polarstern received on 14 MHz.

Figure 4.13.12 shows the southern hemisphere. The spots received at 14 MHz from moving beacon transmitters are superimposed. The resulting tracks can be assigned to individual transmitters. Most of the tracks are created by stratospheric balloons. However, some tracks are also from *Polarstern*.

During the period of observation, an American university had launched several stratospheric balloons with a project at *Neumayer Station III*, which transmitted telemetry data when flying around the pole, coded as WSPR spots and which were all received at Spuso. This is reported on in a special chapter.

Balloons launched by radio amateurs around the world reach several orbits of the earth and also reach the southern hemisphere around the pole. Many of the tracks shown originate from these balloons.

WSPR Transmitter at Neumayer Station III

Operation of the WSPR transmitter was once again impacted by an antenna damage which happened during a severe storm on 6 May 2023. The antenna is a long wire type and mounted on masts on the station's roof. While this location is favourable for antenna performance it makes maintenance almost impossible outside the summer season. The antenna was fixed end of November and broke again in February 2024.

Meanwhile transmissions were switched to a 5-meter-long vertical antenna. This way transmissions could continue. Unfortunately, this antenna performs differently compared to the wire antenna, therefore reception results cannot be compared. This leaves an unfortunate data gap of about nine months.

Nevertheless, the transmitter worked with just minor interruptions so that more than 260,000 messages were transmitted. This resulted in about 734,000 reception reports, 39% less compared to 2022. This decrease is due to the broken antenna because the vertical antenna used as a replacement is less efficient (as it is too short in size for most of the transmitted wavelengths).

Solarcyle 25

Meanwhile solar activity continued to increase, following the expected development of the solar cycle as shown in Figure 4.13.13. Solar minimum had occurred in December 2019. On average a solar cycle lasts 10.7 years +/- 3 years and is somewhat asymmetric as the rising phase takes about one year less than the decaying phase. Therefore, statistically solar maximum is to be expected between mid-2024 and mid-2025.

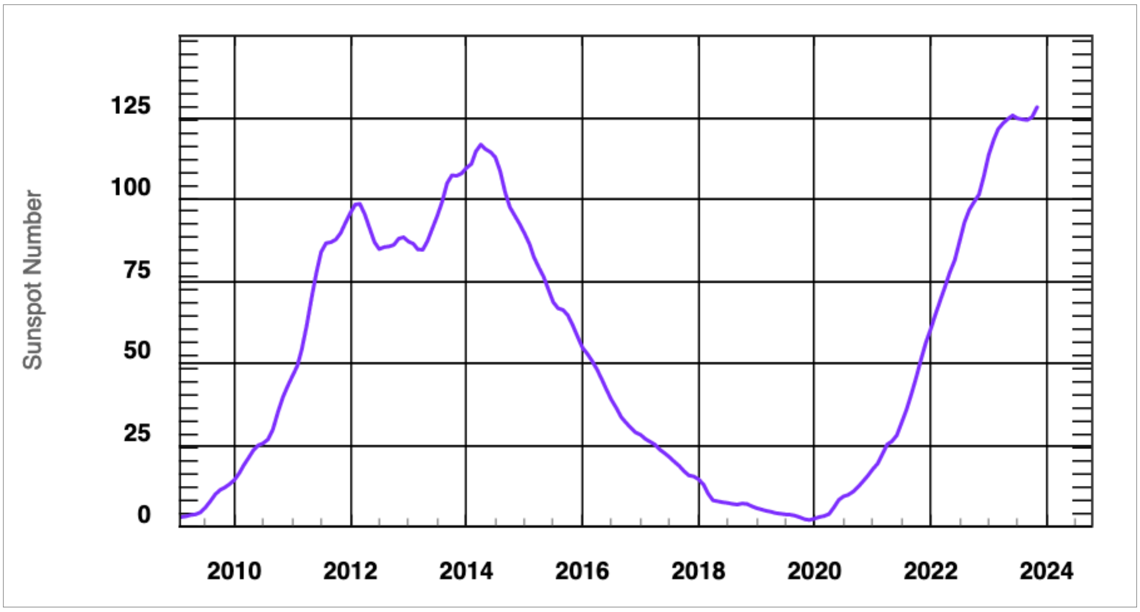

Fig. 4.13.13: Measured Sunspot numbers (NOAA SWPC https://www.swpc.noaa.gov).

Latest measurements suggest that a first maximum has been reached in late 2023 and that it is likely for this solar cycle to develop a „double peak" maximum like seen with his three predecessors. Typically, the second maximum happens 12 to 18 months after the first one.

In fact the observed level of solar activity is greater than anticipated so that solar max is now expected to peak about 20% higher than forecasted. This means that the current solar cycle 25, while still being considered „below average", is stronger than its predecessor which was the weakest cycle in 100 years. However, recent studies suggest that solar activity maxima observed between 1940 and 2000 were exceptionally high, overlooking a time span of 11,400 years for which solar activity could be derived from radiocarbon concentrations in wood. Therefore the classification of solar cycles into „weak"band „strong" ones (based on observations made since the 18th century) have to be reconsidered (Solanki *et al.*, 2004) .

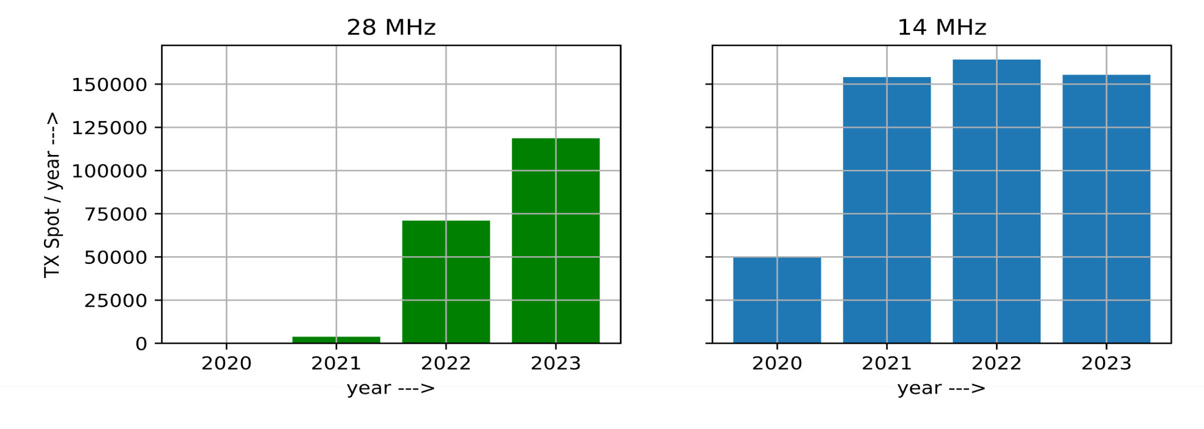

Fig. 4.13.14: Transmitter Spots on 28 MHz and 14 MHz received worldwide per year.

Higher solar activity increases the number and density of free electrons in the ionosphere and this leads to better radio propagation on the higher shortwave frequency bands. This is most prominent on the highest frequency band used in our setup (28 MHz). Figure 4.13.14 shows in the left part the significant increase of the number of reception reports per year on this band for the transmitter spots in comparison to the 14 MHz band (right part). However, it should be noted that the 2023 count of both charts is impacted (reduced) by the antenna problem.

The project team wants to thank AWI and the staff of *Neumayer Station III* for their continuing and excellent support.

Data management

The data generated from the beacon receiver is saved locally on a network storage at *Neumayer Station III* as well as on a worldwide database called “wsprnet.org”. This offers worldwide and very established access via a web interface. Both offer archive functions as well as basic evaluation functionality. In addition, a new API-based access to the database has been developed and is used by several other websites via https://wspr.live .

The wsprnet.org archive collects all received spot reports worldwide since 2008. In June 2024, about 7.7 Billion spot reports are stored. All spots can be downloaded with free access, compiled on a monthly basis, to a compressed CSV-file. In addition, noise measurement results and locally stored results are available on the server at *Neumayer Station* III. In addition, there are some web pages available now, which have access to a specialized database of the total dataset of spots since 2008 (https://wspr.live/gui).

In all publications based on this expedition, the **Grant No. AWI_ANT_15** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

Acknowledgements

The authors are grateful to many voluntary supporters in this project. Our warm thanks go to the radio amateurs Dipl. Ing. Rainer Englert and the IT-Specialist and space weather specialist Christian Reiber from DARC for setting up and remotely operating the transmitter hardware. Christian Reiber prepared the drafting the last part of the report on the work and propagation interpretation results about the transmitter and the transmitters spot evaluation. Special thanks go also to Felix Riess, Karsten Boedecker, Markus Ajasse and several researchers at *Neumayer Station III*, unknown to us, who set up and repaired the antennas and commissioned the transmitter and receiver systems on-site with untiring commitment.

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4.14 VACCINE – Variation in Antarctic Cloud Condenstation Nuclei (CCN) and Ice Nucleatin Particle (INP) Concentrations at *Neumayer Station III*

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[2]DE.AWI

Grant-No. AWI_ANT_16

Objectives

The earth's climate changes at rates unprecedented in thousands, if not hundreds of thousands of years, with the Polar Regions being the fastest warming areas on earth. Polar regions have also a strong global impact on climate conditions and therefore affect lives and livelihoods across the world. Despite the progress polar climate research made, poorly understood processes remain, one of those being the aerosol – cloud – climate interaction, which still cannot be modelled with satisfying accuracy. Clouds and their interactions with the climate system are one of the most difficult components to model, especially in the polar regions. This is, among others, due to difficulties in obtaining high-quality measurements. The availability of high-quality measurements is therefore of crucial importance for understanding processes and for driving and / or evaluating atmospheric models. Increasing the available data-base is one of the main objectives of VACCINE. Starting with December 2019, TROPOS continuously performs *in-situ* Cloud Condensation Nuclei (CCN) and Ice Nucleating Particles (INP) measurements at *Neumayer Station III*. In the future, the captured data such as number concentrations, particle hygroscopicity, INP freezing spectra etc. will be linked with meteorological information (e.g. back trajectories) and information on the chemical composition of the prevailing aerosol particles for identifying sources of INP and CCN (secondary vs. primary) and transport pathways (local vs. long-range transport) over the full annual cycle. A result of this project will be a deeper understanding about processes dominating the CCN and INP population in Antarctica.

Fieldwork

Starting with the austral summer season in December 2019, CCN-measurements are carried out at the AWI Air Chemistry Observatory with a commercially available CCN instrument (Roberts and Nenes 2005). With the instrument total CCN number concentrations can be determined as function of supersaturation in the range between 0.1 and about 1%. The CCN instrument has been measuring almost continuously since then and has been replaced with a freshly calibrated device beginning of the season 23/24 to prevent malfunction. The remote access to the CCN proofed stable, allowing performance checks of the instrument from TROPOS. The daily / weekly on-site maintenance is being carried out by AWI-staff.

Besides CCN also INP sampling was established, using the low volume filter sampling setup available in the AWI Air Chemistry Observatory. These activities aim at the number concentrations of INP in the air, active at temperatures above -25°C. Filter samples are collected on polycarbonate filters and immediately frozen for later analysis in the TROPOS laboratories (Wex et al., 2019). The weekly filter change and handling is done by the AWI-staff, as well. The latest filter samples arrived recently at TROPOS and the analysis is ongoing.

Preliminary results

CCN measurements

The CCN instrument measures CCN number concentrations at 5 different supersaturations (Fig. 4.14.1). Combined with the particle number size distribution measurements, the particle hygroscopicity can be derived (Petters and Kreidenweis 2007). Running continuously since December 2019 more than four full years of CCN data for Neumayer station III have been gained. Number concentrations in general are low and a clear annual cycle is found for CCN as well as for the total particle number (CN). The latter is similar to results reported for the Belgian *Princess Elisabeth Station*, located 200 km inland in the escarpment zone of Dronning Maud Land at an altitude of 1,400 m (Herenz et al. 2019). Lowest number concentrations are observed in austral winter months May to August and highest in austral summer.

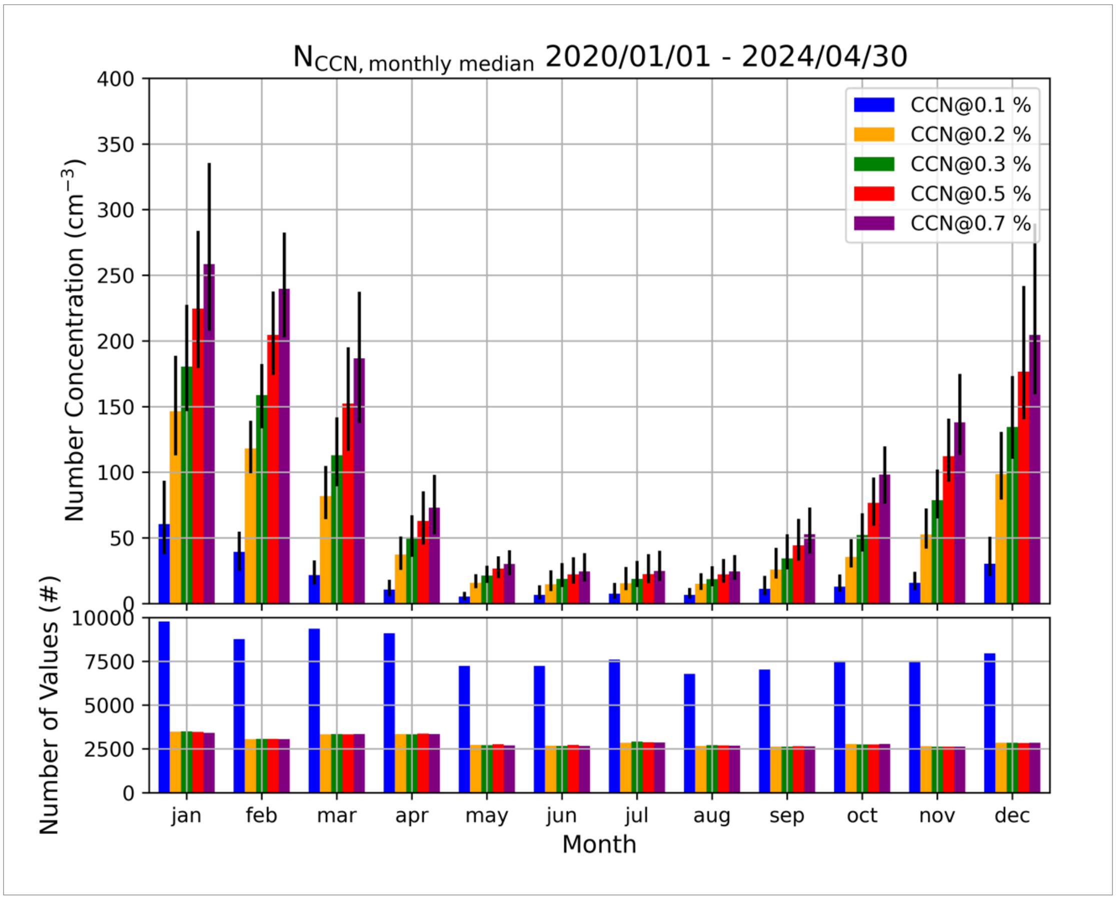

Fig. 4.14.1: Annual cycle of the number concentration of cloud condensation nuclei between 0.1% and 0.7% supersaturation. The current data set ranges from January 2020 until April 2024.

INP results

Each filter is analysed with two different freezing arrays (LINA and INDA, Hartmann et al. 2021) covering a wide freezing temperature range. Samples are also heated to 60°C and 90°C to provide information on the proportion of heat-labile ice-active protein. In general, the INP concentrations are very low even compared to other measurements in the southern hemisphere (e.g. Tatzelt et al. 2022; McCluskey et al. 2018) and thus close to the detection limit. Based on a statistical approach that only considers values significantly different from the field blank, an INP parameterisation for the remote region was developed and successfully tested against other Antarctic INP data (Wex et al. 2024, in preparation). As a preliminary result, only a few samples are ice-active at temperatures above -15°C, and no decrease in ice-activity after heating was observed. This suggests an absence of biological INP sources in the region.

All results are preliminary and will be followed up by an in-depth analysis including a backward trajectory analysis. A further approach applied for source identification will be the potential source contribution function (PSCF), which is a receptor modelling method that is based on air mass back trajectories. The PSCF (Ashbaugh et al. 1985) has been successfully applied to high-latitude studies in the Antarctic (Dall´Osto et al. 2017; Herenz et al. 2019). This model is commonly used to identify regions that have the potential to contribute to high values of measured concentrations at a receptor site.

Data management

CCN raw data are transferred daily from the instrument to the data server at *Neumayer Station III* and from there to the TROPOS server via cronjobs. After their analysis the INP data, will be stored in a long-term archive at TROPOS. Furthermore, the processed CCN and INP data, quality controlled (level 2) 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 project at the latest.

SH position was funded by DFG project HE 6770/3-1 within the DFG Priority Programme 1158 – Antarctic Reseach.

In all publications based on this expedition, the **Grant No. AWI_ANT_16** will be quoted and the following publication will be cited:

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We thank all overwinterers who collected samples for our project so far, namely M. Schumacher, J. Loftfield, L. Ort, H. Keck, N. Wullenweber, M. Radenz, T. Bösch.

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4.15 CARSiMON – A New Atmospheric Remote Sensing Observatory for *Neumayer Station III*

Markus Rex, Holger Schmithüsen, Sebastian Berger, Christoph Ritter (not in the field) DE.AWI

Grant-No. AWI_ANT_36

Outline

The frequency of clouds over the Southern Ocean and the coast of the Antarctic continent is largely underestimated in state-of-the-art climate models, causing models to overestimate surface solar radiation and predict warmer sea surface temperatures than observed, which in turn means the models incorrectly predict the strength and position of storm tracks. These deficiencies are likely caused by an incorrect treatment of aerosol / cloud interaction processes, problems with internal cloud dynamics and microphysics and resulting problems with cloud lifetimes and transport. To provide key data for the improvement of cloud and aerosol physics in climate models, the CARSiMON project has set up a new atmospheric remote sensing observatory at the *Neumayer Station III*. The instruments included are: a cloud radar, a wind lidar, a polarizing aerosol lidar and a microwave radiometer. The remote sensing observation programme is integrated into the cloudnet community (https://cloudnet.fmi.fi/). Cloudnet is an ACTRIS activity to assess high quality data on cloud properties to improve and test climate models. With the new instrumentation we will be able to collect long term data on cloud occurrences, altitude and phase (ice, liquid or mixed), aerosol profiles, the 3-dimensional wind, if possible, turbulence in the clouds and liquid as well as gas phase water columns. *Neumayer Station III* is ideally situated in a region with advection of clouds and aerosols from both, the Southern Ocean region and the interior of the Antarctic continent. The observations shall provide a statistic on cloud properties and occurrences and hence improve and constrain climate models over this region. The large research questions behind this proposal are: how can we explain the large cloud cover over the Southern Ocean / Antarctic coast despite the generally pristine conditions? How do ice clouds form over Antarctica?

Objectives

The core objective of the first CARSiMON project phase (i.e. CARSiMON ANT-23/24 field activities) is to set up a new atmospheric remote sensing observatory at the *Neumayer Station III*. The observatory includes a wind lidar, a cloud radar, an aerosol lidar and a microwave radiometer. Although these instruments are complex, they will run automatically 24/7.

Fieldwork

The main fieldwork phase of the project has been carried out during the ANT-Land 2023/24 summer season. It has focussed on the set-up characterization and calibration of the four new remote sensing instruments which was all successfully carried out during the time period December 2023 to February 2024. Three of the instruments (the wind and aerosol lidar (2), the cloud radar (3) and the microwave radiometer (4)) were installed on the roof of *Neumayer Station III* at their predefined locations (Fig. 4.15.1). This work was supported very efficiently by the technical team of the summer season who used the crane to lift the instruments to the roof of the station. One instrument (the cloud lidar (1), not visible in the figure), was installed under the roof of the station, loking upward through a window in one of the roof hatches.

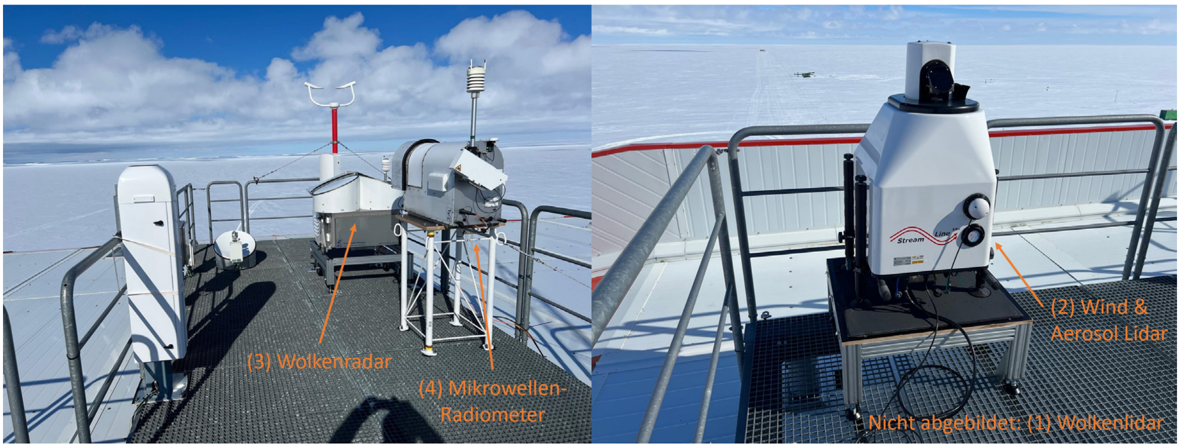

Fig. 4.15.1: Three of the instruments (the wind and aerosol lidar (2), the cloud radar (3) and the microwave radiometer (4)) installed on the roof of Neumayer Station III.

Preliminary (expected) results

The key result of this first field phase of CARSiMON is that the new observatory was successfully installed, all instruments were characterized, calibrated and run nominally.

The scientific analysis of the data collected from the new observatory will be carried out in collaboration with TROPOS and University of Cologne, the Cloudnet consortium and other modelling groups. The analysis of the data will allow to determine statistic on cloud occurrence resolved by cloud type, altitude and season as well as varous key aerosol parameters.

The work will focus on the overarching research questions:

- How can we explain the large cloud cover over the Southern Ocean / Antarctic coast region despite the generally pristine conditions?
- How do ice clouds form over Antarctica?

Specifically, the project is designed to test the following hypotheses:

- Ice formation depends on the aerosol composition (the air trajectory) more than on the seeder-feeder effect from above (He et al., 2022).
- Due to the lower aerosol load, Antarctic clouds consist of smaller particles with a longer life-time, compared to the observations at AWIPEV.
- Internal turbulence and moist layers below or above the clouds are key processes for Antarctic mixed phase clouds (like for those in the Arctic).
- Ice formation in the Antarctic atmosphere is underestimated. We speculate that sporadic bursts of single freezing particles will provide the necessary secondary ice formation. If so, the onset of glaciation in the remote sensing instruments occurs suddenly and in singular altitudes.

Data management

All data collected classifies as environmental data and 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 not be collected and relevant regulations on collecting molecular data do not apply.

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

In all publications based on this expedition, the **Grant No. AWI_ANT_36** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.16 SIBEAT – Sea Ice Biological Essentials at Atka Bay

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[2]NL.RUG
[3]DE.TROPOS

Grant-No. AWI_ANT_38

Outline

Global sea level rise and carbon sequestration are key challenges for ecosystems and societies under a warming climate (Vernet et al., 2019). Sea ice-associated carbon plays a decisive role for the feeding of key species as e.g. the krill Euphausia superba in Antarctica (Kohlbach et al., 2017), which in many Southern Ocean ecosystems is providing a direct food-web link between primary producers and higher trophic levels, e.g. penguins, seals and whales. Sea ice further provides an active biogeochemical interface at the ocean-atmosphere boundary (Uhlig et al., 2019; Vancoppenolle et al., 2013; Webb et al., 2019) that has an impact far beyond the carbon cycle only. Only one of the other climate-active compounds that are produced in and around sea ice is the semi-volatile sulfur compound dimethylsulfide (DMS). In the atmosphere, DMS is oxidised to compounds that form cloud-condensation nuclei (CCN). CCNs affect Earth's albedo and hence climate (Stefels et al., 2007). DMS production is particularly strong in sea ice environments as its precursor (dimethylsulfoniopropionate, DMSP) is used by many ice algae to physiologically adapt to the harsh environment inside brine channels of sea ice.

Sea ice hosts a taxonomically diverse protist community (Hop et al., 2020; Van Leeuwe et al., 2018), which have strongest exchanges with the underlying oceanic habitat during brine rejection and sea ice growth (Hardge et al., 2017b; Kauko et al., 2018). Areas of sea ice growth have thus an important role not only for redistribution of anthropogenic pollutants as microplastic, but also for the biodiversity of the sympagic communities (Hardge et al., 2017a; Peeken et al., 2018).

Land fast sea ice (fast ice) is defined as immobile sea ice, which in Atka Bay is attached to the Ekström Ice Shelf (Hoppmann et al., 2015). A characteristic feature of Atka Bay's fast ice is the presence of so-called platelet ice, which occurs loosely aggregated (=sub-ice platelet layer), and/or accreted (=consolidated platelet ice) beneath the fast ice. Antarctic fast ice hosts some of the most productive (per volume) microalgae habitats in marine systems (Meiners et al., 2018) and shows a strong seasonal cycle (Meiners et al., 2018; Gunther and Dieckmann 1999). Ice algal production reaches its maximum well before the pelagic phytoplankton blooms, thereby extending the productive season and damping seasonal oscillations in food supply for pelagic and benthic food webs. At Atka Bay these extreme high biomasses were not found in 1995 (Gunther and Dieckmann 1999; Gunther and Dieckmann 2001), which was mainly related to higher snow coverage at this site, strongly influencing the under ice light regime (Arndt et al., 2017). However, in general a strong relation between extremely high ice-algae biomass and the occurrence of platelet ice was observed and these communities are widely known to have orders of magnitude higher biomass, when compared to algae biomass from all other ice types (Meiners et al., 2018). The algal communities show a distinct seasonal pattern and once the platelet ice is consolidated into the fast ice, communities shift from centric to pennate diatoms (Gunther and Dieckmann, 2001). Once the ice breaks up in summer, these entrapped organisms could be released in the ocean while drifting with the Antarctic coastal current into the Weddell Gyre, moving towards the western Weddell Sea, while acting as a continuoues seed bank. In addition, anthropogenic particles e.g. microplastic (MP) could be transported to other areas far away from the original sources.

Objectives

The sub-ice platelet layer is a three-dimensional, versatile habitat formed through the continuous accumulation of individual ice crystals below solid sea ice. Despite the heavy snow cover, this habitat builds up large biomass of ice algae sustaining a vivid ecosystem. Thus, the platelet-ice layer is considered to:

1. Export essential nutrients and organic carbon to adjacent pelagic and benthic ecosystems;
2. Contribute greatly to the biological carbon pump;
3. Be an important seeding source for pelagic phytoplankton communities;
4. Be the prime feeding and spawning ground for higher trophic levels (e.g. nursery area of the key forage fish Pleuragramma antarctica);
5. Play an important role in the production of climate-active compounds like dimethylsulfide (DMS).

Since 1995, hardly any detailed biological observations were carried out at Atka Bay leaving a blind spot in the overall role of this habitat for the Antarctic ecosystem. In addition, the remote location of Atka Bay makes it an ideal study area to sample nonship paint contaminated water samples for MP.

We therefore aim to

- Fill the data gap of Sea-ice Essential Variables (SI-EVs) in the land-fast ice region of the eastern Weddell Sea – Atka Bay
- Assess the role of platelet ice for the cryo-pelagic and cryo-benthic coupling of biogeochemical variables
- Contribute to the international effort to collect SI-EVs to validate ice-ocean-atmosphere biogeochemical models
- Obtaining unique biodiversity indicators using state-of-the-art techniques
- Improve our understanding of the coupling between physical, chemical and biological processes
- Assess the role of platelet ice as a nursery for commercial fish

Fieldwork

All fieldworkwas carried out on the land fast ice of Atka Bay, close to the *Neumayer Station III*. The work programme consisted of visiting sites on East-West and North-South transects (Fig. 4.16.1, Tab. 4.16.1). The specific sites were the same as those revisited by the AWI sea ice physics section under the umbrella of the “Antarctic Fast Ice Network” (AFIN). The sea ice conditions were generally good and allowed the fieldwork to be carried out largely without interruption between 10 November 2023 and 17 December 2023. A longer interruption was caused by a storm from 4 December to 8 December 2023. At the beginning of the investigations, the east west transect (ATKA_03 - ATKA_24) was sampled with a detour to the GAP station to get an impression about the algae biomass at this previous not sampled station. This was followed by the eastern of the two North-South transects (ATKA_18SNe to ATKA_00SNe), followed by the western North-South transect (ATKA_16SNw to ATKA_00SNw). The parallel transect to the standard transect was then sampled (ATKA_03p - ATKA_21p). Another East-

West transect (ATKA_03 - ATKA_24) was carried out in one day and finally, the western North-. South transect (ATKA_16SNw to ATKA_00SNw) was repeated. In order to document the seasonal changes in the sea ice biota, station ATKA_07 was sampled regularly at intervals of a few days and, as with ATKA_10SNw, the spatial distribution of the sea ice biota was investigated by taking four additional ice cores around the central location in all directions at a distance of 20 metres.

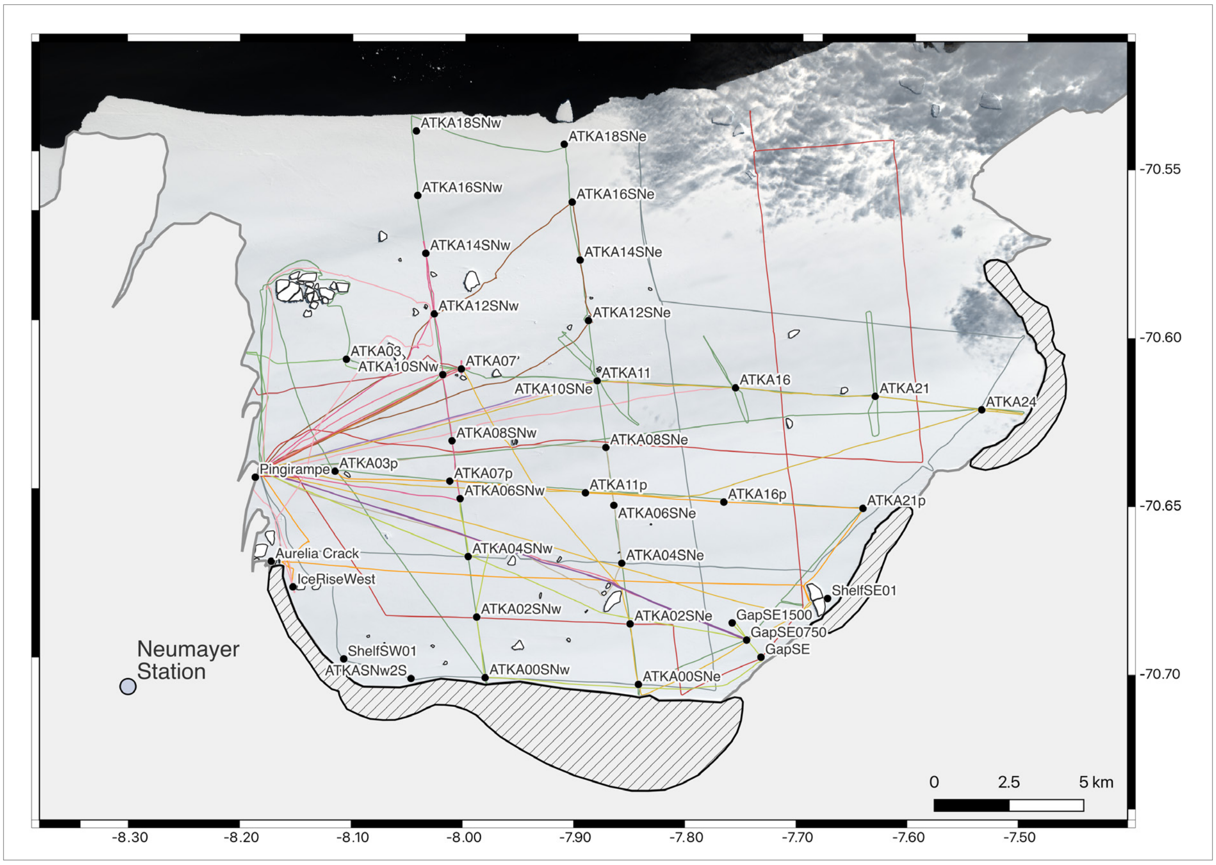

Fig. 4.16.1 Overview of all measurement locations and GEM transects in Atka Bay during the SIBEAT project. The stations ATKA03-24 are the routine measuring points of AFIN, whereby the numbers (03 – 24) indicate the distance to the western ice shelf edge. A parallel transect a little further south is marked by a p at the end. A distinction is made between a western (w) and an eastern transect (e) for the South-North (SN) transects. The numbers 0 – 18 or 16 indicate the kilometres from the southern edge of the ice shelf. The designation GAP stands for the area where the shelf is not grounded (between the Atka-Eiskuppel and the southern Sicheleishöcker) and IceRiceWest refers to a sampling station in the west of Atka Bay. The background is a Sentinel-2 true colour image from 24 November 2023.

Tab. 4.16.1: Overview of all measurements carried out as part of the SIBEAT project between 10 November to 17 December 2023 with the respective positions. The measuring stations mentioned are marked in Fig. 4.16.1. “Cores” stands for the sea ice cores taken for biological and biogeochemical analyses and texture, “Auger” for the sea ice thickness drill measurements, “PI” for platelet ice samples, “UIW” for under-ice water samples (underlined samples mark 20 L, otherwise 10 L), “CTD” for a salinity and temperature probe, “Fluo” for a fluorescence probe and “MP” for microplastic cores taken. At the end of the table, you will find the total number of measurements carried out and cores/samples taken.

Date	Station	Latitude	Longitude	Cores	Auger	PI	UIW	CTD	Fluo	MP
10.11.2023	ATKA_07	-70,58	-7,94	3		2	1	1	1	
12.11.2023	ATKA_11	-70,59	-7,82	2	1	1	1	1	1	
12.11.2023	ATKA_16	-70,60	-7,70	2	1	1	1	1	1	
14.11.2023	ATKA_24	-70,62	-7,48	2	1	1	1	1	1	
14.11.2023	ATKA_21	-70,61	-7,58	2	1	1	1	1	1	
16.11.2023	ATKA_03	-70,57	-8,05	2	2	1	1	1	1	
16.11.2023	ATKA_07	-70,58	-7,94	1	1	1	1	1	1	
17.11.2023	ATKA_24	-70,62	-7,48					1	1	
19.11.2023	ATKA_16SNe	-70,54	-7,82	2	1	1	1	1	1	
19.11.2023	ATKA_12SNe	-70,57	-7,82	2	1	1	1	1	1	
21.11.2023	ATKA_08SNe	-70,61	-7,82	1	1	1	1	1	1	
21.11.2023	ATKA_06SNe	-70,63	-7,82	1	2	1				
21.11.2023	ATKA_04SNe	-70,65	-7,82	2	1	1	1	1	1	
23.11.2023	ATKA_07	-70,58	-7,94	1	2		1	1	1	
23.11.2023	ATKA_00SNe	-70,67	-7,82	2	1		1	1	1	
23.11.2023	ATKA_02SNe	-70,67	-7,82	1	1	1				
23.11.2023	GAP_SE	-70,67	-7,72	1						
26.11.2023	ATKA_14SNw	-70,55	-7,96	2		1		1	1	
26.11.2023	ATKA_10SNw	-70,58	-7,96	2		1		1	1	
26.11.2023	ATKA_06SNw	-70,62	-7,96			1	1	1	1	
28.11.2023	ATKA_04SNw	-70,64	-7,96		3	1		1	1	
28.11.2023	ATKA_02SNw	-70,66	-7,96		2	1		1	1	
28.11.2023	ATKA_00SNw	-70,67	-7,96		3					
28.11.2023	GAP_SE	-70,67	-7,72	2		1		1		
28.11.2023	ATKA_06SNw	-70,62	-7,96		3					
30.11.2023	ATKA_07	-70,58	-7,94	5		1	1	1	5	
02.12.2023	ATKA_07	-70,58	-7,94			1		5	5	
03.12.2023	ATKA_21p	-70,64	-7,60	1	2	1	1			
03.12.2023	ATKA_16p	-70,63	-7,73		3					
03.12.2023	ATKA_11p	-70,62	-7,85	1	2		1			
03.12.2023	ATKA_07p	-70,62	-7,97		3					
03.12.2023	ATKA_03p	-70,61	-8,07	1	2	1	1			
09.12.2023	ATKA_07	-70,58	-7,94	2	1	1	1			

Date	Station	Latitude	Longitude	Cores	Auger	PI	UIW	CTD	Fluo	MP
09.12.2023	ATKA_10SNw	-70,58	-7,96	5						
09.-11.12.	GAP_SE	-70,67	-7,72					25	1	
11.12.2023	Ice-Rise west	-70,64	-8,12	1	2	1	1			
13.12.2023	ATKA_24	-70,62	-7,48		2		1	1	1	1
13.12.2023	ATKA_21	-70,61	-7,58		2			1	1	1
13.12.2023	ATKA_16	-70,60	-7,70		2			1	1	1
13.12.2023	ATKA_11	-70,59	-7,82		2			1	1	1
13.12.2023	ATKA_07	-70,58	-7,94		2			1	1	1
13.12.2023	ATKA_07	-70,58	-7,94	1		1				
13.12.2023	ATKA_03	-70,57	-8,05		2			1	1	1
16.12.2023	ATKA_16SNw	-70,53	-7,96		3					
16.12.2023	ATKA_18SNw	-70,51	-7,95		2			1	1	
16.12.2023	ATKA_14SNw	-70,55	-7,96		2			1	1	
16.12.2023	ATKA_12SNw	-70,56	-7,96		3					
16.12.2023	ATKA_10SNw	-70,58	-7,96		2			1	1	
16.12.2023	ATKA_08SNw	-70,60	-7,96		3					
16.12.2023	ATKA_06SNw	-70,62	-7,96		2			1	1	
17.12.2023	ATKA_04SNw	-70,64	-7,96		3					
17.12.2023	ATKA_02SNw	-70,66	-7,96		2			1	1	
17.12.2023	ATKA_00SNw	-70,67	-7,96		3					
			Total No.	50	80	27	21	62	41	6

All fieldwork and measurements carried out during the SIBEAT campaign:

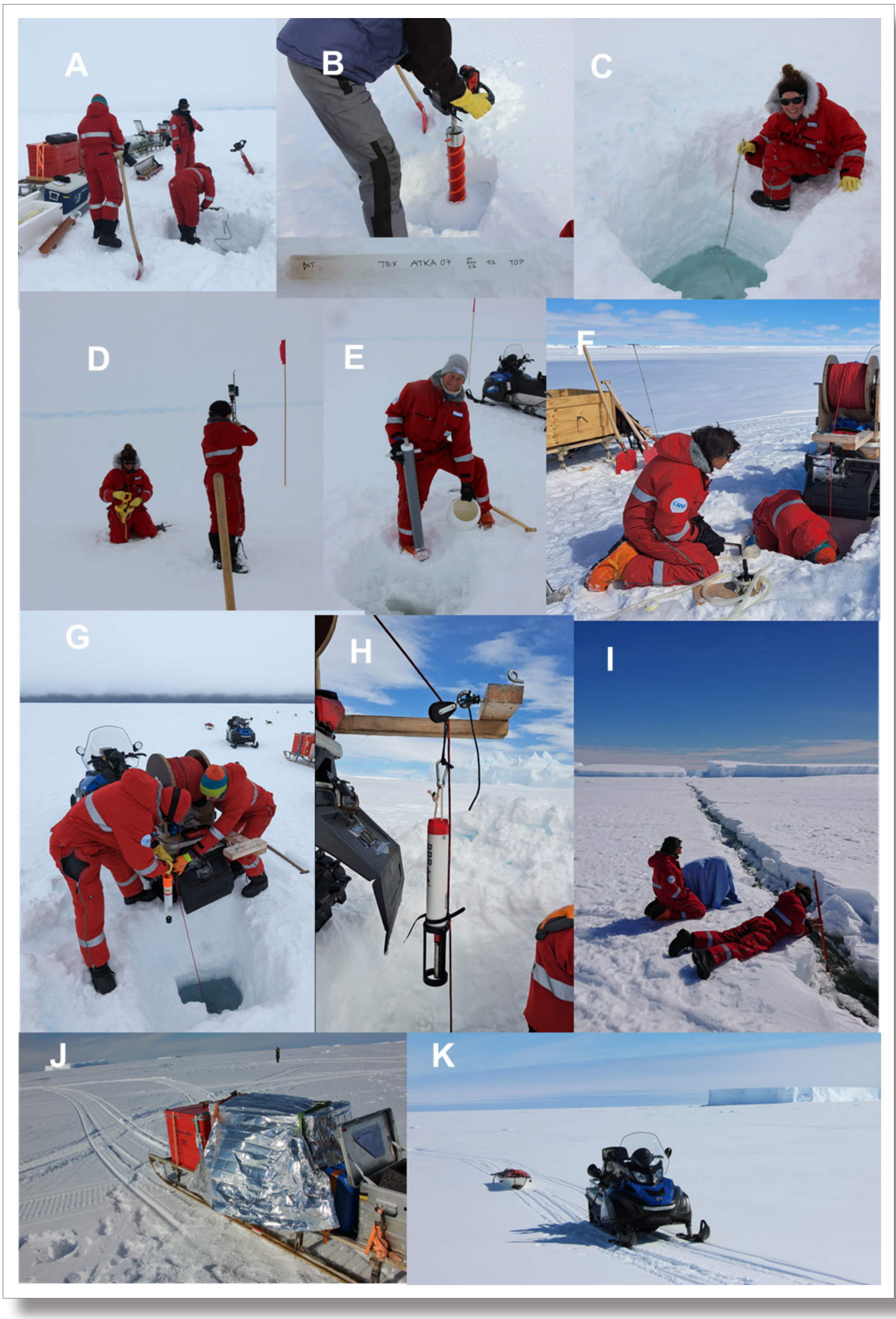

Fig. 4.16.2: Photographic documentation of all measurement principles implemented as part of SIBEAT's sea ice work. A) Snow pit measurements, B) sea ice coring with example ice core, C) snow and freeboard measurements in a flooded borehole, D) Auger and sea ice depth measurements, E) platelet ice sampler and mixed ice water sample in the bucket, F) in the front the manual under ice water pump and preparation of the borehole, G) Attaching CTD-probe, H) Fluorescence probe, I), under ice water camera deployment in a crack, J) Protecting microplastic cores against the warm weather, K) GEM instrument behind the snow mobile

Ice and snow sampling (Fig. 4.16.2 A-D)

Based on the AFIN programme, three snow pits each 5 m apart were dug at the respective ice stations (A_C) and the respective snow depth was determined (C). In addition, the temperature at the ice-snow interface was determined (A). In each pit, a hole was drilled through the sea ice using either a thickness drill (5 cm diameter, A) or a core drill (9 cm diameter, B) and the thickness of the sea ice and platelet ice was determined using an ice thickness plotter (A). The ice freeboard was also measured (C). The cores taken and thickness measurements are listed in Table 4.16.1.

A total of 50 cores were taken for biological, biogeochemical variables and experiments, as well as texture cores. Of these, 14 texture cores were transported to Bremerhaven for further processing.

The other cores were sawn into different sections, packed in containers or plastic bags and stored in a Styrofoam box, and brought to *Neumayer Station III* for further analysis (see below). Some of the sections were further used for the incubation of primary production with natural stable isotopes (see below).

Platelet ice and sub-ice water sampling (Fig. 4.16.2 E-F)

The platelet ice was usually sampled with the platelet ice sampler (E) developed for this purpose and only if access to the borehole was very poor (C), the platelet ice had to be scooped out of the borehole manually. Otherwise, the device was lowered into the borehole and the mixed sample of water and platelet ice was collected via a vacuum and transferred to a container (E). A total of 27 platelet ice samples were taken (Tab. 4.16.1). Subsequently, a manual pump (F) was used to extract sub-ice water from a depth of approx. 3 metres. A total of 21 sub-ice water samples were taken (Tab. 4.16.1). The same variables were taken from the platelet ice and sub-ice water as for the ice cores.

CTD and fluorescence measurements (Fig. 4.16.2 G-H)

To quantify the biomass concentrations in the platelet ice and water, a fluorescence probe (H) was usually lowered manually to 50 m through a borehole already used for cores and then raised again. Subsequently, the temperature and salinity were determined as a function of depth with a CTD (Conductivity-Temperature-Depth) through the same borehole to characterise the water properties under the sea ice. The device (G) was lowered through the ice core hole to just above the sea floor and then raised again. All fluorescence and CTD measurements, including the number of profiles, are summarised in Table 4.16.1. An exception to the standard single measurements was a 24-hour CTD station, which was carried out at the GAP_SE position. Here, a total of 25 profiles were carried out from 9-11 December through an enlarged ice hole (Tab. 4.16.1). In addition, a chain with five temperature sensors (SBE56) was deployed and retrieved in a borehole 20 metres away from the CTD hole.

Underwater camera (Fig. 4.16.2 I)

Deploying the underwater camera through ice core holes proved to be difficult because the platelet ice placed too much strain on the thin cable connection between the camera and the recording device. In addition, the light conditions were difficult due to the high snow cover. No good videos were obtained through the boreholes and eventually at the end of the campaign film recordings were made in existing cracks (I) on 2 December, 11 December, 13 December and 16 December.

Microplastic sampling (Fig. 4.16.2 J)

The microplastic sampling, which was carried out at the end of the campaign, was made more difficult by the extremely warm weather conditions, so that the polystyrene boxes had to be protected with foil while moving on the ice (J). As the ice was already very porous, only six ice cores were taken along the standard transect from East to West (Tab. 4.16.1). These samples were also transported to Bremerhaven for further analysis.

Measurement of sea ice and platelet ice thickness using non-invasive electromagnetic measurement methods (Fig. 4.16.2 K)

In addition to the manual borehole measurements, a ground-based electromagnetic measurement system (GEM-2, Geonics Limited, Mississauga, Ontario, Canada) was used to derive the total sea ice thickness (sea ice thickness plus snow thickness) and the thickness of the platelet ice layer. These measurements were carried out on all sampling days to and from the stations, as well as on 13 November (94 km); on 17 November to ATKA24 (and back) and on 22 November (74 km). The measurement routes are marked in Figure 4.16.1.

Primary production incubation at Neumayer Station III

A total of 9 incubation experiments was performed: 4 with a platelet/water mixture, 3 with melted mid-core sections and 2 with melted bottom-core sections. To the ice-core sections hyper-saline filtered sea water was added before the melting took place, to arrive at a final salinity of the ice-water mixture of around 30 PSU. Of each bulk sample, three or four subsamples were amended with $^{13}C\text{-}NaHCO_3$ and deuterated DMSP and incubated under a snow cover at ~10% of incoming light. After an incubation period of 12 or 24 hours, subsamples were filtered and stored frozen for later analyses in the home laboratory. The samples will provide an estimation of primary production and DMSP production in the various habitats.

Processing of samples at Neumayer Station III

After returning to *Neumayer Station III* the ice cores, platelet ice and under ice water, samples were transferred into water baths, which were cooled with snow from outside *Neumayer Station III*. Snow was regularly added to the water baths in order to avoid a very fast melting of the ice sections. Under ice water samples were immediately filtered or kept cold and dark for a maximum of 8 hours. Ice and platelet ice sections were immediately processed after melting, which was usually within 16 hours after the melting started.

For all samples, the salinity was measured using a WTW Conductiometer and the melted ice cores were further weighted for later brine volume calculations. Thereafter the water was split into separate subsamples and samples were taken for: nutrients, HPLC-marker pigments, POC/PON, biogenic silicate (175 each), particulate and dissolved DMSP (155 each) and fractionated DNA (10 µm, 3 µm, 0,4 µm filters, 94 each). The filters used to prepare the dissolved DMSP samples were examined under a binocular for a rough estimation of the plankton composition. Occasionally, additional microscopy samples were frozen. In additon all cores and platelet ice were concentrated on a 20 µm mesh to investigate the occurrence of fish eggs. All samples were frozen at -20°C, except for marker HPLC and DNA-samples, which were stored at -80°C. In addition, 15 e-DNA samples were collected from under-ice water with eDNA dual-filter capsules (Sylphium, Groningen, NL), which were stored at room temperature. All collected samples were tranferred with a supply vessel back to Bremerhaven for further analysis at the AWI and the RUG.

Preliminary (expected) results

Snow and ice thickness

The mean snow depth (Tab. 4.16.2) was 86 cm, relatively much compared to previous studies at Atka Bay (Arndt *et al.*, 2020). The largest snow depths up to 152 cm in some cases yielded a median negative freeboard of -8 cm during this campaign. The observed average sea ice thickness was about 10 cm less than what was previously reported, suggesting a negative impact of the snow cover on the ice. Median and mean of platelet layer thicknesseswere larger than 400 cm, similar to values previously reported for Atka Bay. After the storm at the beginning of December, a warm weather period hit Atka Bay causing much warmer temperatures during the fieldwork (Tab. 4.16.2), resulting in above-zero temperatures in the air. This led to much warmer temperatures in the snow and at the snow/air interface, while the snow/ice interface was not yet affected.

Tab. 4.16.2: Minimum (Min.) Maximum (Max.), average (MW) ice freeboard (IFB) ice cores (CI), sea ice platelet layer (SIPL) and temperatures (T) in the air and at various interfaces. For all temperature measurements, the values for a warmer period are separated from the remaining sample days, indicated by “period with out (w.o.) 9.-13.12.2023”

Period 10.11.-17.12.23	**snow (cm)**	**IFB (cm)**	**CI (cm)**	**SIPL (cm)**	**Period w. o. 9.-13.12.23**	**T air (°C)**	**T air/ snow (°C)**	**T_ snow (°C)**	**T_snow/ ice (°C)**
Min.	13	-48	106	0	Min.	-6,50	-6,90	-6,10	-6,20
Max.	152	63	410	1306	Max.	0,90	1,30	-0,70	-1,80
MW	86	-6	186	444	MW	-2,61	-2,14	-3,45	-3,64
Median	90	-8	178	414	Median	-2,80	-1,50	-3,70	-3,80
					Period 9.-13.12.23	**T air (°C)**	**T air/ snow (°C)**	**T_ snow (°C)**	**T_snow/ ice (°C)**
					Min.	-0,30	-1,90	-3,40	-3,80
					Max.	4,40	0,00	-1,40	-2,80
					MW	1,98	-0,30	-2,63	-3,38
					Median	2,40	0,00	-3,00	-3,30

Ice core salinity

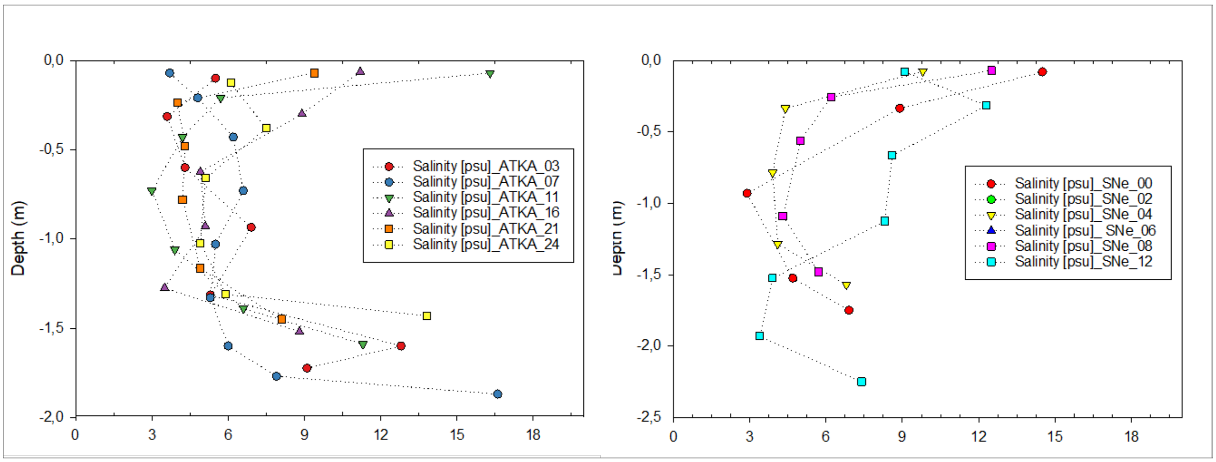

Fig. 4.16.3 Salinity profiles of the ice cores taken from the standard transect ATKA03-24 and the eastern South-North (SN) transects (ATKASNe 00-12).

Sea ice salinity varied between 3 and 17 PSU (Fig. 4.16.3) and showed for most of the cores the typical C-shape. The negative freeboard is also reflected in very high salinities in the surface ice, indicating the intrusion of salt water in these layers. This is less pronounced for station ATKA07 and ATKA24, which had the lowest snow thickness compared to the remaining stations (see also Fig. 4.16.9).

CTD profiles

CTD profiles of temperature and salinity indicate a rather homogenous water column down to 175 m (Fig. 4.16.4). After the 9 December temperatures rise slowly and the salinity decreases in the upper 25 m of the water column. This trend is more pronounced during the last sampling day on 13 December, where most of the water column down to 125 m is warmer and fresher. This trend is also visible during the entire transect ATKA03-ATKA24 carried out on 13 December (Fig. 4.16.5), showing a shift in the salinity and temperature profiles. This indicates an intrusion of other water masses into Atka Bay starting in the second week of December, likely in connection with the large storm, which passed the region at the beginning of December.

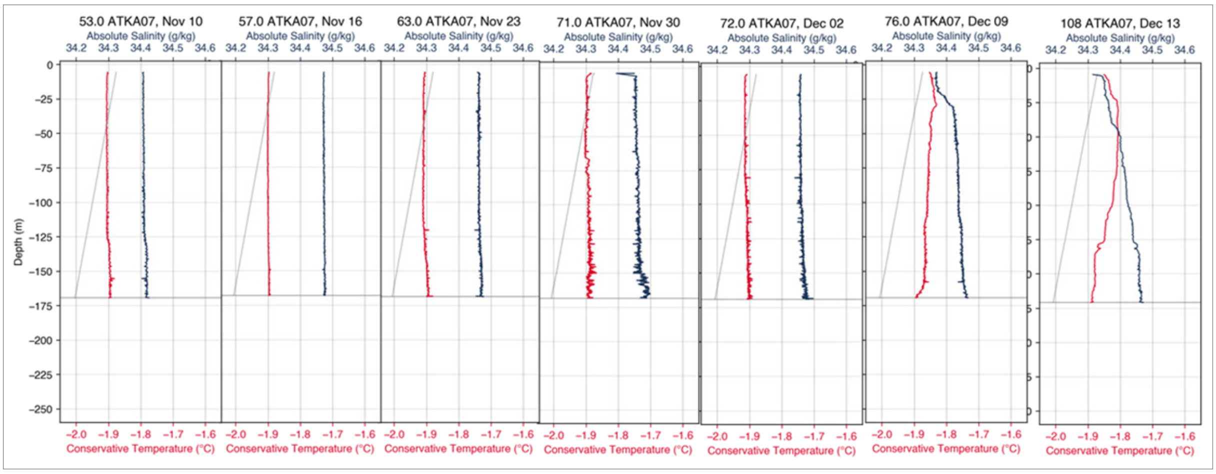

Fig. 4.16.4: Temporal variability of the temperature and salinity profiles carried out between 10 November until 13 December at ATKA07

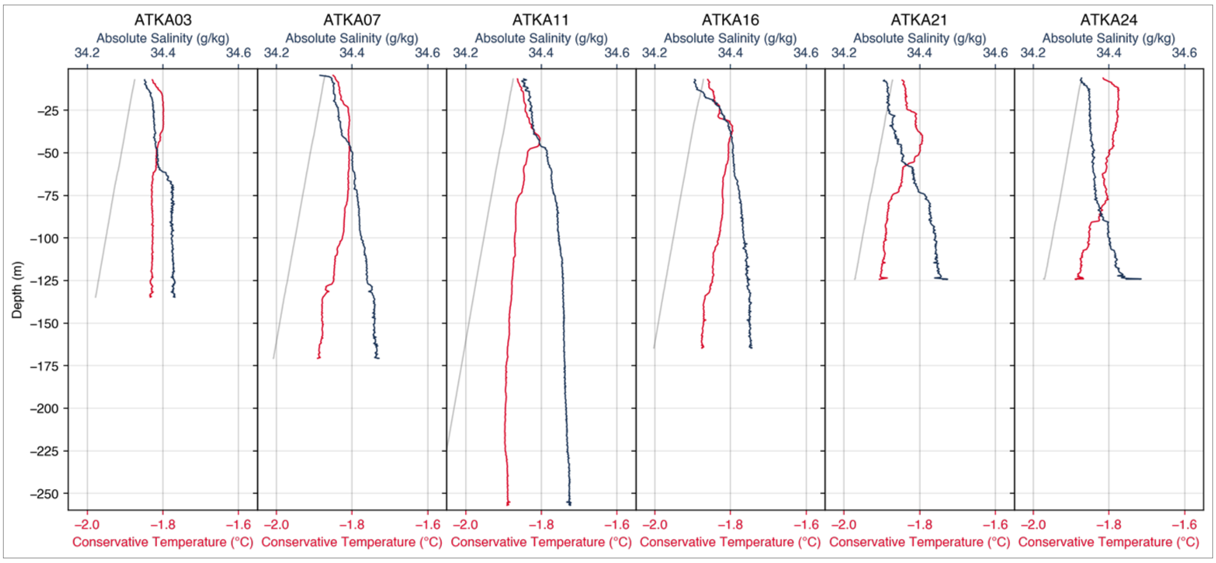

Fig. 4.16.5. Spatial variability of the temperature and salinity profiles carried out on 13 December along the East-West transect (ATKA_03 - ATKA_24).

Fluorescence probe

Depth profiles

Depth profiles of chlorophyll-*a* at the beginning of the study revealed in general a very low biomass below the platelet ice (Fig. 4.16.6). Highest biomass in the SIPL layer were found at ATKA07 and ATKA24, which had also the lowest snow thickness (Fig. 4.16.9). This tendency is reversed towards the end of the sampling campaign, when at ATKA07 the biomass in the SIPL still had doubled, but at all other stations had increased several orders of magnitude. In addition, chlorophyll-*a* biomass increased in time throughout the entire water column, with some depth maxima at e.g. ATKA03 and ATKA16, indicating an intrusion of high biomass water into Atka Bay and/or some sinking out of algal material from the platelet layer.

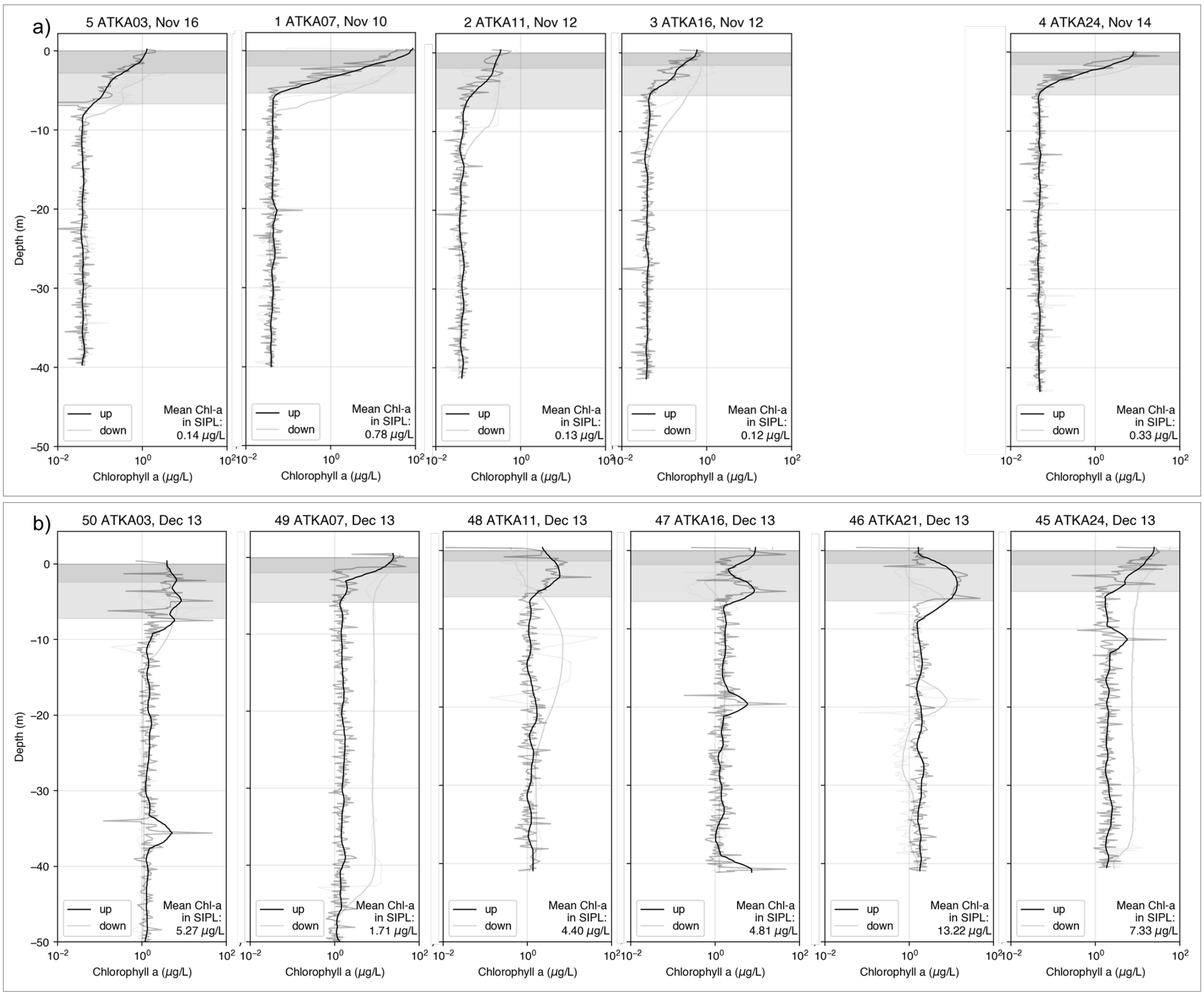

Fig. 4.16.6: Up and down casts of chlorophyll-a measured with the fluorescence probe along the East West transect (ATKA_03 - ATKA_24) at the beginning (a) of the sampling period (10 – 16 November 2023) and at the end (b) of the campaign (13 December 2023). The mean chlorophyll-a of the sea ice platelet layer (SIPL) is indicated in the right corner of each profile. Dark grey areas mark the part of the profile in the sea ice, while the light grey area indicates the thickness of the SIPL.

No clear temporal development of the chlorophyll-*a* is visible in the various depth profiles of chlorophyll-*a* at ATKA07 in the first month of observations (Fig. 4.16.7). Between the first and the second sampling the mean chlorophyll-*a* biomass decreased, and thereafter increased again on the third sampling day followed by another decrease. This led to the study of the spatial variability at ATKA07 and the various depth profiles clearly indicate that the observed variations are in the same range as the spatial variability of chlorophyll-*a* in the SIPL (Fig. 4.16.8).

However, on 9 December again a higher chlorophyll-*a* concentration is found in the SIPL at ATKA07 (Fig. 4.16.7), comparable to the maximum found at the other stations four days later (Fig. 4.16.6, lower panel), but this chlorophyll concentration drops on the last sampling day. The in parallel taken nutrient samples of the ice cores and SIPL might shed some light on this depletion, if the nutrients were exhausted due to the general high biomass observed at this station, or if this is also rather a sign of spatial variability at ATKA07. In general, the chlorophyll-*a* signal of the fluorescence probe was comparable with the coloration of the obtained sea ice cores (Fig. 4.16.8) leading to the assumption that with the fluorescence probe we will get a good indication of the chlorophyll-*a* biomass of the lower most section of the sea ice cores. To study this, the observed chlorophyll-*a* profiles will be calibrated with the chlorophyll-*a* measured by HPLC (High performance liquid chromatography), which were taken from sea ice, platelet ice and the water column to better quantify the real chlorophyll-*a* concentration in the sea ice layer.

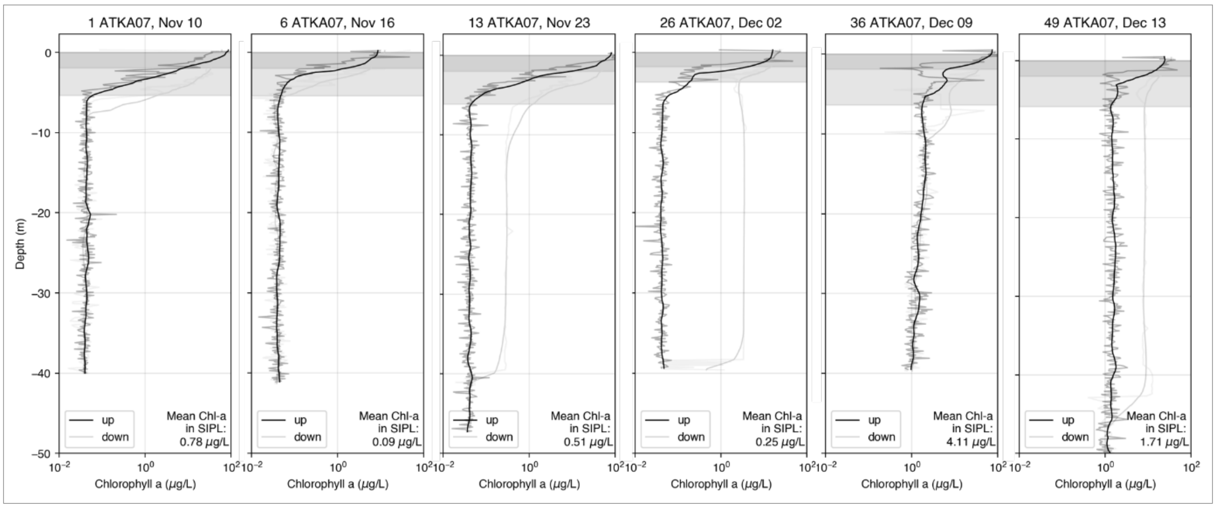

Fig. 4.16.7: Temporal development of up and down casts of chlorophyll a measured with the fluorescence probe along at ATKA_07 from 10 November – 13 Deember 2023. The mean chlorophyll of the sea ice platelet layer (SIPL) is indicated in the right corner of each profile. Dark grey areas mark the part of the profile in the sea ice, while the light grey area indicates the thickness of the SIPL.

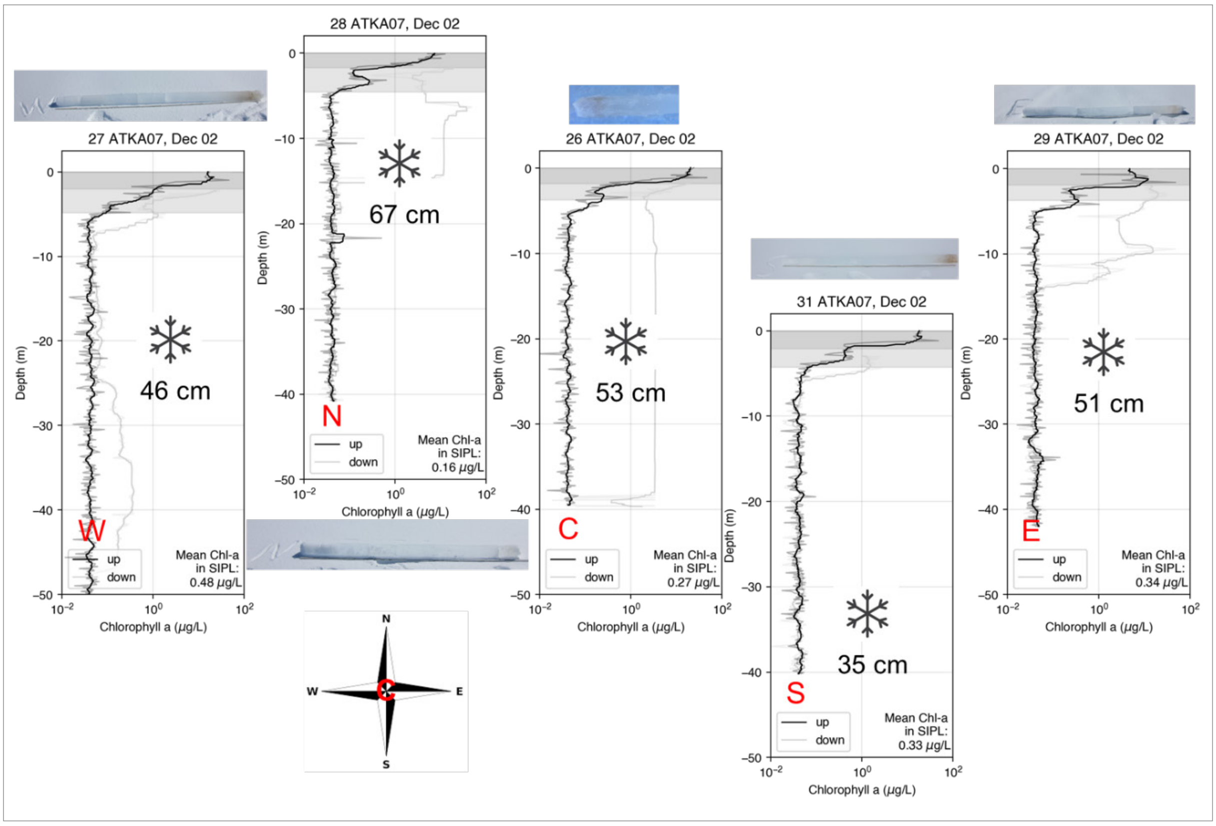

Fig. 4.16.8: Spatial variability of up and down casts of chlorophyll a measured with the fluorescence probe at ATKA_07 on 2 December 2023. The mean chlorophyll of the sea ice platelet layer (SIPL) is indicated in the right corner of each profile. Dark grey areas mark the part of the profile in the sea ice, while the light grey area indicates the thickness of the SIPL. In addition, pictures of each core are inserted for the various directions centred around the main coring site.

Spatial variability in the SIPL

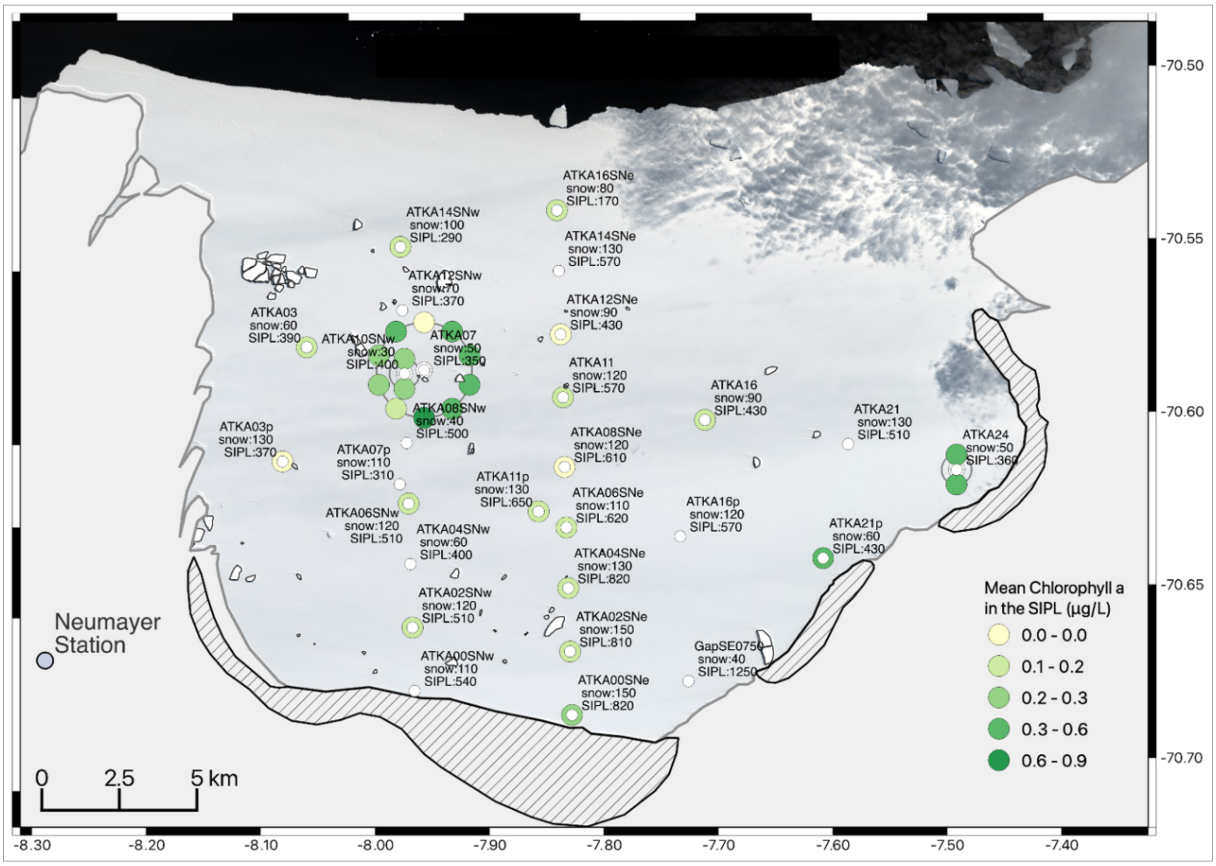

Fig. 4.16.9: Map of Atka Bay with the mean chlorophyll-a content in the sea ice and platelet layer indicated by different colour codes. Due to the repeated sampling at ATKA07 the concentrations are indicated as a circle around the station. In addition, the snow depth and the thickness of the sea ice platelet layer (SIPL) are indicated for each station.

The average mean chlorophyll-*a* concentration during the SIBEAT campaign are summarised in Figure 4.16.9. Hot spots of high chlorophyll-*a* biomass throughout the campaign are observed at ATKA07, Atka24 and ATKA10NSw, the stations with the thinest snow cover. In general, snow cover larger than 80 cm lead to rather low biomass in the SIPL. After all data are analysed we expect to see a clearer picture about the relationship of snow and chlorophyll-*a* in the SIPL.

Microscopy

Only at a few stations (ATKA07, Atka24, ATKA10NSw) dense bottom-ice and platelet-ice communities were observed. Bottom ice consisted mainly of large colonies of *Amphiprora* and *Berkeleya*. The platelet communities contained more single-cell diatoms and short diatom chains. Typical species in platelet samples were *Fragelariopsis, Chaetoceros, Amphiprora, Entemoneis, Thalassionema, Odontella, Eucampia, Nitzschia, Corethron* and *Coscinodiscus* (Fig. 4.16.10). Algal communities in the top sections of the ice cores consisted mainly of small centric diatoms, but there are indications that also the notorious DMSP producer *Phaeocystis* and small dinoflagellates are present in these communities. In addition, foraminfera were present in many sea ice cores, while fish eggs were not observed in any of the screened samples.

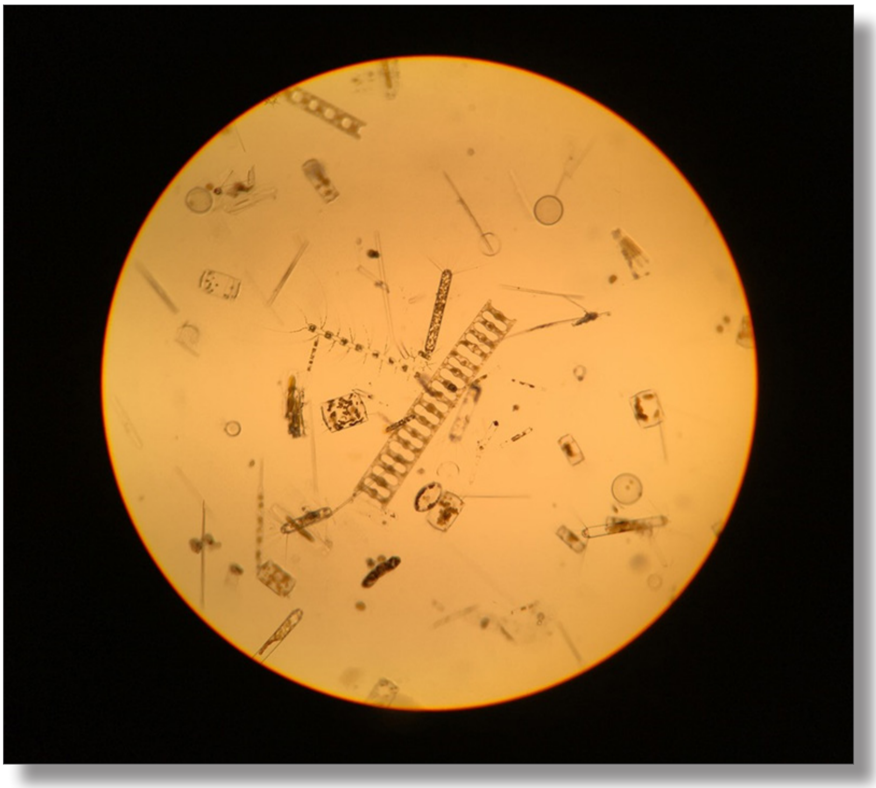

Fig. 4.16.10: Microscopy picture of a diatom mixture from an under-ice water sample of station Atka_07

Summary

All biogeochemical and biological analyses, which were carried out under the project, will help to validate biogeochemical models between ice, ocean and atmosphere. The coupled measurements of physical, chemical and biological processes will improve our understanding of limiting and favouring growth conditions for sea ice biota in Alka Bay. In summary, the current project will give new insights about the role of land fast and platelet ice for the cryo-pelagic and cryo-benthic coupling in Atka Bay.

Data management

All Ice-core, platelet ice and under ice water data will be released following its analysis in the home laboratories after the campaign or depending on the completion of competing obligations (e.g. PhD projects), upon publication as soon as the data are available and quality assessed. The 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 campign. 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). This campaign was supported by the Helmholtz Research Programme “Changing Earth – Sustaining our Future” Topic 6, Subtopic 1, 3 and 4.

In all publications based on this expedition, the **Grant No. AWI_ANT_38** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.17 TRIPLE-IceCraft – A Retrievable Electro-Thermal Drill to Access Subglacial Lakes and Oceans

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Grant-No. AWI_ANT_20

Objectives

The TRIPLE projects, initiated by the German Space Agency at DLR, comprise the research of Technologies for Rapid Ice Penetration and subglacial Lake Exploration. This is to enable *in-situ* exploration of the oceans below the surface of the icy moons in our solar system. To penetrate the icy shield of the moons the retrievable electro-thermal drill TRIPLE-IceCraft (Heinen et al., 2021) is developed. As an intermediate step and to increase the technology readiness level the TRIPLE-IceCraft is deployed in terrestrial analog missions with different scientific objectives. It is designed to melt through ice sheets with a thickness of several hundred meters and penetrate into subglacial water reservoirs. It serves as a modular transport system for arbitrary payloads using the predefined and standardized interfaces provided by TRIPLE-IceCraft.

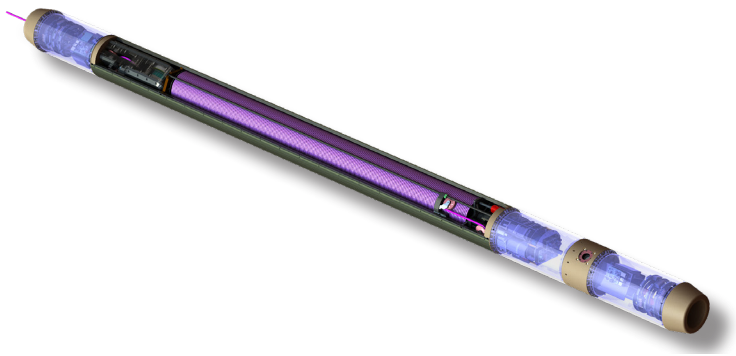

Fig. 4.17.1: Technical drawing of the modular setup of the TRIPLE-IceCraft melting probe

The main objective of the test campaign at the *Neumayer Station III* was to validate the capabilities of the TRIPLE-IceCraft system in a realistic scenario for the cold and harsh environment of the Antarctic ice and to collect diagnostic data from that campaign.

During the tests in the previous season the probe's inner winch system showed an unstable climbing behaviour. It was identified as a low friction issue between the melting probe's cable and the traction sheave. Therefore, the melting probes gear unit which houses the traction sheave was extracted and shipped via air freight to Germany for revision. The issue was solved by redesigning the geometry of the traction sheave and it was verified with an engineering model. The revised unit returned to Antarctica for the demonstration in the field.

In analogue to the previous test campaign, the TRIPLE-IceCraft was equipped with a camera payload module to collect visual data of the icy sidewalls of the hole and the sonar-based acoustic forefield reconnaissance system (FRS) build within the project TRIPLE-FRS (Heinen et al., 2021). This system is designed to detect obstacles in the ice as well as the ice-water boundary below the ice shelf. By providing this information in real-time, the FRS helps to avoid potential hazards during the melting process and ensures a safe entry into the subglacial water reservoir.

In addition, an external ground penetrating radar-based FRS was operated from the surface of the shelf. Within the project TRIPLE-FRS (Heinen et al., 2021) it is developed as a complementary approach for the forefield reconnaissance. This increases the robustness of the TRIPLE-FRS. In this test the performance of the system should be evaluated.

In collaboration with the PALAOA project (Klinck et al., 2016) (AWI_ANT_12), we supported the deployment of their new hydrophones.

Fieldwork

We started by commissioning the field station within our transport container and the TRIPLE-IceCraft melting probe close to *Neumayer Station III* near the radome. The container houses a diesel generator and power electronics and is used as a workspace for the team during the test campaign. All equipment withstood the over-wintering well. At this position we also verified that the radar FRS system worked and acquired first test data. Together with the technical team, we transported TRIPLE-IceCraft into the *Neumayer Station III* for integration of the gear unit, smaller system improvements, sensor calibration and system tests. After finishing this work, we prepared the drilling operations, by setting up the launch crane and starting the power electronics and control and data server. We drilled with TRIPLE-IceCraft a test hole until the full length of the probe had entered into the ice and climbed upwards again. Also, all payload systems worked well. After successfully performing this final acceptance test, we prepared the transport of the equipment to the drill site.

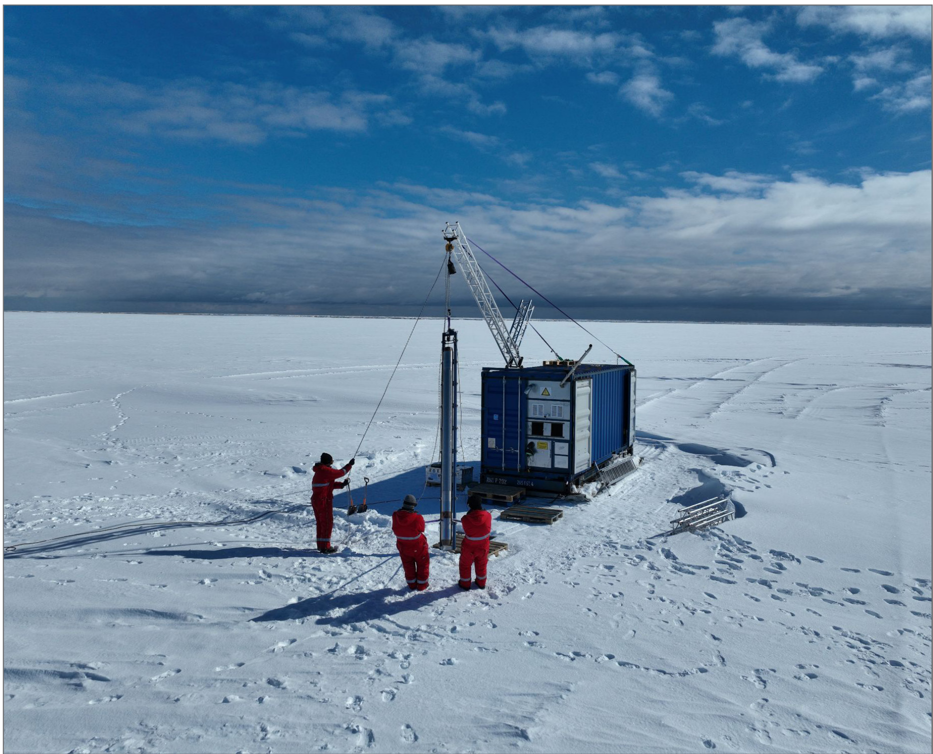

Fig. 4.17.2: Deployment of the TRIPLE-IceCraft Melting Probe

The position of the drill site was chosen in cooperation with PALAOA and is north of *Neumayer Station III* about 1 km next to the ocean. We set up the probe, prepared the operations and started the deployment. During the first drill some minor issues occurred, we extracted the probe and solved them on site and started over again in the same hole. We ended this drill successfully after reaching a depth of 15 m and we returned the probe. Also, the payloads, the sonar FRS and the camera module, worked fine, as in all following drills. We were able to achieve high melting speeds of up to 3 m/h similar to the previous season. The speed was mainly limited due to power transfer restrictions to not overheat the melting probe's main cable during drilling, since the melt water drained out of the boreholes. At the drill site we performed several measurements with the radar FRS at different settings to evaluate the system's performance.

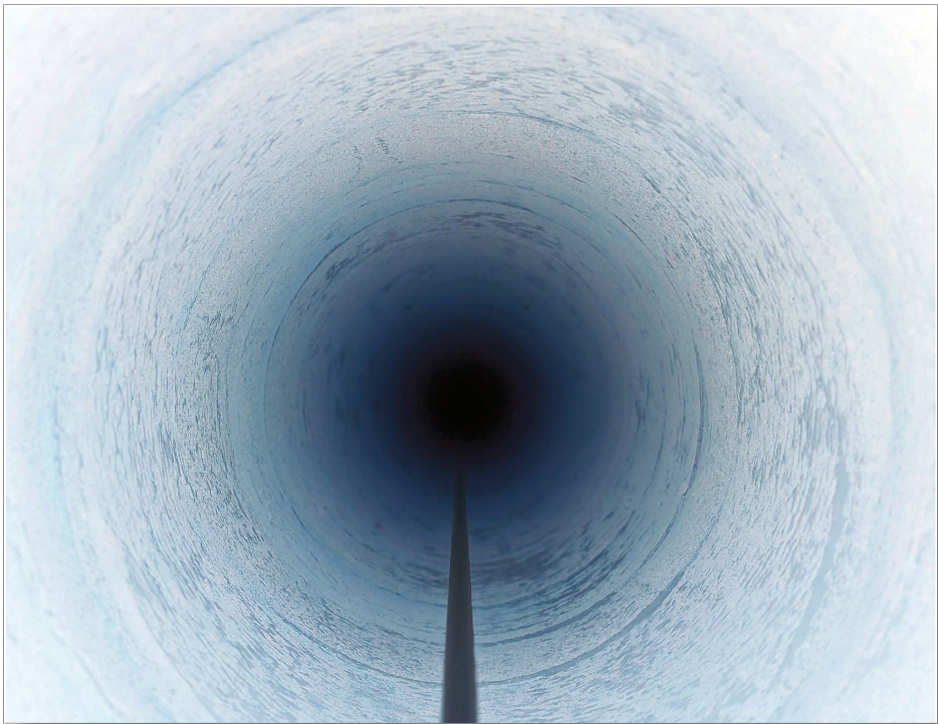

Fig. 4.17.3: TRIPLE-IceCraft melting probe cable within the melting hole

For the next drill we shifted the position of the launch crane on the top of the container, so we started a new hole less than 1 m west of the first hole. We started the next drill and worked in shifts. The drilling was very uneventful and the sensor data showed very stable operations. The data acquisition of the internal systems and the payload systems worked smoothly. The melting speed varied due to layering effects in the firn and decreased slowly during descent caused by the increasing density of the firn in depth. By reaching a depth of about 25 m water started to remain within the borehole, but drained after several decimeters. At a depth of about 35 m TRIPLE-IceCraft was fully submerged and the water column behind it became stable. At that point we were able to increase the melting power, since the winch system was water filled and therefore sustained higher electrical currents. After reaching a depth of about 52 meters, we lost the communication link to one of the probe's subsystems, a heater system, which surrounds the winch. As we were not able to recover the link and as a precautionary measure, we paused the operations and commanded the probe to reverse up. The extraction operation worked fine, moving the probe up while recoiling the cable into the probe. During ascend the sonar FRS was operated in the water filled melting channel while the TRIPLE-IceCraft was climbing back to the surface. The reflections from bottom of the water filled melting channel were recorded during ascent. The inspection and analysis of the lost communication link showed a water leakage into an encapsulated heater system. We were able to restore the communication link, but decided to prevent the submerging of this system in the following drills.

In the next two days we started to vary the force settings of the winch system to validate the system's behavior and the results in the melting speed. Therefore, we drilled two additional holes with depth of 11 m and 8 m. For additional measurement of the sonar FRS, TRIPLE-IceCraft was lowered in the deep hole again (52 m drilling depth). Since the water column was refrozen again, we reached the bottom of the hole at a depth of 37 m. While melting with a low speed, a large set of signals were sent for the validation and optimization of the sonar system. After finishing the data acquisition, the probe was commanded to climb up again. In the last drill we increased the supply voltage of the probe to increase the melting power and therefore also the melting speed. We achieved melting speeds up to 5,5 m/h even though we still had restrictions on the maximum current to not overheat the probe's main cable since we were operating the probe in an air-filled hole.

The following days we stored all our equipment, prepared our container to be picked up by the *Malik Arctic*, and returned the borrowed camp equipment to the station. The last days before leaving we organized our air freight and supported PALAOA with their drilling effort and the deployment of a new hydrophone.

Preliminary (expected) results

The project's main objective of technically smooth operation of all critical elements was successfully achieved and in particular the safe return was impressively demonstrated by several drillings of up to 52 m. It was demonstrated that the TRIPLE-IceCraft melting probe is operational in a polar environment, in particular the complex winch and cable management system. The probe showed a very high system stability. The implemented modifications of the winch system solved the unstable climbing behavior, as experienced in the previous season. The probe achieved high melting speeds of up to 5,5 m/h. During the drill operations, we recorded all system data, internal status information and sensor measurements (internal temperature, internal pressure, external pressure, magnetometer, inertial measurement unit, inclinometer, rotation tracking for cable movement, current/voltage/power, cable forces). This means that a new drilling system is available for use. One project goal, reaching the water's edge, was not achieved. Due to a non-critical failure of a water leak in a side heater, the drilling team decided to prioritize maximum safety for retrieval and fault analysis in favor of continuing the drilling. Despite this, the expedition is considered a success in demonstrating the operational capability of the probe. This is particularly justified because of the successful improvements in the critical cable management system.

The validation of the system performance and its melting behaviour are subject to more detailed ongoing analysis. The water leakage into the side heater system will be investigated after the arrival of the probe in Aachen. After revision of the encapsulation of the system we will qualify it in a new pressure chamber, which we are currently building.

The camera payload module performed well, and the data collected provide insights of the layering of the firn and the behavior of the melting probe. The internal sonar FRS and the external radar FRS was operated successfully. Within the ice the minimum distance to the ice-water interface to the ocean below was about 30 m, for now we did not register a reflection there, but the analysis is still ongoing. During the ascent through the water-filled melting channel the transition between water and ice at the bottom of the about 15 m long channel was detected over the complete distance. At both test locations, the FRS radar was able to successfully detect several reflections at distances of up to 50 meters.

After successfully demonstrating the TRIPLE-IceCraft, it is in preparation to house a miniaturized submarine with docking port, a scientific laboratory for *in-situ* analysis, the radar FRS, and a permittivity sensor. A demonstration of the fully integrated system is currently being planned.

Data management

All melting probe system data, the internal status information and sensor measurements (internal temperature, internal pressure, external pressure, magnetometer, inertial measurement unit, inclinometer, rotation tracking for cable movement, current/voltage/power, cable forces) during system testing and drill operations were recorded. All collected data was stored in the melting probe and transferred to a data server at the surface. All recorded data was transported via mobile data devices up north. This data will be made available on request by interested researchers. The sonar-based forefield reconnaissance system (FRS) recorded data during the in-air validation, within the water column and during the drill operations within the ice. Also, this data is available on request. The pictures recorded by the camera module are currently in preparation for publication on PANGAEA.

In all publications based on this expedition, the Grant No. **AWI_ANT_20** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.18 ZeroPolAr – Incentives for a Zero-Pollution Ambition for Antarctica

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Grant-No. AWI_ANT_26

Outline

This project aims to protect the polar environment from contaminants by studying hazardous substances in Antarctic environmental samples and making these data available to chemical regulation.

Objectives

First investigations of the German Environmental Specimen Bank on the exposure of polar regions to chemicals showed that chemicals such as flame retardants are present in e.g. fish samples from Antarctica (Dreyer et al., 2019). Such samples will also be required in the future as references for remote regions and the identification of those compounds which are liable, for long-range transport potential, one of the main drivers of the Stockholm Convention. Recent studies indicate that the pollutant load in organisms in the polar regions is increasing significantly due to the melting of ice masses at the poles and the re-release of previously bound, in part long regulated, pollutant groups (Joerss et al., 2020). However, systematic chemical monitoring and reliable data are still lacking, especially for Antarctica (Umweltbundesamt 2020, Xie et al., 2020). Monitoring pollution levels is of crucial importance for the protection of the Antarctic, for understanding global interrelationships and for shaping international environmental and chemicals policy.

UBA has recently launched an international research project to compile data from pollutant monitoring programmes of selected Antarctic Treaty states. The aim of the project is to develop a comprehensive concept for a polar environmental monitoring programme (POLEMP) of pollutants in the Antarctic in order to close existing knowledge gaps on chemical pollution in the polar regions. A monitoring programme is planned that will track the occurrence and fluctuations of organic pollutants, drawing on existing initiatives such as the Arctic Monitoring and Assessment Programme (AMAP), the Antarctic Monitoring and Assessment Programme (AnMAP) and the United Nations Environment Programme (UNEP). The approach involves analysing samples from the Antarctic to propose a systematic data approach for sampling and sample analysis. The standardised protocols of the environmental sample banks of the project partners are considered as a basis to further develop the idea of a polar environmental sample bank and the improvement of international research cooperation.

In addition, the project will compile current data on chemical pollution in the Antarctic to inform key international environmental forums and organisations. This will be done through collaboration with the SCAR ImPACT Action Group and the Stockholm Convention. To promote dialogue and consensus between scientists and stakeholders, international workshops are planned for 2024 and 2026. Results will be disseminated through open-access publications, reports and social media to ensure broad stakeholder and public engagement and impact, and to highlight ongoing progress in environmental monitoring in Antarctica.

Environmental sampling within ZeroPolAr is intended as a pilot study for a collection of Antarctic samples as a building block for a structured chemical monitoring.

The following research questions are to be answered within the framework of the project:

i. to characterize the pollution loads in polar regions to identify chemicals with a long-range transport of pollutants into remote areas using environmental samples such as samples from the emperor penguin colony near *Neumayer Station III* sampled in a non-destructive manner.

ii. to investigate the link of polar regions and the consequences of climate change, with regard to pollutant loads along the food chain in order to sustaining biotic interactions. Thus, to monitor a functional polar ecosystem under the combined pressure of growing human impact and ecosystem change.

iii. to check the feasibility of a systematically created archive with samples from Antarctica based on the German Environmental Specimen Bank specifications.

Fieldwork

Samples of the Antarctic Ecosystem were collected on-site near the German research facility *Neumayer Station III*. Abandoned eggs from the emperor penguin colony in Atka Bay were collected and brought to *Neumayer Station III*. To determine the developmental status of the eggs, the frozen eggs were scanned/x-rayed at *Neumayer Station III* and stored and transported in a transport box with a built-in temperature sensor at a constant temperature between -20 and -25°C. The eggs were then transported back to Bremerhaven via *Polarstern* and send to Fraunhofer Institute for Molecular Biology and Applied Ecology (IME), where they will be analysed for chemicals and other parameters. The remaining sample material will be archived at the German Environmental Specimen Bank (ESB).

Preliminary (expected) results

It has been successfully demonstrated that samples from Antarctica can be sampled and stored opportunistically at *Neumayer Station III* and transported to the German ESB at Fraunhofer IME. The penguin egg samples support the investigations of the German Environment Agency (UBA) on the feasibility of an ESB for samples from Antarctica. However, a stringent quality control is needed for sampling and interim storage at *Neumayer Station III* to ensure the quality of the subsequent chemical analysis. First results have been provided for elements, including metals and for per- and polyfluoralkyl substances (PFAS). Further sampling of emperor penguin eggs and other samples is indicated to test the systematic use and chemical analysis of environmental samples from Antarctica and to support the idea of a new ESB for this region.

New samples from *Neumayer Station III* will be transported to Fraunhofer IME. The eggs will be processed according to the ESB protocols, devided into sub samples and will then be stored in the German ESB at ultralow temperatures above liquid nitrogen. Some of the sub samples will again be analysed for a set of elements and PFAS to gain further insights into the variabilty of the substances within the population.

Data management

Data will be submitted to the long-term archive of the Information System Umweltprobenbank (IS UPB) with a web-based data portal and webpage (www.umweltprobenbank.de) that provides unique and stable identifiers for the datasets and allows open online access to the data.

In all publications based on this expedition, the **Grant No. AWI_ANT_26** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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Dreyer A, Neugebauer F, Lohmann N, Rüdel H, Teubner D, Grotti M, Rauert C, Koschorreck J (2019) Recent findings of halogenated flame retardants (HFR) in the German and Polar environment. Environmental Pollution 253:850–863.

Joerss et al. (2020) Transport of Legacy Perfluoroalkyl Substances and the Replacement Compound HFPO-DA through the Atlantic Gateway to the Arctic Ocean – Is the Arctic a Sink or a Source? Environ. Sci. Technol. 54(16):9958–9967.

POLEMP Project: Developing a concept for a Polar Environmental Monitoring Program | Umweltbundesamt

Umweltbundesamt 2020. Schwerpunkt 1-2020: PFAS. Came to stay. 48S. What Matters 1-2020: PFAS. Came to stay. | Umweltbundesamt.

Xie ZY, Zhang P, Wu ZL, Zhang S, Wei LJ, Mi LJ, Kuester A, Gandrass J, Ebinghaus R, Yang RQ, Wang Z, Mi WY (2022) Legacy and emerging organic contaminants in the polar regions. Sci. Total Environ. 835. http://dx.doi.org/10.1016/j.scitotenv.2022.155376.

4.19 SnAcc – Investigating Snowdrifts around *Neumayer Station III*

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[2]CH.EPFL
[3]DE.AWI

Grant-No. AWI_ANT_27

Outline

The present chapter reports the work achieved during season 2023-2024 for the *SnAcc* project, which investigates the snow accumulation around the German Antarctic research station *Neumayer Station III*. Details about field work as well as numerical simulations are presented subsequently.

Objectives

Since its inauguration in 2009, the German Antarctic research station *Neumayer Station III* has experienced significant snow accumulation in its direct vicinity. In addition to increasing the work load of the overwintering staff, the deposited snow largely endangers the statics of the station structure. The SnAcc project addresses this issue and aims to define appropriate snow mitigation strategies at *Neumayer Station III* based on the results of a physics-based numerical snow transport model. Numerical simulations enable the testing of various mitigation solutions with minimal effort and resources compared to wind-tunnel experiments. However, prior to its use in decision making processes, the model needs to be compared to field observations to verify the accuracy of the produced results.

Fieldwork

Numerical simulations of snowdrifts around *Neumayer Station III* were conducted and compared to snow depth measurements taken in June 2009 after the inauguration of the station building (Hames et al., 2024). However, this comparison could only be qualitative (deposition locations) due to the multi-month period of accumulation represented by the measurements and their poor accuracy and resolution. Thus, there is a need for precise snow accumulation measurements at *Neumayer Station III* that could be quantitatively compared to numerical results.

Conducting snow accumulation measurements in the *Neumayer Station III* surroundings would constitute a valuable basis to validate our snow transport model. However, such measurements should be taken during the austral winter when human disturbance on the snow distribution is at its minimum (limited snow removal). For this reason, the field work related to SnAcc is mostly achieved by the station overwinterers. It consists of using a terrestrial laser scanner (TLS) to capture the surface topography around *Neumayer Station III* at a given point in time (Prokop et al., 2008). By conducting successive scans, one can assess the changes in snow distribution (accumulation, erosion) that occurred over the time period between the two scans (Sommer et al., 2018; Hames et al., 2022).

The topography scans are conducted with the RIEGL VZ-6000 (RIEGL, 2020), well suited for the survey of icy and snowy terrain. This device produces three-dimensional (3D) point clouds through the reflection of its laser pulse against surrounding objects. To create a local coordinate reference system (CRS) and tie all the scans together, cylinder reflectors are placed on the building and on the neighbouring structures. Figure 4.19.1 illustrates the TLS (left) and cylinder reflectors (right) employed for the snow accumulation measurements.

Fig. 4.19.1: Left: Terrestrial laser scanner RIEGL VZ-6000 used for the snow topography measurements around Neumayer Station III. Right: Cylinder reflector used as tie point for the local reference coordinate system of the scans.

TLS measurements are conducted from several positions around the station structure to obtain a complete scan of the neighbouring surface. Roof-based positions supplement the ground-based ones to limit the shadowing of the scans by the topography and other obstacles. The snowdrifts that formed over time on the East, North-West and South-West sides are used as scanning positions because they are higher than the adjacent terrain and reduce the shadowing in the measurements. An overview of the scanning positions planned for the data acquisition is given in Figure 4.19.2.

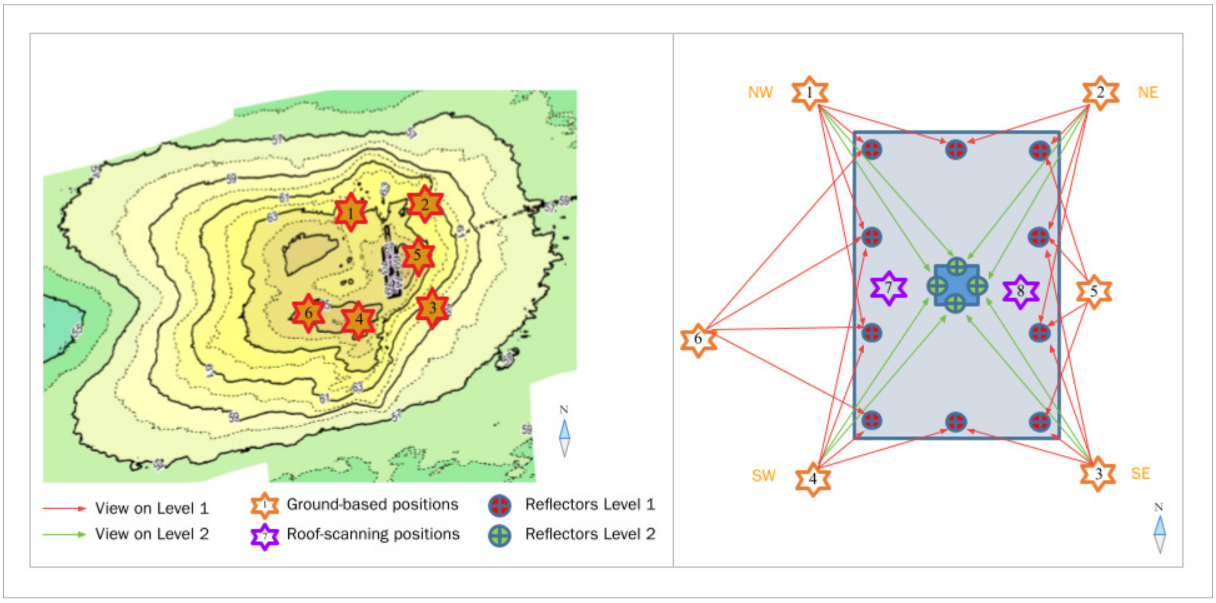

Fig. 4.19.2: Left: Snow surface topography and ground-based scanning positions at Neumayer Station III. Right: Reflector and scanning positions (ground- and roof-based) defined for the snow accumulation measurement set-up.

To adequately compare field observations and numerical results, the two successive scans should be conducted around a defined, distinguishable storm event (pre- and post-storm scans). The snow model employed in SnAcc (Hames et al., 2022) simulates the snow redistribution associated with a specific wind speed and direction. Thus, short storm events with homogeneous weather conditions constitute an ideal dataset for model-measurement comparison. The difference between post-storm and pre-storm scans yields the snow depth redistribution associated with that given storm, which can be compared to snow mass distribution results produced by the numerical model.

Some test measurements were run during the 2022-23 and 2023-24 seasons to develop the laser scanning and stitching concepts. In October 2023, two successive measurements were conducted by the overwinters from the West side only (Position 6 in Fig. 4.19.2). Due to substantial logistic work at the station, scans from other positions could not be conducted. Those data allowed us to verify the rightness of the scan settings (e.g., resolution, duration). In November 2023, additional test measurements were taken by station visitors from five different positions (Positions 2-3-4-5-6 in Fig. 4.19.2). With those measurements, we could improve our stitching procedure and clarify the need for fine reflector search. Results from those two campaigns are shown in the next section.

Two complete successive scans of the topography adjacent to *Neumayer Station III* are planned for the end of May 2024. The measurement concept and TLS settings were extensively studied during the post-processing of the scans acquired at the end of 2023. Those findings can now be applied to future measurements. Once that two scans are successively taken around a storm, we expect to get a reasonable evaluation of the snow depth distribution changes connected to the latter and to compare those to our numerical model. The latter contains plenty of numerical parameters that need to be fine-tuned to ensure an accurate evaluation of snowdrifts – both in terms of location (qualitative) and snow amounts that are displaced (quantitative).

Preliminary (expected) results

On 4 and 6 October 2023, scans were taken from the West side of the station by the overwintering staff. The obtained data was useful to confirm the settings defined earlier through field work in alpine terrain. Moreover, the battery performance under cold conditions as well as measurement duration could be evaluated. Figure 4.19.3 shows a section of the scan conducted on 4 October 2023. This scan was taken from the South-western hill: some shadowed areas created by the presence of the obstructing topography are observed. Taking scans from several positions largely decreases the extent of the shadowed area and allows a better capture of the snow surface around *Neumayer Station III*.

Fig. 4.19.3: Scan taken on 4 October 2023 from the South-West hill of Neumayer Station III. The areas in black correspond to zones that are obstructed by the terrain topography (shadowing). A laser pulse repetition rate of 300 kHz and an angle resolution of 0.025° were used.

On 25 November 2023, scans from five different positions were conducted. First, they were used to identify incorrect reflector positions in the concerned scan areas. Then, the ability to create a local CRS based on reflectors placed on the station was confirmed: the scans could be superimposed with each other in an appropriate way. Finally, those data showed that a fine search of each reflector after the main scans was not necessary, which greatly reduces the total measurement duration. Figure 4.19.4 shows a preliminary result of the point cloud obtained after stitching all the scans together. Each colour corresponds to a scan taken from a specific position. The reflectors were easily identifiable in the scans due to the higher reflectance value associated to the points. They were used to reference the scans relatively to each other and build a complete scan of the area. The next measurements will entail additional scanning positions, from both the ground and the roof (Fig. 4.19. 2).

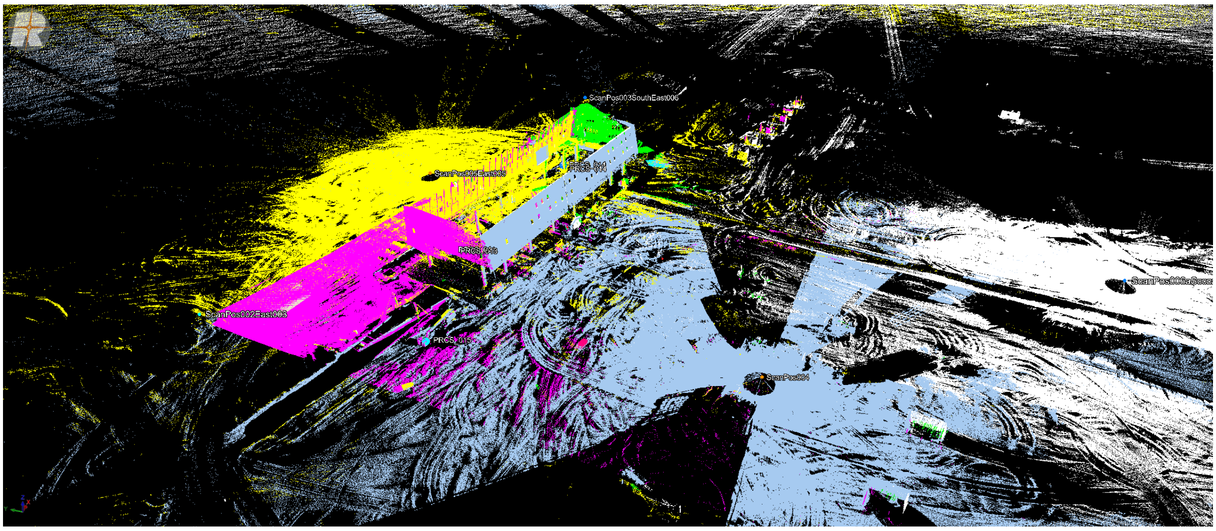

Fig. 4.19.4: Scan taken on 23 November 2023 from various scanning positions around Neumayer Station III. Each of the different colours (pink, yellow, blue, green, white) corresponds to a specific scan. The areas in black correspond to zones that are obstructed by the terrain topography (shadowing). A laser pulse repetition rate of 300 kHz and an angle resolution of 0.02° were used.

The scans described above were taken with various values of horizontal/vertical resolution and laser pulse repetition to define the best settings. A compromise had to be found between scan quality (high resolution) and duration. The scan settings chosen based on the test measurements are reported in Table 4.19.1; they will be used for the measurements planned in May 2024.

Tab. 4.19.1: Settings of the RIEGL VZ-6000 chosen for the snow accumulation measurements at *Neumayer Station III*

Parameter	**Unit**	**Value**
Laser pulse repetition rate	kHz	300
Horizontal resolution	°	0.02
Vertical resolution	°	0.02

To summarize, the campaigns conducted during seasons 2022-23 and 2023-24 were used to improve and confirm the functioning of the TLS measuring concept developed for the SnAcc project. Appropriate values for the scanner parameters as well as scanning and reflector positions were defined through the post-processing of those measurements. To this point, the set-up should be operational and ready to produce snow accumulation measurements that are comparable to numerical results.

Data management

The terrestrial laser scanning data will be submitted to EnviDat (https://www.envidat.ch/#/), which is an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

In all publications based on this expedition, the **Grant No. AWI_ANT_27** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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Hames O, Jafari M, Köhler P, Haas C, and Lehning M (2024) Influence of snow properties, air flow and design on structure-borne snowdrifts at Neumayer Station III. Authorea (in review). 10.22541/au.171386816.64509551/v1

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Sommer C, Wever N, Fierz C, and Lehning M (2018). Investigation of a wind-packing event in Queen Maud Land, Antarctica. The Cryosphere 12:2923–2939. https://doi.org/10.5194/tc-12-2923-2018

4.20 COALA – Continuous Observations of Aerosol-Cloud Interaction in Antarctica

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Grant-No. AWI_ANT_22

Outline

Within the DFG-funded project COALA (Continuous Observations of Aerosol-cLoud interaction in Antarctica), the OCANET-Atmosphere active aerosol and cloud remote-sensing supersite was deployed at *Neumayer Station III* for one year. The data obtained by the synergistic remote sensing instruments will help to understand aerosol-cloud-dynamic interaction in the pristine environment of Antarctica, inclduing the impact of clouds and precipitation on the Ekström Ice Shelf. The results will complement previous observations from places such as continental Europe, South Chile, the subtropical Atlantic, and the Arctic, allowing deeper insights into cloud microphysics under different aerosol conditions.

Objectives

Detailed observations are required to capture the complex relationships between of aerosol particles with radiation, clouds, and precipitation (Radenz, 2021). This is especially the case for the remote region of Antarctica, where ground-based vertically resolved long-term observations of aerosol, clouds and precipitation are scarce and satellite observations are prone to technical limitations. To fill the measurement gap with state-of-the-art observations, Leibniz Institute for Tropospheric Research (TROPOS) deployed its OCEANET-Atmosphere platform at *Neumayer Station III* to acquire data between January and December 2023. OCEANET-Atmosphere comprises a set of active and passive remote-sensing equipment, which is installed in an autonomous, customised 20 ft container that was previously deployed in the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC; Engelmann, 2021). The core instrumentation is a multi-wavelength Raman polarisation lidar, a 35-Ghz cloud radar, a microwave radiometer, a Doppler lidar, a sun-lunar-sky photometer as well as size-resolved observations of precipitation particles and drifting snow.

The aim of collecting a one-year dataset characterising aerosol, cloud, and precipitation properties, as well as horizontal and vertical wind with high temporal and vertical resolution on the order of 30 s (2 s for vertical-velocity observations) and 30 m, respectively was achieved.

Fieldwork

Following the routine operation during the winter (daily monitoring of the measuring instruments, removal of snow and ice accumulations, collecting snow samples, checking data quality, preliminary scientific evaluation), the tasks during summer season 23/24 were end-of-deployment instrument characterization, dismantling of the instrumentation, removal of the container from the platform and shipping the equipment back to Germany. During the first half of the summer season, the routine operation was handeled by the project overwinterer. A second project member arrived in the field with F3 to support the further tasks. Immediately, additional backups of the full dataset and a quality assurance measurement for the polarization characterization of the mulit-wavelength lidar were perfomed. From 29 December onwards, the instruments were consecutively dismantled and packed. The 14-channel microwave radiometer was detached from OCEANET-Atmosphere and set-up on the stations roof for continued observations in support of CARSiMON. The container was removed from the platform on 3 January and loaded during the second ship call.

Preliminary results

The collected dataset will help to understand the transport of aerosol from the Southern Ocean, southern-hemisphere midlatitudes and subtropics to Antarctica and the influence on the formation of clouds and precipitation. Specifically, the following topics will be addressed during the upcoming data analysis:

1. studying the origin, abundance and the characteristics of aerosol in the Atlantic sector of Antarctica,
2. investigating the impact of surface- and boundary-layer-coupling effects on the characteristics and evolution of low-level clouds,
3. studying the contributions of dynamics (orographic waves), aerosol and meteorological conditions on the partitioning of the ice and liquid phase in clouds,
4. studying the vertical structure of clouds and its relationship to precipitation formation,
5. and the evaluation of regional contrasts in the properties of aerosols and clouds and the associated aerosol-cloud-interaction processes by putting the dataset into context with existing datasets from Southern Chile, Central Europe and the Arctic.

Generally, both the temporal coverage of the dataset and the quality of the collected data are more than satisfactory. The measurement operation was essentially continuous. Short interruptions could be promptly adressed. Longer interruptions only occurred for the cloud radar (27 March – 3 April, snow in the radome; 11 – 19 September, aging of the modulator tube) and the sun photometer (19 April – 23 June, data cable problems; 28 July – 9 November, broken azimuth scanner).

An overview publication on the deployment and first results is currently under review. The highlights presented in this study include ice formation in supercooled liquid clouds under aersol-limited regime, omnipresent stratospheric aerosol layers, and frequent warm and moist air intrusions, causing strong precipitation events. A brief overview of such an intrusion that occurred from afternoon on 4 July to early morning of 9 July 2023 is provided in Figure 4.20.2. A maximum value of integrated water vapour content of above 10 kg m^{-2} was observed. Since 21:40 on 5 July, the 2-m temperature rose above −3 °C. It remained above −5 °C until 01:15 UTC on 7 July. Such warm air masses also impacted cloud microphysics and precipitation formation. In the following, the discussion will focus on the period from 22:00 UTC on 5 July to 12 UTC on 6 July. Cloud radar observations show a shallow cloud between 22:00 and 05:30 UTC with the cloud top increasing from 2 to almost 3 km. Radar reflectivity and downward velocity increase with decreasing height peaking at 1.5 dBZ and −1.4 m s^{-1}, respectively. Liquid water path peaked at 400 g m^{-2}. The cloud radar's linear depolarization ratio remained low, close to the detection limit of −26 dB, indicating particles with spherical cross section in their horizontal shape, i.e. supercooled drizzle. On the surface, a layer of clear ice accumulated atop snow fallen the day before. At 01:00 UTC, the layer of ice was observed to be approximately 2 mm thick. After 05:30 UTC, a vertically deeper precipitation system with cloud tops above 5 km and cloud-top temperatures below −32 °C caused snow precipitation at the surface. Once the ice particles from aloft fell into the lower layer, the liquid water path dropped to values below 60 g m^{-2}. By that time, the ice layer on the surface had almost doubled in thickness. The lidar was less affected by the icing, but suffered signal attenuation in the lowest kilometer. However, during the discussed period, the observed volume depolarization ratio at 532 nm remained below 5%, while the values were close to 30% before 22:00 and after 05:40 UTC.

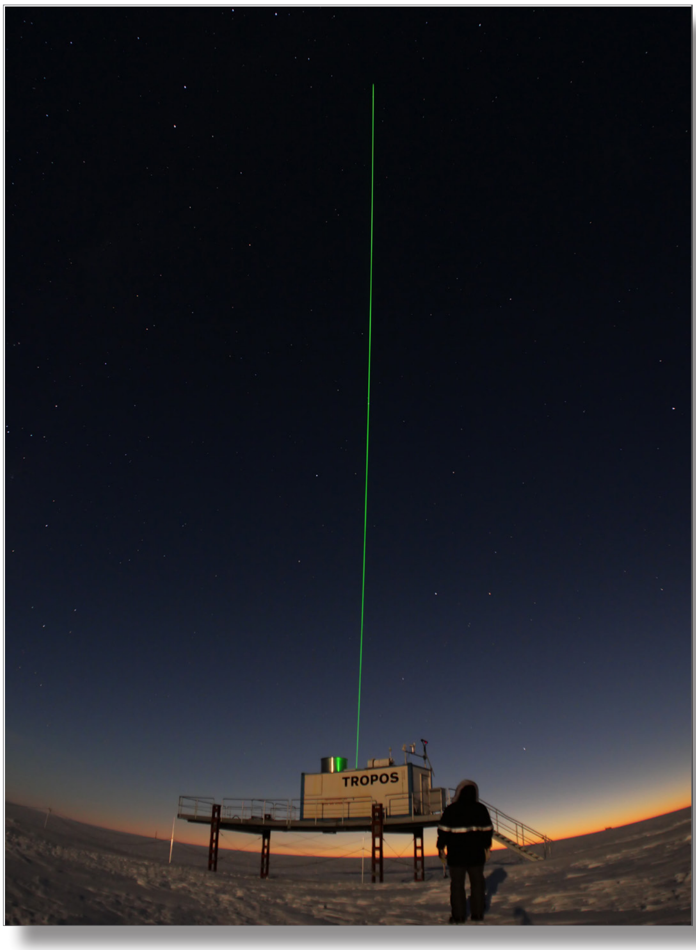

Fig. 4.20.1: OCEANET-Atmosphere in operation during polar night (left) and during disassembly in January 2024 (top).

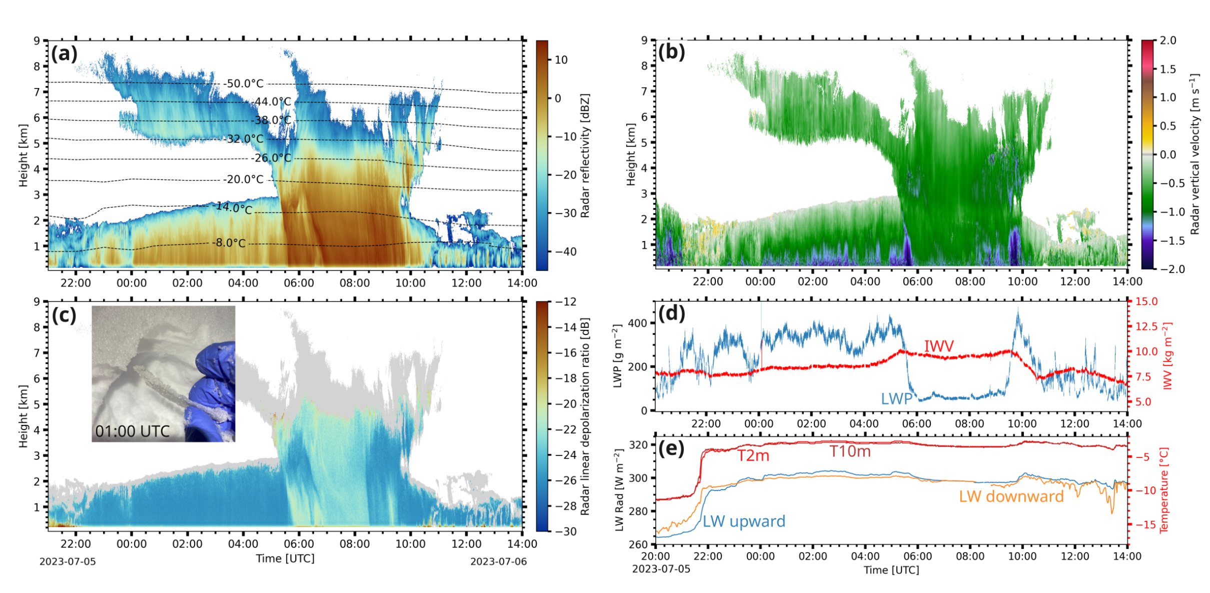

Fig. 4.20.2: Precipitation during the warm air intrusion from 5 to 6 July 2023: (a) Cloud radar reflectivity time-height cross-section overlayed with temperature from ECMWFs IFS analysis (b) Cloud radar vertical velocity (c) Cloud radar linear depolarization ratio with inset picture showing the 2-mm ice layer on the surface at 01:00 UTC (d) Time-series of integrated water vapor and liquid water path (e) Time-series of longwave radiation and temperature at the surface (meteorological observatory).

Data management

All OCEANET-Atmosphere raw data from this project are stored at the data server of TROPOS. Access can be requested via email to ronny.engelmann@tropos.de.

Higher-level data are uploaded, archived, published and disseminated according to international standards by

1. the ACTRIS Data Centre (https://www.actris.eu/topical-centre/data-centre), via the Aerosol Remote Sensing Data Centre Unit (ARES) and the Cloud Remote Sensing Data Centre Unit (CLU)
2. PANGAEA (https://www.pangaea.de) under the keyword OCEANET-ATMOSPHERE within two years after the end of the observational period at the latest.

In all publications based on this expedition, the **Grant No. AWI_ANT_22** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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4.21 MICA-S – Magnetic Induction Coil Array – South

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Grant-No. AWI_ANT_9

Objectives

MICA-S continuously observes geomagnetic pulsations at *Neumayer Station III*. The geomagnetic latitude of *Neumayer Station III* is ideally suited to investigate so-called electromagnetic ion cyclotron (EMIC) waves near the plasmapause by observing these pulsations. EMIC waves are naturally occurring electromagnetic waves in the near-Earth space that can cause loss processes for particles in the Earth's radiation belts as well as the ring current and are therefore relevant for space radiation processes and risks to spacecraft. They are studied by ground and satellite magnetometers and often in conjunction with each other. Both fluxgate and induction magnetometers can be used, but the latter are preferred. Therefore, the MICA-S induction magnetometer at *Neumayer Station III* is relevant for scientific satellite missions like ESA's Swarm mission, NASA's Van Allen Probes, or JAXA's ARASE (ERG) satellite. Also of great importance is a coordinated ground observation effort at both hemispheres and especially at high latitudes.

Fieldwork

During 2023, the MICA-S data acquisition was running without major problems. After strong winds, the flags, which are used to mark the position of the MICA-S, have been checked.

New snow constantly accumulates on top of the instrument pit, which therefore becomes deeper over time. Once a year, we remove the upper layer of snow from the wooden plates on top of the pit and either reinstall the cover at snow surface or move the instrument into a new pit close to the surface. In the summer season 2023/24 at 27 January 2024 the cover of the magnetometer has been indirectly raised by installing a new, second cover at the surface. The two covers are now separated by 1.39 m (which represents the height of the removed accumulated snow on the lower cover above the magnetometer). This provides additional protection of down falling snow onto the instrument when opening the pit.

Due to the ice shelf movement of approximately 154 m per year, the location of the pit also changes. At 1 February 2023 it was located at S70°40.496' W8°16.537', at 27 January 2024 it was located at S70° 40.416' W8° 16.603'.

Preliminary results

Figure 4.21.1 shows an example of geomagnetic pulsations at *Neumayer Station III* (VNA) and other high latitude stations. It demonstrates both the quality of the data from the instrument installed at *Neumayer Station III* and shows that the signal is to some extent coherent with that at other stations in Antarctica and the Arctic, capturing important wave activities peculiar at certain geomagmetic latitudes.

Since its installation in January 2018, results from MICA-S have been published by Kim et al., (2020), Kim et al*.,* (2021) and Salzano et al., (2022).

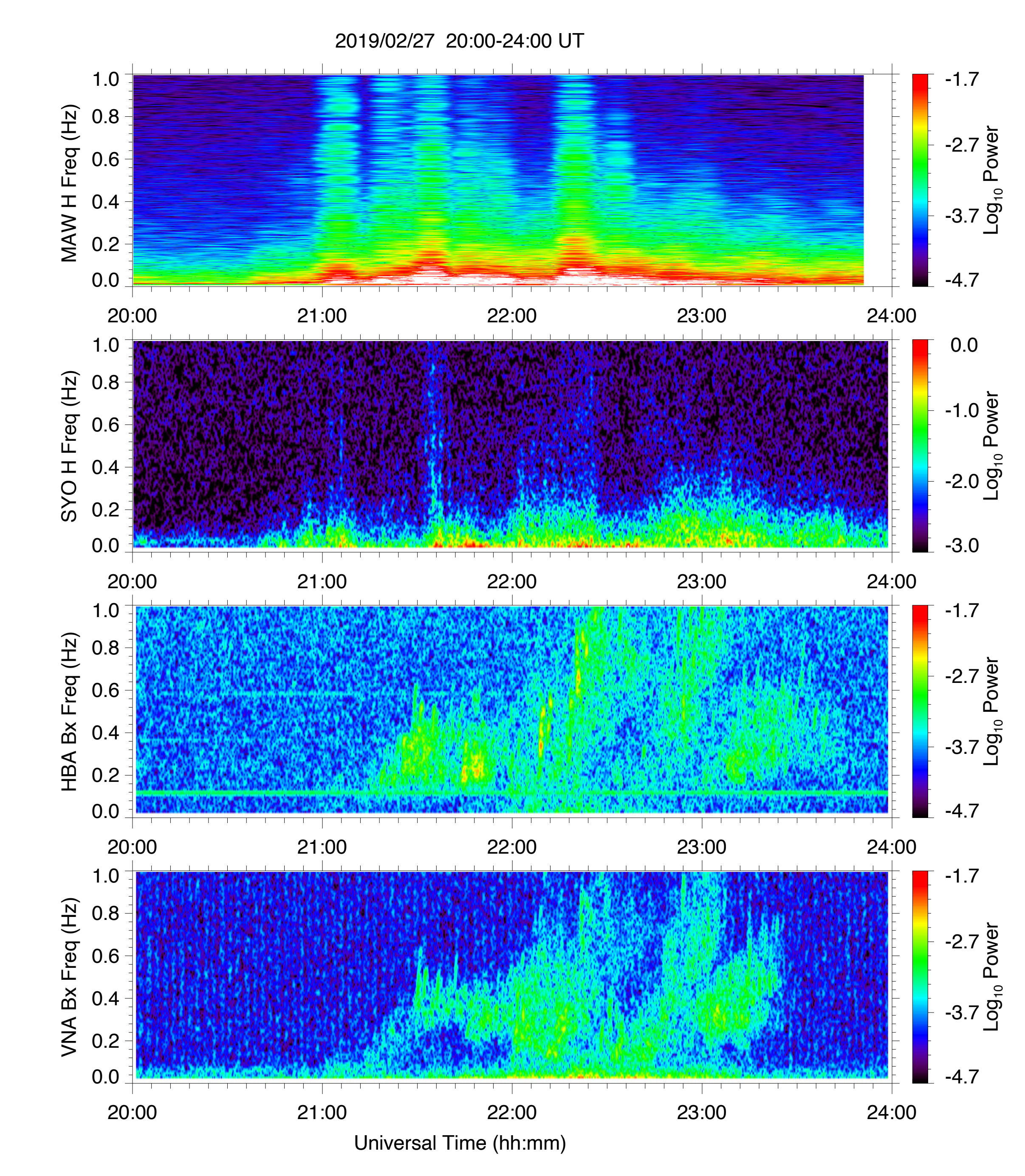

Fig. 4.20.1: Geomagnetic spectrograms for 27 February 2019 using data from Antarctic stations Mawson (MAW), Syowa (SYO), Halley Research Station (HBA), and Neumayer III (VNA). Intervals of Pulsations of Diminishing Periods (IPDPs), a subtype of EMIC waves, are observed at HBA and VNA (-62.2 and -60.6 CGM lat; Salzano et al, 2022). Near-simultaneous Pi1Bs are observed at MAW and SYO (-70.4 and -66.5 CGM lat).

Data management

Data (plots and cdf-files) is currently freely distributed through http://mirl.unh.edu/ulf_status.html. Data will also be curated either at AWI or GFZ and will receive a DOI.

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 3, Subtopic 1

In all publications based on this expedition, the **Grant No. AWI_ANT_9** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III* and *Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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Kim H, Schiller Q, Engebretson M J, Noh S, Kuzichev I, Lanzerotti LJ, Gerrard A J, Kim K-H, Lessard MR, Spence HE, Lee D-Y, Matzk J, Fromm T (2021) Observations of Particle Loss due to Injection-Associated Electromagnetic Ion Cyclotron Waves. Journal of Geophysical Research: Space Physics 126(2). https://doi.org/10.1029/2020ja028503.

Salzano M, Lessard M R, Noh S, Kim H, Waters C, Engebretson M J, Horne R, Clilverd M, Kadokura A, Tanaka Y, Kim K-H, Matzka J, Fromm T, Goldstein J, Kim M J (2022) Modeling the Effects of Drift Shell Splitting in Two Case Studies of Simultaneous Observations of Substorm-Driven Pi1B and IPDP-Type EMIC Waves, Journal of Geophysical Research: Space Physics 127(10). https://doi.org/10.1029/2022ja030600.

5. *KOHNEN STATION*

5.1 Kohnen-Thermometry 23/24

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Grant-No. AWI_ANT_37

Objectives

The Antarctic Ice Sheet represents the greatest potential source of global mean sea-level rise. Its response to climate change is a key source of uncertainty for future projections. Understanding the causes of recent climatic trends and natural variability on the East Antarctic Plateau is hampered by a short instrumental record. Despite dozens of ice-cores drilled in Antarctica, the climate evolution of the last century and millennia, especially on the EAP, is still largely unknown, due to noise terms distorting the climate records of ice cores (Laepple et al. 2018). In recent studies, we provided the foundation for assessing and handling the noise in ice core records (Münch and Laepple 2018) and the tools for an optimal use of stable water isotope profiles in ice cores (Münch et al. 2021). In the expedition Kohnen-Thermometry, we measure the borehole temperatures at existing boreholes around *Kohnen Station*; test and deploy a prototype for a low power autonomous borehole temperature logger unit (LATPU) and obtain new isotope samples to refine our knowledge on the transfer function between climate and ice-cores. In addition to providing the dataset needed for a borehole-based temperature reconstruction of the last 50-100 years around *Kohnen Station*, Kohnen-Thermometry is an important prerequisite for the subsequent expeditions by testing new measurement and sampling devices.

Our specific objectives were

- Measurement of borehole temperature profiles, including replicates and uncertainty estimates; This will allow to (a) reconstruct the temperature trends of the last 50-100 years and (b) to locally calibrate the isotopic thermometer.
- Deployment of a first prototype of a low power autonomous borehole temperature logger unit (LATPU); This provides the basis to use this device in future expeditions.
- Test of the hypothesis that the local topography has an influence on the mean water isotope composition by taking an array of representative snow samples.
- Extension of the 2019 snow trench record to allow a longer comparison of the noise reduced isotope record with the weather station data.

Fieldwork

Work at and near *Kohnen Station* (Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung 2016) was performed from 18 December 2023 to 19 January 2024.

Borehole temperature logging with a winch-based temperature profiling system

We reopened the boreholes B34, B40, B41, B49, B50, and B52, which were mainly drilled during the 2012/2013 COFI-ap expedition. For each borehole (except for B50), the firn density and isotope profiles were extended to the surface. After testing the newly developed winch-based borehole temperature profiling system and calibrating the cable length, we measured the borehole temperature profiles of each borehole. This included extensive replicate measurements (e.g., remeasuring the first logged borehole again on the last day of the expedition) to characterize the uncertainty of the temperature logging setup.

Test and setup of the low power autonomous borehole temperature logger unit

We successfully tested the newly LATPU units. This included tests of the SWARM satellite connection as well as tests and final changes in the firmware. We set up two measurement sites, the first at B40 and a second site in close proximity to B50. At B40 we deployed a 200 m chain with 20 thermistors in the borehole, at the second site, we deployed three shallow chains (8m, 8m, 5m) in the snow to test the effect of different sensor placement strategies on the snow temperature measurements. We used the chains to measure the temperature in a high temporal resolution (1min) before setting them into a slower (one measurement every 30 min) mode shortly before departure to measure for the next 2-4 years. The high temporal resolution measurements allow us to study the influence of fast temperature fluctuations, potentially related to atmospheric pressure variations.

Snow sampling as an extension of the 2019 trench

Replicated vertical profiles sampled in a snow trench allow to reduce the stratigraphic noise and thus to obtain a representative water isotope record (Laepple et al. 2016; Münch et al. 2016). This data can be compared to the weather station data in order to improve the transfer function between surface temperature and the isotopic composition of snow. To extend the isotope data from the 4m snow trench sampled in 2019 to the surface, we made a 50 m long, 2 m deep trench and sampled snow along 11 vertical profiles at the wall.

Representative snow samples to test the topography hypothesis

Our aim was to test the potential relationship between topography, accumulation and snow isotopic composition that we identified during the Kohnen-QK1 expedition in 2018/2019 on the other side of the divide. The sampling positions were derived based on high-resolution topographic data in the vicinity (<60km) from Kohnen station. To resolve the expected isotopic changes, the small-scale stratigraphic noise (Münch et al. 2016) (horizontal decorrelation scale <5m) has to be reduced by spatial averaging. At 28 sites, we sampled 12 x 1m vertical profiles using the dual snow sampler device (Dallmayr et al. 2021).

Ground based radar measurements

To study the snow accumulation and surface mass balance in the same area and the relationship of local topography and accumulation at the sites used to test the topography hypothesis, we performed ground-based radar measurements using a 500 MHz antenna attached to a skidoo.

Preliminary (expected) results

Our tests of the winch based and string-based temperature logging systems were successful and indicate a replicability (across several days) of < 1mK in borehole depths larger than 50 m. For depths down to 100 m we found temperature variations (significant relative to the measurement uncertainty) that are coherent between different sites and replicated using independent measurement devices. The reason for these fluctuations is still under investigation. They might be related to atmospheric pressure changes (Clow et al. 1996). We also found significant temperature differences between nearby borehole profiles (1 km, 10 km distance) that are systematic and replicable and thus not related to measurement uncertainties. They might be related to small topographic differences (< 5 m in altitude) between the sites but more investigations are needed to explain these unexpected differences.

The low power autonomous borehole temperature logger units, including their batteries and satellite connections performs very well. We received temperature data for the first 100 days and the temperature sensors below 150 m depth showed changes of < 0.5 mK demonstrating the stability of the system.

Our preliminary borehole temperature profiles all strongly deviate from the equilibrium profile expected under a constant surface temperature boundary condition and indicate a strong (> 1 K) warming in the last centuries. Preliminary analyses suggest that the quality of the borehole temperature profiles should allow a temperature reconstruction of the last two centuries and thus provide a strong constraint on the effect of global warming on the region around *Kohnen station*.

Tab. 5.1.1: Location of the 28 representative snow sampling sites

ID	Longitude (S)	Latitude (N)
R1	0.01078997	-75.002009
R2	0.09144593	-74.93268
R3	0.17135474	-74.863333
R4	0.25052643	-74.793967
R5	0.27781995	-74.768828
R6	0.31515806	-74.735958
R7	0.41818359	-74.731053
R8	0.49443587	-74.727302
R9	0.56205	-74.724163
R10	0.62963592	-74.721003
R11	0.69719349	-74.717822
R12	0.76472251	-74.714619
R13	0.83222283	-74.711396
R14	0.89028515	-74.701884
R15	0.94782641	-74.692059
R16	1.00529295	-74.682218
R17	1.06268479	-74.672363
R18	1.12000197	-74.662492
R19	1.16162929	-74.655279
R20	1.25419012	-74.639036
R21	1.23419358	-74.666104
R23	1.20256318	-74.701312

ID	Longitude (S)	Latitude (N)
R24	1.12102447	-74.727544
R25	1.0002853	-74.749929
R26	0.89438283	-74.768548
R27	0.78059942	-74.788963
R28	0.60934507	-74.819476
R11	0.69719349	-74.717822
R12	0.76472251	-74.714619
R13	0.83222283	-74.711396
R14	0.89028515	-74.701884
R15	0.94782641	-74.692059
R16	1.00529295	-74.682218
R17	1.06268479	-74.672363
R18	1.12000197	-74.662492
R19	1.16162929	-74.655279
R20	1.25419012	-74.639036
R21	1.23419358	-74.666104
R23	1.20256318	-74.701312
R24	1.12102447	-74.727544
R25	1.0002853	-74.749929
R26	0.89438283	-74.768548
R27	0.78059942	-74.788963
R28	0.60934507	-74.819476

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).

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 2.

In all publications based on this expedition, the **Grant No. AWI_ANT_37** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). Neumayer III and Kohnen Station in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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Clow GD, Saltus RW, Waddington ED (1996) A new high-precision borehole-temperature logging system used at GISP2, Greenland, and Taylor Dome, Antarctica. J Glaciol 42:576–584. https://doi.org/10.3189/S0022143000003555

Dallmayr R, Freitag J, Hörhold M, et al (2021) A dual-tube sampling technique for snowpack studies. J Glaciol 67:84–90. https://doi.org/10.1017/jog.2020.85

Laepple T, Hörhold M, Münch T, et al (2016) Layering of surface snow and firn at Kohnen Station, Antarctica – noise or seasonal signal? J Geophys Res Earth Surf 2016JF003919. https://doi.org/10.1002/2016JF003919

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Münch T, Laepple T (2018) What climate signal is contained in decadal- to centennial-scale isotope variations from Antarctic ice cores? Clim Past 14:2053–2070. https://doi.org/10.5194/cp-14-2053-2018

Münch T, Werner M, Laepple T (2021) How precipitation intermittency sets an optimal sampling distance for temperature reconstructions from Antarctic ice cores. Clim Past 17:1587–1605. https://doi.org/10.5194/cp-17-1587-2021

6. OTHER SCIENTIFIC PROJECTS WITH AWI PARTICIPATION

6.1 BE-OI 2023/2024 – Beyond EPICA – Oldest Ice

Frank Wilhelms[1] (not in the field), Olivier Alemany[2], Matthias Hüther[1], Julien Westhoff[4], Saverio Panichi[3], Andrea Ceinini[3], Nicolas Bienville[5], Rémi Dallmayr[1], Inès Gay[6], Tamara Gerber[4], Fortunat Joos[7], Iben Koldtoft[4], Gunther Lawer[1], Johannes Lemburg[1], Michaela Mühl[7], Philippe Possenti[2], Federico Scoto[8], James Veale[9], Steffen Bo Hansen[4] (not in the field), Melanie Behrens[1] (not in the field), Thomas Laepple[1] (not in the field), Hanno Meyer[1] (not in the field), Elise Fourre[5] (not in the field), Benedicte Minster[5] (not in the field), Amaelle Landais[5] (not in the field), Barbara Stenni[10] (not in the field), Giuliano Dreossi[10] (not in the field), Hans Christian Steen-Larsen[11] (not in the field), Vasileios Gkinis[4] (not in the field), Maria Hörhold[1] (not in the field)

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[6]FR.IPEV
[7]CH.UNIBE
[8]IT.ISAC-CNR
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[10]IT.ISP-CNR
[11]NO.UNIBergen

Grant-No. AWI_ANT_30

Überblick

Frank Wilhelms DE.AWI

Das Beyond EPICA – Oldest Ice Projekt zielt darauf ab, einen Eiskern zu gewinnen, der den mittelpleistozänen Übergang (Mid Pleistocene Transition, MPT) bis in ein Klima überspannt, das von einem 40 tausend Jahre-Zyklus vor etwa 1,2 –1,5 Ma dominiert wurde. Das Ziel der dritten Saison ist ein Bohrfortschritt um bis zu 850 m unter idealen Bedingungen. Die Gewinnung des Eiskerns, der die meteorische Probe für die Rekonstruktion und Interpretation der atmosphärischen Paläozeitreihen darstellt, ist die Grundlage für den Erfolg des Beyond EPICA – Oldest Ice-Projekts. Wir berichten über den Verlauf der Tiefbohrung während der Feldkampagne 2023/24 von 808,47 m bis zu einer Tiefe von 1836,18 m.

Summary

Frank Wilhelms DE.AWI

The Beyond EPICA – oldest ice core project aims at retrieving an ice core spanning the Mid Pleistocene Transition (MPT) back into a 40 kyr cycle dominated climate about 1.2–1.5 Ma ago. The aim of the third season is production drilling of up to 850 m under ideal conditions. The recovery of the ice core, which is the meteoric sample for the reconstruction and interpretation of the atmospheric paleo-records, is the basis for the success of the Beyond EPICA – Oldest Ice project. We report the course of the deep drilling operation during the 2023/24 field campaign, from a depth of 808.47 m down to a depth of 1,836.18 m.

Objectives

The Beyond EPICA field operation at *Little Dome C* aimed at coring as deep as possible and offered the opportunity to conduct ancillary surface studies. This report summarizes the second deep drilling season 2023/24, where the coring advanced from 808.47 m to 1,836.18 m.

Fieldwork

The main group left Europe on 11 November 2023 and stood by for the deployment between 12 – 16 November 2023 in Christchurch, New Zealand. On 16 November 2023 the main group departed from Christchurch (NZ) to *Mario Zucchelli Station* by Italian LC-130H. The logistic team went by Basler BT-67 to *Concordia Station* (IT/FR) between 9 – 14 November 2023, where the drilling and science group followed on 23 and 28 November 2023, and proceeded after three days of high-altitude acclimatisation and COVID isolation to the *Little Dome C* (LDC) drilling camp. This resulted in 55 days (26 November 2023 – 20 January 2024) of available time for the drilling operations on site, where the full team was present for 49 days. For the next eight days the team prepared the core processing infrastructure at Little Dome C and processed the first core on 4 December 2023, drilling started after eleven days on 8 December. Putting the core processing operational, required getting access to the under-snow core-buffer and core processing line. After the processing area at *Concordia Station* failed during the last season and is not available anymore, the core storage at LDC had to be converted into a processing area. The team removed the core troughs and unmounted most of the shelves to provide more space for storage of ice core boxes in the processing line. Then, they re-arranged all the full ice core boxes in the LDC science trench (the former core buffer), which had been left from last year and installed three additional tables, which had been recovered from the processing area at *Concordia Station*. To provide a second exit, and easier movement of core boxes, the crew opened the rear end of the science trench, which is constructed from three containers placed in a row, each with doors at both ends. The horizontal saw and the dielectric profiling (DEP) equipment were moved from *Concordia Station* to LDC, installed and put into operation. We cross checked the DEP calibration back in Europe. In parallel the unpacking of electric and electronic devices from the +4 °C winter storage container started. The heaters, winch and tower motor controls were mounted and the alignment of the logging tables started. The team mounted the heat box, which finally arrived at LDC. This box is designed to heat and dry long drill components, to prevent resp. overcome icing problems in the drill's downhole unit. The electrical installations worked fine right away, but a broken welding seam was observed on one of the piston mounts of the tower. *Concordia Station* supported the repair by providing protective gas welding equipment. The external fans in the drill tent and the liquid processing system had minor issues, which were solved within a few hours. The team also started with initial installations towards a proper camp communication network. On 1 December 2023 the entire crew arrived at LDC. They re-aligned the logging tables and the core extraction system. After further installation of network components to the science- and the drill-trench we placed temperature sensors that are monitored over the camp network. While the team continued mounting steps to facilitate the access to the tower in the drill-trench and mounted the actual down-hole unit of the drill, processing of last year's core started 4 December 2023. In the beginning we focussed on training more people on the processing line. After further maintenance and upgrades of ancillary systems, like e.g. the ventilation in the cabin of the liquid handling system and the fluid extraction device, finally the drilling operation started 8 December 2023.

It took four more days to get into a production mode for drilling. As the AWI electronics still was marginally providing enough power for the 4 m core length drill setup, the Danish electronics was the preferred choice to get into stable drilling mode, but as the top plug had not been shipped back into the field, the team had to manufacture appropriate adaptors on site. From

12 December 2023, basically till the end of the season, drilling went into production mode, that was mainly interrupted by holidays, occasionally slightly slowed by applying countermeasures to limit inclination of the hole, or shortening the cable after it was kinked due to too high tripping speed, when paying out cable into the hole.

Processing of the core started with the core still being stored at LDC from last season (608 m – 806 m) and continued with the depth interval brought back from *Concordia Station* (222 m – 608 m). Then, the newly drilled core from this season was processed from 806 m till 842 m, where the team decided to postpone the processing of the section from 843 m till 950 m until next year, allowing more time for the ice to relax and avoid breaks during processing of the brittle cores. They proceeded with the entirely stable core below 951 m. From then on processing followed the drilling and reached a depth of 1,695 m till closure of the camp had to start. For next season, 107 m from the interval 843 m – 915 m and the production during the last days (1,695 m – 1,836 m) of the season are awaiting to be processed.

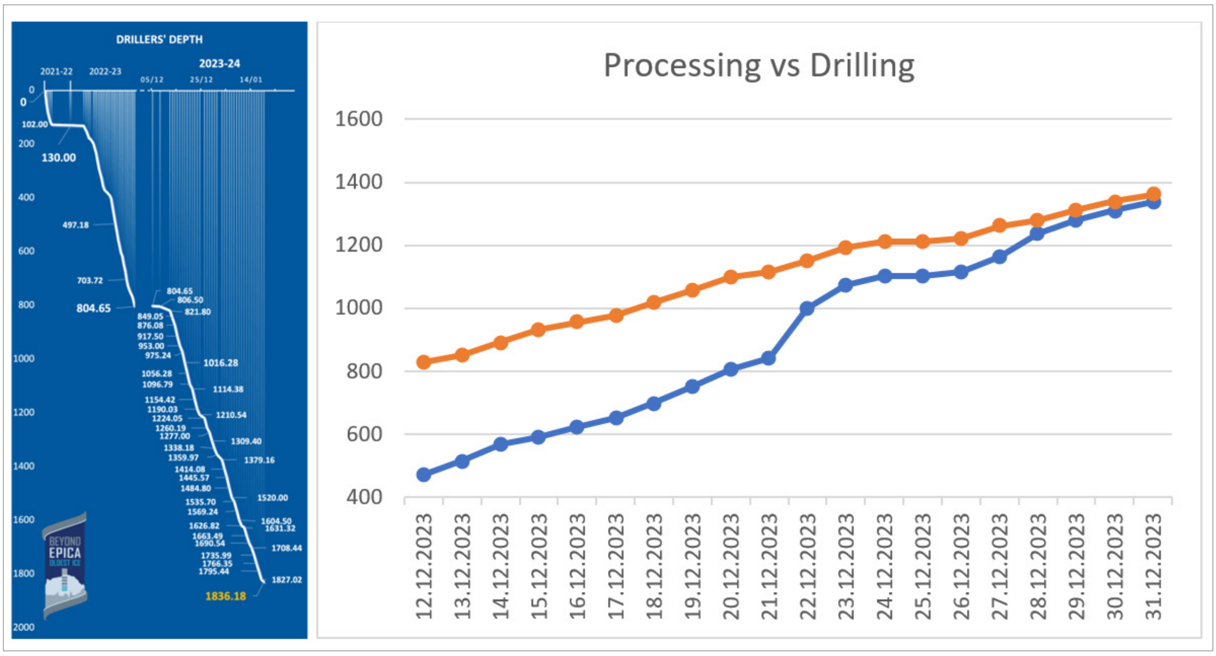

Fig. 6.1.1: Left: The penetration in driller's depth in m on the ordinate versus date on the abscissa. Right: Processing depth compared to the drilling depth

After the end of drilling, the team had time until the 19 January 2024 to pack down everything, tune the liquid level and winter the tents.

Fig. 6.1.2: Group photo: Start of drilling (5 December 2023) back row from left to right: Rémi Dallmayr, Olivier Alemany, Inès Gay, Julien Westhoff, Tamara Gerber, Iben Koldtoft, Johannes Lemburg, Gunther Lawer, kneeling middle row: Philippe Possenti, Andrea Cenini, Michaela Mühl, James Veale, Matthias Hüther, Saverio Panichi, Fortunat Joos, front lying: Federico Scoto

Michaela Mühl and Fortunat Joos moved from *Little Dome C* to *Concordia Station* on 12 January 2024 and departed towards *Mario Zucchelli Statio*n on 13 January 2024. Rémi Dallmayr, Phillippe Possenti, Olivier Alemany and Federico Scoto followed on 18 January 2024, and the rear guard of Matthias Hüther, Gunther Lawer, Johannes Lemburg, Inès Gay, Andrea Ceinini, Saverio Panichi, James Veale, Iben Koldtoft, Tamara Gerber and Julien Westhoff left the morning of 20 January 2024. Fortunat Joos departed from *Mario Zucchelli Station* on 19 January 2024. Matthias Hüther, James Veale, Iben Koldtoft, Tamara Gerber and Julien Westhoff proceeded towards *Mario Zucchelli Station* on 23 January 2024 and embarked the ice breaker *Le Commandant Charcot* on 28 January 2024. Michaela Mühl also joined this group and they all arrived in Lyttleton (NZ) on 5 February 2024. Federico Scoto and Saverio Panichi proceeded to *Mario Zucchelli Station* on 23 January 2024, left towards *McMurdo Station* on 25 January 2024 and arrived in Christchurch on 27 January 2024. Rémi Dallmayr, Gunther Lawer, Johannes Lemburg and Phillippe Possenti departed towards *Dumont d'Urville Station* on 30 January 2024, embarked the research vessel *L'Astrolabe* on 8 February 2024 and arrived in Hobart on 14 February 2024. Olivier Alemany and Inès Gay moved to the Australian *Casey Station* on 31 January 2024 and ultimately reached Hobart on 13 February 2024.

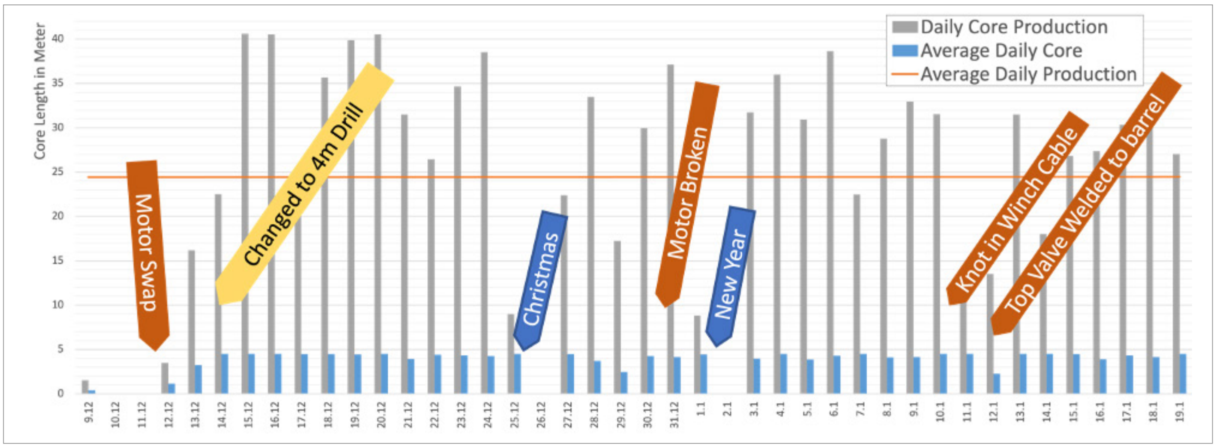

Fig. 6.1.3: Core production during the season

For the definition of the original milestone to proceed from 1,310 m as planned milestone for the second season to 2,160 m for the third drilling season an advancement of 850 m was planned for 60 days on site. During the 55 days on site the drilling advanced 1,031.53 m from the 804.65 m final depth of the past 2022/23 season to the 1,836.18 m final depth of this 2023/24 season. We needed about eleven days to get fully operational and again had just the day of 19 January 2024 to close the camp after the drilling operation ceased just before midnight of 18 January 2024. The production over these exactly 6 weeks of drilling is in average 171.9 m per week, which is close to the 175 m per week we normally achieve for the uppermost few 100 m if drilling is smooth. The excellent production due to stable electronics and the long 4.5 m core length drilling equipment allowed to maintain this production rate far deeper down in the hole.

The inclination increased from around 1° up to 4°, but maintained stable there. The inclination is in the desirable range to deviate from the hole later, when we will try to replicate the core older than 700 ka. The drilling operation consumed 14,300 litres of drill liquid, which is 13.9 litres per drilled metre, where 13.2 litres per metre are needed to geometrically fill the hole, which is a net loss of 5.2 % and an exceptionally good recovery that can only be achieved in stable drilling with long runs and effective drill chips handling. This altogether gives a good prospect for the coming season, where we envisage the targeted old ice a rapidly increasing age with depth.

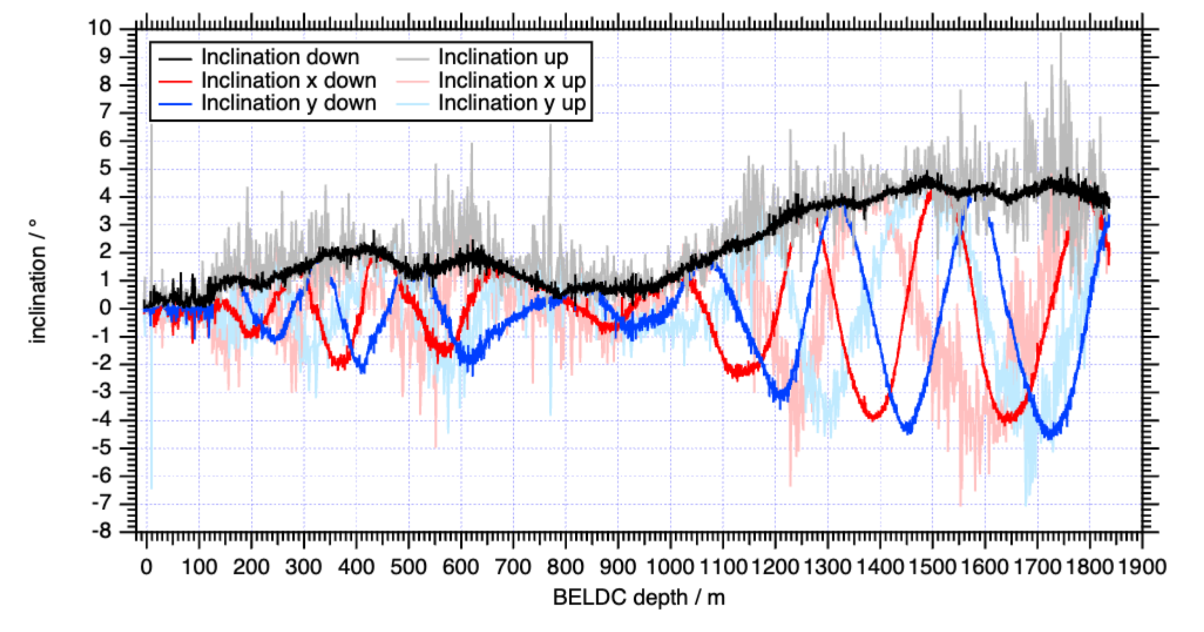

Fig. 6.1.4: Inclination of the hole recorded during the final filter run on 18 January 2024. When dripping into the hole we pay out at about 15 cm/s, while reeving is at higher speeds up to 100 cm/s. Therefore, the measurement downwards is used, while the readings upwards are much more noisy.

Temperatures when handling the core

The temperatures the core is exposed to during handling are critical. The field team installed ventilation systems to supply cold air to the processing area and insulated the entrance with core boxes and plywood. They also actively cooled the transport box, where the last bag of core is stowed away while waiting for the next run, by supplying fresh cold snow. The temperatures have been monitored by loggers and also sensors that acquired data over the camp's intranet.

The recorded temperature profiles demonstrate the measures were effective and sufficient. The core storage area was maintained below –30 °C and the processing area below –28 °C at all times, where the temperatures during night dropped to –35 °C. This is well in accord with the project standards for handling the core (BEOIC Deliverable No 4.1), that permits storage between –30 °C and –45 °C for up to three month and was envisaged for temporary storage at LDC. More critical were the temperatures at the logging table, which followed the ambient temperatures at the surface and varied between –15 °C and –35 °C. To minimize the exposure of the core to high temperatures, it was logged immediately after the run and brought to the cold storage area. However, the last piece not filling an entire bag was needed to fit the next core, when continuing the logging of the subsequent run. This piece was either stowed away in the core storage area or kept in an insulated box at the logging table. By constant supply of cold fresh snow, the temperature could be maintained below –25 °C to –28 °C. This is well in accord with project standards for handling the core, which acknowledges the need of storing between –20 °C to –30 °C for up to two weeks and envisages 1 week needed between drilling and cutting. Here we talk about typically less than 2 hours in between two runs.

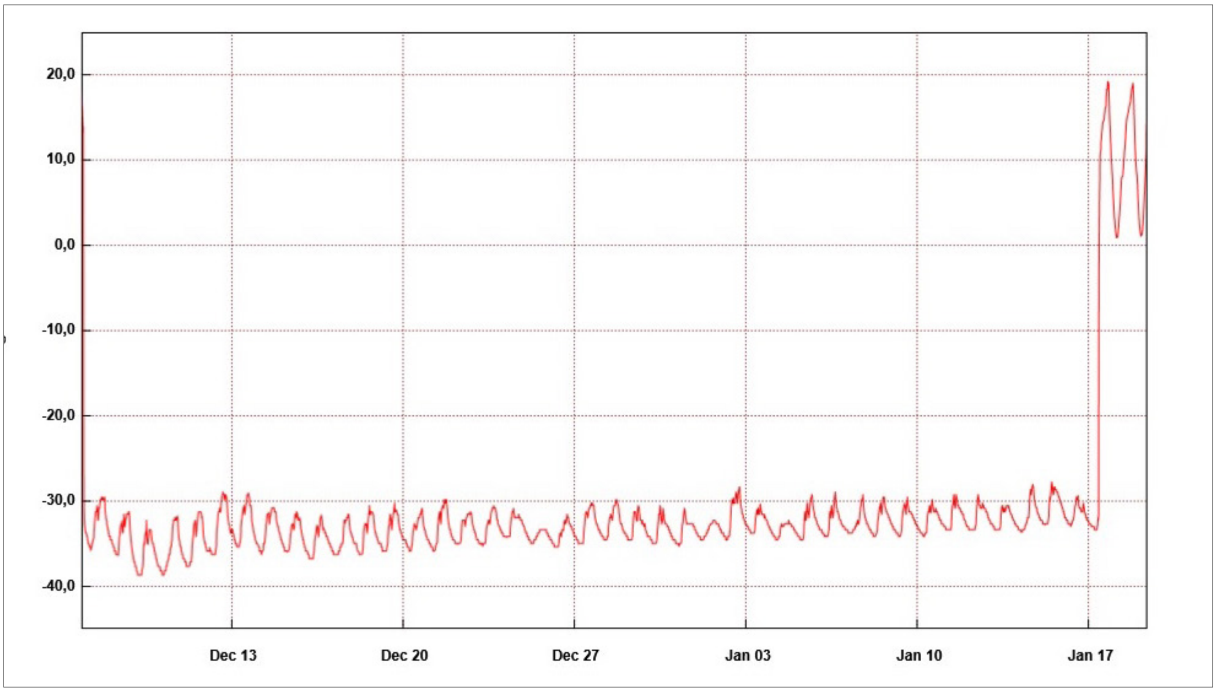

Fig. 6.1.5: Temperature as recorded by a logger in the processing area. Notice the days without processing (25 December 2023 and 1 and 5 January 2024). Processing stopped around 16 January 2024 and the positive temperatures were recorded after the logger had been moved to the recreation tent.

Fig. 6.1.6: Additional insulation of the processing trench with white core boxes
Photo: J Westhoff. Credit: Westhoff©PNRA/IPEV

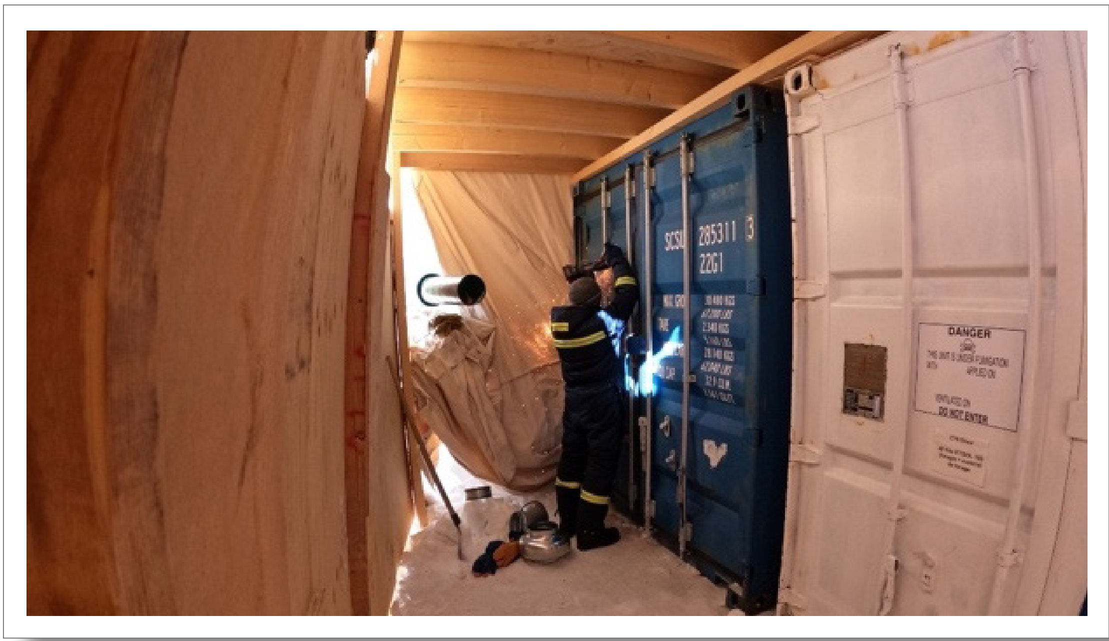

Fig. 6.1.7: Active cooling by venting cold air from the firn (pipe in the back) and shielding of the sun's radiation with plywood sheets to the left. Photo: J Westhoff. Credit: Westhoff©PNRA/IPEV

Fig. 6.1.8: Installation of the cooling pipe in the firn. Photo: J Westhoff. Credit: Westhoff©PNRA/IPEV

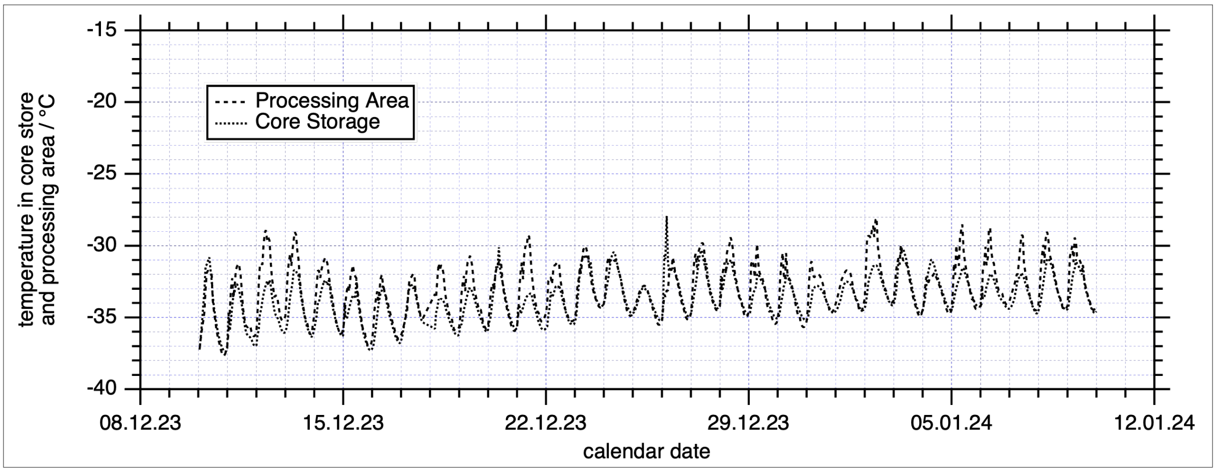

Fig. 6.1.9: The recorded Temperature in the core storage and the processing area

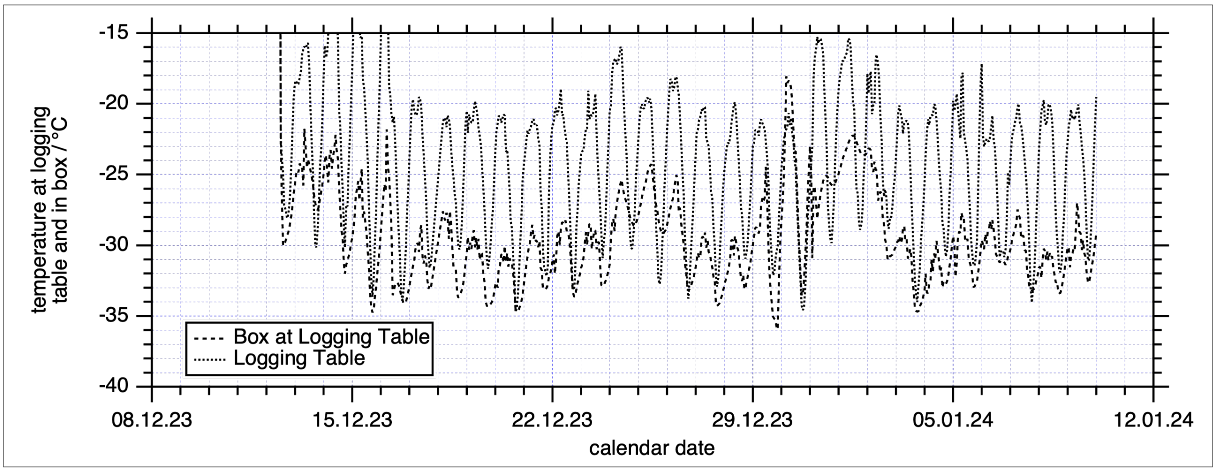

Fig. 6.1.10: The temperature at the logging table and inside an insulated box to place the freshly logged core

*Fig. 6.1.11: The temporary storage for the last core piece at the logging table.
Photo: J Westhoff. Credit: Westhoff©PNRA/IPEV*

Age of the core

To estimate the age of the core, we recorded its dielectric profile (DEP) already in the field and wiggle matched it to the EPICA Dome C record (Parrenin et al. 2012), which recently received an updated common timescale AICC2023 Bouchet et al. 2023). The processed ice is about 160 ka, while we expect for the drilled core an age around 200 ka.

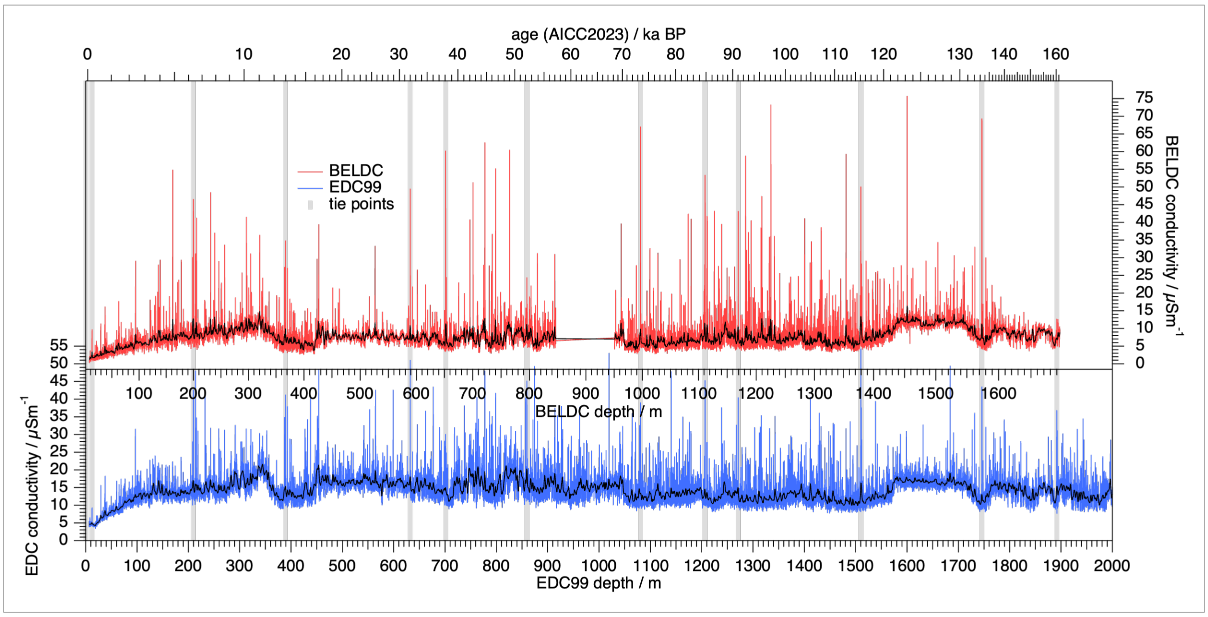

Fig. 6.1.12: Dielectric profile (DEP) of the BELDC and the EDC99 core plotted at their respective depth scales and with the latest ice core time scale AICC2023 plotted on top

Fig. 6.1.13: Dielectric profiling of the core.
Photo: J Westhoff.
Credit: Westhoff©PNRA/IPEV

Fig. 6.1.14: Scraping and packing of bag mean samples.
Photo: J Westhoff.
Credit: Westhoff©PNRA/IPEV

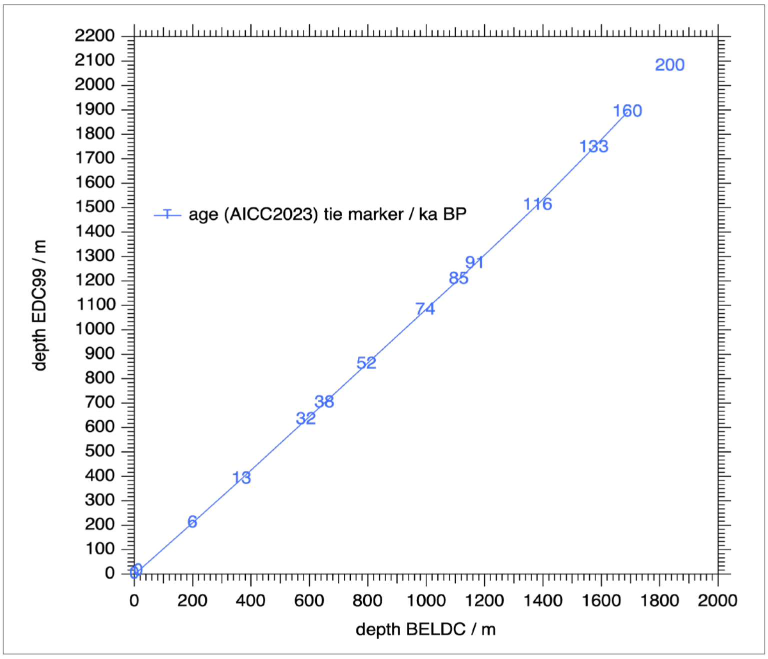

Fig. 6.1.15: The tie points of the initial wiggle match of DEP records between EDC99 and BELDC

Besides the DEP, we also collect bag means of ice chips from the horizontal saw and or scraped off the surface. While the wiggle match of the records with the DEP alone is still reliable in the upper core section, we expect much more ambiguity deeper down and envisage much higher confidence by also matching water stable isotope records. The bag mean samples are measured by Cavity-Ring-Down-Spectrometry directly in the field.

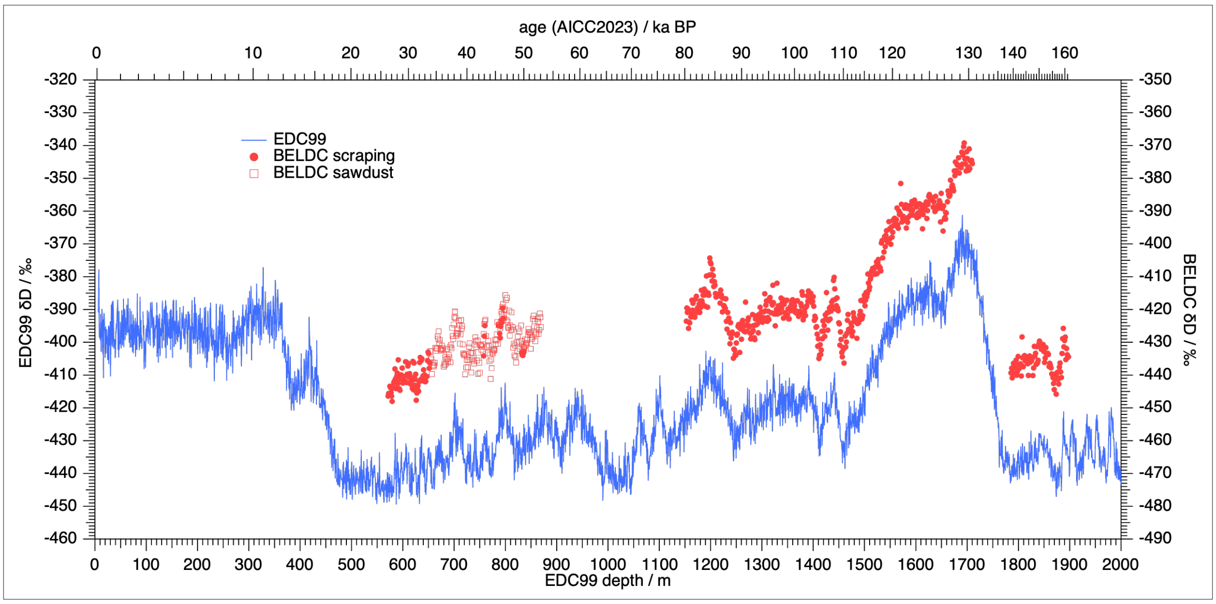

Fig. 6.1.16: Wiggle match of δ D for the BELDC and the EDC99 cores. The two ordinates of the records are shifted by 30 ‰ for better readability.

This approach was very successful and we determined independently the age of the processed core down to 1,694.95 m to 161.4 ka before present. By continuation of the trend, we estimate the age of the already drilled interval down to 1,836.34 m to roughly 200 ka before present.

Data management

Environmental data will be archived, published and disseminated according to the data management plan of BE-OIC and therefore are in accord with international and European Union standards, most prominently the FAIR principle.

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.

In all publications based on this expedition, the **Grant No. AWI_ANT_30** will be quoted.

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III and Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152

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Jouzel J et al. (2007) Orbital and Millennial Antarctic Climate Variability over the Past 800,000 Years. Science 317:793–796. https://doi.org/10.1126/science.1141038

Parrenin F et al. (2012) Volcanic synchronisation between the EPICA Dome C and Vostok ice cores (Antarctica) 0–145 kyr BP. Clim. Past 8:1031–1045. https://doi.org/10.5194/cp-8-1031-2012

6.2 ITGC-GHOST – International Thwaites Glacier Collaboration - Geophysical Habitat of Subglacial Thwaites 2023/24

Olaf Eisen[1], Ole Zeising[1], Hannes Laubach[1], Sridhar Anandakrishnan[2], Alex Brisbourne[3], Coen Hofstede[1] (not in the field), Florian Koch[1] (not in the field)

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[3] UK.BAS

Grant-No. AWI_ANT_31

Objectives

As part of the International Thwaites Glacier Collaboration (ITGC) AWI participates in the project Geophysical Habitat of Subglacial Thwaites (GHOST, https://thwaitesglacier.org/index.php/projects/ghost). The aim of GHOST is to identify the structure and materials of the bed of Thwaites Glacier using geophysical methods such as passive and active seismics (explosives and a seismic vibrator as sources), gravimetry, magnetotellurics, phase-sensitive radio-echo sounding (repeat, polarimetric and autonomous – pRES, PpRES, ApRES) and ground-penetrating radar profiling. This information will help improve estimates of the contribution of Thwaites Glacier, which rests on a retrograde bed well below sea level, to global sea level rise in the next decades to centuries. AWI's task in GHOST 2023/24 was to continue the recording of seismic reflection profiles on Thwaites Glacier using our seismic vibrator (Envirovib, EV, Eisen et al. 2015) as a seismic source and a 1,500 m long, 60 channel snowstreamer for recording.

Seismic profiles give us the topography and stratigraphy of the shallow subglacial bed. With the reflection coefficient of the ice-bed contact, derived from the shot records, we can identify the subglacial material and, in the case of sediment, its water saturation. In addition, englacial reflections originating from changes in crystal fabric can be unambiguously mapped by seismics, thus complementing and guiding interpretations of radar observations.

The planned seismic profiles were focused on the across-flow direction to cover the region from the centerline eastwards over a suspected subglacial lake, which showed surface lowering over the last year, and beyond the eastern shear margin of Thwaites Glacier, thus complementing the along-flow centerline profile obtained in season 2022/23 (Hofstede et al. 2024).

Fieldwork

The project was logistically hosted by the United States Antarctic Program (USAP) and the British Antarctic Survey (BAS). The initial plan foresaw departure from Europe on 1 November 2023, arrival at the United States Antarctic research station *McMurdo* (McM) on 6 November, at the WAIS-Divide (WSD) summer camp on 16 November and departure via the traverse hosted by BAS to Thwaites Glacier on 28 November. Due to operational difficulties, the overall deployment was delayed by 25 days, thus considerably reducing the time available for measurements on Thwaites Glacier.

After leaving Germany on 1 November, Hannes Laubach, Ole Zeising and Olaf Eisen arrived, with other GHOST team members, at MCM. From there we travelled to WSD where our equipment had overwintered over the last five years due to COVID interruptions and logistic delays. The early arrival of HL & OE at WSD on 1 December, hosted by the BAS traverse independently of WSD camp, allowed to start the mobilisation of the EV and data acquisition system already before WSD was open for science. Most equipment was stored in Zarges boxes on berms and a Lehmann sled. The EV overwintered in a Weatherhaven tent, well protected from snow and solar radiation. Mobilisation of the system took a total of four days for two people and was completed by 8 December. WSD opened up late for science, effectively on 14 December due to operational delay of the USAP schedule. By that time all GHOST project field team members, including our third AWI colleague Ole Zeising, and freight had finally arrived at WSD so that the preparation of the main GHOST traverse could commence.

At WSD, the existing borehole of the WAIS divide ice-core drilling project was used to deploy a 2 km long fibre optic cable for performing vertical seismic profiling (VSP) of the borehole using Distributed Acoustic Sensing (DAS), with additional 2 km deployed at the surface. Accessing the borehole required two days of digging on 14 and 15 December by a team of 3–6 people to access the buried science trench (“arch”) of the former ice-core drilling project. After setting up the DAS recording system, explosive shots as well as the EV were used at the surface along the fibre optic cable as seismic sources.

The main GHOST traverse with various members and equipment of GHOST’s SWATH, ACTIVE, PASSIVE and VIBE teams left WSD on 22 December, arrived at the field depot Lower Thwaites Glacier (LTG) on 26 December and the northernmost field camp late on the same day (End of Line, EOL). After unloading the freight for the other teams, the VIBE and SWATH teams traversed back to LTG the next day to start the acquisition of the main across-flow seismic profile, accompanied by ground-based swath imaging radar operations. The traverse setup and operation procedures were identical to the one used in season 2022/23 and are described in further detail in Hofstede et al. (2024).

Initially, it was planned to acquire several seismic profiles with the EV-streamer setup: one along-flow, parallel to 2022/23, two across-flow across the eastern shear margin (ESM), a short section through the array of the ITGC TIME project at T2 at the ESM, and a short section overlapping with the ACTIVE seismic profile. However, given the above-mentioned operational delays, it was decided to focus on one across-flow profile only, following an earlier airborne radar profile. A summary of the timeline of the operations with a focus on the vibroseismic activities and the traverse period from/to WSD is provided in Table 6.2.1, which shows the timeline, location, and production of the 133 km recorded seismic reflection profile during the traverse. The recording was optimized to obtain a production speed of approximately 20 km/day. During the actual 16-day long vibroseis traverse LTG-ESM-LTG, we acquired vibroseis data on 6.5 days, spent 2 days on mobilizing and demobilizing the EV-streamer system, lost 5 days due to bad weather, and spent 2.5 days for the traversing back and other tasks.

After arriving at WSD, demobilizing the vibroseis system, and preparing it for overwintering, took two days for three people. As the system will be transported towards the Antarctic Peninsula with a BAS overland traverse in the 2024/25 season, all items were already packed on sleds ready to traverse. The streamer winch, all Zarges boxes and a crate with vehicle fluid are all mounted on a polysled while the EV is now mounted on a Lehmann sled. To avoid damage by strong winds or strong radiation over the next year, it is covered with an old Weatherhaven canvas, providing sufficient shelter.

After completing demobilization, the team left WSD for MCM on 27 January, after several days of waiting because of regular cancellations of flights to WSD. Departure from MCM was delayed by another week, with final arrival at CHC in the very early morning on 3 February 2024.

Operations

The vibroseis traverse from LTG to the ESM was accompanied by the swath radar survey (K. Christianson, N. Holschuh), having joint overnight camps. Apart from the length of the streamer blocking the way over 1.5 km, the two acquisition methods did not interfere with each other.

The EV operation can be accomplished by a three-person team (1 PB driver, 2 EV operators) for data acquisition for 10 h/day for limited time periods, as implemented this season. However, it would also be possible to work in a shift system with 2 persons per shift (1 PB driver, 1 EV operator) for a maximum of 6 h/day per shift. This would increase the possible vibroseis production by another 5 km/day, i.e. to 25–28 km/day in total.

Streamer

We had inspection walks along the streamer every evening and morning, taking between 30' and 1h for 1–4 people with one snowmobile. During the lunch break, the streamer was pulled by a few meters every 15–20 minutes to prevent freezing on the snow surface. During longer breaks, the Envirovibe was pushed back to reduce the tension on the streamer- In total, only one channel was lost. We attribute this to very safe operations as no manoeuvres (no other turns than 180°) were carried out; the main cable was effectively kept from rotating (see Hofstede et al. 2024), and surface conditions were favourable (relatively soft snow with few sastrugi).

Reeling the streamer out and in took each 2.5 h with five people (one driver, one winch operator, one cable handling behind the winch, one taking care of tied-on geophones, one cable handling on the ground). While reeling out took place directly behind the streamer in a straight line, spooling in was done with a “U” manoeuvre directly behind the winch, going parallel to the streamer, to reduce the tension on the main cable.

Sweep frequency

Acquisition parameters were kept as the year before, with a shot point spacing of 75 m, i.e. a 10-fold coverage, but the source characteristics were changed to a 10 s linear up-sweep in the band 10–200 Hz at 60% peak force (compared to 10–250 Hz the year before). The reason was that higher frequencies are mostly lost during propagation to the bed at around 2 km depth, and included the spurious frequency of the streamer geophones at 208 Hz. Thus, sweeps < 200 Hz increased the energy in our main frequency band.

Sweep position and time

During normal data acquisition with the streamer, only the position of the EV is recorded with a geodetic DL-V3 GPS receiver. The actual sweeping time is only noted to the minute, as the sweeping triggers directly the Geodes' streamer signal recording. However, near the TIME site T2 at the ESM more than 1000 seismic notes were deployed. To be able to absolutely tie their recording time to the sweep time we also triggered a Verif-i GPS logger directly from the sweep trigger (time break) in the 15 km vicinity near T2 on the 8 and 9 January.

Peak force

On 8 January peak force was raised from 60% to 80% to increase the signal-to-noise ratio because of wind of 15–20 kt. However, this resulted in exceeding several QC parameters of the vibroseis system during sweeps (peak force, peak reaction mass force, average distortion, maximum phase error) so that it was first reduced to 70% and then again to 60%. Preliminary analysis showed no advantage of data acquired at 80% compared to those with 60% peak force, but the load and wear on the vibrator system is considerably reduced at 60%.

Environmental conditions

Measurements along the profile were not influenced by 15–20 kt winds, in contrast to the previous season. We attribute this to: (i) the wind direction being parallel to the profile, i.e., along the streamer; (ii) the surface snow being rather soft, i.e. the main streamer cable and all geophones were in self-dug shallow trench and thus well protected from the wind; (iii) there was no precipitation; (iv) and the surface was rather flat without large sastrugi, i.e. individual geophones were not hanging in the air and thus exposed to wind. This should be taken into account when making operational decisions for future surveys.

Technical issues

A number of failures of the EV occurred after its fourth overwintering: the DC-DC converter for the gear module burnt, several fuses were blown (engine, radios), the hydraulic tank temperature sensor and the fuel gauge were broken. Replacement of the DC-DC converter was possible by ordering a replacement in the US and having it delivered by a person with late arriving field personnel to McM. The temperature sensor has to be ordered and replaced in a later season, before the next operational survey. As engine temperature and hydraulic temperature are linked, we carefully monitored engine temperature to avoid exceedingly hot hydraulic oil temperatures.

After a few hours of operation on the 31 December the vibration unit stopped working. After half a day of analysis the replacement of the main stage of the hydraulic servo valve provided remedy. The cause for the failure is unclear and will be investigated after the season by the producer of the valve.

The Force Two Decoder unit occasionally did not respond adequately when receiving radio trigger signals from the Universal Encoder with triggering a sweep. Rebooting the hydraulic system and the Force Two provided a quick remedy (pressure down to 20 bar, restart, pressure up again to 200 bar). The origin of this failure is not known.

Otherwise, both systems (streamer and EV) performed extraordinarily reliably, with only having to replace one geophone group on the streamer

Logistics

The traverse train back from LTG to WSD also had to redeploy also all cargo and fuel still stored at the LTG depot. In addition to the scientific equipment for GHOST, this turned out to be roughly 95 t (Lehmann sled with living module Cab1; Lehmann sled with seismic equipment and drummed fuel; double polysled: four fuel bladders, two weatherhavens, general cargo; double polysled: Envirovibe, swath antenna, general cargo; single polysled: RAM drill & accessories, two compressors) for three vehicles (2 PB300 Polar, 1 PB100). Six snowmobiles were also placed on the polysleds. For flat hard surfaces, the vehicles were able to tow this load at a speed of 8 km/h. However, in the rolling-hill landscape of Thwaites and the very soft and deep snow conditions the vehicles got stuck with a double load. Therefore, PBs first operated in tandem on steeper slopes, pulling a double load together. Later, when picking up some more cargo left along the way during input, the traverse switched to a relais system over legs 10-20 km long, i.e. each vehicle only towing a single load of 25 t maximum at a speed of 10 km/h and then going back to pick up the remaining load. This gave an effective speed of 3 km/h. Sufficient progress was only possible by driving around the clock with switching shifts of 2–3 people.

During the main GHOST traverse from and to WSD, the EV – already strapped down to its own polysled – was strapped onto the front of the BAS traverse long double polysled (two polysleds pulled side by side), thus bridging the 0.5 m wide gap between the long polysleds. The EV polysled was then strapped to the BAS polysleds. The reason was to allow a reasonably balanced load between the two polysleds making up the double polysled to enable straight towing. This worked very well, but care has to be taken to remove metal parts or cover them with wooden boards on the underside of the EV polysled to avoid scratches on the double polys. Therefore, the wooden blocks were removed and wooden boards were used underneath the metal mounting points underneath the EV polysled, but this turned out to be difficult during travel. The larger wooden boards did not remain in place because of the strong movement over rough surfaces. On the return traverse to WSD the metal mounting points of the EV polyseld were completely removed and the EV strapped to its own polysled using the long slits on its sides.

Tab. 6.2.1: A summary of the timeline of the operations with a focus on the vibroseismic activities and the traverse period from/to WSD.

Dates 2023/24	Location (end of day)	Duration (effective) days	Tasks	Comments
3-8 Dec	WSD	4	EV & streamer mobilization	
14-15 Dec	WSD	1.5	Access to WAIS divide ice-core borehole	
17 Dec	WSD	0.5	Sweeps for VSP	
22 Dec	WSD	3	Start of GHOST traverse WSD-EOL	
26 Dec	LTG	1	Resupply of GHOST traverse	
27 Dec	EOL	2	Unloading GHOST traverse, return to LTG	
29 Dec	LTG	2.5	Bad weather	
31 Dec	SP0020		Reel-out streamer Start vibroseis data acquisition	Daily production 1.5 km, sweep 10–200 Hz, 10 s, 60% peak force. Failure of EV vibration unit
1 Jan	LTG	1	Fault analysis, replacement of main stage of EV servo valve	
2 Jan	SP0220	1	Vibe data acquisition	Production 15.0 km
3 Jan	SP0500	1	Vibe data acquisition	Production 21.0 km
4 Jan	SP0810	1	Vibe data acquisition	Production 23.2 km
5 Jan	SP1103	1	Vibe data acquisition	Production 22.0 km
6 Jan	SP1420	1	Vibe data acquisition	Production 23.8 km
7 Jan	SP1420	1.5	Bad weather	
8 Jan	SP1559	0.5	Vibe data acquisition	Production 10.4 km, partly with 80% peak force Crossing Thwaites' ESM

Dates 2023/24	Location (end of day)	Duration (effective) days	Tasks	Comments
9 Jan	SP1770	1	Vibe data acquisition Reel-in streamer Prepare return traverse to LTG	Production 15.8 km End of profile 20240551 across ESM, total length 132.75 km.
10 Jan	SP1700	1	Bad weather	
11 Jan	LTG	2	Traverse ESM-LTG	Redeployment of two ApRES' & GPS stations
13 Jan	LTG	3	Preparation of traverse to WSD	
16 Jan	WSD	4	Traverse LTG-WSD	Total load weight 95 t, towing vehicles 2 x PB300 Polar, 1 x PB100 Relais system for 150 km because of soft snow and steep slopes
21 Jan	WSD	2	Demobilization	Packing for overland traverse to SB9 in 2024/25 season

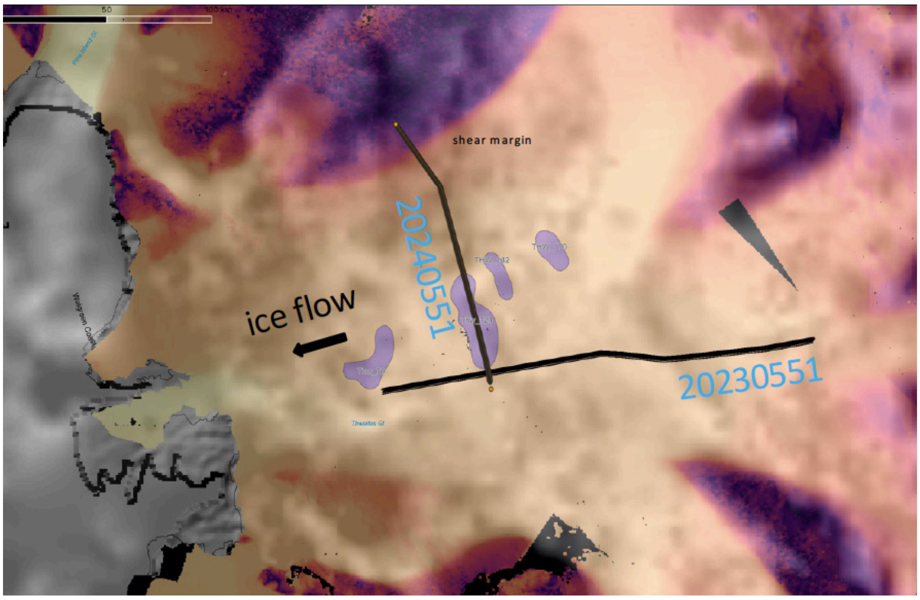

Fig. 6.2.1: The position of the recorded seismic profile (red) on Thwaites Glacier; colour: MEaSUREs ice flow velocity; grey: bedrock topography; light purple: suspected subglacial lakes. Coordinates start at SP0001: 76.44°S 108.03°W, turn: 76.47°S 104.30°W, end at SP1770: 76.35°S 102.99°W.

Preliminary (expected) results

Here we present the pre-processed (bad trace removal, 10–200 Hz Butterworth filter, notch filter 195 Hz to reduce ringing) 133 km stack (Fig. 6.2.2). The profile contains the following main features:

- Englacial reflections, throughout all sections typically 10% of TWT above ice–bedrock interface. They usually form when there is a shift in preferred crystal orientation in the ice which is usually related to a changing stress regime.
- Outside of the ESM (beyond shot 1600), early englacial reflections (already at least at 0.5 s TWT) are visible in the unfiltered data.
- The main distinction of the profile is the western part (lower shot point numbers), where a subglacial lake is suspected and changes in surface elevation have been observed in 2023, and the eastern part with higher ice–bedrock interface with stronger topographic changes of larger wavelengths with cross-cutting troughs. Trough depth ranges between 0.1 and 0.4 s (approximately 200–800 m). However, in the current pre-processing stage, it is not possible to identify changes in the reflection coefficient of the ice–bedrock reflection.
- Numerous tails of reflection hyperbolas are visible, indicating the necessity to perform suitable migration processing.
- Some events appear below the dominating ice–bedrock reflection, but at this stage, it is not clear whether they are off-nadir events or indeed signals originating from within the subglacial strata.
- After migration, a number of reflection hyperbolae collapse and reveal units of high transparency, i.e. little seismic contrast, in particular in the low-lying western third or the profile. These are interpreted as water bodies or soft, water-filled porous sediments.

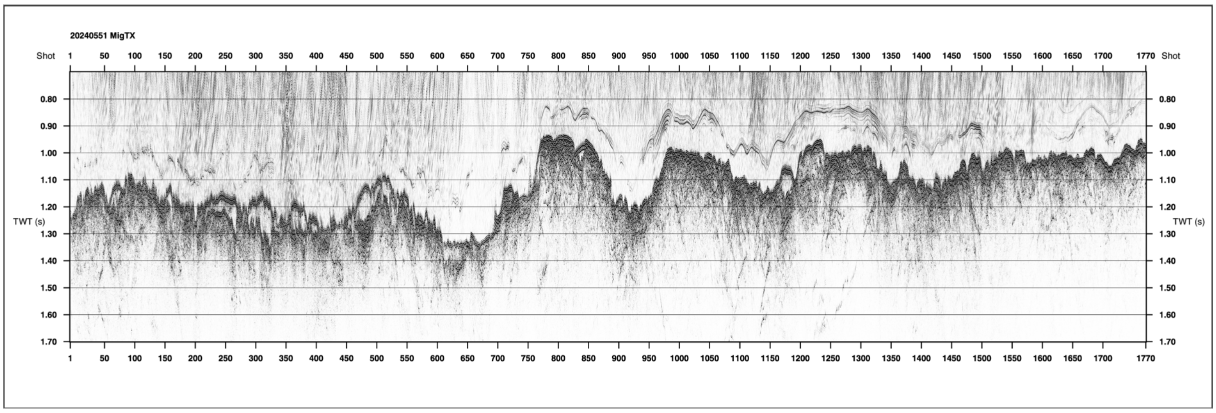

Fig. 6.2.2: Cross-sectional seismogram through Thwaites Glacier (stacked and migrated profile 20240551). Ice flow is into the page. The western part (left) indicates several seismically transparent units underneath the ice base.

Outlook

The data still needs considerable processing, especially before a proper interpretation can be made. We need to complete and finetune the velocity analysis. Velocities (P-wave) of the subglacial material are a first-order identification of those materials. The most important step is time migration and depth conversion. This will clarify the structure of the bed better, allowing an improved interpretation. The last step will be an Amplitude vs. Angle- (AVA) Analysis where the angle (of incidence, θ) dependent reflection coefficient $R(\theta)$ is calculated. At the ice-bed interface $R(\theta)$ depends largely on contrasts in P-wave and S-wave velocities, density ρ and θ

(Aki and Richards, 2002). As the top material of the interface is ice, the P-wave, S-wave velocity and density of the subglacial material can be derived from R(θ).

Together with the vibroseis line acquired in season 2022/23 and other seismic and radar recording the interpretation of the spatial variation basal and englacial properties will eventually allow us to get a comprehensive understanding of the basal properties and their role in ice dynamic flow.

Data management

After final processing and publication, the seismic 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.

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In all publications based on this expedition, the Grant No. **AWI_ANT_31** will be quoted.

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6.3 PolarConnection 2023

Simeon Lisovski[1], Martha Maria Sander[1], Silke Bauer[2] (not in the field), Anne M. Günther[3] (not in the field)

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Grant-No. AWI_ANT_33

Überblick und Expeditionsverlauf

Die Expedition PolarConnection 2023 ist die zweite von mehreren geplanten Expeditionen nach King George Island (Südliche Shetlandinseln, Antarktis), die sich mit der Seevogelgemeinschaft und ihren Bewegungsmustern, sowie der damit verbundenen Diversität von Viren und Schadstoffen beschäftigt. Die Südlichen Shetlandinseln haben eine besonders hohe Diversität von brütenden Seevögeln und durch ihre geographische Lage an der Spitze der Antarktischen Halbinsel kommen diese aus den unterschiedlichsten Regionen der Weltmeere zusammen, um auf den eisfreien Inseln und Halbinseln zu brüten. Unsere Arbeiten konzentrierten sich auf die Fildes Halbinsel und die von dort bei Niedrigwasser zugängliche Insel Ardley. Während der Expedition konnten wir eine für die Artengemeinschaft repräsentative Anzahl von dort brütenden Vogelarten fangen, besendern und beproben (Blut, Abstriche). Erste Ergebnisse zeigen die hohe Variabilität von Nahrungsflügen zwischen den Arten. Zudem geben die gewonnen Proben und deren Analyse auf die derzeit zirkulierende Vogelgrippe (H5N1) keinen Hinweis auf eine Einschleppung des Virus in der frühen Saison.

Das Expeditionsteam, bestehend aus Simeon Lisovski und Martha Maria Sander, ist am 17. November 2023 mit dem chilenischen Schiff *Aquiles AP-41* auf der Fildes Halbinsel angekommen und hat die Halbinsel am 21. Dezember 2023 mit einem uruguayischen Transportflug wieder verlassen. Alle wissenschaftlichen Arbeiten wurden in diesem Zeitraum durchgeführt. Wir wurden für den gesamten Zeitraum in der uruguayischen Station *Base Científica Antártica Artigas* untergebracht und dort verpflegt.

Am Ankunftstag begannen wir mit der Vorbereitung der Technik, insbesondere der neuen GPS tracker, sowie der Entwicklung der Methoden zur Befestigung auf den verschiedenen Vogelarten. Die Insel war noch weitestgehend schneebedeckt und wenige Territorien waren bisher klar besetzt, sodass wir den zweiten Tag zum Erkunden der möglichen Fanggebiete, sowie dem allgemeinen Vorkommen der Vögel nutzten. Hierbei wurde auch besonders auf verdächtiges Verhalten bei allen Tieren geachtet, um die Vogelgrippe-Situation abzuschätzen. Uns sind während des gesamten Zeitraums keine verdächtigen Tiere aufgefallen, sodass wir durchgehend in der Lage waren, nach den vorgeschriebenen Sicherheitsprotokollen im Umgang mit der global anhaltenden Epidemie von Vogelgrippe (H5N1) Tiere zu fangen, zu besendern und zu beproben (Fig. 6.3.1, Tab. 6.3.1).

Fig.6.3.1: Location of King George Island, Shetland Islands, Antarctica. Fieldwork was carried out on Fildes Peninsula and Ardley Island in walking distance from Artigas Base. (Photo: Martha Maria Sander)

Summary and Itinerary

The PolarConnection 2023 expedition is the second of several planned expeditions to King George Island (South Shetland Islands, Antarctica) to study the seabird community and its movement patterns, as well as the associated diversity of viruses and contaminants. The South Shetland Islands have a particularly high diversity of breeding seabirds and due to their geographical location at the tip of the Antarctic Peninsula, they come together from many different regions of the world's oceans to breed on the ice-free islands and peninsulas. Our work focused on the Fildes Peninsula and Ardley Island, which is accessible from there at low tide. During the expedition, we were able to capture, tag and sample (blood, swabs) a representative number of bird species breeding there. Initial results show the high variability of foraging flights between species. In addition, the samples obtained and their analysis for the currently circulating avian influenza (H5N1) give no indication of an introduction of the virus in the early season.

The expedition team consisting of Simeon Lisovski and Martha Maria Sander arrived on the Fildes Peninsula on 17 November 2023, with the Chilean ship *Aquiles AP-41* and left the peninsula again on 21 December 2023, with a Uruguayan transport flight. All scientific work was carried out during this period. We were accommodated and fed at the Uruguayan station *Base Científica Antártica Artigas* for the entire period.

On the day of arrival, we began preparing the technology, especially the new GPS tracker, and developing the methods for attaching it to the various bird species. The island was still largely snow-covered, and few territories were clearly occupied, so we used the second day to explore the possible trapping areas and the general occurrence of the birds. We also paid particular attention to suspicious behaviour in all animals in order to assess the bird flu situation. We did not notice any suspicious animals during the entire period, so we were consistently able to capture, tag and sample animals in accordance with the prescribed safety protocols for dealing with the ongoing global epidemic of avian influenza (H5N1) (Fig. 6.3.1, Tab. 6.3.1).

The Origin and Diversity of Viruses transported To King George Island via Migratory birds

Objectives

Migratory animals connect the world. The vast majority of migratory birds undertake journeys towards higher latitudes to breed in the north and south and take advantage of seasonally higher pulses in food supply, less competition and lower predation pressure (Dingle, 2014). This has led to distinct major flyways connecting regions across similar longitudinal bands. In the polar regions, global flyways overlap. Thus, the Arctic and Antarctic stand out as hubs where migratory birds from all over the world meet during the breeding season. The connecting movements of birds into the polar regions has likely an effect in the spread and the dynamics of viruses, including pathogens; besides the unparalleled links migratory birds establish across the globe, bird migration involves an immense number of individuals from different taxa, which can lead to an increase in contact rates with other hosts (Altizer et al. 2011). In addition, hosts that move between regions are naturally exposed to parasites and pathogens in multiple regions, with the consequence that migratory species experience a higher diversity of pathogen exposure and infection compared to resident species (Koprivnikar & Leung 2015; Hannon et al. 2016). Ultimately, long-distance migration can be demanding and may include strenuous physical exertion interspersed with periods of frantic energy acquisition and recovery (Piersma & van Gils 2011). These intense physiological demands can result in reduced immune responses rendering migrants more susceptible to infection (Buehler et al. 2010). Therefore, bird migration has the potential to generate superspreader hosts and the polar regions may represent so called hotspots of virus transmission. Yet, due to several reasons, the polar regions and notably Antarctica is largely ignored when it comes to virus surveillance and ultimately to an understanding of the role of polar sites in the global dynamics of wildlife diseases.

The major objectives of this project and for the initial fieldwork expedition to King George Island (Fildes Peninsula and Ardley Island) was to sample seabirds during the early arrival season and identify the diversity and origin of transported viruses into the local ecosystem.

Fieldwork

On Fildes Peninsula and Ardley Island, we caught individual birds (see Tab.6.3.1 for information on species and numbers) by hand, a casher, a baited snare or mist nets. Caught birds where banded (except for Penguins), using a metal band with a unique engraved id supplied by the Vogelwarte Hiddensee (Germany). We took morphological measurements, a blood sample from the brachial vain (150 – 300 µl), as well as a pharyngeal and cloacal swab. Blood was collected using a capillary tube with a clotting activator (Sarstedt Microvette ® 300 Serum). Blood was centrifuged after 12 hours for 10 minutes with 13.000 rpm. Serum was separated from the red blood-cells and frozen (approx. -18ºC) until further analyses in the lab (in Germany). Swabs were stored in RNALater and kept cool (approx. 4ºC) until RNA extraction (at Friedrich Löffler Institute, Riems, Germany). Birds were tagged with GPS tags and transmitters (Druid Technology Co., Ltd., data stored on ecotopiago.com) and light-level geolocators (GLS, Migrate Technology Ltd) (Fig. 6.3.2). Attachment methods were adapted from common procedures for similar species. Seventeen GPS tags (Models YAWL C2 S 11.4 g, and NANO 3.6 g) were deployed on five species. Tags were used for multiple individuals to achieve a higher sample size of foraging trips per species (Tab. 6.3.1) and deployed with tape on the back feathers of the bird (Fig. 6.3.2, middle). By this, the device will last about two weeks on the bird until it will be recaptured (own experience). This tag deployment technique has proven useful and safe for all previously captured species and was used on all bird species tracked in this project. GPS transmitters (three individuals) were attached with a harness to be carried throughout the whole year. GLS were attached with two cable ties on the metal ring (Fig. 6.3.2, right). Fieldwork was carried out with the permit to enter the special protected areas of Fildes Peninsula (ASPA No. 125) and Ardley Island (ASPA No. 150), issued by the Umweltbundesamt (II 2.3 – 94 033/240). Catching techniques and sampling of birds were also approved by the Bundesumweltamt (II 2.3 – 94 033/240).

Fig. 6.3.2: Left: Capture method for Skuas. Middle: South Polar Skua with a GPS tag. Right: Brown Skua equipped with an individual colour ring and a light-level geolocator attached to the metal ring. Fildes Peninsula, King George Island, Antarctica (Photos: Martha Maria Sander).

Tab. 6.3.1: Number and species caught during the expedition to collect movement data with GPS tags and transmitters (global positioning system) and light-level geolocators (GLS), as well as blood samples and swabs.

Species / Scientific Name	**Location**	**Ringing**	**GPS transmitter**	**GPS tags**	**GLS**	**Swab**	**Blood**
Brown skua *Catharacta antarctica lonnbergi*	Fildes/Ardley	0	1	10	19	28	28
Sputh polar skua *Catharacta maccormicki*	Fildes/Ardley	2	1	12	29	37	37
Southern giant petrel *Macronectes giganteus*	Fildes (Drake, Point Nebles)	25	0	11	32	33	33
Chinstrap penguin *Pygoscelis antarcticus*	Fildes/Ardley	-	0	0	0	15	15
Gentoo penguin *Pygoscelis papua*	Fildes/Ardley	-	0	0	0	43	43
Adelie penguin *Pygoscelis adeliae*	Fildes/Ardley	-	0	0	0	9	9
Blue-eyed Cormorant *Leucocarbo atriceps*	Ardley	4	0	1	3	4	4
Wilson's Storm Petrel *Oceanites oceanicus*	Fildes (Artigas Station)	8	0	0	7	1	1
Antarctic Tern *Sterna vittata*	Fildes	1	1	(1)	0	2	2
Summe (9 Arten)	Fildes/Ardley	40	3	34	90	172	172

Preliminary results

Due to the current pandemic of Avian Influenza Viruses (H5N1) in wild birds, and the devastating consequences for bird populations in the northern hemisphere, sampling was conducted already during the 2022/23 breeding season, with no positive results in Antarctica. During the breeding season 2023/2024, the first confirmed H5N1 cases were detected on the Falkland (Malvinas) Islands in October, and in November on South Georgia Island in the sub-Antarctic, which lead to increased safety measures undertaken while sampling on King George Island in November and December 2023. Since mid-February, first positive cases were reported from the Antarctic Peninsula. However, so far there is no evidence for large outbreaks in Antarctica and its offshore islands. Despite intensive sampling effort there are no positive test results from King George Island (Lisovski et al. preprint).

Tab. 6.3.2: Avian Influenza Virus infections of individuals and species sampled during the expedition (Matrix protein qPCR test results).

Species	positive	negative
Adelie Penguin	0	9
Gentoo Penguin	0	43
Chinstrap Penguin	0	15
South Polar Skua	0	37
Brown Skua	0	28
Southern Giant Petrel	0	33
Blue-eyed Cormorant	0	4
Antarctic Tern	0	2

Preliminary analyses of the movement data show pronounced differences between species, with South Polar Skuas foraging almost exclusively offshore in the larger area of the breeding site (<50 km). In contrast, individuals from the closely related Brown Skua undertook shorter and more frequent trips scanning the beaches and penguin colonies of King George Island. Southern Giant Petrels performed multi-day foraging trips as far as 1,000 km from the breeding site. Most of these long-distance foraging trips were done towards the south connecting King George Island with marine and potentially terrestrial areas of the Antarctic Peninsula (Fig. 6.3.3).

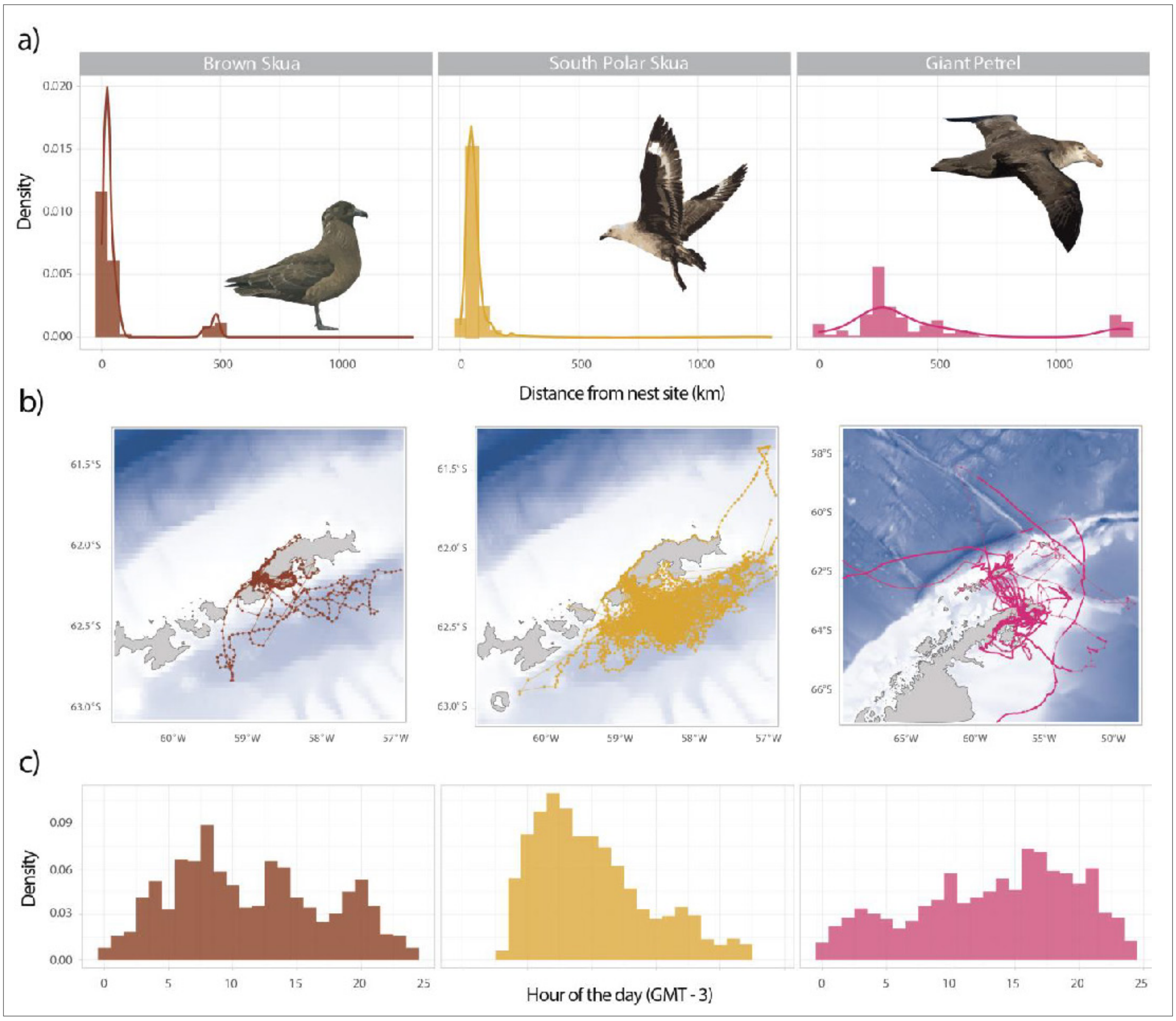

Fig.6.3.3: Local and regional movements of Brown Skuas (n = 11), South Polar Skuas (n = 13) and Southern Giant Petrels (n = 11) tagged and tracked during breeding season (November-December 2023) on King George Island, South Shetland Islands, Antarctica a) Trip distances are calculated as the distance from the territory/nest. b) Maps show the positions of all individuals (dots) and foraging trips drawn for one individual, respectively (lines). Foraging trips were derived from all positions connected chronologically. c) Mean distances from the territory/nest of different species are shown along a 24 hours day across the entire sampling period. Figures made with R (R Core Team 2023) and the Natural Earth Dataset.

Further analysis and research agenda

While parts of the collected swab samples have already been analysed for Avian Influenza (by AG at the Friedrich Loeffler Institute), the plan is to also detect other pathogens in the samples and conduct full virome analyses (Cobbin et al. 2021). This will help to identify the diversity of pathogens, their origin and significance for Antarctic wildlife seabird populations. We further aim to link individual and population level virus occurrence and diversity with the movement ecology of the species, as well as their long-distance migration routes.

Ultimately, and following this approach, we aim to get a better understanding of the role of migratory seabirds and Antarctica in the global dynamic of wildlife disease dynamics.

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).

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 5, Subtopic 3.

In all publications based on this expedition the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (2016a). *Neumayer III* and *Kohnen Station* in Antarctica operated by the Alfred Wegener Institute. Journal of large-scale research facilities, 2, A85. http://dx.doi.org/10.17815/jlsrf-2-152.

In all publications based on this expedition, the **Grant-No. AWI_ANT_33** will be quoted.

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Cobbin JC, Charon J, Harvey E, Holmes EC & Mahar JE (2021) Current challenges to virus discovery by meta-transcriptomics. Curr Opin Virol 51:48–55.

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Hannon ER, Kinsella JM, Calhoun DM, Joseph MB & Johnson PTJ (2016) Endohelminths in Bird Hosts from Northern California and an Analysis of the Role of Life History Traits on Parasite Richness. Journal of Parasitology 102:199–207.

Koprivnikar J & Leung TLF (2015) Flying with diverse passengers: greater richness of parasitic nematodes in migratory birds. Oikos 124:399–405.

Lisovski S et al. (2023) Unexpected delayed incursion of highly pathogenic avian influenza H5N1 (clade 2.3.4.4b) in the Antarctic region. BioRixv. https://doi.org/10.1101/2023.10.24.563692

Piersma T & van Gils JA (2011) The flexible phenotype: a body-centred integration of ecology, physiology, and behaviour Oxford University Press Oxford, UK.

6.4 Discovery Deep Drill

Charlotte Carter[1], Andrew Gorman[2], Elizabeth Keller[3,4], Hamish Bowman[2], Oban Hansen[2], Olaf Eisen[1], Coen Hofstede[1] (not in the field)

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Grant-No. AWI_ANT_42

Objectives

Our primary objective is to image the seafloor geology – using seismic and gravity methods – in the region of Discovery Deep, the deepest part of the Ross Sea underlying the Ross Ice Shelf – about 150 km south of *Scott Base*. This will contribute to further discussions of possible future drilling operations that could penetrate the overlying ice shelf and ocean cavity to recover sediments from the seafloor. These sediments are needed to better understand the history of glacial processes in this part of the Ross Ice Shelf.

Our understanding of seafloor bathymetry in this part of Antarctica will be greatly enhanced by the high-resolution data collected. This will enable improvements to the current models of seafloor bathymetry underlying the Ross Ice Shelf that are based on airborne geophysical surveys constrained by sparse depth sounding control points.

Tab. 6.4.1: Overview of how the event objectives are linked to the overall research objectives.

Event objective	Link to overall research objectives
Explosive-sourced seismic streamer survey along < 80 km of transects linked to the transect collected in 2021/22	This expands on the single high-resolution line collected previously and expands our understanding of the deepest parts of the Discovery Deep basin.
Gravity survey along same transects as seismic data	This enables direct ties between airborne gravity models of bathymetry and actual bathymetry as determined by the seismic data.
Filming of geophysical data acquisition (including drone footage) for outreach activities with NZ high schools.	An outreach opportunity that can help spread the information being collected more widely and encourage future scientists to consider a career in our field.
Local gravity grid survey (not along seismic lines)	Facilitates linkage of our datasets with airborne datasets collected previously.

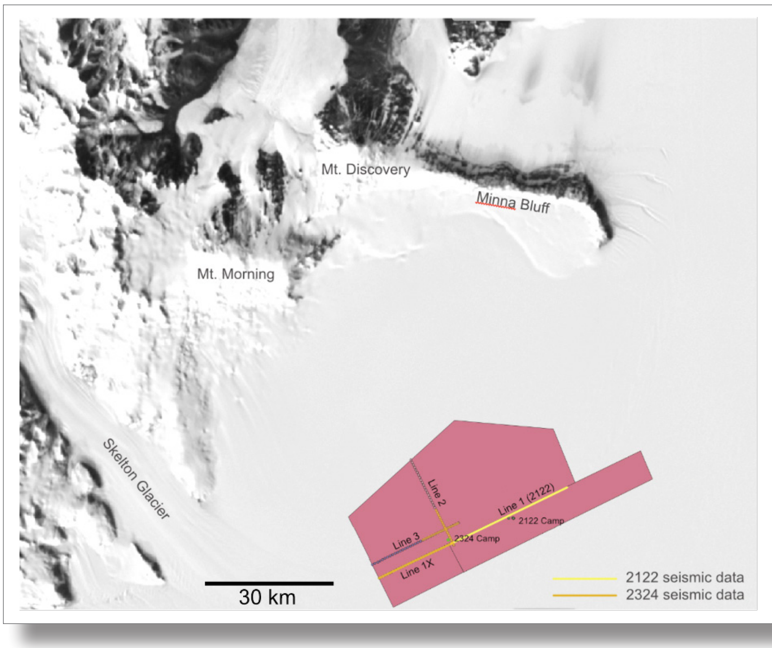

Fig. 6.4.1: Map of the study area lying east of the outflow of the Skelton Galcier and south of Minna Bluff

Fieldwork

The project was hosted by Antarctica New Zealand, and AWI's participation amounted to the lending of a geophone streamer (seismic recording equipment) and the participation of Charlotte Carter in the field season. The US Antarctic Programme from time to time helped with fixed wing logistics to and from the field as well as storage of explosives in their explosives magazine at *McMurdo Station*. The map in Figure 6.4.1 outlines our working area and the data collected in the 2023/24 season.

The field team departed from Christchurch to *Scott Base* on 5 December, where various field training activities and preparation for the field deployment took place over the next 14 days. Deployment to the field was delayed due to a combination of weather and logistical issues as a result of positive covid cases on the base. An initial party was sent out to the field on 19 December to transfer the previously-cached 21/22 camp to our new field site (23/24 Camp – see Fig. 6.4.1). The rest of the team followed over the next few days as well as the science equipment and other cargo.

Seismic data was collected each day whilst in the field (weather permitting). This was carried out either with all five members of the team, or three members whilst the other two collected gravity data at 600 m intervals along each survey line. Three seismic lines (see Fig. 6.4.1 for locations) totalling 34.6 km were collected using surface sources of detonator cord (10 m lengths, 100 g of explosive per shot) recorded into 96 geophones distributed over a spread of 300 m. The geophone streamer from the Alfred Wegener Institute was towed behind a ski-doo and recorded by a four Geode system of seismographs. Shots were separated by 60 m. Up to 70 shots were recorded per day, with the team becoming more efficient as the season progressed. Processing of the seismic data was undertaken at the end of each day to inform plans for the next day. Field deployment lasted for 24 days until 11 January when the field team returned to *Scott Base*. The planned field time was around 40 days, so this meant that the amount of seismic data was less than anticipated, however, the data collected was of high quality. Early return from the field also resulted in camp equipment being cached and left out in the field for use in an upcoming field season or return to *Scott Base* at a later stage.

Preliminary (expected) results

Figures 6.4.2 and 6.4.3 show the details of the seafloor geology imaged by the three seismic lines. Initial results suggest a lack of Quaternary sediment in the region with erosion at the seafloor exposing older sedimentary units that exhibit moderate tectonic deformation. Faulting is possible in some places within the sections. Erosion (possibly by glacial processes during the Quaternary) is clear near the seafloor resulting in substantial bathymetric variability. The greatest depths observed are 1,625 m at the west end of line 3 and the shallowest at about 1,370 m at the north end of line 2. Unfortunately, time constraints in the field did not allow further imaging to the west or north to study the extremes in depth further.

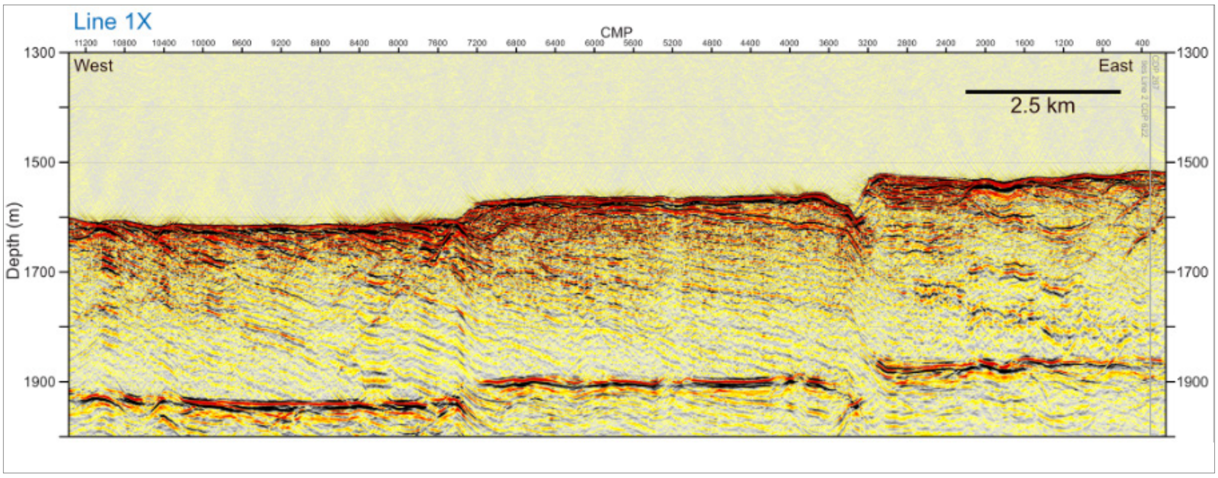

Fig. 6.4.2: Line 1X (western extension of the 2021/22 season line 1). Processing includes velocity analysis (based on ice-water and seafloor interface picking), spherical-divergence gain compensation, post-stack finite-difference migration, and depth conversion. Total length: 17.52 km.

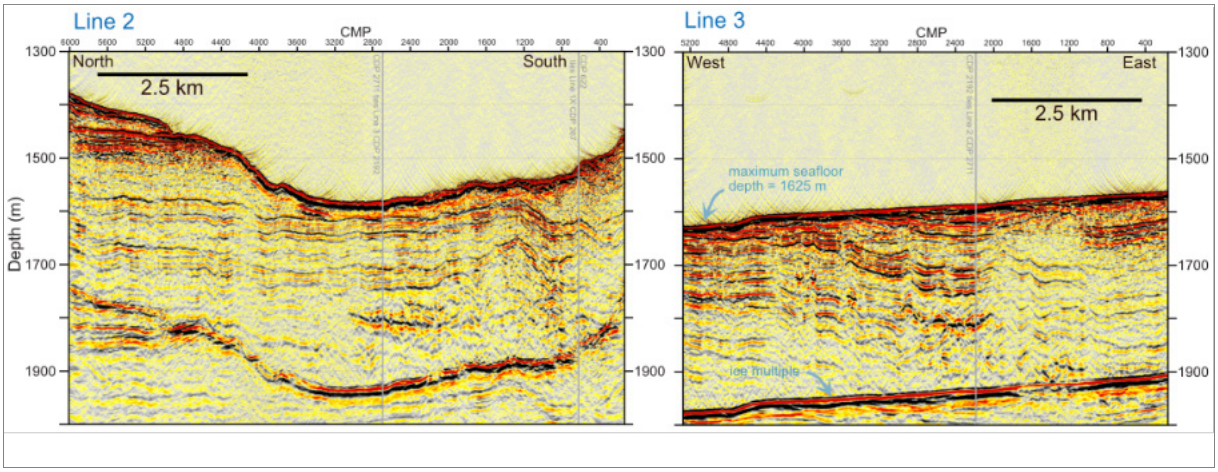

Fig. 6.4.3. Lines 2 (total length: 9.12 km) and 3 (total length: 7.92 km). Processing includes velocity analysis (based on ice-water and seafloor interface picking), spherical-divergence gain compensation, post-stack finite-difference migration, and depth conversion.

Data management

After final processing and publication, the seismic data will be archived, published and disseminated according to international standards. Data management is subject to NZ policies and will be carried out by the main PI (Gorman).

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 2, Subtopics 1 and 3. Charlotte Carter was funded by AWI's INSPIRES III Program 2022-2025.

In all publications based on this expedition, the **Grant-No. AWI_ANT_42** will be quoted.

APPENDIX

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

A.2 EXPEDITIONSTEILNEHMER:INNEN / EXPEDITION PARTICIPANTS

A.3 LOGISTISCHE UNTERSTÜTZUNG, ÜBERWINTERNDE / LOGISTICS SUPPORT, WINTERING TEAM

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EDU.UNH	University of New Hampshire Space Science Center Durham New Hampshire USA

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Pohl	Hannes	DE.DNVGL-HH	Inspector	Logistics
Radenz	Martin	DE.TROPOS	Scientist	ÜWI2023

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Reichwein	Petra	DE.LAEISZ	Housekeeping	Logistics
Riess	Felix	DE.LAEISZ	Inspector	Logistics
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Schötz	Johannes	DE.LAEISZ	Technician	ÜWI2024
Steinhage	Daniel	DE.AWI	Scientist	Logistics
Stranzinger	Viktoria	DE.LAEISZ	Cook	Logistics
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