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Expeditions to Antarctica: ANT-Land 2022/23 NEUMAYER STATION III, Kohnen Station and Field Campaigns

Edited by

Julia Regnery, Thomas Matz, Peter Köhler
and Christine Wesche
with contributions of the participants

HELMHOLTZ

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Cover: Neumayer Station III in the midnight sun. (Peter Köhler, AWI)

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ANT-LAND 2022/23

3 November 2022 – 3 March 2023

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

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Scientific Coordinator
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Logistical Coordinator
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Contents

1. ÜBERBLICK UND EXPEDITIONSVERLAUF

Thomas Matz und Peter Köhler (Logistik) DE.AWI

Auch in dieser Saison beeinflusste die CoV-2 Pandemie die Vorbereitung und Durchführung der ANT-Land 2022/23 Kampagne, allerdings mit deutlich weniger Aufwand, um eine Ausbreitung des Virus auf dem antarktischen Kontinent zu vermeiden. Mit diesen international beschlossenen Maßnahmen im Rahmen des Councils of Managers of National Antarctic Programs (COMNAP) und des Dronning Maud Land Air Network (DROMLAN), konnte an der *Neumayer-Station III* eine Ausbreitung des Virus erneut verhindert werden.

Aus politischen Gründen wurde für diese Sommersaison ein neuer An- und Abreiseweg über den norwegischen Partner Norwegian Polar Institute (NPI) gewählt. Das bedeutete, dass Wissenschaltler:innen und Techniker:innen über das Alfred-Wegener-Institut (AWI) gemeinsam mit den norwegischen Kollegen direkt ab Oslo oder Bremen mit einer Linienmaschine anreisten. Nach einem nächtlichen Zwischenstopp in Kapstadt gingen die Flüge weiter bis zur norwegischen *Troll-Station* in die Antarktis und von dort mit Unterstützung von Basler und Twin Otter Flugzeugen von White Desert und der *Polar 5* weiter zur *Neumayer-Station III* und wieder zurück. Die vom NPI geplanten 6 interkontinentalen Flüge wurden mit Passagiermaschinen durchgeführt. Dabei wurden insgesamt 79 Personen (inkl. des 43. Überwinterungsteams) im Verlauf des Sommers zur *Neumayer-Station III* transportiert.

Die eingeschränkten CoV-2 Maßnahmen sahen vor der Abreise mit den Norwegern eine 5-tägige Selbstisolation zu Hause vor. Bei Hotelaufenthalten wie in Kapstadt durfte das Hotelzimmer nicht verlassen werden, um eine Infektion zu verhindern. Während der gesamten Anreisedauer war das Tragen einer Maske verpflichtend. An der *Neumayer-Station III* angekommen, war auch hier das Tragen einer Maske über eine Zeitdauer von 5 Tagen Pflicht. Wiederkehrende Corona Tests wurden zur Überwachung einer potentiellen Infektion durchgeführt.

Die Sommersaison an der *Neumayer-Station III* begann am 3. November 2022 und endete am 3. März 2023. Insgesamt konnten in dieser Sommersaison viele Aktivitäten, Feldkampagnen und dringend notwendige technische Arbeiten umgesetzt werden. Allerdings war auch deutlich anzumerken, dass von der doch sehr eingeschränkten Saison 2021/22 einige wissenschaftliche, aber auch technische Projekte nun in der Saison 2022/23 zusammen mit den bereits zuvor geplanten Kampagnen stattfanden. Die Infrastruktur der Station war deutlich beansprucht, hiermit verbunden die Bereitstellung von technisch/logistischem Equipment.

Trotz allem konnten viele wissenschaftliche Daten vor Ort gesammelt werden, auch Langzeitmessungen der Observatorien verliefen erfolgreich. Feldkampagnen sowohl auf dem Meereis als auch weit im Hinterland, Einsätze an der Pinguinkolonie und auch eine zweigeteilte umfangreiche Flugkampagne mit der *Polar 5* konnten durchgeführt werden.

Wie auch im letzten Bericht zur Polar- und Meeresforschung wird in den nachfolgenden Kapiteln ein Überblick über das Wettergeschehen über die Sommersaison an der *Neumayer-Station III* gegeben, sowie der Verlauf der technischen Arbeiten und Logistik. Anschließend werden die jährliche Wartung der Observatorien, weitere wissenschaftliche Projekte an der *Neumayer-Station III* und andere Feldkampagnen in der Antarktis unter Beteiligung des AWIs beschrieben.

SUMMARY AND ITINERARY

Also during this season, the CoV-2 pandemic influenced the preparation and implementation of the ANT-Land 2022/23 campaign, but with significantly less effort to prevent the spread of the virus on the Antarctic continent. With the internationally agreed measures within the framework of the Council of Managers of National Antarctic Programs (COMNAP) and the Dronning Maud Land Air Network (DROMLAN), a spread of the virus could once again be prevented at *Neumayer Station III*.

For political reasons, a new arrival and departure route was chosen for this summer season with the collaboration of the Norwegian partner, the Norwegian Polar Institute (NPI). Scientists and technicians travelled directly from Oslo or Bremen on a scheduled flight together with their Norwegian colleagues. After a nightly stopover in Cape Town, the flights continued to the Norwegian *Troll Station* in Antarctica and from there, with the support of Basler and Twin Otter aircraft from White Desert and the *Polar 5*, to *Neumayer Station III* and back again. The 6 intercontinental flights planned by the NPI were carried out with passenger aircraft. A total of 79 people (including the 43rd wintering team) were transported to *Neumayer Station III* over the course of the summer.

The restricted CoV-2 measures included a 5-day self-isolation at home before leaving with the Norwegians. During hotel stays, such as in Cape Town, participants were not allowed to leave the hotel room in order to prevent infection. Wearing a mask was compulsory for the entire duration of the journey. Once at *Neumayer Station III*, wearing the mask was also mandatory for a period of 5 days. Recurrent corona tests were conducted to monitor for potential infection.

The summer season at *Neumayer Station III* started on 3 November 2022 and ended on 3 March 2023.

Overall, many activities, field campaigns and urgently needed technical work could be implemented during this summer season. However, some scientific but also technical projects as well as previously planned campaigns finally took place in the 2022/23 season after the very limited 2021/22 season. The infrastructure of the station and the provision of technical/logistical equipment were clearly strained.

Despite all this, a lot of scientific data could be collected on site, and long-term measurements of the observatories were also successfully continued. Field campaigns both on the sea ice and far inland, missions to the penguin colony and also a two-part extensive flight campaign with the *Polar 5* could be carried out.

As in the last Report on Polar and Marine Research, the following chapters give an overview on the weather in the surrounding of *Neumayer Station III* during the summer season, as well as the course of technical work and logistics. This is followed by a description of the annual maintenance of the observatories, other scientific projects at *Neumayer Station III* and other Antarctic field campaigns involving the AWI.

2. WEATHER CONDITIONS DURING ANT-LAND 2022/23 AT *NEUMAYER STATION III*

Holger Schmithüsen DE.AWI

After a rather windy October 2022 the weather situation at *Neumayer Station III* during ANT-Land 2022/23 (Fig. 2.1) was mostly normal in terms of the basic meteorological parameters listed in Table 2.1. With 8.4 m/s November windspeed was slightly below its long-term average of 9.4 m/s. This resulted in comparably few white-out cases (7 %) for this time of the year (mean is 23 %). Nevertheless, several low-pressure systems caused various instances of peak windspeeds of more than 20 m/s. Typical for this month also was the well pronounced daily cycle in temperature, with night-time temperatures below -25°C. There was one short event of snowfall at the beginning of November, follow by several weeks without precipitation until 24 November 2022. December 2022 was right at its long-term average temperature of -4.8°C. Due to various precipitation events in this month snow drift was reported in 47 % of the synoptic records, which is significantly more frequent than on average (29 %). The first half of January 2023 was rather calm, followed by some intense low-pressure systems passing by in the second half of January. The storm event around 20 January caused the first substantial snow accumulation of the season of around 10 cm. February was also rather calm with a mean windspeed of 5.8 m/s and relatively few storm events for this time of the year. Also, precipitation was scarce during that final month of ANT-Land 2022/23.

Statistically, the parameters shown in Table 2.1 during ANT-Land 2022/23 are mostly within one standard deviation of their long-term mean values. Exception is the rather low average air pressure from November till January, and the compatibly windy January followed by a rather calm February in terms of wind speed.

Concerning snow accumulation (Fig. 2.1) there were two substantial and persistent events of accumulation during ANT-Land 2022/23. Even though there was a major technical issue with the snow height sensor (which was resolved in the second half of December), based on co-located GNSS-based accumulation estimates it is assumed that no major accumulation event was missed. Before the outage, the last valid measurement was taken on 11 October reading 9.03 m. Assuming typical compaction and sublimation, this compares well with the first reading after reactivation on 19 December of 8.95 m. Overall snow accumulation in 2022 was very low (0.6 m) compared to earlier years (Fig. 2.2). After this low accumulation year, 2023 stared off with a fairly average accumulation record.

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

	Temperature	Pressure	Wind speed	White-out
November 2022	**-10.8°C** (-9.8 ± 1.4)°C	**975.8 hPa** (984.3 ± 4.6) hPa	**8.1 m/s** (9.4 ± 1.6) m/s	**7%** (23 ± 12)%
December 2022	**-4.8°C** (-4.8 ± 0.8)°C	**978.4 hPa** (987.1 ± 5.7) hPa	**8.4 m/s** (7.3 ± 1.4) m/s	**9%** (17 ± 10)%
January 2023	**-4.0°C** (-4.1 ± 1.0)°C	**979.9 hPa** (989.0 ± 4.2) hPa	**7.8 m/s** (6.6 ± 1.2) m/s	**10%** (12 ± 8)%
February 2023	-9.3°C (-8.1 ± 1.5)°C	986.7 hPa (987.0 ± 3.6) hPa	5.8 m/s (7.6 ± 1.5) m/s	3% (14 ± 9)%

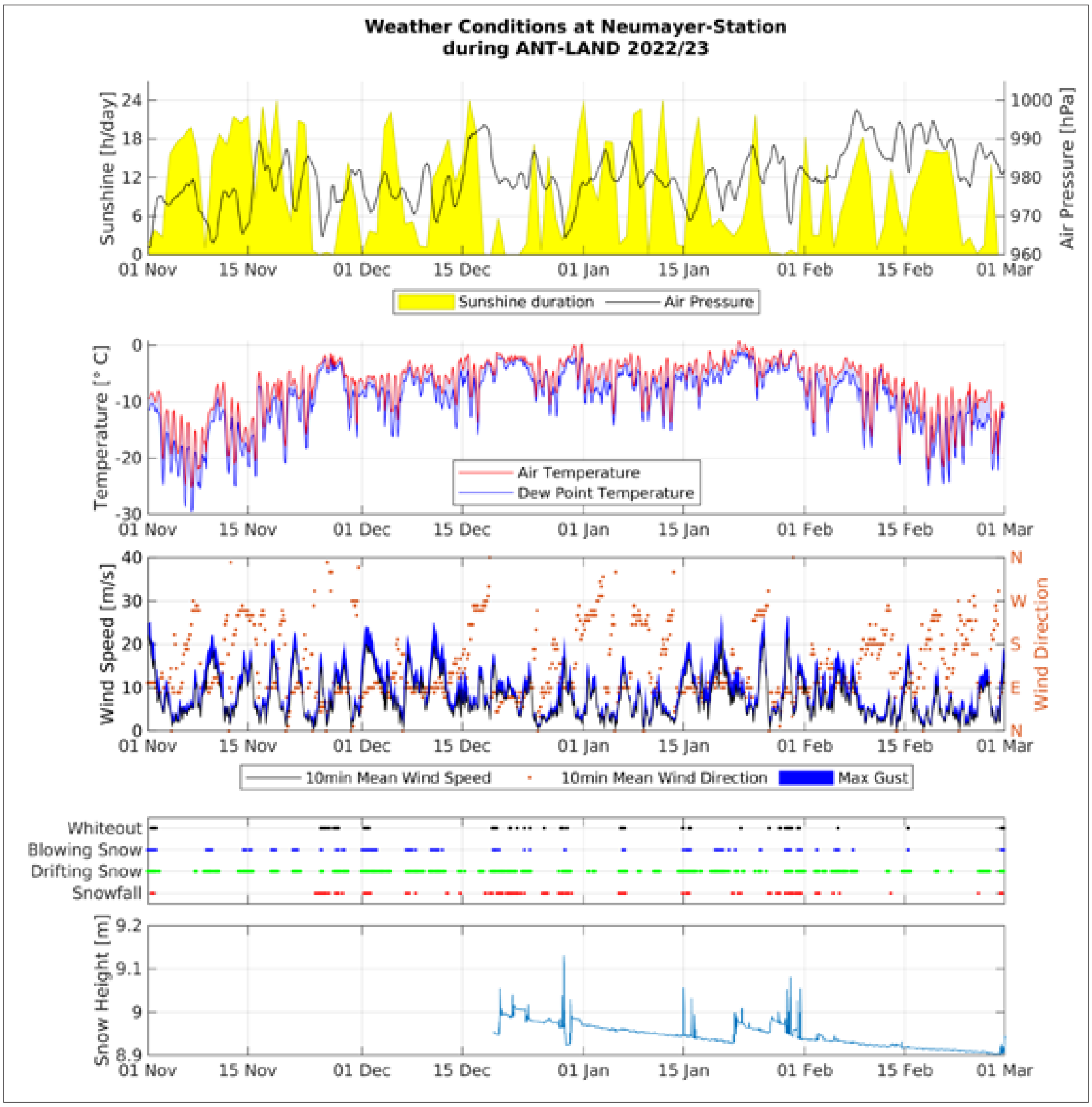

Fig. 2.1: Weather conditions at Neumayer Station III during ANT-Land 2022/23

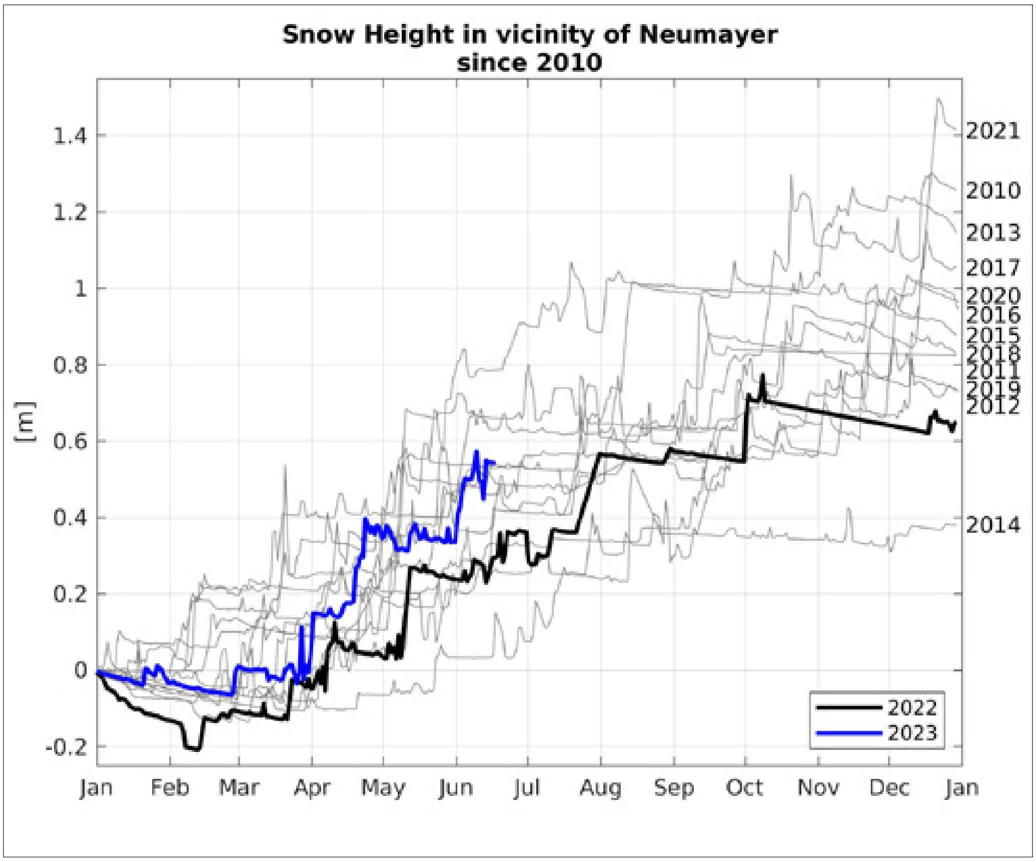

Fig. 2.2: Snow height measured in the vicinity of Neumayer Station III with sensor Jenoptik SHM30 from 2010 until December 2022, and with its successor Lufft SHM31 from December 2022 until June 2023. Most recent data is shown in blue, accumulation of 2022 in black, earlier years in grey. All data shown here is relative to the snow height at the beginning of the respective year. Since October 2011 the measurements are conducted near the Air Chemistry Observatory "SPUSO" (1,500 m south of Neumayer Station III). Before the instrument was mounted at the meteorological mast approximately 300 m south-east of the main station building.

3. STATION OPERATIONS

Thomas Matz and Peter Köhler (Logistics) DE.AWI

The first flight NPI-F1 together with the Norwegian colleagues took off on 28 October 2022 from Oslo, Norway. With a stopover for refueling, a hotel night in Cape Town, the first group with 23 scientists, technicians and the field operation manager reached *Troll Station* in Antarctica on 30 October 2022. As bad weather was always to be expected at the beginning of the season, it also caught us, so we were given accommodation for three days at the Norwegian station under Cov-2 conditions. After the weather cleared up, we flew to *Neumayer Station III* on 3 November 2022 and were warmly welcomed by the wintering team for the start of the season.

The scientific campaigns and technical work, such as the two station elevation processes, began. In the course of this, further maintenance and repair work by the technical team took place. Technicians from external companies also started their modification and extension works, as well as maintenance works on the elevator, the Arctic Truck vehicles and the snow groomers.

Already on 11 November 2022 the second group with 18 persons reached *Neumayer Station III* with the NPI-F2 flight, including two TV teams consisting of three persons each.

The station was occupied by 50 people together with the overwintering team. Skidoos and sleds were now in full use for trips over the sea ice and to the penguin colony.

Also on the NPI-F2 flight was a Finnish group of 10, *en route* to their summer station, *Aboa*, on a Twin Otter from White Desert with a stopover at *Neumayer Station III*.

On 16 November 2022, coming from *Rothera Station*, *Polar 5* arrived at *Neumayer Station III*. The next day, the aircraft transferred to *Troll Station* for scientific scaffolding. *Polar 5* was stationed there for the first part of the scientific campaign and flew from there to the most diverse measurement areas.

A logistics flight on 29 November 2022 allowed gasoline, stored at *Neumayer Station III,* to be flown by the Twin Otter from White Desert to the Finnish station *Aboa*.

When the aircraft returned, it transported two colleagues from the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) to the South Africans' *Sanae Station* for Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) seismometer maintenance. The two returned to *Neumayer Station III* as planned on 3 December 2022 after successful work.

After the flight had to be postponed due to bad weather, three geophysics scientists with extensive equipment flew with the Twin Otter from *Neumayer Station III* to Utpostane for seismometer maintenance on 3 December 2022. A field camp was established for 3 days. A mechanic from Arctic Truck, who in cooperation with the Finns maintained and repaired the vehicles at *Neumayer Station III* and *Aboa Station*, flew with the group and on to *Aboa Station*. Due to upcoming bad weather the field campaign had to be aborted on 6 December 2022.

Nevertheless, work on the seismometer at Utpostane and on the vehicles at *Aboa Station* could be completed.

On 12 December 2022 the first half of the *Polar 5* flight campaign ended with the transport of scientific equipment from *Troll Staion* to Wolf's Fang airfield of White Desert, for a return transport of the material to Germany. In mid-December, the aircraft shifted to *Neumayer Station III* to transport a group of 25 to *Troll Station*, along with another Basler from White Desert.

This group departed Antarctica on the Norwegian's NPI F3 flight. 26 scientists and technicians arrived at *Troll Station* on the intercontinental NPI-F3 flight and were taken to *Neumayer Station III* on both Basler aircraft. With them was the new wintering team consisting of 10 people. A change of field operation manager also took place with this flight. A colleague of the German Weather Service (DWD) from Hamburg also arrived with the NPI-F3 flight at *Troll Station* and started from there with the work on the DROMLAN flight weather consulting.

3.1 Technical Operations

Thomas Matz and Peter Köhler (Logistics) DE.AWI

This season, despite the CoV-2 measures taken on the arrival, the staff was able to reach *Neumayer Station III* almost without restrictions in order to carry out the maintenance, repair and conversion work according to plan.

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 were transported from the winter storage to the station for the summer operation.

After the three-day stay at *Troll Station* due to bad weather, the technical team also arrived at *Neumayer Station III* and work started immediately.

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.

Also, this season, various works for scientific programs were done by the technical team.

Recurring storms and bad weather days hampered the work throughout the season.

In connection with the future refurbishment of the energy supply of the station by using renewable wind and solar energy, the mounting and implementing of a photovoltaics test device with a special data entry function was planned at the frontage of the building years before. The installation of the electrical wiring up to the planned assembly locations of the modules could be completed. 2/3 of the planned modules are still in the assembly phase.

In the outdoor area, the wooden top layer at deck 0 should be partly renewed. Both projects could not be performed due to unfavourable weather conditions and an extensive amount of work. Once again, this work will have to be pushed into the next summer season.

A large part of the work for the technical team was the installation of a new wind turbine with the installation of the electrical switchgear as the sensitive link into the station grid. as well as the installation of a new filtrate pipe to drain off excess water from the operation of the station.

Station maintenance work and repairs

In the months of November and December two station elevations could be carried out as planned. The 28th station elevation started on 4 November 2022 and was finished after eleven days. As the station was lifted twice within a summer season, the 29th station elevation started on 29 November 2022 and was completed on 13 December 2022. In total, the *Neumayer Station III* was lifted nearly 2.4 m (without settling in the snow).

Accompanying the station elevations, the control computer was replaced with a new one after 13 years of operation. A software of the user interface for driving and monitoring the station, previously revised and tested in Germany, was successfully i mplemented. In the vehicle hall, additional sensors were mounted on the 16 bipods (legs) and foundation plates of the station in order to permanently detect misalignments and tilts in the future. An engineer from the hydraulic company that developed this system implemented the project at the station.

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

An external company consisting of two technicians carried out reconstruction work in the station. In the area of the energy center, a small staircase was installed down into the tween deck. This allows the wintering personnel easier access to the station's technical equipment installed there. In the future, this area will also be further expanded as part of the station's energy renovation.

In the +5 °C provision room, the floor was equipped with more effective thermal insulation.

In the vehicle hall, a tent curtain was created that can be pulled around a Pistenbully for heating with warm air via a blower. Due to the higher air temperature in the tent, this ensures better work on the Pistenbully vehicle. In the vehicle hall, temperatures of -25 °C and even lower prevail in winter, which makes work on the vehicle technology more difficult.

For the installation and commissioning of the new Vertical Axis Windturbine (VAWT), three specialists from the respective manufacturers were present at the station. The steel components of the wind turbine mast and the turbine were delivered to the station when *Polarstern* arrived at the beginning of January 2023. Frequently interrupted by bad weather, the VAWT was built north-east of the station and connected to the station building via a cable system. Allowing for the respective elevations of the station building and the VAWT, the power and control cables were routed through the building to the WKA room and connected to the new electrical switchgear. This electrical switchgear could be set up regardless of the weather. They are designed to feed the electrical energy from the current 2 turbines and in the future from another 4 VAWT and a battery storage system into the station network. Extensive tests, which included the planned security functions in the grid to ensure the energy supply, were successfully completed.

The test PV system was fully connected to the grid with the extent of the PV modules now installed on the east side. The sensors for evaluating the mechanical loads on the PV modules and the energetic yield have been fully installed. Remote evaluation in Germany is made **possible.**

Since the heated water line for discharging treated wastewater from station operations – the filtrate – failed last winter, it had to be replaced with high priority. This large component was delivered with the arrival of *Polarstern*. The filtrate line was installed in a sloped snow ditch and connected both electrically and hydraulically. Operation is now guaranteed without restrictions.

Actions in the terrain, airfield and routes

Around the station, significantly more terrain maintenance was necessary than usual, due to an increased snow accumulation. 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 the route to the winter storage facility were prepared.

Scientific/technical outdoor facilities

The Air Chemistry Observatory, the EDEN-ISS greenhouse and the Radom (satellite link) had to be elevated.

The EDEN project with the two greenhouse containers on the platform was completed. The containers were 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 BGR.

The exit shafts at the magnetic observatory and at the balloon trench were elevated. Moreover, at the magnetic observatory the wooden ceiling and the ice walls were treated.

As part of the “Triple Ice Craft” project, test drilling was carried out first in the vicinity of the station building and later at the new location of the PALAOA Observatory on the “Northern Pier”.

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 Pistenbullys.

IT and communication

A new cable was installed from the station to the shortwave antenna in the near area of the station.

The VHF omnidirectional antenna on the roof of the station’s balloon filling hall was renewed by using the crawler telescopic crane.

Routine work was performed in the IT area of the station.

Vehicle engineering

For the Pistenbully vehicles, 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. Towards the end of the season PB25 had a major brake down. Serious damage to the drive was found on the PB25. It was decided to transport the vehicle to the manufacturer Kässborer for repairs. The vehicle was prepared for transport by ship for December 2023 on a heavy-duty sled without chains and snow blade.

Repair and maintenance work was carried out on the defective Arctic Truck vehicles by a mechanic from the company at the beginning of the season, so that both vehicles were ready for use again for upcoming scientific campaigns in the Kottas Mountains, among other places.

The inventory of heavy-duty sleds for transporting 20 ft containers was increased again by 3 units. Among other things, they replace 3 old sleds that date back to the *Georg von Neumayer Station III*. Maintenance and repairs were carried out on the heavy-duty sleds, e.g. drawbars were replaced.

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.

6 new metal sleds from a Swedish manufacturer were used for trips on the sea ice.

Kohnen Station

Kohnen Station was not opened in summer season 2022/23.

3.2 Ship Operations

Peter Köhler (Logistics) DE.AWI

For the supply and disposal of *Neumayer Station III*, 3 ship calls took place during the summer season.

On 4 January 2023, *SA AGULHAS II* was the first ship this season to arrive at the North Pier. We have successfully taken over 155,000 liters of polar diesel. A container with skidoos from the Swedish and South African NAP was handed over to the ship.

On 8 January 2023, *Neumayer Station III* was supplied with food, supplies, scientific equipment and fuel by *Polarstern*. 26 containers, 6 new sleds and various large general cargo were taken ashore and 5 containers were handed over to the ship. With 70,700 liters of Jet A1, the tank capacity is fully filled with aviation fuel.

On 2 February 2023, the ship's call of the *Silver Arctic* was processed in partly heavy weather. 21 containers and various general cargo were handed over to the ship.

3.3 General Flight Operations

Thomas Matz and Peter Köhler (Logistics) DE.AWI

As mentioned in the expedition progress overview, the itinerary chosen for the 2022/23 summer season was the intercontinental flights to *Neumayer Station III* from the partner Norwegian Polar Institute (NPI) to *Troll Station*. The flights were operated by passenger aircrafts and departed from Europe, Bremen and Oslo via Cape Town to Antarctica. This route was also chosen for the return transport. A few flights ended in Cape Town. The rest of the journey was then via the normal scheduled service to Europe.

Feeder flights from *Troll* Airfield to *Neumayer Station III*, but also for logistical scientific flights were performed with Basler and Twin Otter aircraft from White Desert. Especially in the second half of the season and exclusively towards the end of the season, the *Polar 5* was used for AWI flights.

During the season, a total of 6 intercontinental flights were offered and used by the NPI to transport personnel and cargo. The Wolf's Fang Runway from White Desert was also used on a few flights to transport some persons and cargo to and from the *Neumayer Station III*.

Once again, rules previously established via COMNAP and DROMLAN were implemented to prevent the spread of CoV-2. A spread to *Troll Station* and *Neumayer Station III* was successfully prevented.

During the first half of the summer season, the *Polar 5* aircraft was stationed at *Troll Station* Airfield. From there, different scientific measurement flights were performed. Coordination took place proportionally from *Neumayer Station III*.

In the second half of the season, the aircraft was stationed directly at *Neumayer Station III*.

Scientific equipment for *Polar 5* was transported from Cape Town via Wolf's Fang to *Troll* Airfield and back. Due to the size of boxes for antennas, for example, this route had to be chosen because the NPI wasn't able to handle them safely.

Besides the transportation of personnel, a few cargo flights for the Finnish Antarctic Program were supported at *Neumayer Station III*. Beside this *Neumayer Station III* also provided Finnish cargo and fuel, which was stored in containers at the station.

About 5 km north of *Neumayer Station III*, a skiway was established by White Desert and used for the majority of the season. This runway was used to allow tourists to visit the Emperor penguin colony at Atka Bay. A large proportion of aircraft movements in the Atka Bay region happens due to increased tourist traffic.

At the beginning and end of the summer season, all feeder planes operating in Dronning Maud Land stayed briefly at *Neumayer Station III* to bunker fuel and wait for a favourable weather window to cross the Weddell Sea.

4. *NEUMAYER STATION III*

4.1 Yearly Maintenance of the Meteorological Observatory *Neumayer*

Loretta Preis, Holger Schmithüsen (not in the field) 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 2022/23 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
- satellite picture reception (HRPT)
- single column precipitation radar

During the previous season (ANT-Land 2021/22) various maintenance tasks could not be carried out due to pandemic related transport issues (no permanent staff on site). Hence, several tasks were postponed to ANT-Land 2022/23. During this season all planned maintenance tasks were carried out.

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

- AWS Søråsen: serviced as planned
- AWS Halfvarryggen: serviced as planned
- AWS Kohnen: not serviced, no activities at *Kohnen Station* in season 2022/23. Service in season 2023/24 necessary
- AWS Filchner: station was visited, no major work performed, station was left in the field

Within DROMLAN, the meteorological observatory of the *Neumayer Station III* continued to support the weather forecasting services offered by the German Weather Service (DWD). This holds for all activities in Dronning Maud Land, especially all aircraft operations. This service is delivered in close cooperation between the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) and the DWD. This season the service was intermittently provided by DWD from *Troll Station*. During the remaining time the service was provided from Hamburg, Germany. General weather observations and if needed landing weather observations at *Neumayer Station III* for the DROMLAN community were provided as usual.

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[1] (not in the field), Olaf Eisen[1,2] (not in the field), Nellie Wullenweber[1], Hannes Keck[1]

[1]DE.AWI
[2]DE.UNI-Bremen

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 overwinterer, usually an airchemist 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 repaired a broken Electrostatic Classifier (part of the Scanning Mobilitiy Particle Sizer to measure aerosol size distribution between 10 nm and 224 nm particle diameter), and an uninterruptible power supply. In addition, we replaced the TROPOS CCN counter by a recently calibrated identical device. In December, the Air Chemistry Observatory was jacked up. This procedure entailed an interruption of all measurements for several hours. Finally, the operation of the observatory was taken over by the new air chemistry overwinterer Nellie Wullenweber, arriving at *Neumayer Station III* on 16 December 2022. Nellie took on the responsibility for the Air Chemistry Observatory thanks to the competent and dedicated instruction by Hannes Keck.

The new project **REBCASA** (title: *Investigating the Radiative Effect due to Black Carbon by combining Atmospheric and Snow measurements in Antarctica*, PI: Andreas Herber, AWI) is successfully operative since January 2022. The objective of REBCASA is to assess the impact of black carbon (BC) aerosol regarding radiative forcing and a comparison with the situation in the Arctic. REBCASA also serves as a pilot study for a planned combined aerosol experiment with AWI aircraft and ground investigations in Antarctica. Comparable campaigns studying horizontal and vertical aerosol and BC distribution and their seasonal variability have never been carried out so far in Dronning Maud Land. Within the scope of REBCASA, dedicated BC measurements in snow and firn samples were conducted in this summer campaign (see separate contribution by Andreas Herber and Anna-Marie Jörss, Chapter 4.19).

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 overwintering 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 (see Chapter 4.18). VACCINE strongly supports the TROPOS **COALA** project (*Continuous Observations of Aerosol-cLoud interaction in Antarctica*, PI: Ronny Engelmann, project overwinterer: Martin Radenz). The scientific focus of COALA is on profiling observations of water vapor, aerosol, clouds, and precipitation (see separate contribution by Ronny Engelmann, Chapter 4.20).

Preliminary (expected) results

Meanwhile, we completed an in-depth evaluation and validation of the established long-term observations (LTO). Because of laboratory and logistic issues, the chemical analyses of the aerosol filter samples is scheduled not till May. 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 Figures 4.2.1–4.2.5 show exemplarily the obtained validated time series of these parameters for the year 2022. Further information on metadata can be found in data sets archived in PANGAEA (e.g.: https://doi.pangaea.de/10.1594/PANGAEA.945533)

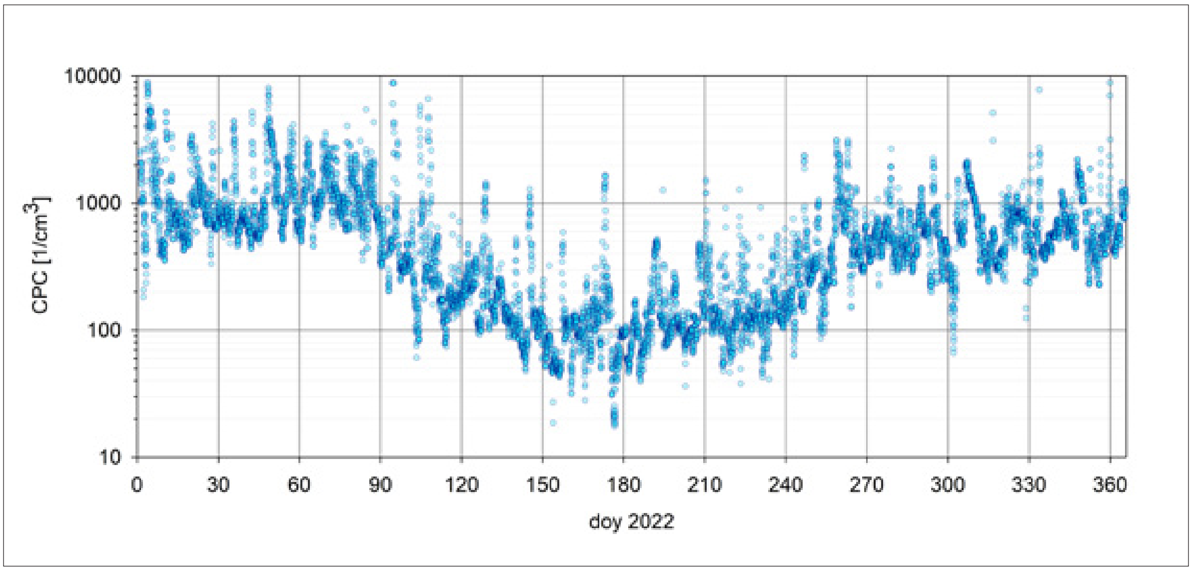

Fig. 4.2.1: Time series of the CP concentrations for the year 2022 measured with a TSI type CPC 3775 condensation particle counter. This instrument detects all particles above the lower 50 % cut-off diameter of 4 nm (doy 2022 = day of the year 2022).

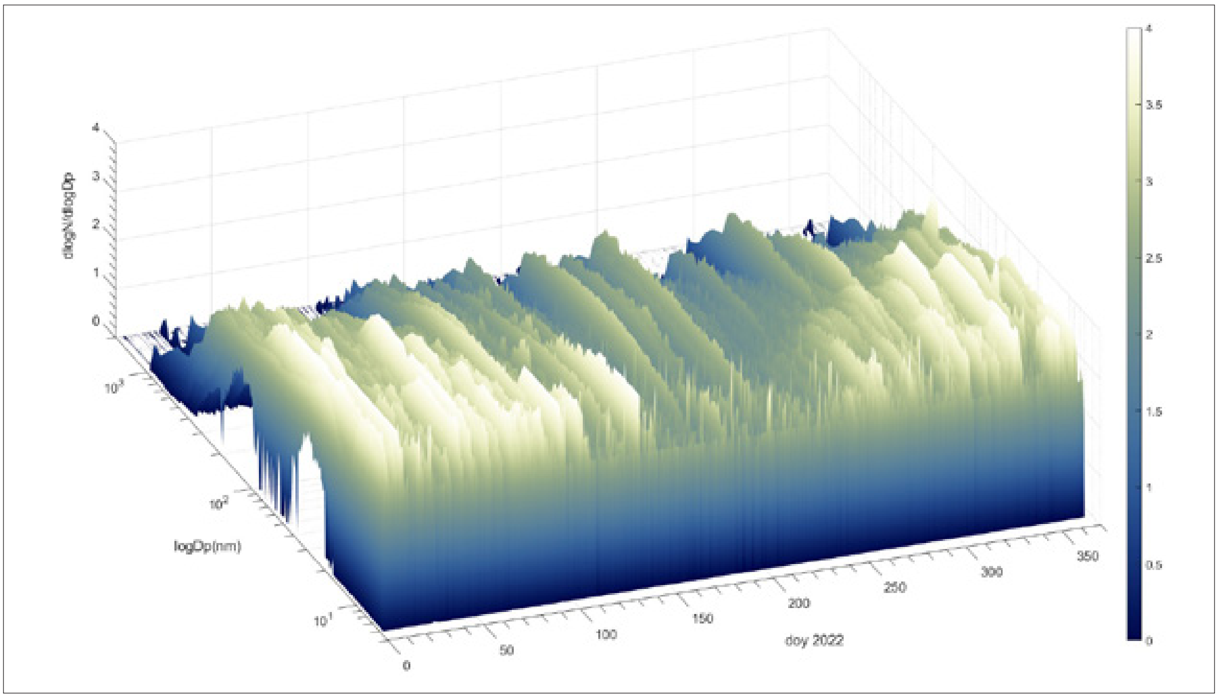

Fig. 4.2.2: 3D contour plot of the particle size distribution dN/dlogD$_p$ (cm^{-3}) with a dlogN/dlogDp (cm^{-3}) scale as z-axis (logarithmic colour scale to the right; D$_p$ = particle diameter). The plot shows the merged size distribution between 10 nm and 220 nm measured by a Scanning Mobility Particle Sizer (SMPS Model 3936, TSI) and between 90 nm and 5,000 nm by a laser aerosol spectrometer (LAS 3340, TSI). Presented data are one-hour averages based on the originally size distribution spectra taken in 10-minute intervals.

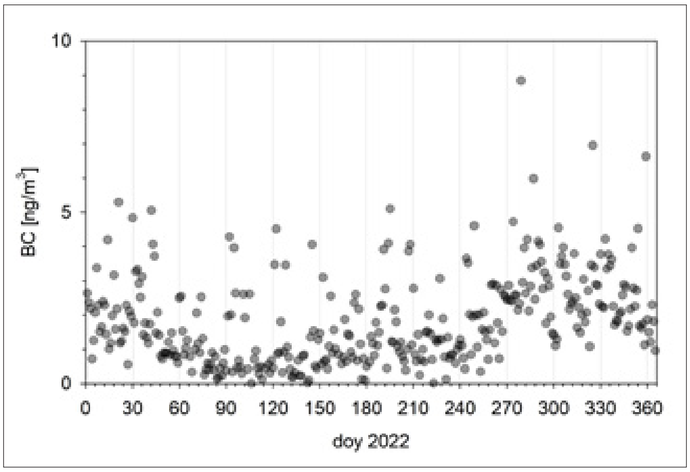

Fig. 4.2.3: Time series of BC concentrations measured at Neumayer Station III with a so-called Multi Angle Absorption Photometer (MAAP, Thermo). Note that the BC data shown were rigorously cleaned from local contamination, which is feasible considering wind direction and particle concentrations. Here, the presented data are daily medians based on the originally data taken in 1-minute intervals (see: https://doi.pangaea.de/10.1594/PANGAEA.956056).

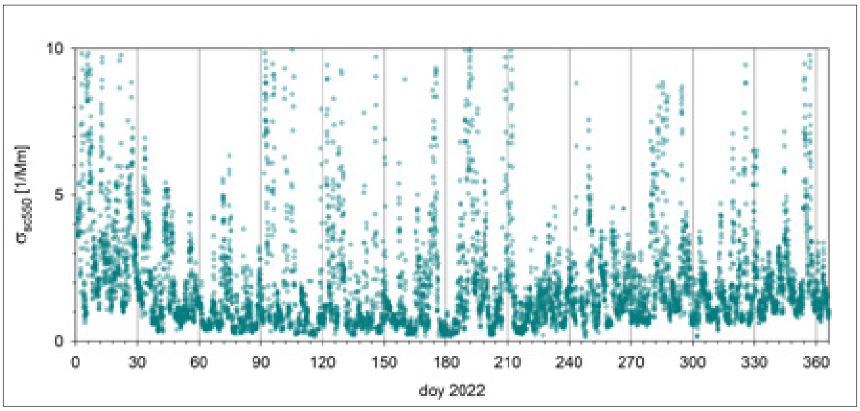

Fig. 4.2.4: Time series of aerosol scattering coefficient at 550 nm, s_{sp}(550), measured with an integrating nephelometer (TSI Model 3563). Presented data are one-hour averages based on originally one-minute data.

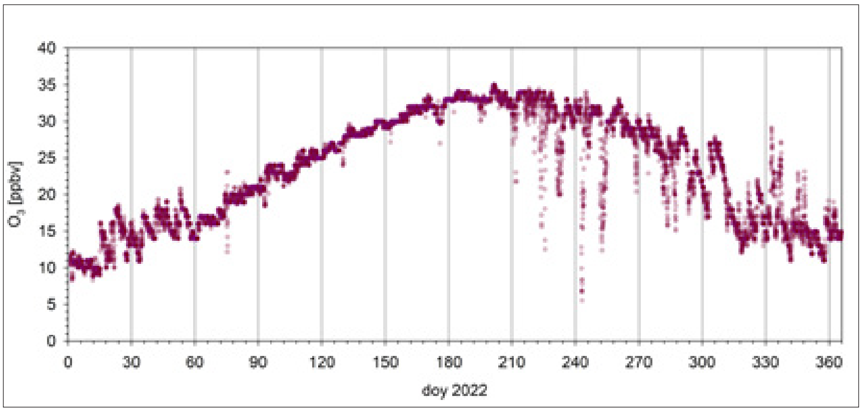

Fig. 4.2.5: Measured surface ozone time series (ppbv: parts per billion by volume) at Neumayer Station III for the year 2022 (measured with an UV photometer O3 41M, Environnement). Presented data are one-hour averages based on originally one-minute data.

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 Spuso III.

Preliminary (expected) results

With the completion of the year 2022 the snow surface accumulation measurements at the Pegelfeld Süd completed 31 years of measurement. In contrast to the previous two years, 2020 and 2021, with considerably higher than normal snow accumulation at the surface, 2022 turned out to be a year of average accumulation of roughly 1 m/a.

Data management

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

- PANGAEA: we will submit the complete data set after chemical analysis of the aerosol filter samples.
- PANGAEA: The density measurements are currently in the queue for publication (PDI-31615)
- 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 in the final testing stage before publication on github.
- GAW: http://ebas.nilu.no/default.aspx

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], Benita Wagner[1], Alicia Rohnacher[1], Nora Schoeder[1], Felix Strobel[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 edge 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 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 Halvfar Ryggen 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 record data at logistically feasible locations (see Fig. 4.3.1).

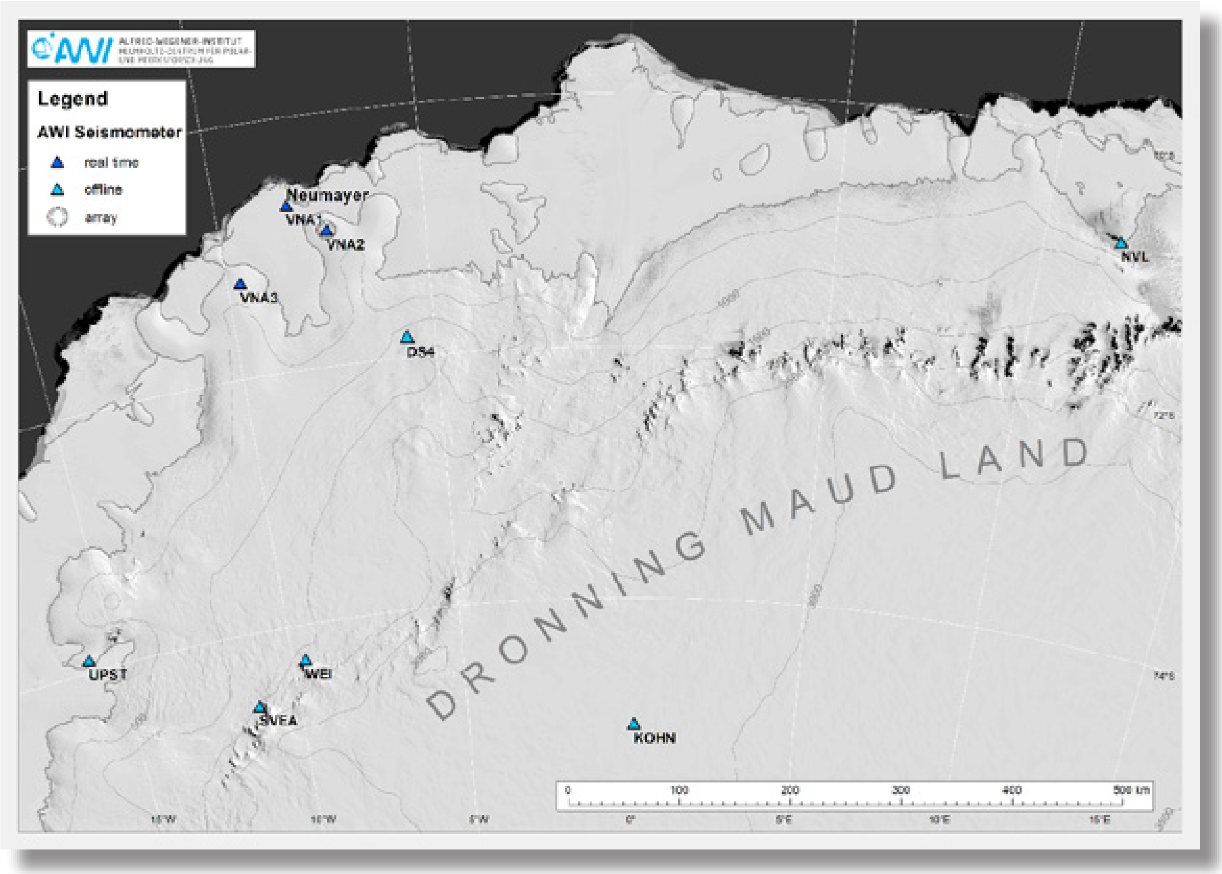

Fig. 4.3.1: Map showing the active seismometer stations in Dronning Maud Land of the AWI network during 2022

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 sensors recording directional changes (FGE) and high frequency induction coils for ionosphere research (MICA-S, see Chapter 4.16). Every 3 – 4 days declination and inclination of the geomagnetic field are measured manually using a non-magnetic theodolite with a single-axis fluxgate sensor mounted on the telescope. For declination measurements the knowledge of Geographic North direction is necessary. Since there is no stable reference for Geographic North it has to be determed 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 eight INTERMAGNET observatories in Antarctica.

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 Ekstroem Ice Shelf dynamics. During the winter of 2021 we increased the sample rate of the receiver to 50 Hz and added support for GLONASS and Galileo.

Fieldwork

In summer season 2022/23 all AWI seismometer stations except KOHN and NVL have been visited for maintenance and data transfer. At VNA2 and VNA3 new radio transceivers have been installed for more stable data transmission with lower energy consumption.

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

Preliminary results

1. On 22 September 2022 a magnitude 6.5 earthquake close to the South Sandwich Islands was recorded. This major event led to a series of aftershocks and increased seismic activity in the general area. Due to the favourable location of VNA1-3 for earthquake detection from that area, a lot of earthquakes could be picked and localized by station personnel in the following weeks. A total of 29.545 phase arrivals were picked during the year 2022. Phase picks of 2,258 earthquakes were associated with earthquakes listed in international catalogues. In addition, 7,624 regional/local seismic events were located (Fig. 4.3.2).
2. The total magnetic field intensity decreased by 22 nT from a mean of 38,025 nT at 1 January 2022 to a mean of 38,003 nT at 31 December 2022. 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. 4.3.3).
3. During 2022, *Neumayer Station III* moved 154.5 metres from 70°39’46.61”S, 8°16’57.56”W to 70°39’41.72”S, 8°17’0.49”W.

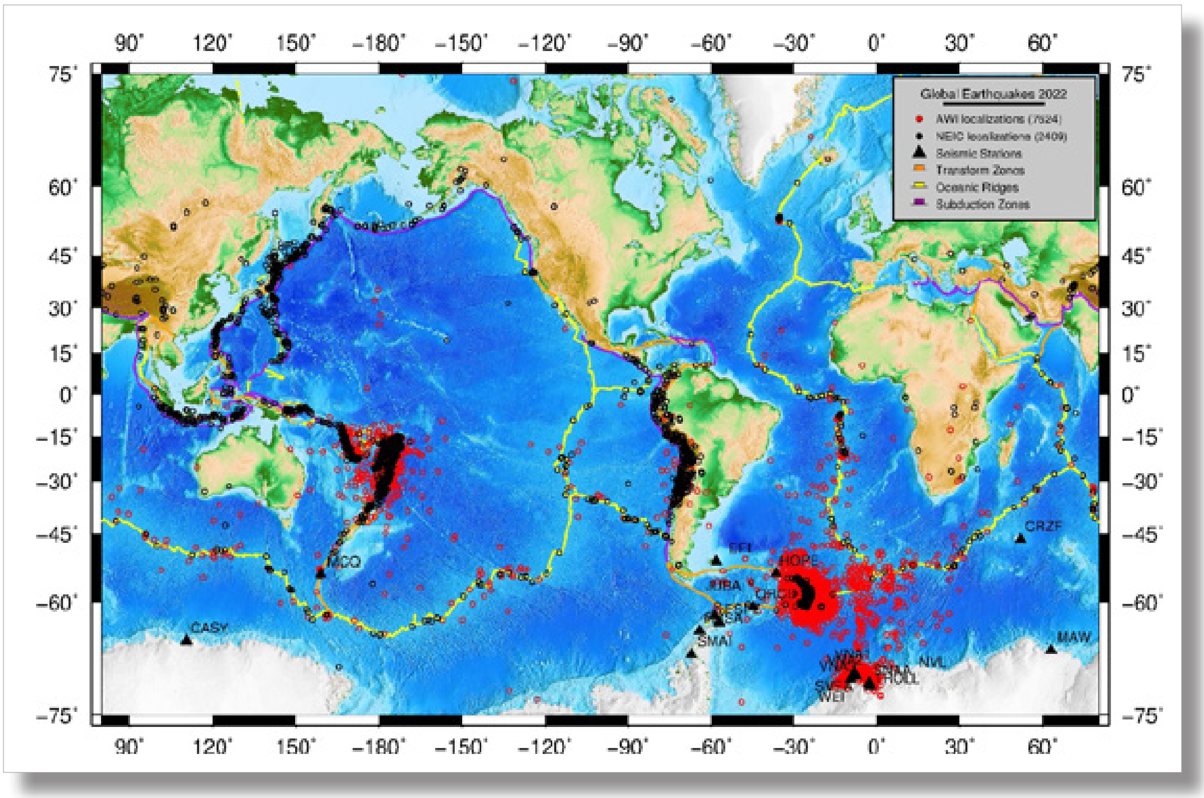

Fig. 4.3.2: Map showing seismic events recorded by the AWI network in 2022

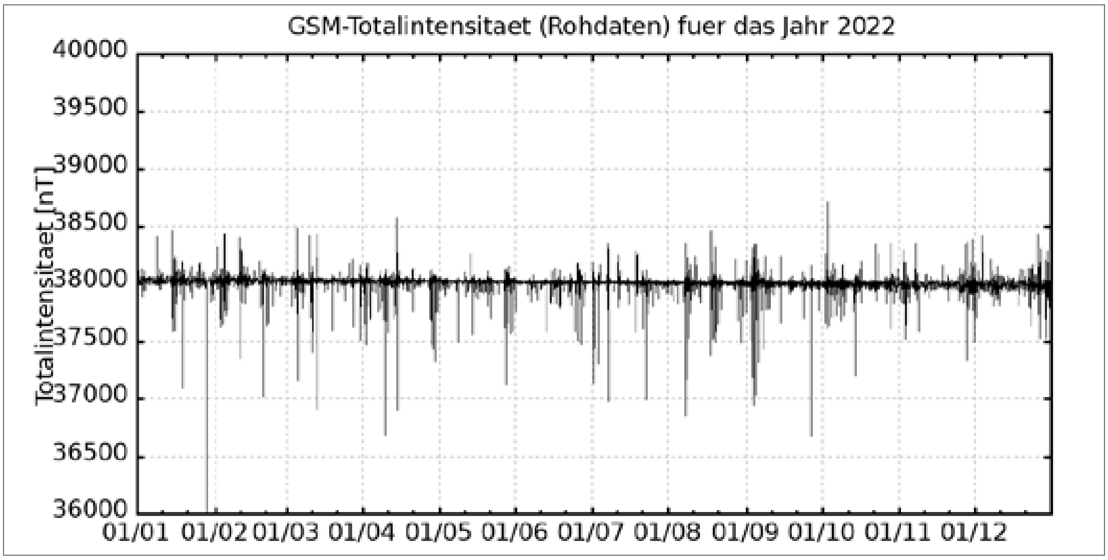

Fig. 4.3.3: Total Intensity of the geomagnetic field at Neumayer Station III, recorded by the Overhauser GSM-19.

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 (https://www.isc.ac.uk).

Data from the geomagnetic observatory can be accessed via INTERMAGNET (https://intermagnet.github.io) and SuperMAG (https://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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GFZ German Research Centre for Geosciences (2016) Geomagnetic Observatories. Journal of large-scale research facilities, 2, A83. http://dx.doi.org/10.17815/jlsrf-2-136.

4.4 CTBTO – IS27 Infrasound Station

Torsten Grasse[1], Mathias Hoffmann[1], Alicia Rohnacher[2], Benita Wagner[2], Nora Schöder[2], Felix Strobel[2]

[1]DE.BGR
[2]DE.AWI

Grant-No. AWI_ANT_4

Objectives

According to 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. Therefore, they are mainly focussed on the monitoring of the compliance of the CTBT with respect to atmospheric nuclear explosions. Due to the neighborhood of the VNA seismic array, seismo-acoustic studies are possible. The IS27 array is located about 3 km southwest of *Neumayer Station III* (Fig. 4.4.1).

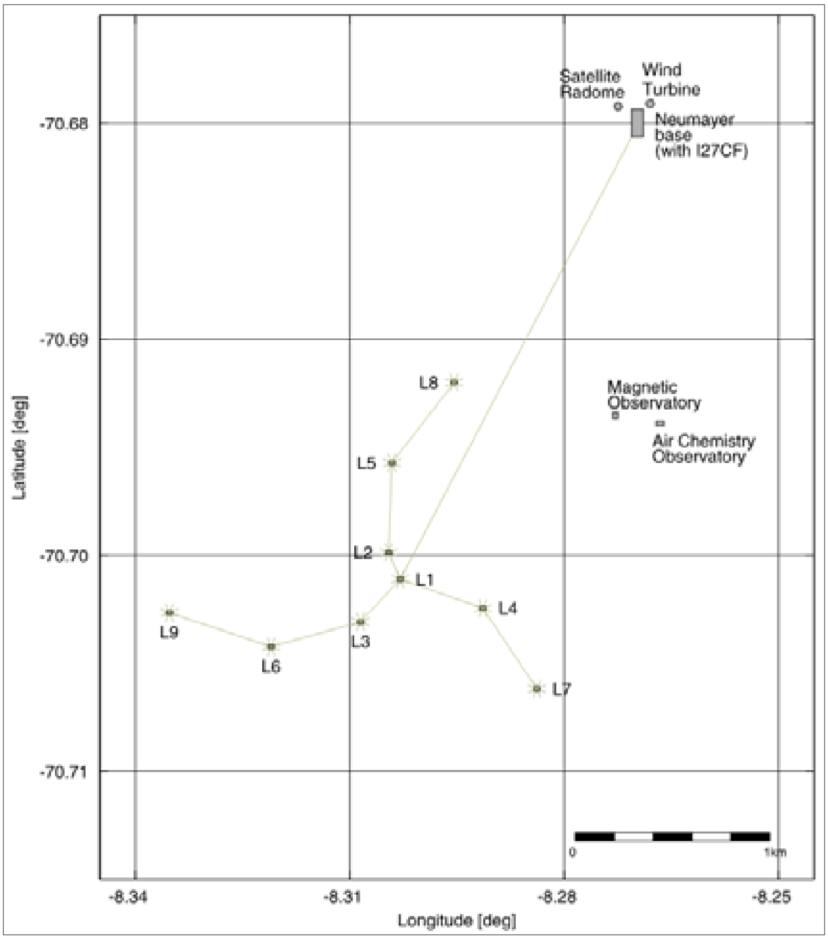

Fig 4.4.1: Map showing the location and layout of the Infrasound Array IS27 with reference to Neumayer Station III.

It consists of nine elements (Fig. 4.4.2) each equipped with a microbarometer and a data acquisition system (Fig. 4.4.3). They are arranged on a spiral at regularly increasing radii from the center point. The aperture of this array is about 2 km. The central array control system is installed in *Neumayer Station III*. IS27 went operational 2003.

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.

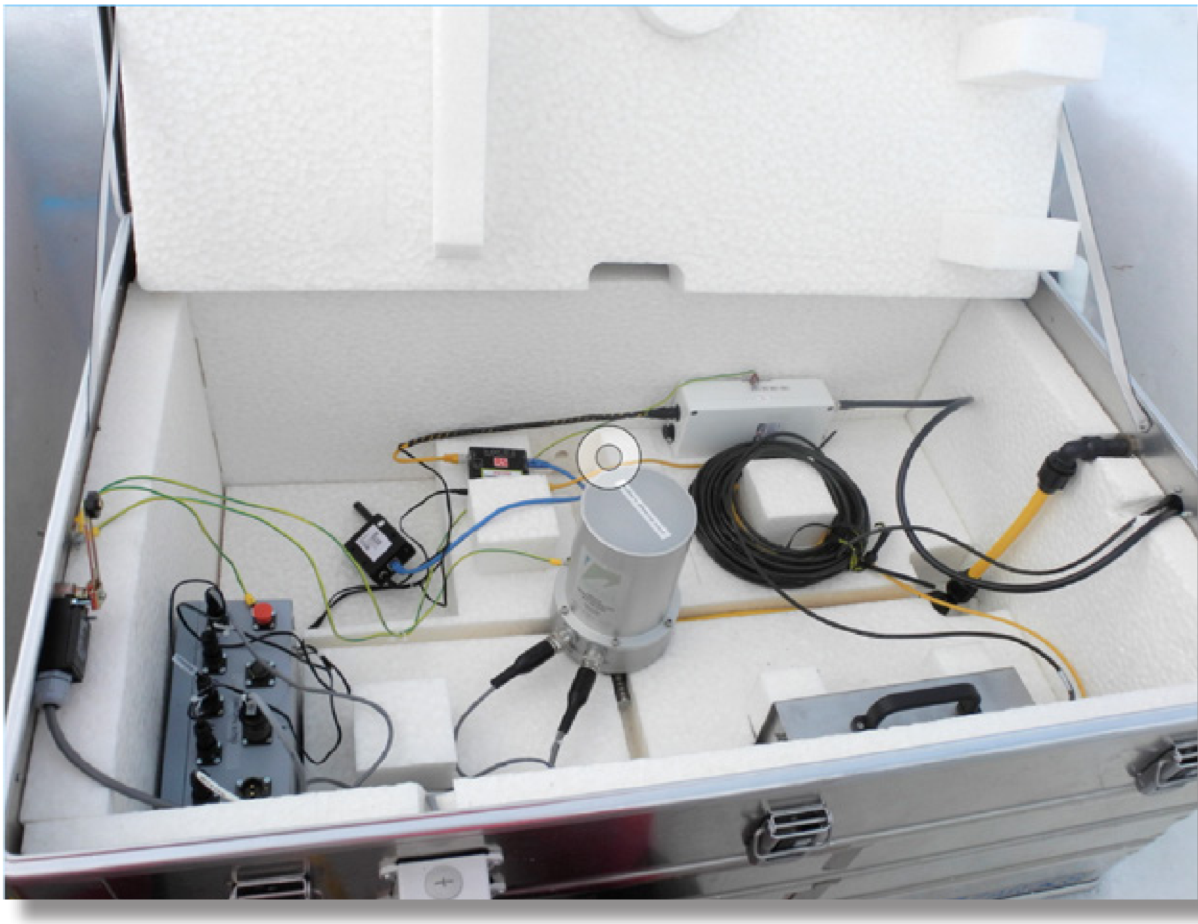

Fig. 4.4.3: The insulated field-box contains the microbarometer (in the middle), data acquisition system as well as the power supply and a communication unit.

Fieldwork

IS27 is to be operated continuously with at least 98 % data availability over a year's time, which is required for an IMS station. Routine maintenance of the array is a prerequisite to ensure the high reliability and is normally carried out every year during the Austral summer between December and February. The condition of the equipment has to be checked, hardware and software upgrades have to be installed. All nine elements have been raised to the surface without any problems notably because of the great work of the "AWI Bauteam".

Preliminary (expected) results

Data availability and quality for year 2022 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 (see references list below).

Data management

Archived data as well as real-time infrasound waveform data and metadata are publicy available. They can be obtained from BGR via 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 PALAOA – Ocean Acoustics

Stefanie Spiesecke, Olaf Boebel (not in the field), Elke Burkhardt (not in the field), Karolin Thomisch (not in the field), Ilse van Opzeeland (not in the field) — DE.AWI

Grant-No. AWI_ANT_12

Outline

The restricted accessibility of the Southern Ocean throughout most of the year confines our knowledge of the distribution patterns, habitat use and behaviour of marine mammals in this area. Most of the Antarctic marine mammals produce species-specific vocalizations during a variety of behavioural contexts. Hence, passive acoustic monitoring (PAM) offers a valuable tool for research on these species, capable of covering large temporal and spatial scales. Particularly, in remote areas such as the Southern Ocean, moored PAM recorders are the tool of choice, as data can be collected year-round, under poor weather conditions, during darkness and in areas with dense ice cover.

PALAOA (the Perennial Acoustic Observatory in the Antarctic Ocean) located on the Ekström Ice Shelf since 2005, collected continuous underwater recordings from a coastal Antarctic environment using a hydrophone deployed at ca. 160 m depths. With the ice shelf advancing by about 150 m per year, the position was constantly changing. On 23 March 2022 during PS129 it was detected that the hydrophone cable must have been ripped during a recent calving event. Consequently, the recording box was removed and electronics, including the data storage, was taken back to *Polarstern*. Analysing the acoustic data revealed that the calving event took place on the 27 February 2022 at approx. 08:16 UTC. From this event on the observatory was out of service.

Objectives

This season's objective was the re-installation of up to 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. As hot-water drilling could not be realized this year, it was planned to use holes drilled by the melting probe from the project "TripleIceCraft" (see Chapter 4.26). All field work was planned to be realized during the stay at *Neumayer Station III* from End of January till the end of the summer season in the beginning of March 2023.

Fieldwork

All three potential drilling sites were marked with bamboo posts on 26 January 2023 using a GPS to get the correct positions (Tab. 4.5.1).

Tab. 4.5.1: Marked positions of the old PALAOA recorder unit position “PALAOA-old” and the planned positions for the new installations.

Name of position	**LAT**	**LON**	**Distance to shelf-ice edge close to PALAOA-old in m (+-10 m)**
PALAOA - old	70° 30.057´	008° 12.257´	30
PALAOA - North	70° 30.561´	008° 12.836´	1030
PALAOA - Center	70° 30.935´	008° 13.770´	1900
PALAOA - South	70° 31.295´	008° 14.642´	2750

While preparations and tests for the drilling probe were undertaken by the “TripleIceCraft” team, all three new PALAOA hydrophones (TC4032, Teledyne RESON) and the two existing recorder electronics (SV1067, SV1068) were tested and calibrated in the laboratory at *Neumayer Station III*.

A hand-held frequency generator (MRPro, NTI) was used to test the Hydrophones including their pre-amplifier.

Calibration of the hydrophones and electronics was done using a Brüel & Kjaer Pistonphone Type 4229 with the RESON mount TL8089, emiting a sound pressure level of 156 dB.

While calibrating the system, the two existing PALAOA recording units were tested to make sure they still perform as expected after 9 years in the field.

To prevent the drilling hole from freezing before the hydrophone was lowered into the drilling hole, sea salt was planned to be mixed with the melting water inside the hole. For easier dumping into the drilling hole, an oversaturated brine solution was prepared before it was transported to the drilling site on 20 Febuary 2023 with the drilling equipment.

Preliminary results

The preparation of the hydrophones and electronics for further data acquisition at the PALAOA site was concluded successfully.

Unfortunately, the drilling with the melting probe was not successfully completed at the PALAOA drilling site(s).

All PALAOA equipment is stored at *Neumayer Station III* and remains ready for deployment.

Data management

Does not apply for this season.

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.

4.6 AFIN – Antarctic Fast Ice Network

Markus Schulze, Lukas Ole Muser, Stefanie Arndt, Mara Neudert, Jölund Asseng, Marcel Nicolaus (not in the field), Christian Haas (not in the field), Markus Janout (not in the field)

DE.AWI

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 program at *Neumayer Station III* started in 2010 (Arndt et al., 2020).

Fieldwork

Sea-ice conditions

After several years in which parts of the fast ice remained in the bay, the ice completely broke up and drifted out at the end of February 2022. First sea ice, platelet ice, and snow thickness measurements were carried out on 19 May 2022. Since entering the sea ice was not yet safe in the entire bay, only the first measurement site of the route, ATKA03, could be worked on. From end of June onwards, the entire transect could be sampled once per month (Tab. 4.6.1).

In late December, the first pieces of fast ice began to break up in the northern part of the bay. In the night from 31 December 2022 to 1 January 2023, due to the prevailing southerly wind, large parts broke off, including the area between ATKA11 and ATKA16. Afterward, the bay was sampled only in the southern part, until 10 January, when the fast ice was closed due to crack widening and increased potential for instability in the bay. Mid to end of February, the fast ice area broke up completely and drifted off the bay.

AFIN2022/ AFIN2022plus

For the season 2022, the fast ice program in Atka Bay can be divided into two phases. First, the part during the wintering period until the end of October (AFIN2022), in which both, the manual measurements of snow, ice and sub-ice platelet layer thickness in drill holes and the ground-based electromagnetic induction system (GEM-2) to determine the total ice thickness and sub-ice platelet layer thickness along the AFIN standard transect, were carried out. At the beginning of the season, in addition two sea-ice buoys were deployed on the ice in the bay.

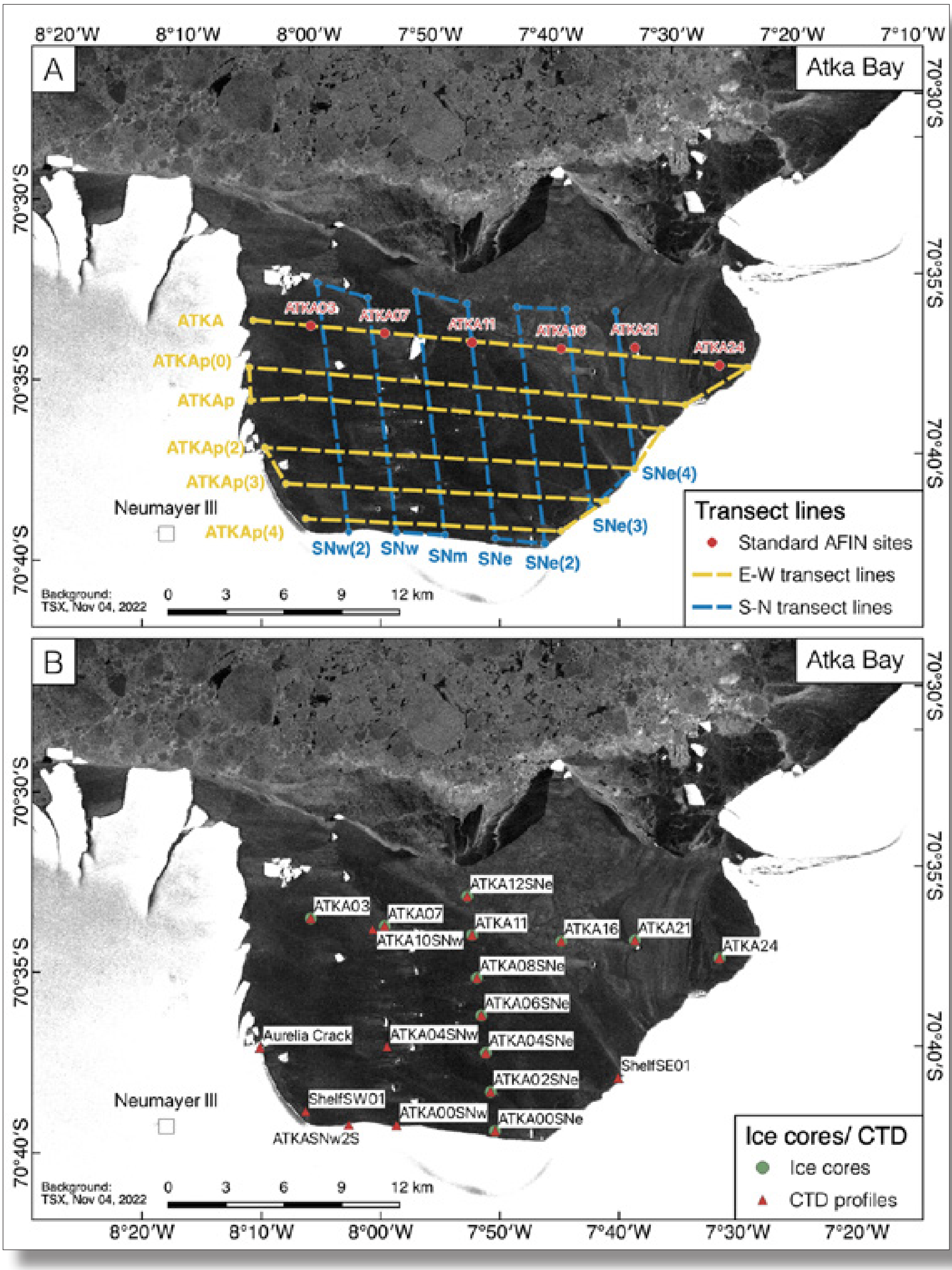

Fig. 4.6.1: Overview on all transects and measurement sites in Atka Bay for the season 2022. In panel (A), ATKA03-24 denote the routine measurement sites of AFIN. Numbers (03-24) state the distance to the western shelf ice edge. In addition, surveyed east-to-west (E-W, yellow) and south-to-north (S-N, blue) transect lines with the GEM-2 device are noted. Panel (B) shows all sampling sites for drilled ice cores (green circles) and CTD profiles (red triangles). Background: TerraSAR-X image recorded on 4 November 2022.

Subsequently, the AFIN summer campaign, AFIN2022plus, started in early November, in which the previous measurement program was expanded and intensified to cover the entire bay. In addition, ice cores were taken, conductivity-temperature-depth profiles (CTDs) were sampled in the vertical water column, and an autonomous electromagnetic induction sounding system (autoEM) was installed on the ice.

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. 4.6.1A, Tab. 4.6.1). From November onwards, additional drill hole measurements were carried out on a parallel east-to-west transect (ATKAp) as well as on two perpendicular south-to-north transects (SNw and SNe) (Fig. 4.6.1A, Tab. 4.6.2). All conducted drill hole measurements are summarized in Table 4.6.2.

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. In winter, the measurements were carried out together with the drill hole measurements along the AFIN standard transect. However, due to technical problems, the system could not be used for every sampling survey (Tab. 4.6.1).

As part of the summer campaign, AFIN2022plus, the GEM-2 was operated for every sampling survey on the fast ice. In addition, extensive additional E-W and N-S transects (Fig. 4.6.1A) 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 (Tab. 4.6.2).

Due to reoccurring Bluetooth connection problems between the GEM-2 device and the external logger, a WLAN connection system between both components was developed and also tested in the field. Also, this system allows to plot the GEM-2 data immediately on a tablet. However, this system is still work in progress, but might be a good solution for a more stable connection between the logger and the sensor for future field campaigns. All conducted GEM-2 measurements are summarized in Table 4.6.1 and 4.6.2.

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) have been deployed on the fast ice in Atka Bay in the close vicinity of ATKA11 (see Fig. 4.6.1) on 29 June 2022: One Ice Mass Balance buoy (IMB, 2022T88) deriving the sea-ice growth as well as one Snow Buoy (2022S110) measuring the snow accumulation over the course of the year.

During the breakup of the northern edge of the bay, the area of the buoys also broke off in the early morning hours of 1 January 2023. This caused both buoys to drift with the ice within the Antarctic Coastal Current towards the Weddell Sea. Given the small ice floe (about 200 meters in diameter), it did not survive the summer melt. Consequently, the IMB stopped transmitting data on 22 January and the Snow Buoy on 29 January 2023.

In addition, snow accumulation measurements with the Snow Buoy next to the air chemistry observatory near *Neumayer Station III* were continued (since January 2013) at the same location. During this season, the Snow Buoy was lifted twice (4 Apri 2022 and 24 January 2023) to avoid a complete coverage in snow.

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. The autoEM system was installed on the ice for the first time on 19 November at ATKA11 in the immediate vicinity of the other autonomous measurement systems. However, due to calibration and configuration issues, the system had to be dismounted again and adjusted accordingly. Finally, on 29 November, the autoEM was successfully re-installed at ATKA11 (see Tab. 4.6.2).

With the breakup of the northern fast ice edge, ATKA11 also broke off as a floe in the morning hours of 1 January 2023. Thus, the autonomous EM31 drifted out of Atka Bay unexpectedly. However, thanks to the other deployed buoys at ATKA11, we received hourly positions via satellite connection. Thus, on 7 January, the autoEM could completely be recovered by helicopter thanks to outstanding support of *Polarstern* 40 nm west of the “Nordanleger”.

Ice coring

To draw conclusions on the ice growth processes in Atka Bay, two ice cores were taken along the AFIN standard transect in the E-W direction as well as on the S-N transect SNe (Fig. 4.6.1B) at each of the drill hole sampling sites in the framework of AFIN2022plus. The cores were drilled with an ice corer with a diameter of 0.09 m, were stored in core bags after retrieval and kept frozen at -20°C. One ice core per sampling site was sawn into 2- to 10-centimeter segments at *Neumayer Station III*. The sectioning of the 12 ice cores resulted in 456 individual ice samples. All sections were melted for the following analysis of vertical salt (at the station) and isotope profiles (in laboratory back home). Salinities were determined with a conductivity meter (pocket conductivity meter WTW 3110) with a stated accuracy of 0.5 % for each measurement. The melted samples were poured into sampling vials that were filled completely and tightly sealed. The vials will be shipped at 4°C to the AWI ISOLAB Facility in Potsdam, where they will be analyzed for stable water isotopes.

All second cores were stored as whole cores at -20°C and were shipped with *Polarstern* to Bremerhaven, where ice texture and biological analyses will be carried out.

All taken ice cores are summarized in Table 4.6.2.

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. Apart from a test CTD on a small crack in the ice and several CTDs in the ROV team’s sawed hole at the Aurelia Crack (project SEAICE, see Chapter 4.27), a hole was drilled in the ice with the ice-core drill for each CTD (Fig. 4.6.1B).

All CTD measurements including the number of casts are summarized in Table 4.6.2.

Snow pit

To describe vertical snow properties and processes, one reference snow pit was analyzed in the close vicinity of ATKA11 (Tab. 4.6.2). Sampled parameters are snow density, temperature and stratigraphy. In addition, snow samples were taken for the analysis of snow salinity and its isotopic composition.

Tab. 4.6.1: Overview of all conducted measurements within the framework of AFIN until end of October 2022. The sampling sites/transects are marked in Figure 4.6.1. (1-6p) denote the number of sampled sites along the drilling transects.

Date	Drilling	GEM
19.05.22	ATKA03	along whole trip
24.06.22	ATKA (6p)	along whole trip
21.07.22	ATKA (6p)	
22.08.22	ATKA (6p)	
30.09.22	ATKA (6p)	from ATKA07 onwards
27.10.22	ATKA (6p)	path towards ATKA24

Tab. 4.6.2: Overview of all conducted measurements within the summer campaign AFIN2022plus from November 2022 until January 2023. The sampling sites/transects are marked in Figure 4.6.1. (1-6p) denote the number of sampled sites along the drilling transects.

Date	Drilling	GEM	Ice core	CTD	autoEM	Snow pit
05.11.22	SNw (8p)	SNw				
07.11.22	SNe (7p)					
08.11.22		SNe,SNm				
11.11.22		SNw(2)		test CTD (crack, 35 m depth)		
12.11.22	ATKAp (5p)	ATKAp,ATKAp(2)				
16.11.22	ATKA (6p)	along whole trip		ATKA11		
19.11.22		along whole trip	ATKA11-03 (2 cores each, except ATKA03 and ATKA07 only 1 core each)	ATKA11-03 (1 cast each)	deployment (ATKA11)	
20.11.22		along shelf ice edge from pingi ramp to ATKA24; ATKA24-16	ATKA24-16 (2 cores each)	ATKA24-16 (1 cast each)	checking setup (ATKA11)	
22.11.22		along whole trip		Aurelia crack (Horst's ROV hole, 2 casts)	recovery due to missing calibration	

Date	Drilling	GEM	Ice core	CTD	autoEM	Snow pit
23.11.22		along whole trip (return trip via ATKAp(0))	ATKA00SNe-04SNe (2 cores each)	ATKA00SNe-04SNe (1 cast each)		
24.11.22		calibration close to pingi ramp			calibration close to pingi ramp	
26.11.22					calibration at ATKA03p	
29.11.22		along whole trip	ATKA12SNe, 08SNe, 06SNe (2 cores each)	ATKA12SNe, 08SNe, 06SNe (1 cast each)	calibration and redeployment (ATKA11)	ATKA11 (1 pit)
30.11.22		test of new data acquisition system (via WLAN instead of Bluetooth); calibration of old and new setting at ATKA03p				
03.12.22		test drive with WLAN acquisition system to ATKA03				
04.12.22		SNe(2-4)				
05.12.22	ATKA (6p)	along whole trip				
06.12.22		SNe, SNm, SNw, SNw(2)	ATKA03, ATKA07 (1 core each)	ATKA00SNe, ATKA11, ATKA03 (1 cast each)	battery change (ATKA11)	
10.12.22		along whole trip				
12.12.22		along whole trip		ShelfSE01 (1 cast), ShelfSE02 (failure), ShelfSW01 (failed salinity)		
13.12.22	SNw (7p)	along whole trip		Aurelia crack (Horst's ROV hole, 2 casts); ATKA00SNw, ATKA04SNw, ATKA10SNw (1 cast each)		
14.12.22		along whole trip			data download (ATKA11)	
15.12.22		along whole trip				

Date	Drilling	GEM	Ice core	CTD	autoEM	Snow pit
17.12.22		along whole trip in the southern part of Atka Bay to the eastern shelf ice edge				
23.12.22		along whole trip			recovery for software update (ATKA11)	
25.12.22		SNw(2), SNw, SNm, SNe(1-4)				
25.12.22					redeployment (ATKA11)	
26.12.22	ATKA03-11 (3p)	along whole trip				
30.12.22		along whole trip		ATKA_SNw2, ATKA_SNwS (1 cast each)		
31.12.22		along whole trip		ATKA00SNe, ATKA11 (1 cast each)		
01.01.23	ATKA21-24 (2p)	along whole trip			planned recovery but ATKA11 broke up during the previous night	
03.01.22		ATKAp-p(4)				
07.01.22					recovery by *Polarstern* helicopter	

Preliminary (expected) results

Fast ice, sub-ice platelet ice and snow thickness

Figure 4.6.2 summarizes all snow, sea ice and sub-ice platelet layer thickness measurements as well as the observed freeboard over the season. The snow layer shows annual maximum thickness values between 0.19 m in the east at ATKA24 and 1.09 m at ATKA21 in the close vicinity to an iceberg. The mean annual maximum thickness of the fast ice is 2.20 ± 0.20 m with an average annual platelet ice accumulation of 4.34 ± 0.68 m. The latter ranges from 3.67 m close to the eastern and western shelf ice edge (ATKA03 and ATKA24) and 5.21 m at ATKA21 related to iceberg in the vicinity which may prevent the platelets from venting northwards due to tidal movements. Overall, both the average maximum thickness of the fast ice and the sub-ice platelet layer is comparable to the measurements of previous years.

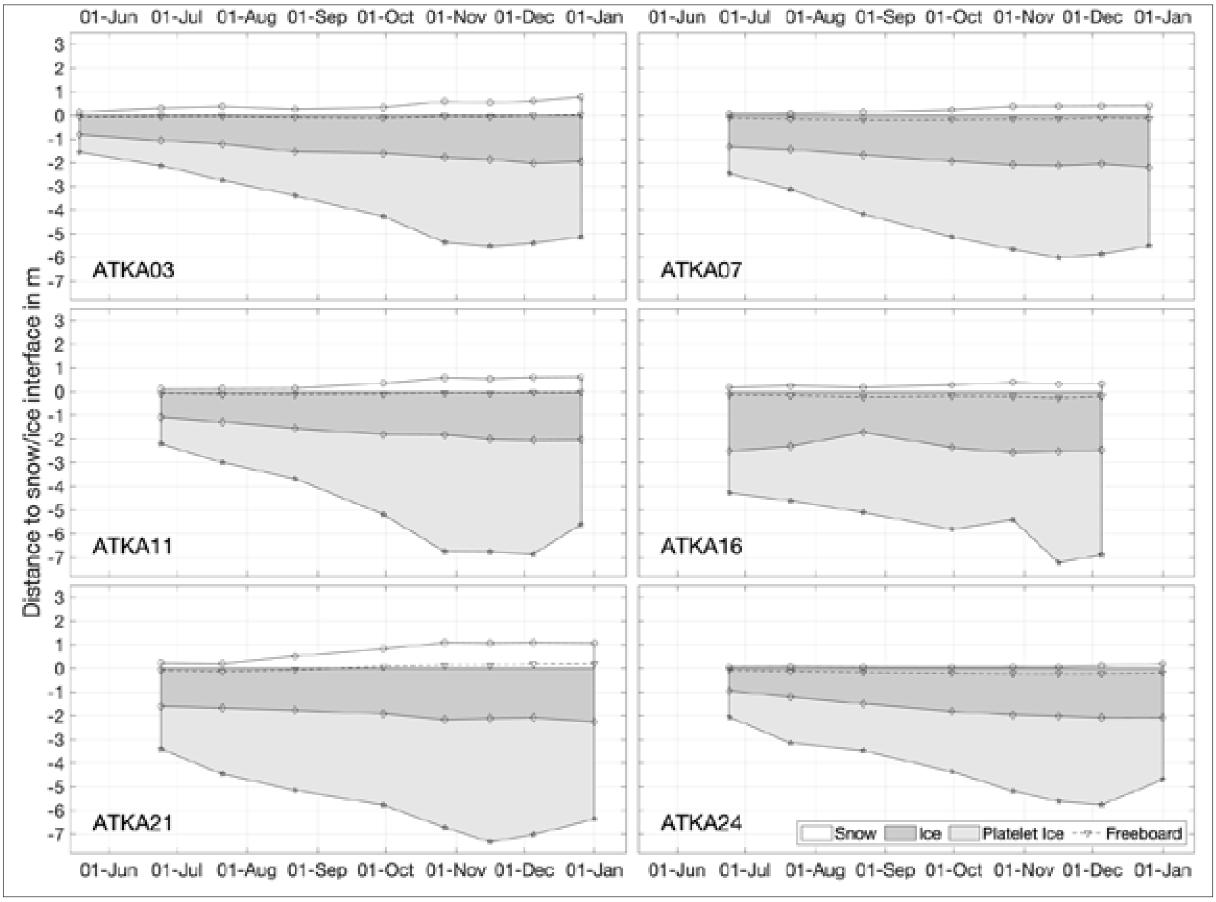

Fig. 4.6.2: Overview of all manual snow depth, sea ice and sub-ice platelet layer thickness as well as freeboard measurements for the six sampling sites along the standard AFIN transect (Fig. 4.6.1A) in 2022.

Based on the intensive GEM-2 surveys across Atka Bay, a data processing and inversion scheme algorithm could be developed and applied to derive the layer thickness of the consolidated fast ice as well as the sub-ice platelet ice beneath. A preliminary example composite of the derived thicknesses for the time period from 1 December to 15 December is shown in Figure 4.6.3. It is subject of future work to derive based on these data sets, e.g., the seasonal and regional distribution of platelet ice throughout Atka Bay.

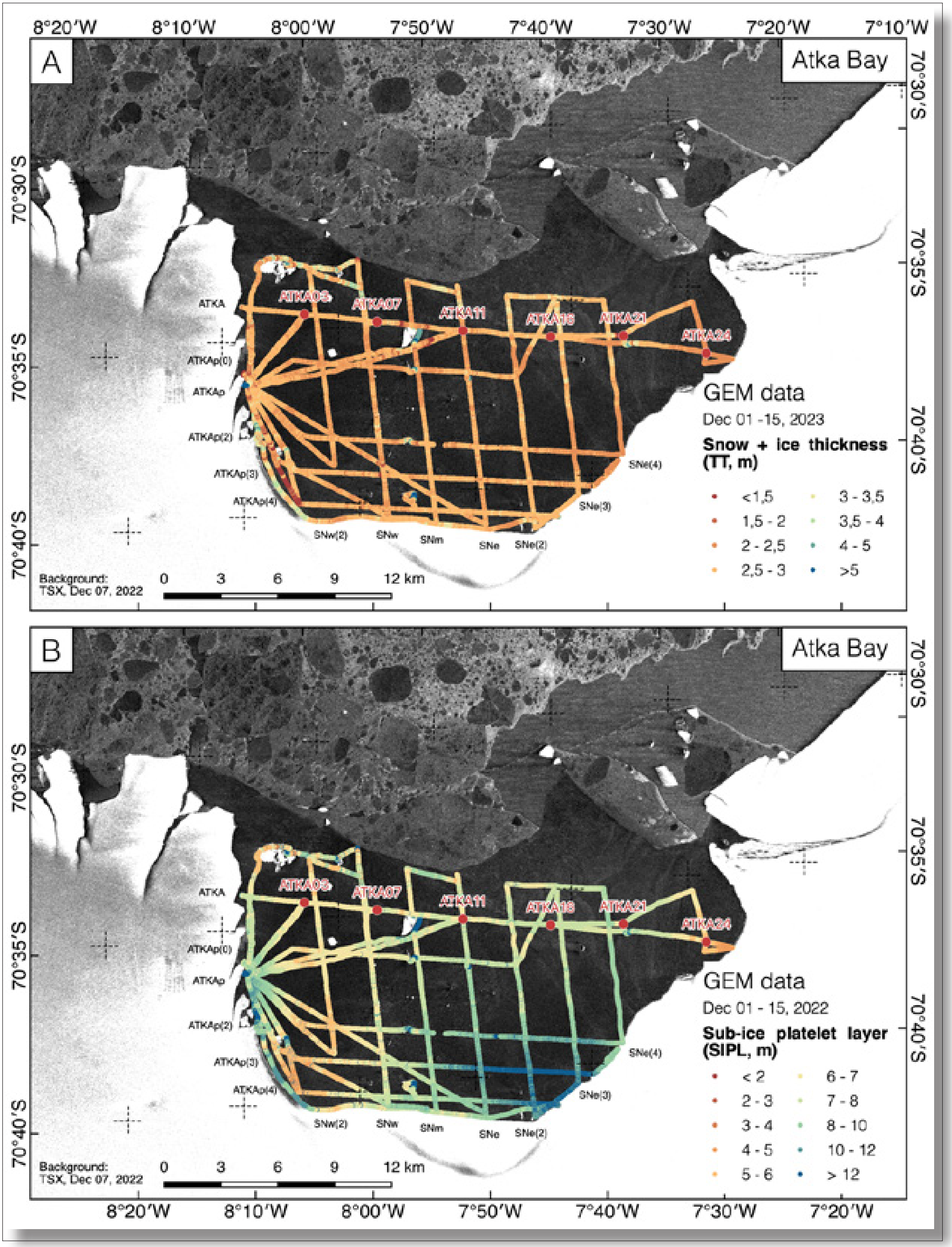

Fig. 4.6.3: Composite of derived (A) consolidated total sea-ice thickness (sea ice plus snow) and (B) sub-ice platelet layer thickness from GEM-2 data for 1 December to 15 December 2022 (Tab. 4.6.2). Shown thickness data are preliminary derived data sets. Background: TerraSAR-X image recorded on 7 December 2022

Figure 4.6.4 shows the snow accumulation of the deployed Snow Depth Buoy 2022S110 (at ATKA11) for the time period from 29 June 2022 to 29 January 2023. The initial snow depth at the deployment site was approx. 6 cm. In July and August, snowfall events added another 10 cm of new snow each month. Following that, both in late September and mid-October, repeated heavy snowfall and strong wind event accumulated an additional 35 cm at the Snow Buoy location. Snow accumulation was then fairly constant until early December, when rising air temperatures and light snowfall caused an increase in snow accumulation of another 10 to 15 cm. Another storm and snowfall event at the end of December resulted in a further increase in snow accumulation of 20 cm within one day.

With the break-up of the northern edge of Atka Bay and the associated drift of the buoys at ATKA11 with the ice in the Antarctic Coastal Current toward the Weddell Sea, the snow surface shows a significant loss of snow mass of 20 cm during January before the buoy sank or flipped due to summer sea-ice melt or decay of the ice in the ice edge zone.

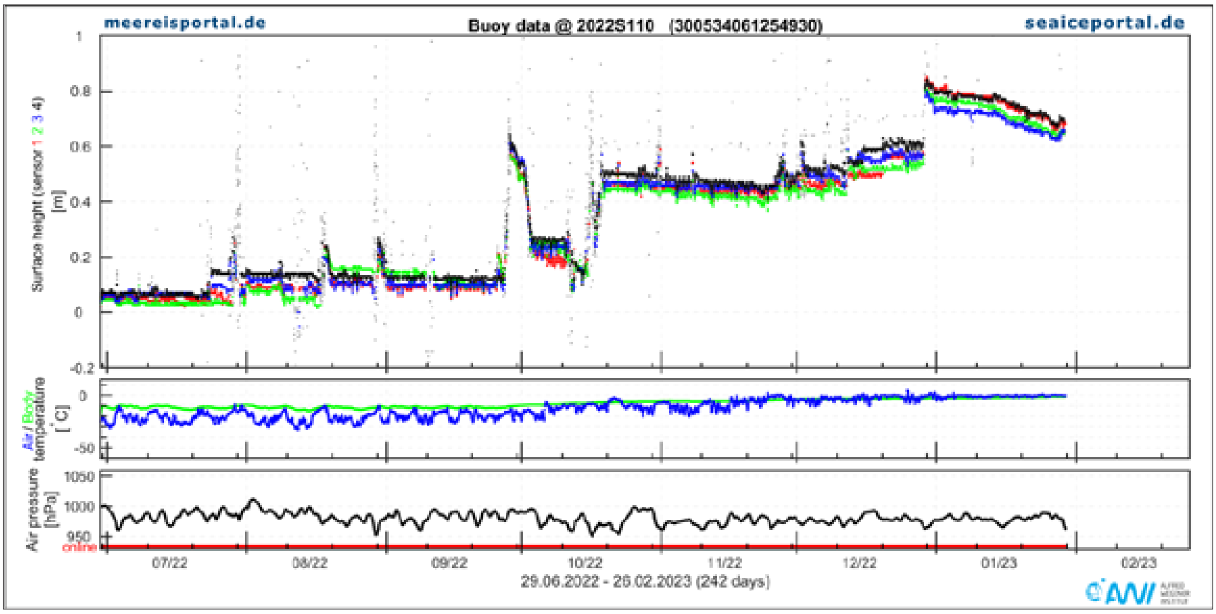

Fig. 4.6.4: Time series of snow accumulation along with the respective meteorological conditions for Snow Buoy 2022S110, deployed on 29 June 2022 at ATKA11 (Fig. 4.6.1, data.meereisportal.de).

Ice cores

In total, 12 ice cores along two transect lines, in E-W and S-N direction respectively, have been sampled for salinity.

Figure 4.6.4 shows the salinity profiles of six ice cores along the standard AFIN transect in E-W direction (Fig. 4.6.1B). All ice cores show a C-shape salinity profile, i.e. higher salinities in both the upper and lower parts than in the central part of the ice core. The increase of the salinity in the lower 50 to 20 cm could be due to the onset of summer and desalination by increasing porous structures in the lower ice layers, the formation of the so-called skeletal layer in the bottom part of the ice core. On the other hand, the ice in this section is likely to consist primarily of consolidated platelet ice, which also has an influence on the salinity profile.

The higher salinity values in the upper part of the ice core suggest the formation of snow ice, i.e., refrozen flooded snow.

The additional ice crystal and isotope analyses of the ice cores in Bremerhaven and Potsdam will help to describe the ice growth processes as well as the internal structural properties more precisely.

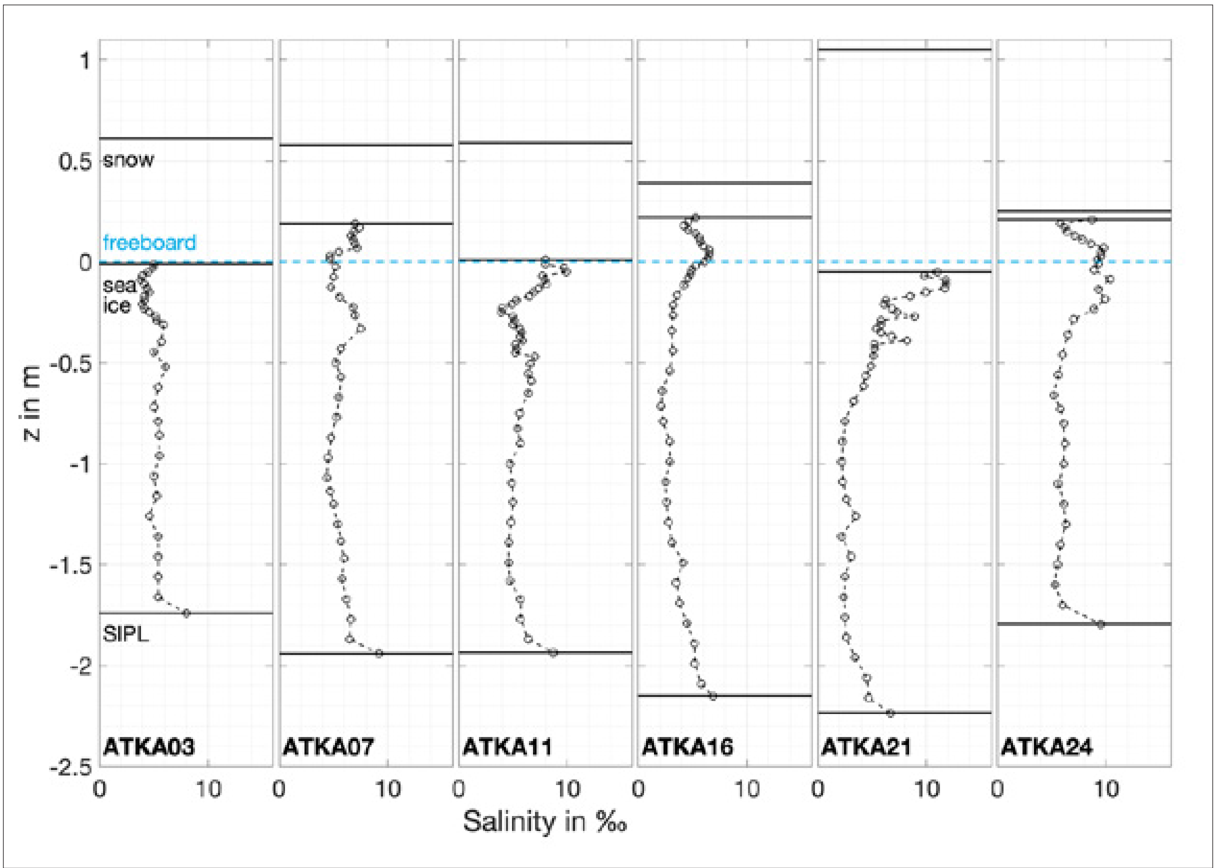

Fig. 4.6.5: Salinity profiles of the ice cores sampled on the AFIN standard transect, ATKA03-24 (Fig. 4.6.1). The salinity profiles are plotted relative to the water level (z = 0 cm, dashed blue line). Vertical solid lines denote the air/snow, snow/ice and ice/sub-ice platelet layer (SIPL) interfaces.

CTD profiles

In total 29 CTD casts at 19 locations across Atka Bay have been conducted (Fig. 4.6.1B).

Figure 4.6.6 shows an upcast and a downcast of the CTD on 16 November and 6 December at ATKA11, respectively. For the detailed analysis only the down cast is used, because the stratification of the water masses is already modified and mixed when the CTD is lowered, so that, e.g. the salinity profiles for the upcast become rather constant over the entire water column.

Both the temperature and salinity profiles of the mid-November cast show a relatively constant pattern throughout the water column, with only the upper 25 meters indicating interlayered warmer water, presumably due to the temporary breakup of the pack ice and associated open water in front of the fast ice.

In comparison, the early December temperature profile shows a significant increase in the upper 75 meters, while salinity tends to decrease slightly. The combination of both, together with the onset of summer and the progressive decline of the pack ice off the bay, suggests the inflow of warmer surface water, combined with the onset of weak melting at the bottom of the sea ice.

It is the subject of future work to elaborate detailed relations between the seasonal and regional platelet ice distribution and water mass distribution beneath the fast ice in Atka Bay.

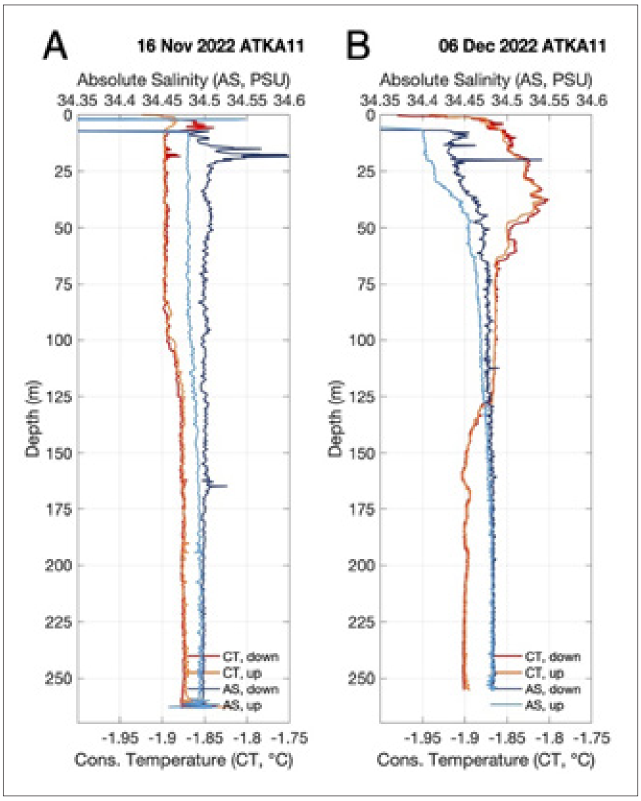

Fig. 4.6.6: Profiles of absolute salinity and conservative temperature for the down- and upcast respectively (dark/light blue, red/ orange) at ATKA11 on (A) 16 November and (B) 6 December 2022.

Data management

All manual drilling measurements are already post-processed and will be published in PANGAEA within one year.

All sea-ice thickness data from electromagnetic induction sounding as well as CTD and ice-core data will be released following their 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.

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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4.7 Spot – Single Penguin Observation and Tracking

Daniel Paranhos Zitterbart[1,2], Loïcke Baille[2], Alexander Winterl[1] (not in the field), Aymeric Houstin[2] (not in the field), Céline Le Bohec[3,4] (not in the field), Sebastian Richter[1] (not in the field), Ben Fabry[1] (not in the field)

[1]DE.FAU
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[3]FR.CNRS
[4]MC.CMS

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 behavioural and ecological problems, from an individual animal to population trends. Time lapse imaging has gain 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. 4.7.1) specifically designed to operate in Antarctic conditions.

The observatory is designed with the aim to investigate the population and behavioural 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 behavior 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 2012/2013 at Atka Bay (70°37.0'S, 8°9.4'W), approximately 8 km north of *Neumayer Station III*, on the Ekström Shelf Ice (Richter et al. 2018). Since 2013, we have been collecting wide-angle overview images at a rate of one 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).

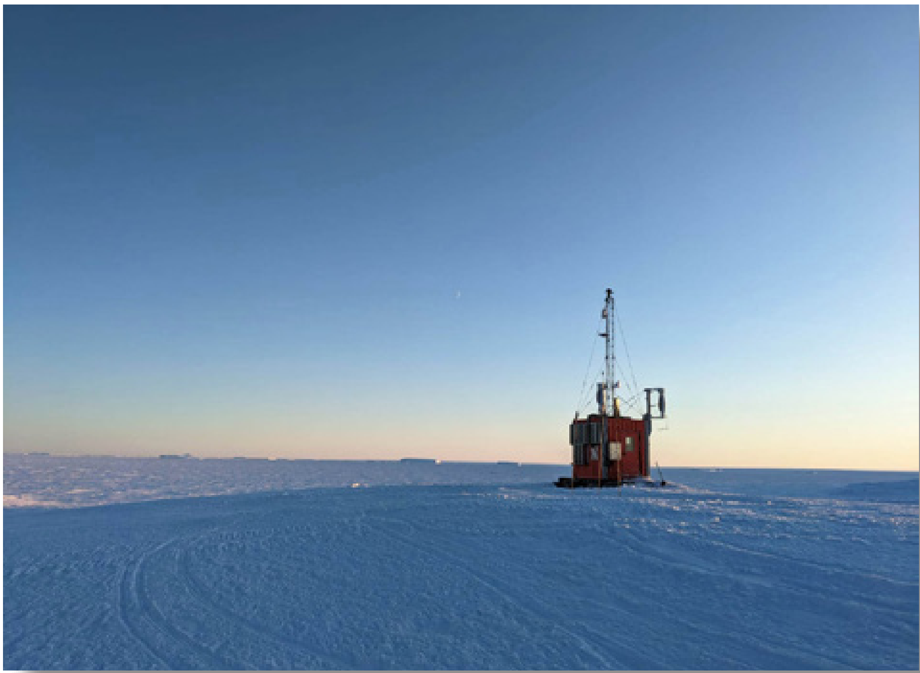

Fig. 4.7.1: SPOT penguin observatory in 2022

Fig. 4.7.2: New automatic lubrication system installed in 2022

Fieldwork

Data collection throughout the winter 2022 went without major problems. SPOT had lost one wind turbine in 2021 that could not be replaced in the 2021/22 summer season, so the winter season was conducted only with one turbine, which led to a shortage in power.

Unfortunately, during most of the 2022 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 was not observable during this time. 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 had lead to significant damage to the cables.

Overview cameras recording the position and density of the colony were operational throughout the year. The high-resolution RGB camera was operational throughout the year and recorded images on demand when daylight, penguin's position was favourable and the power reserves of SPOT observatory enough. The thermal imaging camera was operated, when possible, in conjunction with the RGB camera and did not experience fogging due to the automatically closing flap installed in 2019/20.

During the summer field season (ANT-Land 2022/23), a major overhaul of SPOT was conducted. Both wind turbines were replaced and an automatic lubrication system was installed (Fig. 4.7.2), the overview camera system (Fig. 4.7.3) was extended by a new camera system now based on industrial monochrome cameras instead of security cameras. The high-resolution camera was replaced by a newer more performant model.

Fig. 4.7.3: New overview camera system installed in 2022

Preliminary (expected) results

We have been operating SPOT now for 10 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 overwinterers in case it is needed. Most assistance is needed to grease the wind generators every 3 months, as well as to de-ice the overview cameras, which do not have a dedicated heating, especially in autumn when rare freezing fog is possible. Counts throughout the seasons 2018 to 2020 clearly show the arrival pattern as well as the occupation peak of the colony when presumably the whole population is present in May. SPOT phenology and population data is now being used by the international emperor penguin scientist community to ground truth satellite imagery for continent wide emperor penguin abundance assessments (Larue et al., 2022, in review).

Data management

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

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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Gerum RC, Fabry B, Metzner C, Beaulieu M, Ancel A & Zitterbart DP (2013) The origin of traveling waves in an emperor penguin huddle. New Journal of Physics 15:125022.

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

Daniel Paranhos Zitterbart[1,2],
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Céline Le Bohec[3,4] (not in the field),
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Grant-No. AWI_ANT_14

Objectives

MARE is 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, a 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 scenarios. 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. Micro-tagged 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 bio-loggers 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 (collaboration with Dr. G. Gerdts, AWI, Prof. G. Seralini, University of Caen, Drs. C. Alonso and M. Metian, IAEA).

Fieldwork

The ANT-Land 2022/23 summer season for MARE program ran from November 2022 to mid-January 2023 on the Atka Bay emperor penguin colony.

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

3 RFID-antenna-sledges have been deployed on different access passageways of the emperor penguins from the sea to their breeding colony in order to identify microtagged birds and start to collect longitudinal capture-mark-recapture data for our population dynamic modelling. New tests were performed with the ECHO rover to approach groups of penguins from the sea-ice sub-colony.

2 breeding emperor penguins were successfully equipped with CatsCam (sounds, video, depth, and accelerometers) +VHF dataloggers (Fig. 4.8.1). After identifying an adult feeding its chick at the peripheral of the colony, we isolated the duo outside of the colony, in a corral. Chicks were measured (flippers and beak), weighted, temporarily marked and equipped with a small VHF on the flipper using Colson-ties. Adults were measured (flippers and beak), externally equipped with data-loggers using Tesa-tapes and Colson-ties, and temporarily marked before release (for identifying the bird for the recapture/retrieval of the equipment). Then, visual observations and checks with VHF-antennas were performed every ca. 4 to 6 hours throughout the 24h-day over the whole season to recover the equipped birds and the material. We were able to recover all the deployed devices. 1 out of 2 of the pairs (adult-chick) was PIT-tagged and blood-sampled at recovery of the equipment. Our arrival at the field site early in the season and the installation of a shelter closer to the colony were the keys of the success of our deployment goal this season.

Fig.4.8.1: Deployment of a CatsCam-datalogger on an adult emperor penguin

12 well-molted fledglings, leaving the colony in groups to reach the sea, were captured and equipped with ARGOS-dataloggers (current locations – May 2023 – in Fig. 4.8.2).

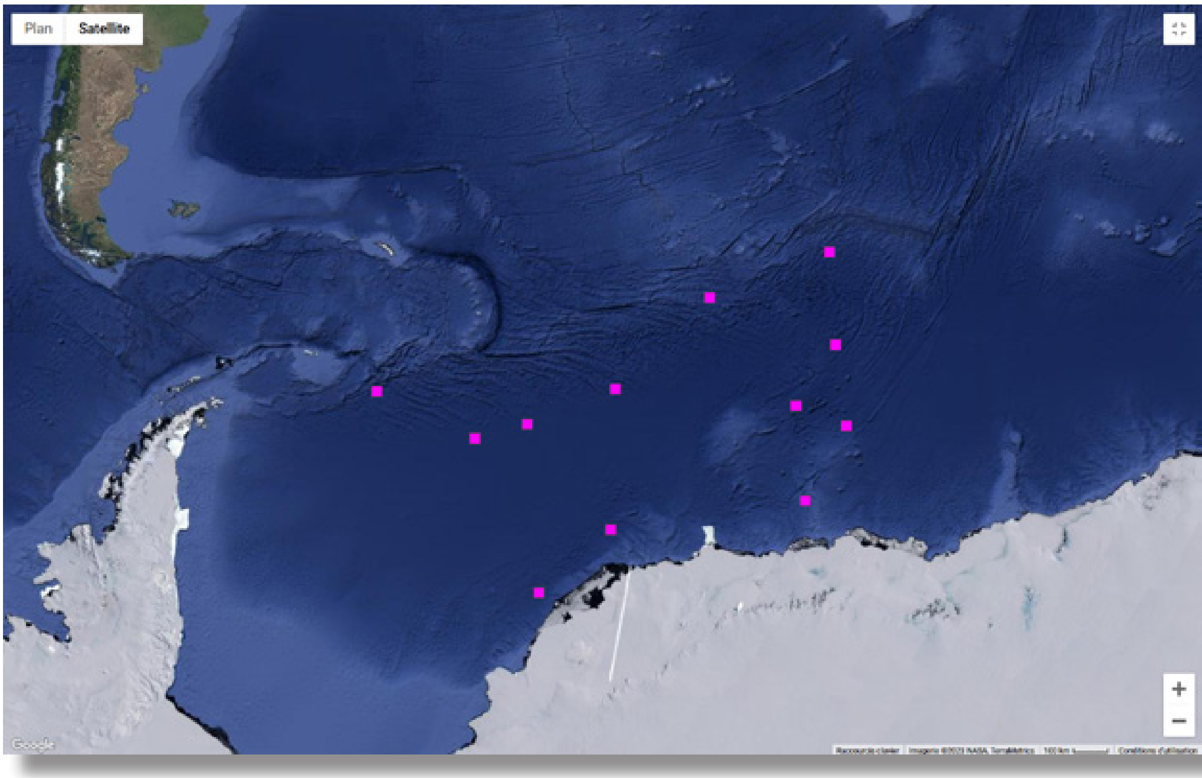

Fig.4.8.2: Position in May 2023 of the juvenile emperor penguins equipped with ARGOS-dataloggers in December 2022/January 2023

Colony census (direct and temporal population estimations through SPOT panorama), and classical phenological/breeding parameters, chick mortality, and major constraints were monitored over the course of the season. A total of 111 dead emperor penguin chicks were collected for biometry.

Finally, during the stay of the Netflix and AppleTV teams, we spent several hours to half-days with the team to advise them and providing information concerning the emperor penguin behaviour.

Preliminary (expected) results

The first "on-land" objective of MARE program, which aims to model the population dynamics/trends of Atka Bay colony thanks to the yearly micro-tagging of fledging chicks and identification through MIS (use of RFID-antenna-sledges and ECHO-Rover (Fig. 4.8.3) started last season 2021/22, 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 starts to reproduce in average at 5-year old). This season 2022/23, we detected for the first time some previously PIT-tagged emperor penguins.

Regarding the phenology/census of Atka Bay emperor penguin colony this season 2022/23: as last year, the colony was and remained mainly on the ice shelf, divided in several sub-colonies: one near the "Pingirampe", one near the "Meereisrampe" and several sub-colonies on the ice shelf between these two ramps. Groups of penguins (chicks and adults, from a couple of individuals to several dozens) ventured to and around *Neumayer Station III* during the course of the season.

Fig. 4.8.3: ECHO-Rover approaching emperor penguins to scan them

The second at-sea objective of MARE program, which aims to identify foraging strategies of emperor penguin breeding in Atka Bay using biologging technology, was highly fruitful in terms of publications over the last years (Houstin et al., 2022a,b), and additional analyses are still in progress, so the publication (Houstin et al., *in prep.*). The equipment with CatsCams on wild emperor penguins is the first ever done to our knowledge: the success of this pilot study opens a great opportunity for future research on penguin communication at sea and their foraging behaviours, which are fundamental to determine if/how this species will be able to adapt to future environmental challenges. Finally, our work on stomach contents, analyzed at the AWI Heligoland in collaboration with partners from Switzerland (University of Basel) to determine the presence of microplastics, was published this year (Leistenschneider et al., 2022).

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. Data material of the at-sea study (Houstin et al., 2022a,b) is already archived in AWI's PANGAEA repository (https://doi.pangaea.de/10.1594/PANGAEA.913447) or in MOVEBANK (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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Houstin A, Zitterbart DP, Heerah K, Eisen O, Planas-Bielsa V, Fabry B & Le Bohec C (2022b) Juvenile emperor penguin range calls for extended conservation measures in the Southern Ocean. Royal Society Open Science 9:211708.

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

Alexander Stahn[1,2] (not in the field), Mathias Basner[1] (not in the field), David Dinges[2] (not in the field), Hanns-Christian Gunga[2] (not in the field), Ruben Gur[1] (not in the field), Simone Kühn[3] (not in the field), Brad Nindl[4] (not in the field), David Roalf[1] (not in the field), Suzanne Bell[5] (not in the field)

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Grant-No. AWI_ANT_11

Objectives

The overarching objective of the project is to investigate the effect of long-duration Antarctic stay on crew health and behaviour. The research will be performed as part of the NASA sponsored project "NSCOR for Evaluating Risk Factors and Biomarkers for Adaptation and Resilience to Spaceflight: Emotional Valence and Social Processes in ICC/ICE Environments". The project leverages the NIMH Research Domain Criteria (RDoC) heuristic framework to conduct experimental studies to identify biological domains (molecular, circuitry, physiology) and behavioural domains that relate to individual adaptation and resiliency (as well as behavioural vulnerability) (Maestripieri et al., 2016). RDoC's emphasis on examining each construct provides an integrative approach that is appropriate for identifying individual differences in vulnerability to multiple stressors in extreme environments. In addition, RDoC's focus on neural circuits facilitates the examination of observed individual, phenotypic differences and variations in the nature and degree of damage to those circuits, as well as the variations and contributions of a complex interplay of developmental, compensatory, and environmental factors (Morris et al., 2012). We will identify predictive indicators and biomarkers for resilience and adaptation in individuals and teams, to aid in selection and individualized countermeasure development with the goal to maintain and optimize performance capability and behavioural health during long-duration missions. The project will be based on a close cooperation between the Alfred Wegener Institute for Polar and Marine Research and several international partners, including Charite, Ludwig Maximilian University of Munich, the University of Pennsylvania, Harvard, and NASA.

Fieldwork

Data were collected in crew members at *Neumayer Station III* as part of ANT-Land 2018/19, 2019/20, 2020/21, 2021/22, and 2022/23. Our primary outcome will be structural and functional brain changes assessed by MRI before and after the winter-over. In addition, we will also assess behaviour 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. We also propose to draw and subsequently freeze about 25 ml of blood from all experimental subjects 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 (Palinkas & Suedfeld 2008), we will assess additional physiological measures and endpoints, which have already been successfully implemented in previous experiments in Antarctica. The sample rate will vary from continuously to once monthly, and is optimized relative to crew burden/ compliance and scientific return. Pre-, in-expedition and post-expedition data collection for the 39th, 40th, and 41st and 42nd overwintering have been successfully completed.

Preliminary (expected) results

It is expected that the multiple stressors associated with long-duration overwintering lead to neurobehavioural changes as assessed by structural and functional brain imaging, key neurotrophins and behaviour (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 neurobehavioural 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, MPI, Penn and Pitt. Data will be pseudonymized and stored on a central server that is backed up and managed by the universities' IT programs. Results will be publicly disclosed in a timely manner after completion of the data collection by submission to peer-reviewed journals with authorships that accurately reflects the contributions of those involved. One year after final data collection the data will be submitted to NASA, which will be archived in the NASA Life Sciences Data Archive (LSDA) (http://lsda.jsc.nasa.gov/) for the benefit of the greater research and operational spaceflight community. We will meet all requirements set forth by NASA to share our data with the research community in general and NASA's Life Sciences Data Archive (LSDA). De-identified data will be submitted to the LSDA that can then be made available for internal and external-to-NASA peer- reviewed research studies following a thorough review and approval process by LSDA and after appropriate JSC IRB approval. The de-identified that we will submit to LSDA will include individual data points but any identifying information will be removed. We will carefully attend to any characteristic that might make the data fields identifiable (e.g., campaign, analog, mission length and/or sex). This expedition was supported by NASA Grant 80NSSC17K0644, and will be quoted in all publications.

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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Morris SE & Cuthbert BN (2012) Research Domain Criteria: cognitive systems, neural circuits, and dimensions of behavior. Dialogues Clin Neurosci 14(1): 29–37.

Palinkas LA & Suedfeld P (2008) Psychological effects of polar expeditions. Lancet 371(9607):153–163.

Stahn AC, Gunga HC, Kohlberg E, Gallinat J, Dinges D & Kühn S (2019) Brain changes in response to long Antarctic expeditions. New England Journal of Medicine 381(23):2273–2275.

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

Alexander Choukér (not in the field), Dominique Moser (not in the field) — DE.Med.Uni-Muenchen

Grant-No. AWI_ANT_6

Objectives

The overarching purpose of this field study (CHOICE@Neumayer) is to determine the interaction between stress and the immune system and its impact on the health of overwintering crews at the *Neumayer Station III*, Antarctica. This investigation is closely linked to previous and ongoing scientific studies in Antarctica (*Concordia*, acronym CHOICE) as well as in Space (ISS, acronym IMMUNO and IMMUNO_2).

The international research team under the lead of the Hospital of the Ludwig Maximilian University of Munich (Department of Anesthesiology) aims to investigate at *Neumayer Station III*:

a) how the immune system responds to an isolation and confinement period for several months and which stress-dependent, neuroendocrine and metabolic changes may occur and

b) how this can impact on the health of the participants.

Fieldwork

For the overwintering season 2022, after a baseline data collection in the fall of 2021, the examinations of all nine subjects started on the station in February 2022 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 2022 for the post-collection in Berlin (joint activity and kindly organized by PD. Dr. Alexander Stahn). Blood, saliva, urine, hair and stool samples were collected and also questionnaires were filled in.

Preliminary (expected) results

The series of investigations in the extremes of the Antarctic environment seems to trigger some distinct stress and immune responses and are ongoing to incease the debth and the statistical strenght of any major relevant environmental and sex-specific differences. Stated sex differences were shown to be independent of enhanced psychological stress and seem to be related to the environmental conditions. However, sources and consequences of these sex differences have to be further elucidated and these investigations are under way and need high n-number.

Current analyses on samples collected during former overwintering seasons focus the impact of fresh food on the immune system on both the transcriptional and the functional level as well as on the microbiome profile. Preliminary data on the latter revealed a dynamic shift of microbiome diversity during mission which however recovers after return to Europe. Subsequent in-depth analyses are ongoing.

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 of 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.

4.11 Kottaspegel 2022/23

Stefanie Arndt[1], Martin Petri[1], Olaf Eisen[1,2] (not in the field)

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Grant-No. AWI_ANT_8

Objectives

Specific surface mass balance is one of the most important parameters to determine the current overall mass balance of the Antarctic ice sheet. At the same time, it is also one of the inaccurately known quantities. Although remote sensing methods have been developed to track surface accumulation over time and interpolate in space, reliable estimates still crucially depend on on-site measurements of surface accumulation. To track the development of surface mass balance in a changing climate, it is not only important to cover white spots, but also obtain continuous records of snow accumulation at selected sites. Only long-term time series, which cover larger distances, allow to reliably characterise the statistical properties of snow surface accumulation, i.e., the changes from year to year and changes in space. To date only few of such records exist, mostly along regularly visited traverse routes between permanent stations and summer field camps or stations. Measurements of snow accumulation and density can be relatively easily determined in the field. The objective of Kottaspegel is to obtain continuous records of surface mass balance from measurements of snow accumulation and density.

As there was no *Kohnen* Traverse this season, the measurements were only carried out on the section between *Neumayer Station III* and Kottas mountains.

Fieldwork

After arrival at *Neumayer Station III* on 17 December 2022, the newly developed measurement set-up was first tested. It was found that the device meets the requirements for the measurements, but could not be sensibly transported on a Nansen sled if raw GPS data were to be recorded underway. The instrument was then rebuilt and equipped with a different sensor to achieve a more compact design. In the current design the system is put at the base of the stake, a string is pulled out and put to the top of the stake to be measured. Upon pressing a button, the position and the measured length of the string are stored. We hope that this system will facilitate faster measurements in the future.

On 5 January, the stake measurements of the first 30 km along the main transects starting at *Neumayer Station III* were carried out. On 12 January, the measurements were continued until kilometer 100. Both surveys were carried out by two snowmachines.

On 1 February, the team then set off together with the GrouZe Traverse in the direction of the grounding line. On 2 February, the measurements were continued seamlessly from kilometer 100 further south. On 5 February, the last survey location, the Kottas depot, was successfully accessed. On the same day, the return trip towards the grounding line camp was started, which was reached on 6 February.

A total of 779 bamboo stakes were surveyed and 248 stakes were renewed. South of the grounding line, stakes were renewed only in 1 km intervals, whereas north of it a distance of 500 meters was aimed at. Up to stake KP717 4 m long bamboos with a red-painted tip were used for replacement, from KP718 south bamboos stakes with a black-painted tip (this helps to identify the year of deployment when multiple stakes are encountered at a single site).

At the end of each day, a snow core was drilled to obtain snow density. The snow core (length: ~ 1 m, 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.

Preliminary (expected) results

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 4.11.1 summarizes the calculated snow core densities along the traverse.

Tab. 4.11.1: Location of density measurements performed with the Kovacs ice corer.

Date	CoreID	Lat °	Lon °	Mean density kg/cm^3	Maximum depth/cm
05.01.23	DML_KO22_SC01	-70.943533	-08.547167	404	74
02.02.23	DML_KO22_SC02	-71.581474	-08.384043	311	101
02.02.23	DML_KO22_SC03	-72.270339	-08.943475	371	110
03.02.23	DML_KO22_SC04	-73.004253	-09.680968	376	117
04.02.23	DML_KO22_SC05	-74.014547	-09.740220	421	112

Data management

The height measurements and density data are currently quality checked 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 cruise at the latest. By default, the CC-BY license as well as the meta-data base sensor.awi.de will be applied.

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_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.

4.12 MIMO-EIS – Monitoring Melt where Ice meets Ocean – Continuous Observation of Ice-Shelf basal Melt on Ekström Ice Shelf, Antarctica

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Objectives

On-ice seismic measurement over the last ten years on Ekströmisen resulted in a mapping of its bathymetry to that extent, that it is now the best known of all ice shelves in the Dronning Maud Land region (Eisermann et al., 2020), only topped by those ice shelves in Antarctica where sub-shelf AUV observations from swath sonars are available. It turned out that the bathymetry of Ekströmisen is much more complex than previously assumed and as currently implemented in all tidal and other numerical ocean models (Smith et al., 2020). Instead of a homogeneously flat seafloor, as for instance released in the BEDMAP2 compilation, the bathymetry shows a deep trough in the center of the ice shelf, more than 900 m below the surface of the up to 350 m thick ice shelf. Consequently, it is obvious that all previous ocean model results were not able to consider the correct bathymetry and thus produced results which might be considerably wrong. Coming along with our improved knowledge of the bathymetry, we now have the opportunity to assess the influence of errors and uncertainties in the bathymetry on ocean-modelling results. This would also enable us to predict basal melt rates of Ekströmisen more realistically than previously possible. Such efforts, however, will strongly benefit from direct observations of the basal melt rates on Ekströmisen. In addition, satellite-based estimates of basal melting of ice shelves are highly uncertain (Berger et al., 2020) as are those derived from models (Richter et al., 2022), and widely lack validating/calibrating points. Ground-based measurements of basal melting on Ekström ice shelf would therefore offer an invaluable asset to constrain satellite-based measurements. The main research questions of this project therefore are:

- How variable are basal melt rates over the course of a year underneath Ekströmisen?
- How are temporal changes in melt rates linked to atmospheric, cryospheric or oceanic conditions?
- Can these melt rates reliably be reproduced by a state-of-the-art ocean model when using the new bathymetry?

The method of choice consists of repeatedly measuring the ice thickness with a phase-sensitive radar (pRES). The change of ice thickness over time, under consideration of other effects, basically results in the basal melt rate.

Fieldwork

After preparation of the maintenance during December 2022 the autonomous pRES (ApRES) system at the site MIMO-EIS-8 was dug out by a team of four people over five hours, then dismounted on 31 December 2022 and data downloaded. The station was raised to the new level of the surface redeployed by a team of two persons and put in operation in the autonomous

(ApRES) mode on 2 January 2023 with an antenna separation of 8 m (Fig. 4.12.1). 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 were performed on 31 December 2022 and 2 January 2023 at seven locations (MIMO-EIS-4 to MIMO-EIS-8, 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. 4.12.1)).

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.

While maintenance of all stations west and south of *Neumayer Station III* could most effectively and efficiently be performed with the canopy Hilux during a period of good weather (at least two days after fresh snow accumulation), measurements of the site MIMO-EIS-4 were conducted with a snowmachine.

Fig. 4.12.1: Maintenance and new deployment of the ApRES system controller (center pit) and two frame antennas (front and back pits) of the site after completion of the new deployment on 2 January 2023, with the system buried at about 20 cm depth below the current surface (left picture) and system controller (two flags in center) and each frame antenna (left and right flag) covered with wooden boards. The Iridium antenna is mounted on the bamboo pole with black tape (right picture).

Preliminary results

Preliminary analysis of the repeated pRES measurement, couples measured at different seasons, and taking into account strain thinning and firn compaction, yield average basal melt rates (Tab. 4.12.1). 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 the 2021/22 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 2022. 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.

As the objectives of MIMO-EIS are strongly overlapping with 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 (see Chapter 4.15) will continue the operation as a longer-term station as site MIMO-EIS-D. 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 second winter 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.

Tab. 4.12.1: Position of pRES measurements on Ekströmisen and preliminary values for the long-term average basal melt rates a_b.

Station	Latitude 2021/22 °	Longitude 2021/22 °	Latitude 2022/23 °	Longitude 2022/23 °	a_b m/a
MIMO-EIS-4	-70.64796	-8.20670	-70.64662	-8.20719	2.66
MIMO-EIS-5	-70.74620	-8.81913	-70.74422	-8.82184	0.33
MIMO-EIS-6	-70.80960	-8.62408	-70.80771	-8.62620	n. a.
MIMO-EIS-7	-70.83208	-8.71745	-70.83056	-8.72028	0.37
MIMO-EIS-8	-70.82350	-8.73742	-70.82139	-8.74583	0.41
MIMO-EIS-A	-70.76477	-8.86800	-70.76293	-8.87127	0.41
MIMO-EIS-B	-70.87695	-8.87823	-70.87500	-8.88083	0.45
MIMO-EIS-C	-70.68480	-8.45070	-70.68314	-8.45211	0.57

Data management

After primary publication, the ApRES and pRES 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 cruise at the latest. By default, the CC-BY license will be applied. Metadata for new measurements is already available in sensor.awi.de.

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_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 & 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

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Richter O, Gwyther DE, King MA & Galton-Fenzi BK (2022) The impact of tides on Antarctic ice shelf melting, The Cryosphere 16:1409–1429. https://doi.org/10.5194/tc-16-1409-2022

Smith EC, Hattermann T, Kuhn G, Gaedicke C, Berger S, Drews R et al. (2020) Detailed seismic bathymetry beneath Ekström Ice Shelf, Antarctica: Implications for glacial history and ice-ocean interaction. Geophysical Research Letters 47:e2019GL086187. https://doi.org/10.1029/2019GL086187 EGU2020-15477

4.13 GNSS – Reflecto-/Refractometry

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Grant-No. AWI_ANT_8

Objectives

The project aims at developing a methodology for deriving automated and continuous specific surface mass balance (SMB) time series for fast moving parts of ice sheets and shelves (>10m/a) by an accurate and simultaneous estimation of continuous *in-situ* snow density, snow water equivalent (SWE), and snow deposition and erosion, averaged over an area of several square metres. A combined Global Navigation Satellite Systems reflecto-/refractometry (GNSS-RR) approach based on *in-situ* refracted and reflected GNSS signals is being developed and thoroughly evaluated regarding its applicability on the fast moving, high latitude Ekström Ice Shelf, in the vicinity of the *Neumayer Station III* in Antarctica. The newly developed combined GNSS-RR approach is expected to improve SMB estimates of polar ice sheets, ice streams, and glaciers due to the simultaneous, continuous, and accurate quantification of snow density, SWE, and snow deposition and erosion with a high temporal resolution, independent on weather conditions.

Reliable *in-situ* surface mass balance estimates are scarce due to limited spatial and temporal data availability. While surface accumulation can be obtained in various ways, conversion to mass requires knowledge of the snow density, which is more difficult to obtain. The individual GNSS-RR methods have already been successfully applied on stable grounds and seasonal snowpacks and are now being combined and transferred to moving surfaces like ice sheets. The deployed devices are geared towards prototype applications for reliable low-cost applications, which will allow large-scale retrieval of surface mass balance for general cryospheric applications, not only on ice sheets or shelves, but also sea ice. Regional climate models, snow modelling, and extensive remote sensing data products will eventually profit from calibration and validation based on the derived field measurements, once such sensors can be deployed on larger scales.

Fieldwork

Since the installation of the GNSS-RR system in November 2021, the system was reliably running without any problems until mid-January 2023. In February 2023, we realized that no data from the GNSS base station was transmitted anymore to the Neumayer data server since 18 January 2023. The air chemistry overwinterer checked and restarted the GNSS base receiver in the field on 22 February 2023. The restart did not help to fix the problem. The base receiver was de-mounted on the 25 February 2023 and tested individually inside the *Neumayer Station III*. All missing data was available at the receiver internal SD card and manually copied to the Neumayer server. Thus, the receiver was always working, but seemed to had a problem with the Ethernet connection. A missing network cable was needed for testing the receiver configuration, but could not be brought back from the GNSS-RR system due to stormy weather conditions.

The problem with the GNSS base receiver was fixed by IT after the missing power cable could be removed from the Pelican box on the mast. The receiver had probably lost its assigned IP address after a power failure in mid-January. After it was given back its IP address, it was able to access the network again. On 7 March 2023, the receiver was returned to the Pelikan box on the mast, connected and switched on. On 18 March 2023, the receiver was again finally fixed in the box with cable ties (self-made adapters necessary to connect the two open ends). The data transmission is since then running again without any problems. Photos of the setup on the mast were also taken.

Preliminary results

The combined GNSS-RR (Fig. 4.13.1) method was successfully applied on a fast moving, polar ice shelf. Snow accumulation results could be accurately determined using reflected GNSS observations. SWE was successfully estimated with a high temporal resolution (15 min) using GNSS refractometry based on the biased-up component. A high level of agreement to available reference data was achieved for both individual methods. Combining results from both methods illustrated the potential of using a combined GNSS-RR approach for deriving *in-situ* snow densities (Fig. 4.13.2) with a 15 min resolution. A minimum amount (20 cm) of snow above the buried GNSS antenna was thereby shown to be crucial to achieve reliable results. Results of the first 16 months of data show a high level of agreement with reference observations from the same site. Snow accumulation is derived with an RMSE around 9 cm, SWE around 40 mm w.e., and density around 72 kg/m^3 (Steiner et al., 2023, in preparation).

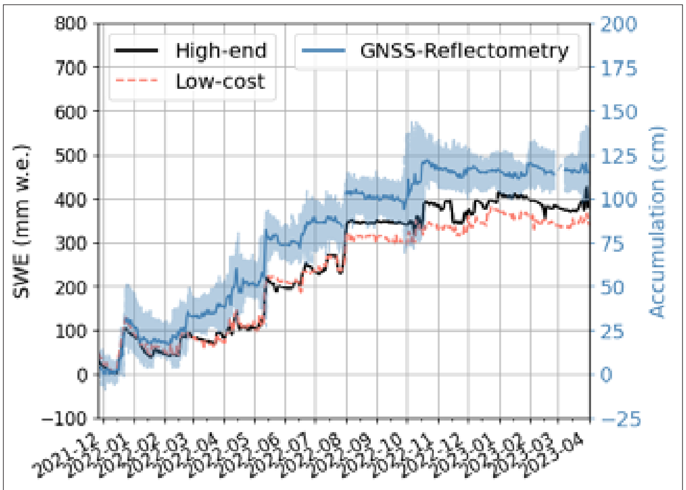

Fig. 4.13.1: Derived timeseries from GNSS reflectometry and refractometry for accumulation and SWE

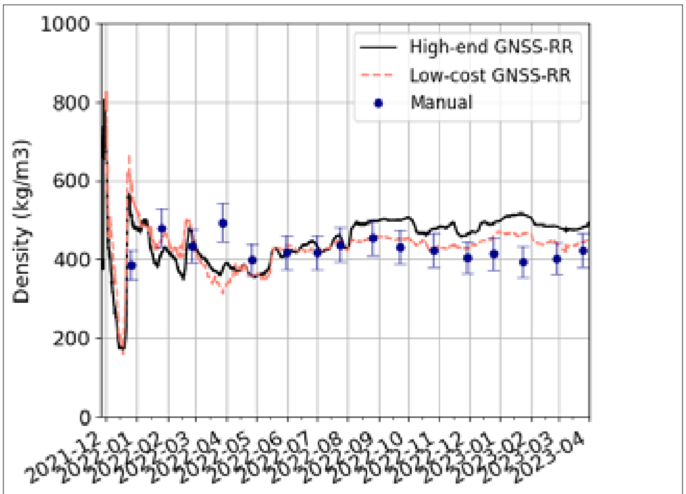

Fig. 4.13.2: GNSS-RR derived density time series from the high-end and low-cost system compared to manual observations.

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.

At the current stage, PANGAEA data are ticketed at PDI-34852. The GNSS data are streamed to AWI and available via a dashboard: https://dashboard.awi.de/?dashboard=27826

As part of AWI's O2A strategy, the individual sensors are available at:

https://sensor.awi.de/?id=8283

https://sensor.awi.de/?id=8282

https://sensor.awi.de/?id=8281

The analysis code is available on Gitub and will be made public upon first publication (Steiner et al., in preparation): https://github.com/lasteine/GNSS_RR

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 2, Subtopic 1, 3, 4.

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 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

Steiner L, Schmitthüsen H, Wickert J, Eisen O, Combined GNSS reflectometry/refractometry for automated and continuous in situ surface mass balance estimation on an Antarctic ice shelf, The Cryosphere, 2022, *in preparation*.

4.14 Grouze – Grounding Zone of the Ekström Ice Shelf – Geophysical Characterization with GNSS, Seismology and Magnetotelluric

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Grant-No. AWI_ANT_23

Objectives

Antarctica's ice shelves are the main drain for mass loss of the ice sheet and the interface to the ocean. A major control of this process is ice-ocean interaction. Tides are the most direct forces acting on the ice shelves, inducing vertical and horizontal motion and a recent study revealed a strong impact of tides on the ice flow rates at the Ekström Ice Shelf (Fromm et al., 2023). The northward flow of the ice stream is mainly modulated with 3 and 4 cpd (cycles per day), whereas the dominant vertical tides have a periodicity of 1 and 2 cpd and 10 times larger amplitudes than the 3 and 4 cpd tides. Particularly the causes of the higher frequency tidal modulations are still poorly understood and observational constrains are sparse. During tide induced grounding line migration a thin water layer forms beneath the ice at the grounding zone. Within this thin water layer friction becomes important for the tides and could cause the observed high harmonic tidal constituents. The thin water layer also reduces basal drag between the ice and the bedrock and such enhances the ice flow observed further downstream the ice shelf.

We investigate these ice dynamic processes with a geophysical/geodetic study of an exemplary region of the grounding zone of the Ekström Ice Shelf. We capture vertical and horizontal motions of the ice using GNSS stations along the ice flow direction, from the freely floating ice shelf to permanently grounded ice. A seismological network allows us to locate ice quake activity from e.g., tidal motion or sticky spots at the ice-bed interface, which act as pinning points within the ice. With the magnetotelluric method (MT) we can image the sub-ice ocean-land transition and the crustal structure beneath. Another objective is to estimate the volume of highly conductive sea water beneath the resistive grounded ice and to test for possible temporal variations related to tidal motion.

The objectives of this project are in line with the glaciological project ReMeltRadar (see Chapter 4.15) which targets the same area around the grounding zone to estimate basal melt rates, ice rheology and local bed topography. Integrating the results of these two projects with previous research at *Neumayer Station III* and the Ekström Ice Shelf has the potential to establish the Ekström Ice Shelf as a reference for small ice shelves in East Antarctica and to reveal key processes in ice-ocean interaction.

Fieldwork

After the field teams arrived *at Neumayer Station III* on 26 January 2023, they began to prepare the traverse and to test the magnetotelluric (MT) equipment in the lab. The traverse departed on 1 February and reached the field camp on 2 February. Within the next 18 days, 15 three-component broad band seismometer stations and 7 geodetic GNSS stations were dismantled, which were setup in January 2022 (Tab. 4.14.1, Fig. 4.14.1). Data coverage ranges between 75 and 358 days. 6 of the GNSS stations were redeployed in a small temporary network around the camp to measure deformation and strain during the period of stay (approximately 10 days).

A total of 19 MT stations with an average site spacing of 5 km were deployed in the vicinity of the grounding line of the Ekström Ice shelf. The data were recorded in a broad-band configuration covering a frequency range of approximately 10 kHz to 1 mHz.

The members of the GrouZE traverse arrived at *Neumayer Station III* on 19 February.

Tab. 4.14.1: Positions, setup and dismantle dates of seismological, GNSS and MT stations

Station	Setup Date	Lat	Lon	End Date
CAMP @ GPS03	02.02.23	-71.71318	-8.66493	18.02.23
GPS01	06.01.22	-71.68914	-8.61441	08.02.23
GPS02	04.01.22	-71.70590	-8.64981	07.02.23
GPS03	06.01.22	-71.71318	-8.66493	02.02.23
GPS04	06.01.22	-71.72010	-8.68133	05.02.23
GPS05	05.01.22	-71.73454	-8.71058	05.02.23
GPS06	06.01.22	-71.77009	-8.79550	06.02.23
GPS07	09.01.22	-71.88210	-8.93874	03.02.23
GPS07.1	03.02.22	-71.88210	-8.93874	17.02.23
GR01	03.01.22	-71.66424	-8.44632	02.02.23
GR02	03.01.22	-71.60346	-8.40712	01.02.23
GR03	06.01.22	-71.66758	-8.62589	08.02.23
GR04	04.12.22	-71.67220	-8.77891	05.02.23
GR05	06.01.22	-71.71391	-8.68844	06.02.23
GR06	04.01.22	-71.72048	-8.36772	13.02.23
GR07	06.01.22	-71.69957	-8.65631	07.02.23
GR08	06.01.22	-71.71231	-8.62793	09.02.23
GR09	04.01.22	-71.72679	-8.52812	10.02.23
GR10	04.01.22	-71.73443	-8.71543	05.01.23
GR11	09.01.22	-71.79163	-8.70724	06.02.23
GR12	09.01.22	-71.88509	-8.78618	04.02.23
GR13	09.01.22	-71.88868	-8.91540	03.02.23
GR14	10.01.22	-71.92461	-8.71886	04.02.23
GR15	10.01.22	-71.92182	-8.84858	03.02.23
GRS0	03.02.23	-71,71145	-8,66470	17.02.23
GRS1	08.02.23	-71,67816	-8,58968	17.02.23
GRS2	07.02.23	-71,69032	-8,47308	17.02.23
GRS3	07.02.23	-71,74595	-8,56624	17.02.23
GRS4	06.02.23	-71,74169	-8,76618	17.02.23
GRS5	08.02.23	-71,68809	-8,68883	17.02.23
MT103	08.02.23	-71.85419	-9.15837	10.02.23
MT105	08.02.23	-71.88387	-9.04466	10.02.23
MT107	10.02.23	-71.91748	-8.91477	13.02.23
MT205	05.02.23	-71.84423	-8.94525	08.02.23
MT301	12.02.23	-71.76838	-9.00067	15.02.23
MT303	11.02.23	-71.78189	-8.96034	14.02.23
MT305	04.02.23	-71.80953	-8.85762	08.02.23

Station	Setup Date	Lat	Lon	End Date
MT307	07.02.23	-71.83923	-8.73937	11.02.23
MT309	10.02.23	-71.86955	-8.62550	13.03.23
MT405	03.02.23	-71.77033	-8.75782	07.02.23
MT501	14.02.23	-71.67820	-8.90251	17.02.23
MT503	15.02.23	-71.70815	-8.78971	18.02.23
MT505	03.02.23	-71.73808	-8.67582	06.02.23
MT507	13.03.23	-71.76643	-8.56892	16.02.23
MT509	06.02.23	-71.79481	-8.46468	09.02.23
MT511	09.02.23	-71.82464	-8.34753	12.02.23
MT605	02.02.23	-71.71666	-8.61442	05.02.23
MT655	13.02.23	-71.69069	-8.54829	16.02.23
MT705	02.02.23	-71.67286	-8.51095	05.02.23

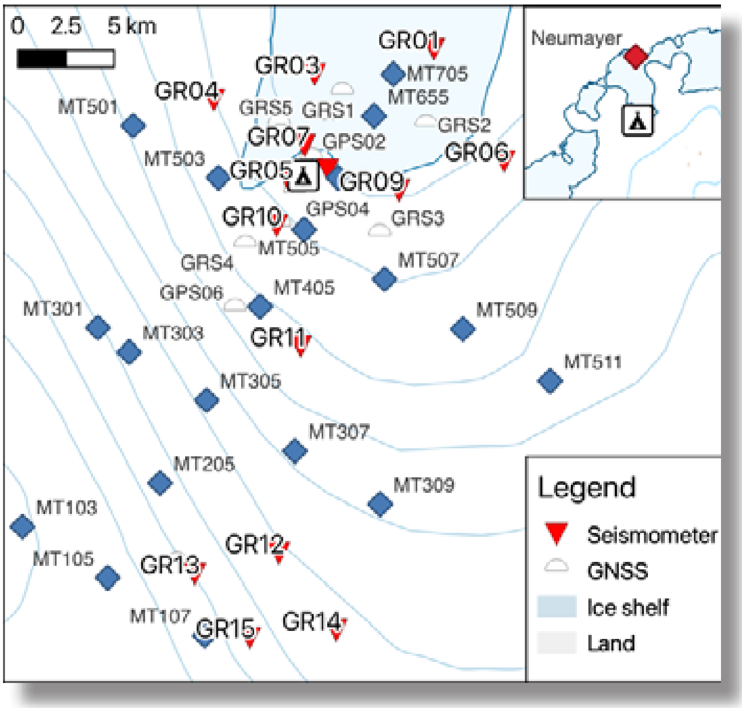

Fig. 4.14.1: Positions of seismological stations (GR01-GR15), GNSS Stations (GPS1-GPS7, GRS0-5) and MT stations (MT103-MT705)

Preliminary results

All collected data is of high quality. The seismic data reveal abundant local cryoseismic and teleseismic events. The local cryoseismicity is affected by tidal forcing only at the stations close to the grounding line, whereas stations in more than 10 km distance show only weak tidally modulated seismicity with diurnal tides.

The GNSS sites GPS01-GPS06 also show good quality with a small number of outliers in the processed coordinate timeline. GPS07 has about 50 % cycle slips on the L2 frequency and hence is affected by larger uncertaintys. The tidal analysis in the three coordinate directions shows the strongest amplitudes in the north component (approximatley in ice flux direction) for semi-diurnal and longer tides. In the east component, a high amplitude on a frequency of 3 cpd can be found. The tidal deformation within the GNSS network is still to be analyzed.

A preliminary processing of the MT data was carried out in the field camp. Figure 4.14.4 shows apparent resistivity and phase curves of two exemplary sites. Smoothly varying curves with very little scatter and generally small error bars indicate superb data quality. Site 655 was collected north of the grounding line where the shelf-ice covers ocean water, while site 507 is situated south of the grounding line where the shelf-ice is expected to be on Archean basement rocks (see Fig. 4.14.1 for site locations). This situation is reflected in the general behaviour of the apparent resistivity curves. The highly conductive ocean water causes a drastic decrease of the apparent resistivity at site 655, while resistivities are generally high over the entire period range for site 507. A more thorough interpretation of the data requires 3D inversion of the data.

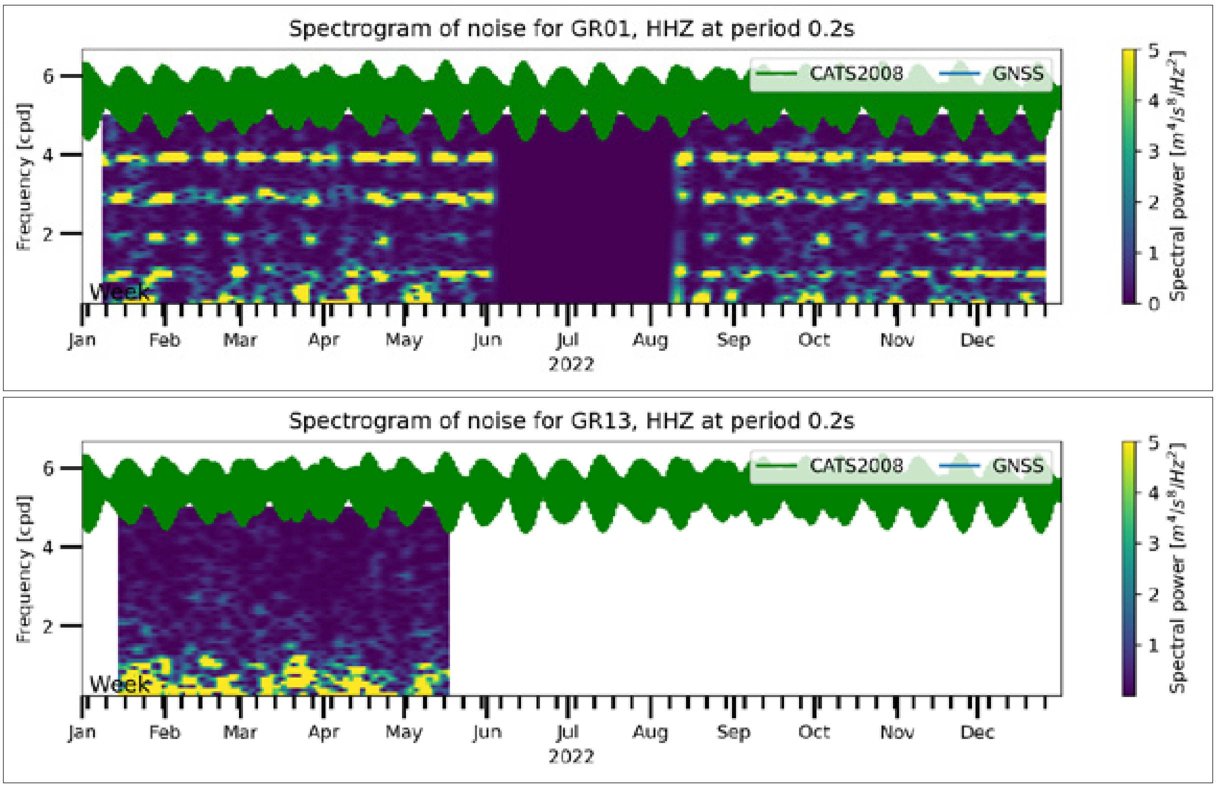

Fig. 4.14.2: Spectrograms of seismic noise levels calculated from probabilistic power spectral densities (PPSD, McNamara and Buland, 2004; Fromm et al., 2023) reveal tidal signals with 1-4 cpd (cycles per day) at station GR01 which is close to the grounding line, whereas station GR13, approximately 20 km away from the grounding line, is not affected by tidal forcing.

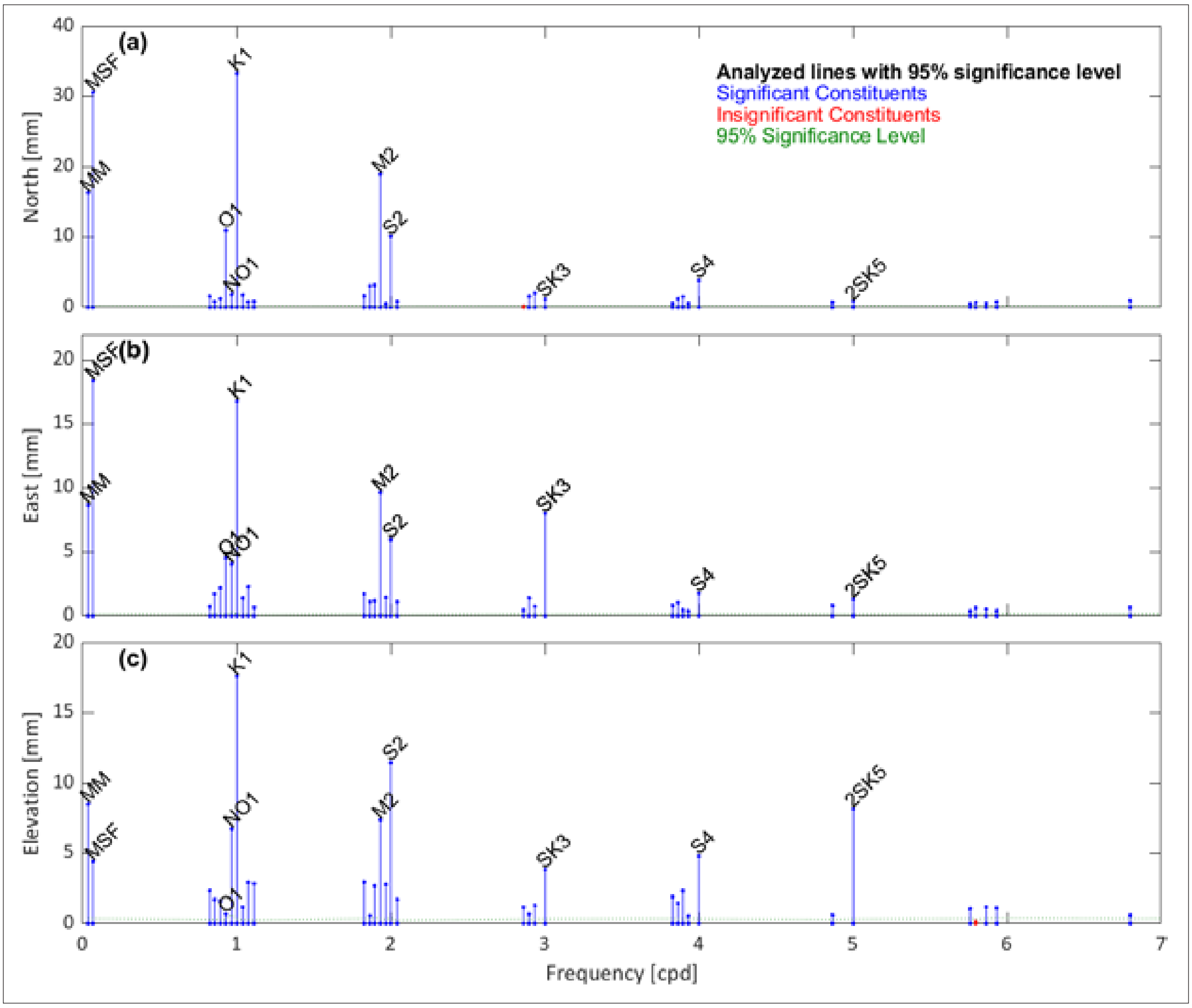

Fig. 4.14.3: Amplitudes of the tidal ice movement at GPS02 for (a) the north, (b) the east and (c) the hight component

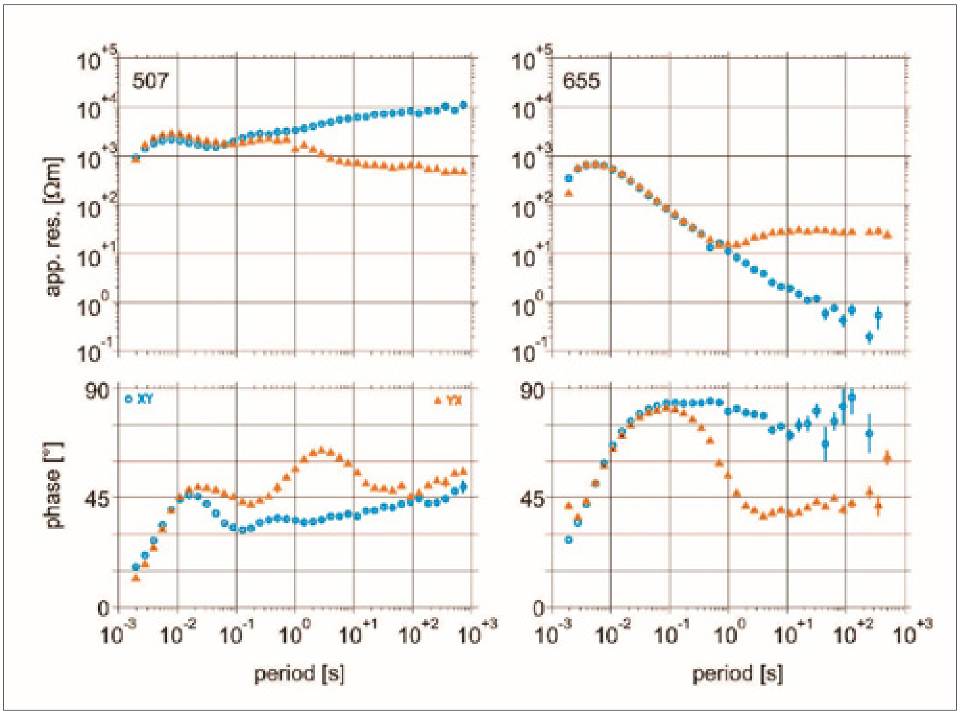

Fig. 4.14.4: Preliminary results (sounding curves) of the magnetotelluric measurements; the diagram on the left shows apparent resistivity in [Ωm] and phase curves in [°] over period in [s] of site 655, the data on the right-hand side are from site 507. The different colours indicate the two main directional components, which would lie on top of each other in case of a one dimensional subsurface.

Data management

After primary publication, the seismological data will be archived, published and disseminated according to international standards via Geofon (https://geofon.gfz-potsdam.de/doi/network/AW).

The GNSS data will be submitted to an appropriate long-term archive that is known within the GNSS community and allows open online access to the data.

The magnetotelluric data will be archived and published in the GIPP data repository (gipp.gfz-potsdam.de/projects).

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_23** 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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Fromm T, Schlindwein V, Helm V, Fofonova V (2023) Observations of the quarter- and terdiurnal ocean tides affecting ice shelf dynamics of Ekström Ice Shelf, Antarctica, https://doi.org/10.1017/jog.2023.4

4.15 ReMeltRadar – Determing Ice Shelf Rheology and Ocean induced Melting across Timescales

Mohammadreza Ershadi[1], Falk Oraschewski[1], Reinhard Drews[1] (not in the field), Inka Koch[1] (not in the field), Vjeran Višjnević[1] (not in the field) , Guy Moss[1] (not in the field), Paul Bons[1] (not in the field), Daniela Jansen[2] (not in the field), Olaf Eisen[2,3] (not in the field), Ilka Weikusat[2] (not in the field), Lai Bun Lok[4] (not in the field), Jonathan Hawkins[4] (not in the field), Keith Nicholls[5] (not in the field)

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Grant-No. AWI_ANT_18

Outline

Ocean induced melting at the bottom of Antarctic ice shelves accounts for approximately half of the total ice-mass loss of the Antarctic Ice Sheet. However, processes that govern the heat exchange at the ice-ocean interface are notoriously difficult to observe. Consequently, the coupling between ice- and ocean models rely on a number of poorly constrained parametrizations which require more observational support both spatially and temporally. Moreover, ice shelves decelerate the ice discharge from tributary glaciers, and the magnitude of deceleration depends on the mechanical rigidity of the ice shelf itself. This rigidity is governed by a non-Newtonian, temperature dependent and anisotropic ice-shelf rheology. This also requires observations as model calibration to today's ice thickness or velocities is strongly underconstrained.

Objectives

ReMeltRadar's objectives are (1) to quantify the spatial variable ocean-induced melting from seasonal to centennial timescales, (2) understanding processes that govern ocean-induced melting at sub-kilometers scales, and (3) to map spatial variability in ice anisotropy across different flow regimes. We aim to achieve these objectives with a combination of methods that include model-data fusion (i.e., inversion of the radar stratigraphy using ice-flow forward models), instrument development (i.e., a novel radar combined with an autonomous rover), and profiling with radar polarimetry that is sensitive to the crystal lattice structure.

The specific targets of the 2022/23 field season contain a number of repeat measurements of the 2021/22 season (cf. Reports on Polar and Marine Research 767/2022 section 4.18), an extension of existing ground-penetrating radar grids, and proof-of-concept studies for envisaged radar developments.

Fieldwork

RMR partnered with other projects (GrouZE – Chapter 4.14, Mimo-EIS – Chapter 4.12) in order to share logistics for the traverse from *Neumayer Station III* towards the grounding line. The traverse took place from 1 February 2023 to 19 February 2023. Fieldwork included revisiting of all static radar sites from the 2021/22 season, maintenance of a continuously measuring radar at the grounding-line, ground-based radar profiling with frequencies 50 – 500 MHz, and proof-of-concept studies for advanced radar surveys such as polarimetric common-midpoint measurements and along-track focusing with synthetic aperture radar techniques.

Preliminary (expected) results

Revisits of the static radar sites from 2021/22 season (coloured circles in Fig. 4.15.1) with a phase-coherent radar suggest that the observed thickness change can successfully be disentangled to separate ocean-induced melting from strain-induced thinning for about 50 % of the sites. The time series from the continuously measuring phased coherent radar near the grounding line equally provides promising results and quantifies ocean-induced melting in a sub-daily resolution over an entire year. Signatures inferred from the polarimetric measuring technique (Ershadi et al., 2022) suggest that the majority of the inferred patterns have remained stable over the one-year time period as expected. It seems therefore viable to use the polarimetric radar backscatter as constraints to map ice-fabric changes across different flow regimes.

The revisits of the ground-based radar profiles show that basal features (here basal terraces), can reliably be tracked across a 1-year time difference (Fig. 4.15.2). The degree of signal stability is remarkable and suggests that the spatiotemporal evolution of these features can reliably be observed over longer time spans. This is expected to deliver insights into processes leading to their formation and stability. Many ground-based radar profiles were also spatially extended. In particular, the along-flow transect covers now the entire Ekström Ice Shelf and provides internal layering to a depth of about 200 m. This can be used as an integrated memory for ocean-induced melting and atmospheric precipitation over centennial timescales (Višnjević et al., 2022). Moreover, signatures just upstream of the grounding line indicate the existence of kinematic waves in the shallow firn stratigraphy, possibly providing another archive of interlinked processes between snow deposition and undulations in the surface topography.

Other proof-of-concept studies included feasibility measurements of phase-coherent & polarimetric common midpoint surveys. This can provide additional constraints on the ice-fabric characteristics using oblique ray paths. Moreover, the feasibility of phase-coherent profiling was tested using a center frequency of 300 MHz. This complements studies of the same type from the previous season using a similar radar centered at 30 MHz. The latter has also been deployed near *Neumayer Station III* to collect static time series of multiple weeks. Such proof-of-concept studies lend themselves for improved signal processing techniques which are capable to image steeply inclined basal structures and weak internal layering just above the ice-bed interface. This is important for a number of questions in glaciology, e.g., linking the depth-age scales of ice cores at larger depths and across longer distances.

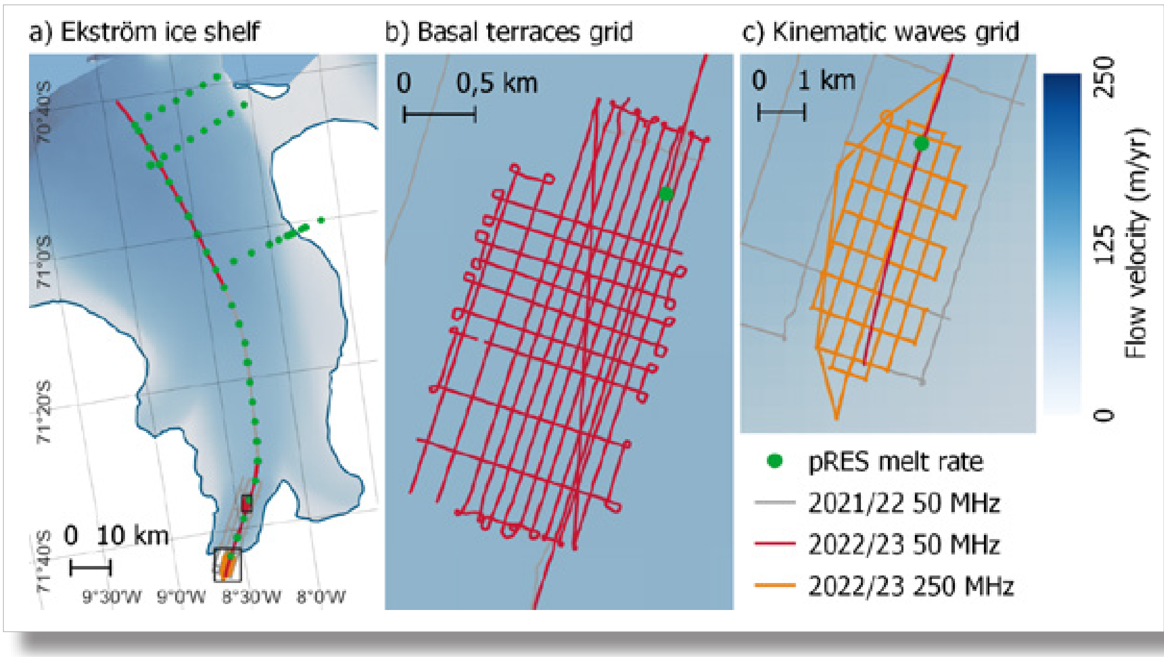

Fig. 4.15.1: Location of ground-penetrating radar transects (lines) and static radar measurement points (circles). Transects form 2021/22 (grey) were revisited with the 50 MHz radar to map temporal changes (red). 250 MHz data were collected to map kinematic waves in the firn (orange).

Fig. 4.15.2: Example of static data collection with a phase-coherent polarimetric radar; four antennas are used to measure the polarization dependency of the radio-wave trajectory through the ice.

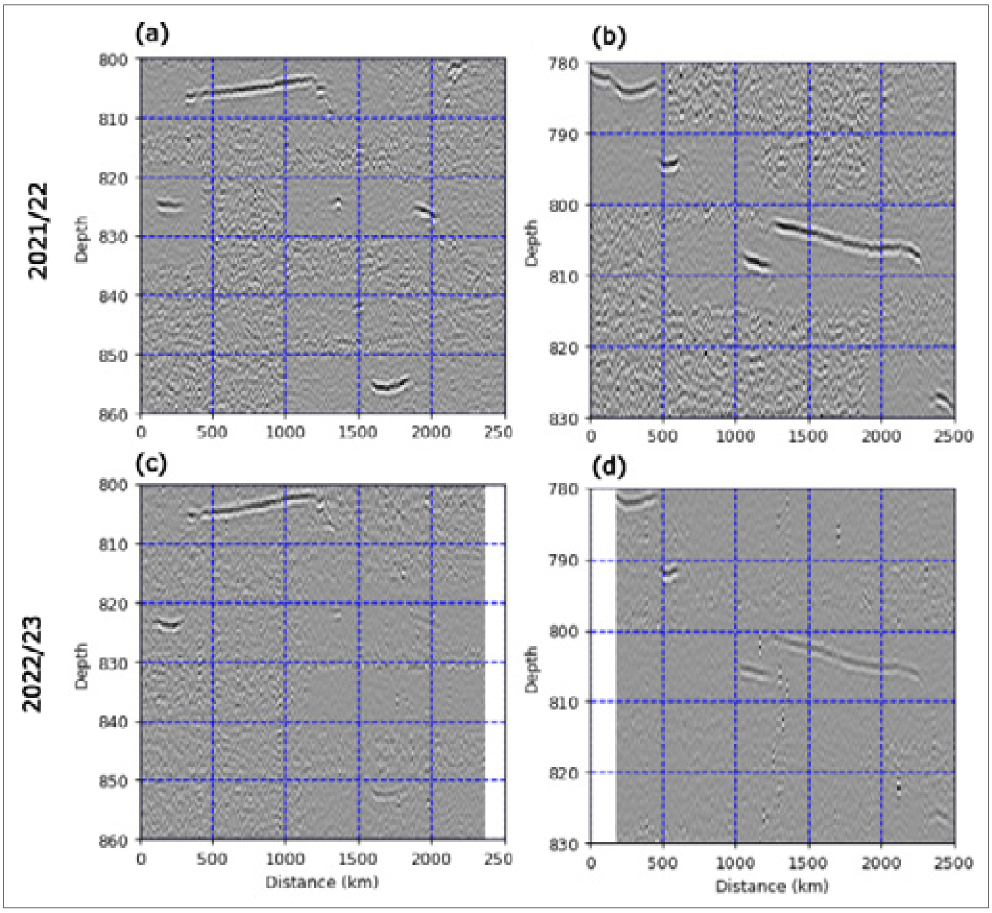

Fig. 4.15.3: Snapshots for basal terracing observed at the ice-ocean interface at Ekström Ice Shelf. Profiles (a,b) were collected in 2021/22 whereas profiles (c,d) stem from repeat visits in 2022/23. The signal stability is remarkable, and such time series can be used to decipher ocean-induced melting on small spatial scales.

Data management

Data will be submitted to an appropriate long-term archive (e.g. World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) 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 3 and by an DFG Emmy Noether Grant (DR 822/3-1).

In all publications based on this expedition, the **Grant No. AWI_ANT_18** 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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Hawkins J, Lok LB, Brennan PV, Nicholls KW (2020) HF Wire-Mesh Dipole Antennas for Broadband Ice-Penetrating Radar, IEEE Antennas and Wireless Propagation Letters, Vol. 19(2), https://doi.org/10.1109/LAWP.2020.3026723

Višnjević V, Drews R, Schannwell C, Koch I, Franke S, Jansen D, Eisen O., Predicting the steady-state isochronal stratigraphy of ice shelves using observations and modeling, https://doi.org/10.5194/tc-16-4763-2022

4.16 MICA-S – Magnetic Induction Coil Array – South

Tanja Fromm[1], Jölund Asseng[1], Benita Wagner[1], Alicia Rohnacher[1], Nora Schoeder[1], Felix Strobel[1], Hyomin Kim[2] (not in the field), Marc Lessard[3] (not in the field), Khan-Hyuk Kim[4] (not in the field), H.-J. Kwon[5] (not in the field), Jürgen Matzka[6] (not in the field), Michelle Salzano[3] (not in the field

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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 2022, the MICA-S data acquisition was running without major problems except an interruption during a power loss at *Neumayer Station III* on the 16 December. Furthermore, the magnetometer was temporarily shut down on the 29 June from 10:33 am to 10:52 am in order to exclude the instrument being the source of a radio disturbance found at the station.

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 2022/23 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 1.25 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. On 1 February 2023 it was located at S70°40.496' W8°16.537'.

Preliminary results

Figure 4.16.1 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 geomagetic 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).

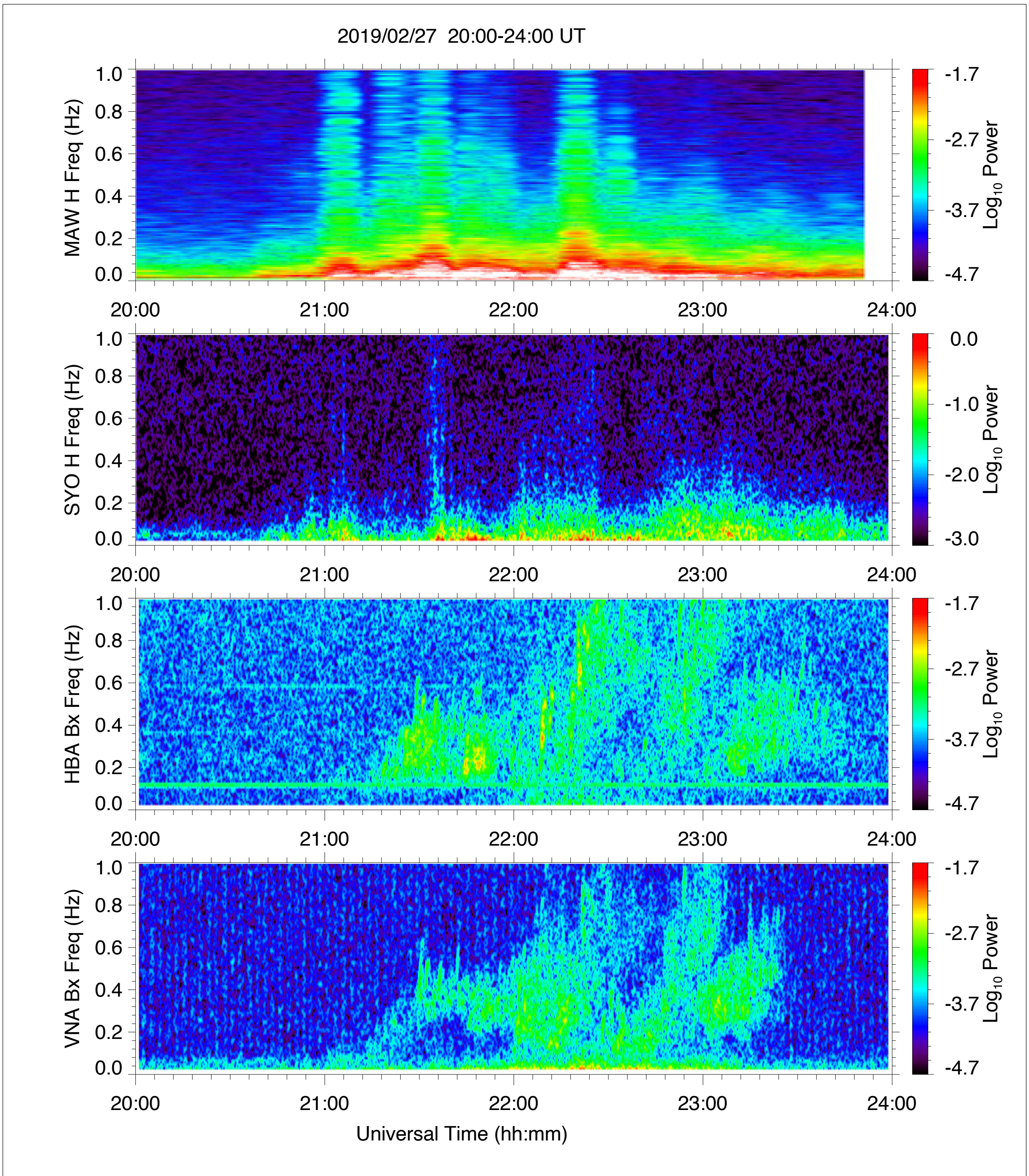

Fig. 4.16.1: Geomagnetic spectrograms on 27 February 2019 using data from Antarctic stations Mawson (MAW), Syowa (SYO), Halley Research Station (HBA), and Neumayer Station III (VNA). Intervals of Pulsations of Diminishing Periods (IPDPs), a subtype of EMIC waves, are observed at HBA and VNA (-62.2 and -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 according to international standards either at AWI by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the cruise at the latest. By default, the CC-BY license will be applied or by 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), http://dx.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), http://dx.doi.org/10.1029/2022ja030600

4.17 NODEMPICE 2022/23

Dimitri Zigone[1] (not in the field), Céline Le Bohec[2,3] (not in the field), Daniel Zitterbart[4,5], Alicia Rohnacher[6], Benita Wagner[6], Jölund Asseng[6], Stefanie Arndt[6], Olaf Eisen[6,7] (not in the field), Vera Schlindwein[6,7] (not in the field), Christian Haas[6,7] (not in the field)

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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 10s to 100s 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 – behavioural 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 means, 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* 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 preliminary study where only one seismometer was installed to get a first recording of environmental noise and estimate its characteristics to optimize the deployment in the winter season 2023.

Fig. 4.17.1: Left: buried three single-channel vertical component geophones (encircled in red); right: a submerged freeboard leads to flooding of the sea-ice surface.

Fieldwork

On 26 June 2022 the recording system consisting of a Guralp seismometer (SNR T35658) and a DataCube (SNR B6H) recording unit with an external power supply was deployed at the location 70.59908°S/8.14373°E, around 60 m west of a small penguin colony. The system was marked with two bamboo flags in a distance of 10 m to the seismometer. The GPS antenna of the DataCube was fixed to the southern flag, next to which a box with the DataCube was located. The seismometer was leveled on a wooden board.

In September 2022 the configuration was changed so that the Lennartz seismometer was connected to a Reftek data acquisition, and the DataCube acts as a data logger for three 1D geophones (Fig. 4.17.1) that are buried about 10 meters south of the seismometer. Both stations were powered by a 12V battery each. When attempting to remove the system on 14 October 2023 water was encountered after digging to about 1 meter due to a negative freeboard, which caused water to accumulate between the sea ice and snow cover (Fig. 4.17.1). Nevertheless, all systems were still operating nominally.

After dismounting the system, the data was downloaded and transferred to Bremerhaven.

Preliminary (expected) results

A first analysis of the recordings indicates the following findings:

- The initial logger used with the seismometer caused clipping of strong amplitudes. After changing the logger, the data quality of the Lennartz seismometer is very good and no clipping occurs.
- A periodogram for the time period 10 to 17 July 2022 is shown in Figure 4.17.2.
- Comparison of Lennartz with geophone data shows that the signal-to-noise ratio is lower for the geophones. Weaker events are not clearly detectable.
- The data clearly indicate higher noise during strong wind events (Fig. 4.17.3).
- Harmonic signals (independent of tides and wind) are recorded several times per day.

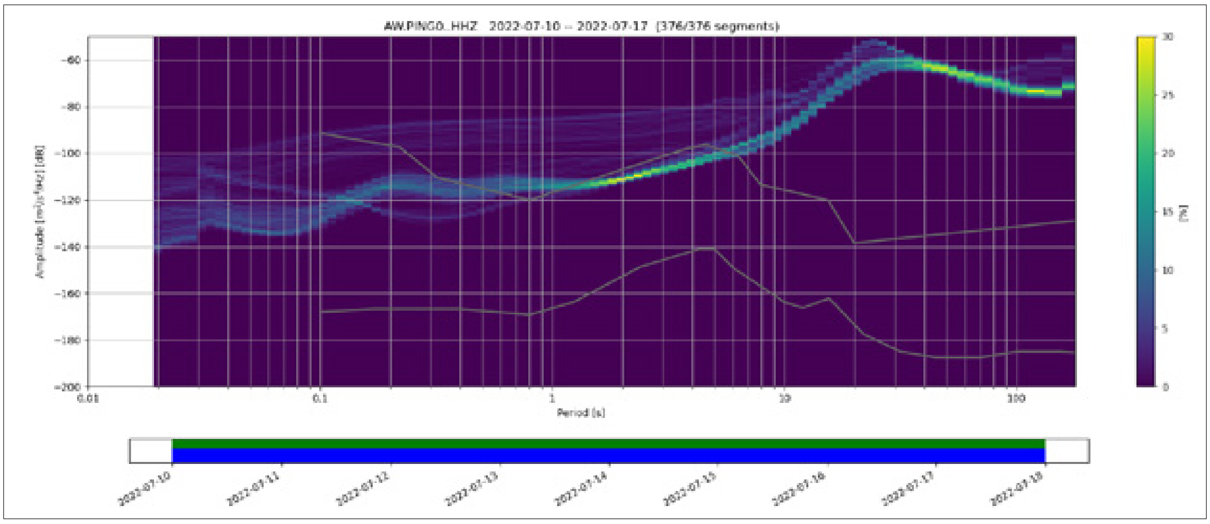

Fig. 4.17.2: Periodogram of two components of the seismometer.

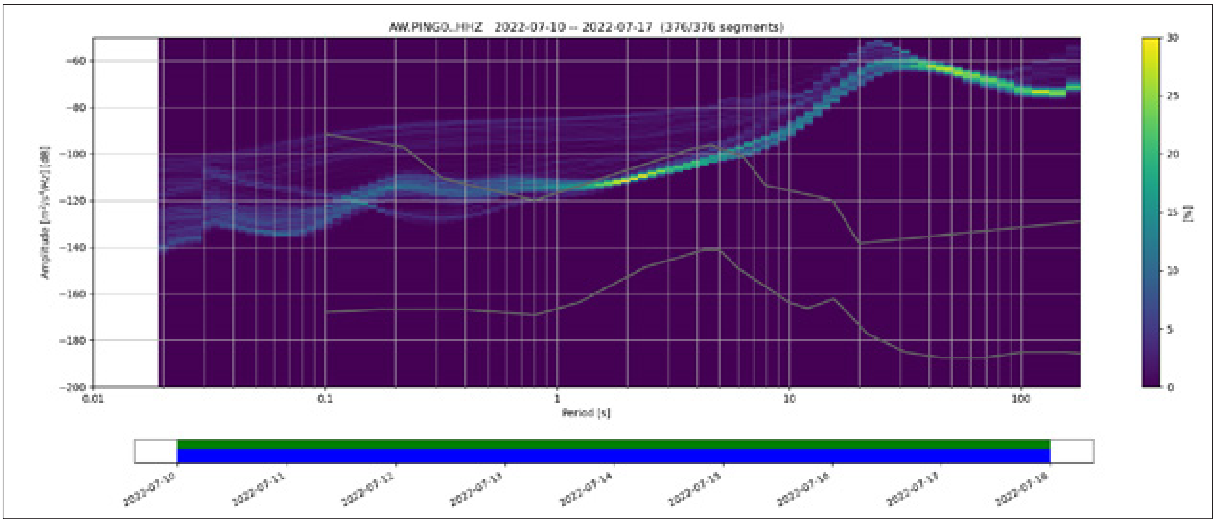

Fig. 4.17.3: Spectrogram time series on day 195, 2022.

Data management

The raw measurements are currently quality checked 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. Metadata for new measurements is already available in sensor.awi.de.

This expedition was supported by the Helmholtz Research Programme "Changing Earth – Sustaining our Future" Topic 6, Subtopic 1 and 2 and Topic 2.

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

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References

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

4.18 VACCINE – Variation in Antarctic Cloud Condensation Nuclei (CCN) and Ice Nucleating Particle (INP) Concentrations at *Neumayer Station III*

Silvia Henning[1] (not in the field), Rolf Weller[2] (not in the field), Heike Wex[1] (not in the field)

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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 Neumayer 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 2022/23 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 the overwintering staff.

Besides CCN also INP sampling was established, using the low volume filter sampling setup available in the Neumayer 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 here presented data cover already 34 months of samples, and thereby already two full annual cycles. 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. 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 three 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 1400 m (Herenz et al., 2019). Lowest number concentrations are observed in austral winter months May to August with monthly averages below 20 cm^{-3} at, e.g., the supersaturation of 0.1% and an CN concentration below 100 cm^{-3} during this time. In January, CCN increased to 90 cm^{-3} at 0.1% and CN increased to 610 cm^{-3}.

New particle formation events were observed in the summer months. Some of them were followed by particle growth into the CCN diameter range. April is a transition month between summer and winter; while the ratio between winter and summer concentrations is about 10 for both CCN and CN, for April the ratio to the summer values is only 3 for CN, but 4.5 for CCN. In April new particle formation events do still occur, but might not be followed by particle growth to CCN sizes anymore. Also, the hygroscopicity parameter exhibits an annual cycle. In summer, low values were found, ranging from 0.3 at 0.7 % to 0.6 at 0.1 % supersaturation, suggesting a strong influence of organic matter for smaller particles. In winter the particle hygroscopicity was on average much higher – around 1 – at all supersaturations, which might be caused by an increasing influence of long-range transport to the station. However, the back trajectory analysis, which will allow further insights with this respect, is ongoing.

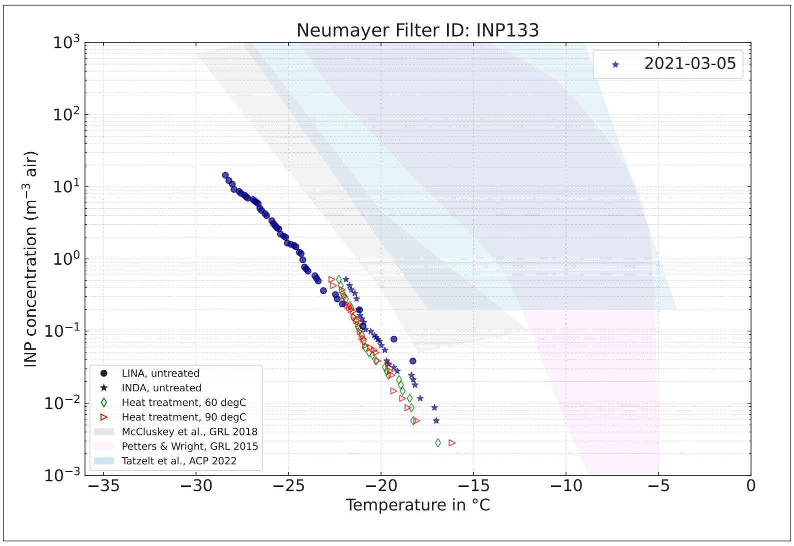

Fig. 4.18.1: Example of INP freezing spectra (blue area: Tatzelt et al., 2022, grey area: McCluskey et al., 2018); sample period was two weeks, the date gives the start day of the sampling period. Each filter is analysed with two different freezing arrays covering by this a wider freezing range. Besides the samples are heated to 60°C and 90°C to gain information on the fraction of heat-labile ice active protein.

INP results. An example for an INP freezing spectra from the off-line analysis is shown in Fig. 4.18.1. Each filter is analysed with two different freezing arrays (LINA and INDA, Hartmann et al., 2021) covering by this a wider freezing range. Besides the samples are heated to 60°C and 90°C to gain information on the fraction of heat-labile ice active protein. In general, the INP concentrations are very low even compared to other measurements in the southern hemisphere (blue area in Fig. 4.18.1: Tatzelt et al., 2022, grey area: McCluskey et al., 2018) and by this close to the detection limit. Based on a statistical approach that only considers values significantly different from the field blank values (Fig. 4.18.2), an INP parameterization for the remote region is currently being evaluated. As a preliminary result only, few samples are ice active at temperatures warmer than -15°C and no reduction of ice- activity after heating has been observed. This points towards the absence of biological INP sources in the region. The INP freezing spectra will in the further course of the project be linked with meteorological information and information on the chemical composition of the prevailing aerosol particles for identifying sources of INP and CCN over the full annual cycle.

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.

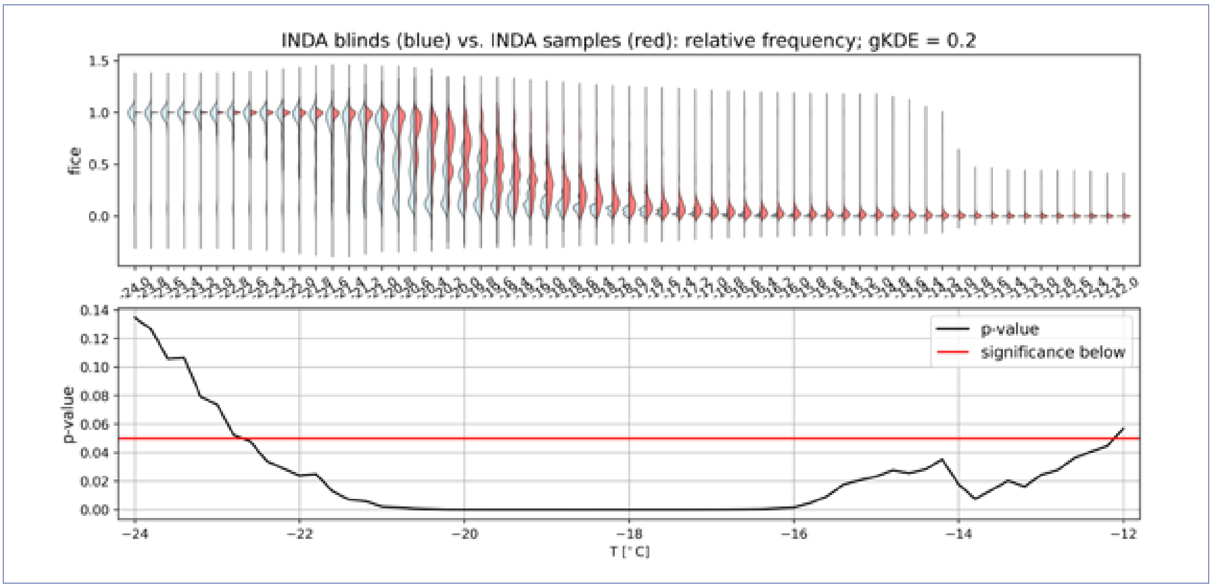

Fig. 4.18.2: Violin plot of ice fraction spectra including all currently analysed samples (red: samples, blue: field blinds). The sampling period ranges from February 2019 until December 2021 with weekly to biweekly resolution.

With the dataset resulting from the measurements introduced herein, we will be able to make significant progress in understanding the Antarctic aerosol in the future, helping to improve model predictions.

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.

This project was funded by DFG project HE 6770/3-1.

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_16** 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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Dall´Osto M, Beddows DCS, Tunved P, Krejci R, Ström J, Hansson HC, Yoon YJ, Park K-T, Becagli S, Udisti R, Onasch T, O´Dowd CD, Simó R, Harrison RM (2017) Arctic sea ice melt leads to atmospheric new particle formation. Scientific Reports 7: 3318. https://doi.org/10.1038/s41598-017-03328-1

Hartmann M, et al. (2021), Terrestrial or marine - indications towards the origin of ice-nucleating particles during melt season in the European Arctic up to 83.7 degrees N, *Atmospheric Chemistry and Physics*, *21*(15), 11613-11636. https://doi.org/10.5194/acp-21-11613-2021

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Wex H, Huang L, Zhang W, Hung H, Traversi R, Becagli S, Sheesley RJ, Moffett CE, Barrett TE, Bossi R, Skov H, Hunerbein A, Lubitz J, Loffler M, Linke O, Hartmann M, Herenz P, Stratmann F (2019) Annual variability of ice-nucleating particle concentrations at different Arctic locations. Atmospheric Chemistry and Physics 19: 5293-5311. https://doi.org/10.5194/acp-19-5293-2019

4.19 REBCASA – Investigating the Radiative Effect due to Black Carbon by Combining Atmospheric and Snow Measurements in Antarctica

Anna-Marie Jörss, Daniela Krampe, Andreas Herber (not in the field), Zsófia Jurányi (not in the field)

DE.AWI

Grant-No. AWI_ANT_24

Objectives

Black Carbon (BC) plays an important role in the radiation budget of the polar regions, both in the atmosphere, as well as in deposited form in snow. Upon BC deposition on a white surface, its albedo decreases, less incoming radiation is reflected and more heat is absorbed, warming the surface. This can lead to accelerated snow melt.

As a reference for investigations by our group in the Arctic and to provide further insight into the role of BC deposition, comparable measurements were conducted in Antarctica with the following main research questions:

1. How high is the BC concentration in the snow in the coastal Antarctic Dronning Maud Land and what is the resulting radiative forcing?
2. How do BC concentrations in snow and atmosphere in Antarctica differ from measurements in the Arctic and what are the causes (long-range vs. local)?
3. Can we identify linkages between atmospheric BC concentrations and their deposition in snow?

Fieldwork

Locations

The measurement locations were roughly placed along different transects in all four celestials (*cf.* Fig. 4.19.1). Towards the north to determine, among other things, via the salinity of the BC samples, how far the influence of the sea on the ice shelf extends. Towards the south of the station to have as little station influence as possible (periphery measurement, since there is only very rarely north wind). Using the east and west transects, which map the windward and leeward of *Neumayer Station III*, a possible footprint of the station and its range can be investigated, compared to the presumably more uninfluenced south. In addition to these transects originating from the station, further measurements were made on the sea ice of Atka Bay in east-west and north-south directions.

Conducted measurements

Different types of snow pits were excavated for BC sampling and measurement of the physical snow properties that are listed below.

To represent the entire past year, snow pits were dug to a depth of one year's snow accumulation (Type A). As a guide to the snow accumulation for the whole year, measurements at the "Pegelfeld Sued" were used, as well as measurements from the snow depth sensor and snow buoy south of the air chemistry observatory and measurements to determine the construction level of the station. For the year considered, 2022, this corresponded approximately to a snow depth between 110 and 130 cm.

In addition, repeated measurements were made at smaller snowpits (Type B) representing only the uppermost 20 to 30 cm of the snowpack (Type B), where a possible change of the snow cover during the summer can still be expected.

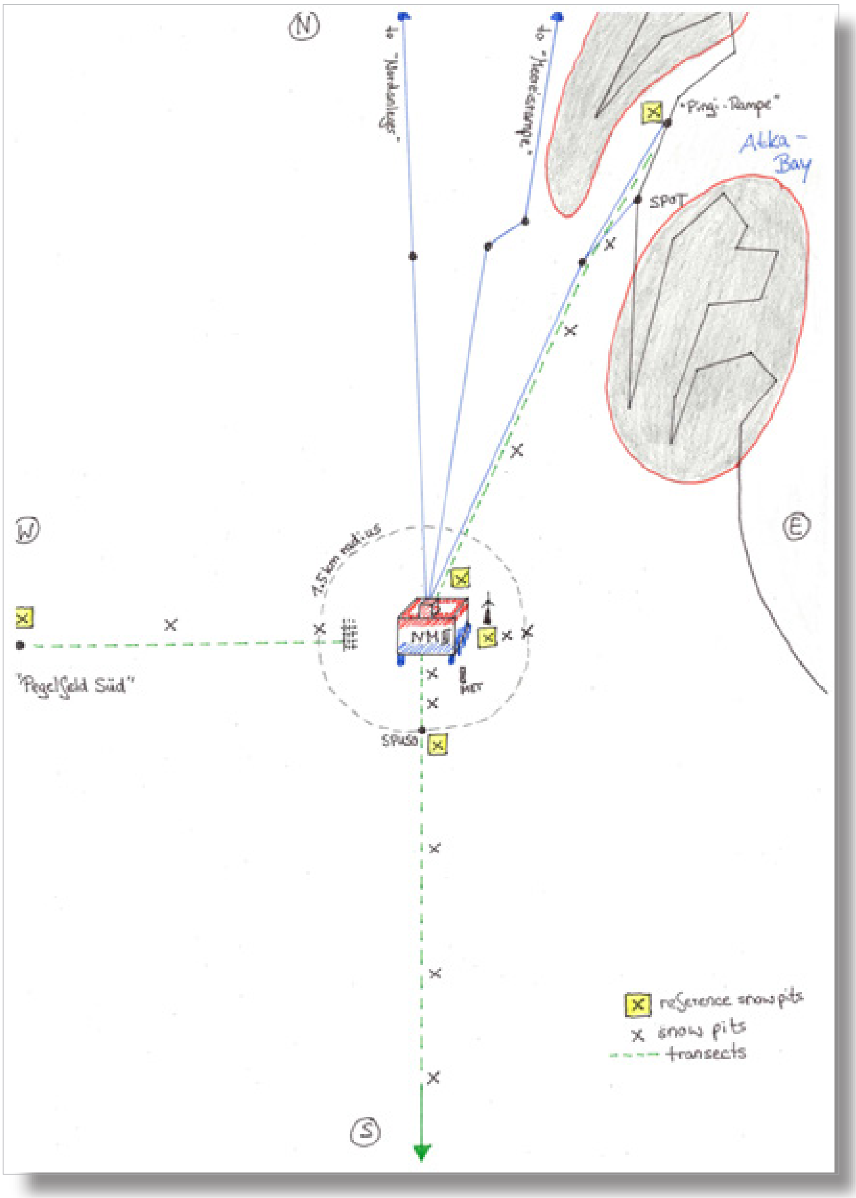

Fig. 4.19.1: Sketch of the BC transects around Neumayer Station III

Black Carbon

BC samples were collected using disposable gloves. Snow surface samples with a volume of 50 ml were collected at each site and continuous profiles always for the top 10 cm of a pit (3 vials) and then every 10 cm (resulting in gaps of 7 cm in between, since the diameter of the vial is about 3 cm) (*cf.* Fig. 4.19.2). At some measurement sites, only surface samples for BC analysis were taken.

Temperature profiles

In each snow pit, continuous temperature profiles were measured (every 2-5 cm) as well as surface temperatures at the snow air interface and air temperature. The latter ones were difficult to measure due to large radiation caused errors.

Snow density measurements

Snow density was measured with a density cutter and two different weights, a spring scale and a digital scale for comparison. Whenever possible, snow density was continuously measured along the entire vertical profile (*cf.* Fig. 4.19.1)

Specific Surface Area (SSA)

The specific surface area (SSA) was measured by an Ice Cube (A2 Photonic Sensors). Since the snow was often wet and radiation had a big influence on its consistency in the black sample holder, this became difficult and was not conducted often (see Tab. 4.19.1).

Snow Water Equivalent (SWE)

Snow water equivalent was measured with metal tubes that were pushed vertically into the snow layer and then weighted with the snow trapped. This measurement additionally serves as a comparison for the density measurements but was also not conducted at each site and during each snow pit measurement (see Tab. 4.19.1).

Stratigraphy

Snow stratigraphy determinations were made at selected pits, particularly to provide clues for simplifying seasonal classification of snow layers within the year under consideration and to better understand possible metamorphoric processes, also within the interpretation of the other measurements.

Preliminary (expected) results

The snow samples will be analysed with the Single Particle Soot Photometer (SP2) in the laboratory. Since the measuring device has not been available again since the end of the expedition due to a defect, the samples could not yet be investigated.

However, it is expected that the BC concentrations in the snow samples are significantly lower than in comparable measurements in the Arctic. Furthermore, it is assumed that a BC gradient can be observed in the East-West direction. The main wind direction East is likely to play a role in this. It would also be obvious that the lowest BC concentrations should occur in the south direction, since in this region where *Neumayer Station III* is located is rarely a north wind and vehicles or in general combustion engines, are operated only rarely and at some distance south of the station.

Examining the stratigraphies showed that the further one moves away from the coast and into the hinterland, the vertical profiles of the snow become much more homogeneous with less layers and show in general smaller crystal structures.

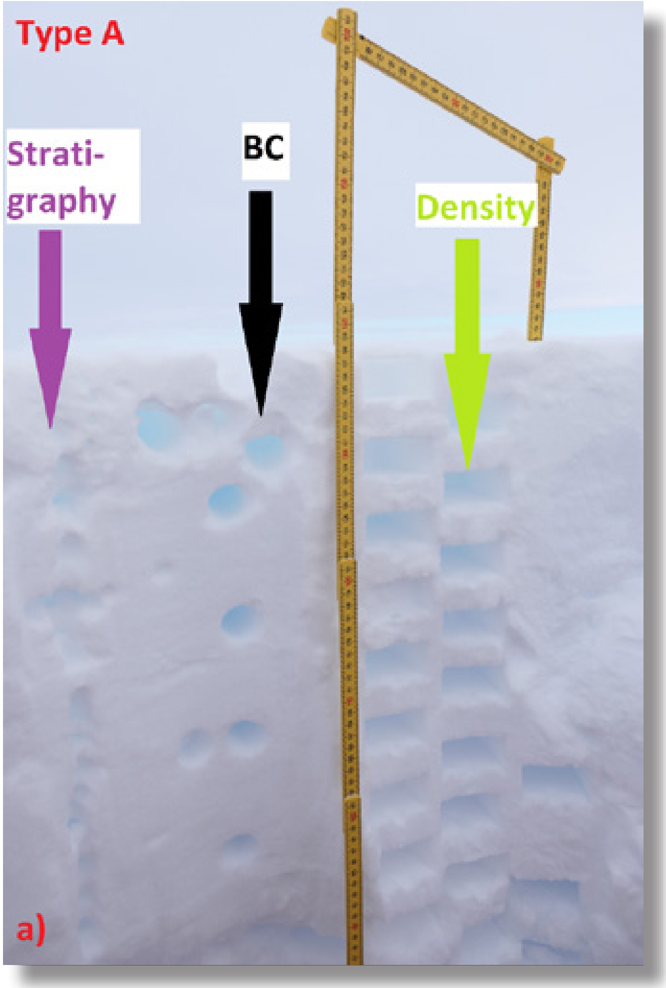

Fig. 4.19.2: Photographic documentation of a snow pit (Type A) with markers for BC sampling, density cutter and stratigraphy measurements

Tab. 4.19.1: Overview of conducted measurements during REBCASA. Crosses indicate that at the given location those measurements were done but without giving an indication on the number of measurements. In total, approximately 400 BC samples were taken.

Location	Snowpit A	Snowpit B	Sur-face BC	Tem-pera-ture	Den-sity	SSA	SWE	Stratigraphy
NM_W			X					
West_1.5			X					
West_2.5		X	X	X	X	X	X	
West_3.5			X					
West_4.5	X	X	X	X	X	X	X	X
West_5.5			X					
PF_Sued	X	X	X	X	X	X	X	X
NM_E			X					

Location	Snowpit A	Snowpit B	Surface BC	Temperature	Density	SSA	SWE	Stratigraphy
East_0.45			X					
East_0.75	X	X	X	X	X	X		X
East_3.2	X		X					
NM_N			X					
North_0.75		X	X	X		X	X	
North_5.8			X	X				
North_10.8		X	X	X		X	X	
North_14.8			X	X				
Nordanleger		X	X	X		X		
Nordanleger_N			X					
Nordanleger_S			X					
South_0.45		X	X	X			X	
South_0.75		X	X	X				
SpuSO_N		X	X	X	X	X		
SpuSO_E		X	X	X	X	X		
SpuSO_W		X	X	X	X			
SpuSO	X	X	X	X	X	X		X
South_2.0a		X	X	X	X	X		
South_2.0b		X	X					
South_2.0c		X	X					
Wa_NM_5			X					
Hal_Wa_5			X					
Hal_Wa_15			X	X				
Hal_Wa_25			X					
AWS_Halvfa	X		X	X	X			X
Others_south		X	X	X	X			
Atka03		X	X					
Atka07		X	X	X	X	X		X
Atka11		X	X	X	X	X	X	X
Atka16		X	X					
Atka00SNW		X	X	X	X		X	X
Seals_berg			X					
Atka04_SNW		X	X	X	X		X	X
Atka06_SNW			X					
Atka08_SNW			X					
Atka10_SNW		X	X	X	X		X	X
Atka12_SNW			X					
Others_seaice		X	X	X	X		X	X

Data management

After post-procsssing all measurements 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 new measurements is already available in sensor.awi.de.

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_24** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III 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.

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

Ronny Engelmann[1], Martin Radenz[1], Patric Seifert[1] (not in the field)

[1]DE.TROPOS

Grant-No. AWI_ANT_22

Outline

Within the DFG-funded project COALA (Continuous Observations of Aerosol-cLoud interaction in Antarctica), TROPOS performs combined active aerosol and cloud remote-sensing measurements at *Neumayer Station III*. Among a variety of instruments for cloud/aerosol observations, a 35-GHz cloud radar and a three-wavelength polarization Raman lidar were installed to measure a one-year dataset. This dataset will help to understand aerosol-cloud-dynamic interaction in one of the cleanest natural environments on the planet and to contrast cloud microphysics at different places such a continental Europe, South Chile, and different subtropical stations under dominant influence of mineral dust.

Objectives

The incomplete understanding of the interaction of aerosol particles with radiation, clouds, and precipitation is a key issue in atmospheric research. Detailed observations are required to capture the complex relationships between the involved processes (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 austral summer 2022/23 and end of austral summer 2023/24. OCEANET-Atmosphere comprises a set of active and passive remote-sensing equipment which is installed in an autonomous, customised 20ft container that was just successfully 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 as well as size-resolved observations of precipitation particles and drifting snow.

The aim is to collect 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.

Fieldwork

For logistical reasons, the field party arrived at the station mid December, before the ship call of *Polarstern*. The OCEANET-Atmosphere container arrived at *Neumayer Station III* early January. On 12 January the container was lifted onto the former EDEN-platform (approx. 400 m south of the station) by the technical team (Fig. 4.20.1a). Already on the same day, the container was connected to the station's power line and the installation of the instruments began. Milestones were the installation of the 1.2 m diameter cloud radar antenna, including radome (13/14 January), the integration with the station's network (17 January), absolute calibration of the microwave radiometer (17 January) and adjustment of the Raman polarization lidar (18 January). By 20 January all instruments were set up and commenced to collect data. The rapid setup benefited from a weeklong period of favourable weather. The final days before the departure of the setup support with F4 were used for fine tuning the Raman lidar and the Doppler lidar scan patterns, as well as a guided tour for interested expedition participants. The operational state of the OCEANET-Atmosphere is depicted in Figure 4.20.1b.

Routine operation on-site is handled by the project overwinterer. The tasks include daily checks of hardware for failure, removing ice accumulation, preemptive maintenance, data stream monitoring and near-realtime data analysis. In case any issues are encountered, they can be addressed with minimum delay. A second absolute calibration of the microwave radiometer with liquid nitrogen was performed on 23 February with the help of the meteorologists. In late March, a strong storm (mean wind 65 kt) caused drift snow collection in the radome, resulting in a gap of cloud radar data between 26 March and 3 April. Additionally, samples of surface and drifting snow are collected once per week, when weather conditions are suitable.

Preliminary (expected) 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 shall be addressed:

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.

A first impression of the collected data is provided in Figure 4.20.2. During the night from 18 to 19 April 2023 a multi-layer cloud was observed above *Neumayer Station III*. Below 1.5 km height, an aerosol layer developed into a shallow cloud layer, becoming optically thick around midnight. At the same time aloft, an ice cloud with a cloud base at 4 km height. In the following hours, the liquid water path in the lowest cloud layer increased to 150 g m^{-2}, while base height of the cloud above decreased. The cloud radar's vertical velocity indicates ice particle sedimentation velocities of approximately 1 m s^{-1}. During the whole period, the scanning Doppler lidar observed north-easterly winds of 11 m s^{-1} from the surface to 400 m height. In the cloud layer, winds were weaker (5-10 m s^{-1}) and from West to Northwest (not shown). Once the ice particles seeded into the lower cloud, around 06:15 UTC, precipitation at the surface started. The ice consumed all the liquid water present in the lower layer. After the period of strongest precipitation, around 09:40 UTC, a deeper mixed-phase cloud with multiple liquid layers remained.

Another striking feature that has been observed since the measurements started is a persistent high-altitude aerosol layer in the stratosphere between approximately 9 and 18 km height. Until this moment, further analysis has not yet been performed. However, this layer most likely stems from the Hunga Tonga–Hunga Ha'apai eruption in the Tongan archipelago on 15 January 2022. More than a year after this eruption the aerosol is still present in the southern hemisphere. From the quicklook shown in Figure 4.20.3, a preliminary aerosol optical depth between 0.02 and 0.04 can be estimated for this volcanic aerosol for May 2023 (lidar ratio 50-60 sr).

*Fig. 4.20.1: Top (a):
The TROPOS OCEANET-Atmosphere container
is placed onto the platform 400 m south
of the station. Bottom (b): The final setup where all instruments
are installed on top of and next to the container*

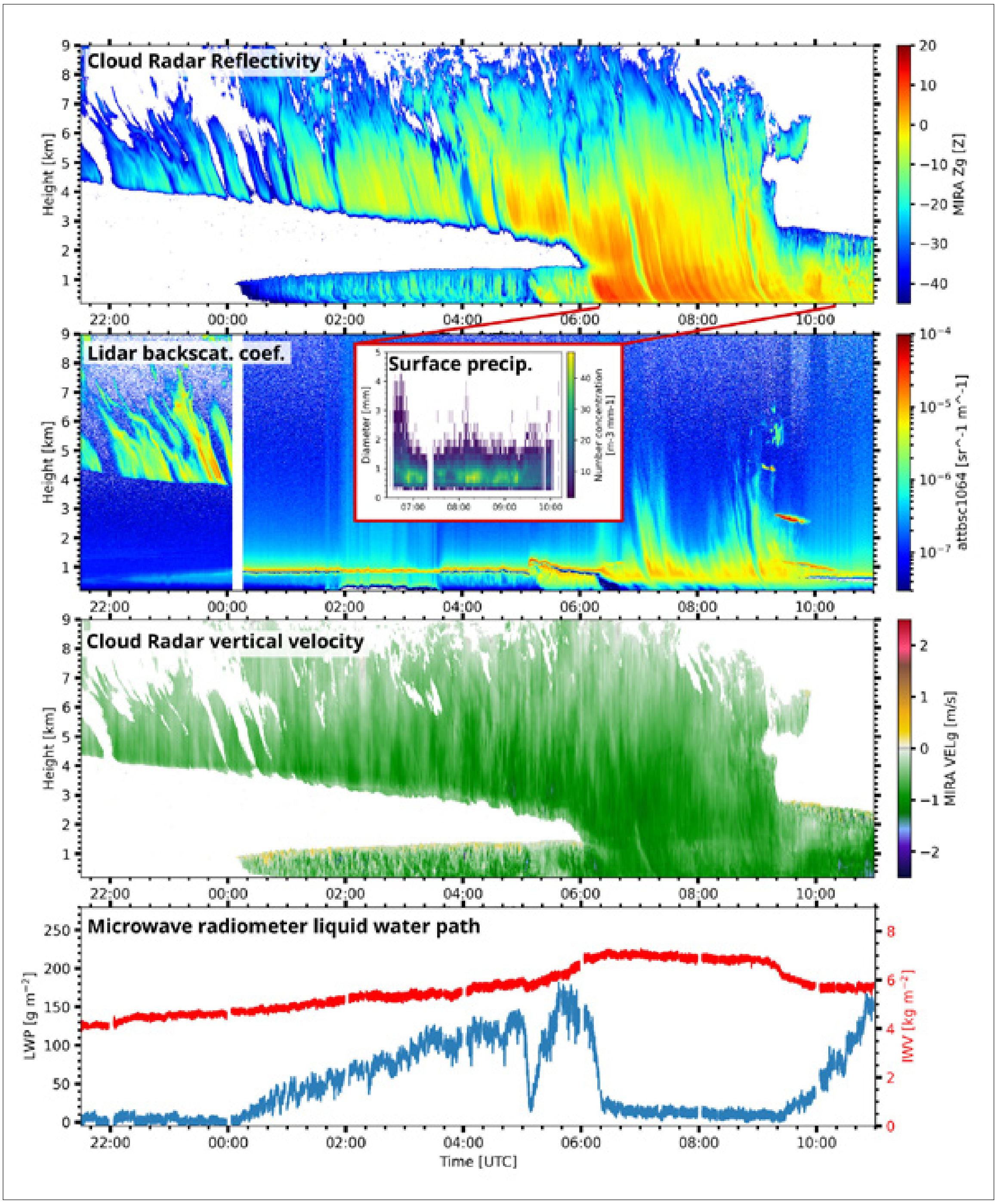

Fig. 4.20.2: An exemplary dataset from 18-19 April 2023: Shown are the cloud radar reflectivity, lidar backscatter, cloud particle vertical velocity, liquid water path and integrated water vapour. The inset shows precipitation data from the disdrometer.

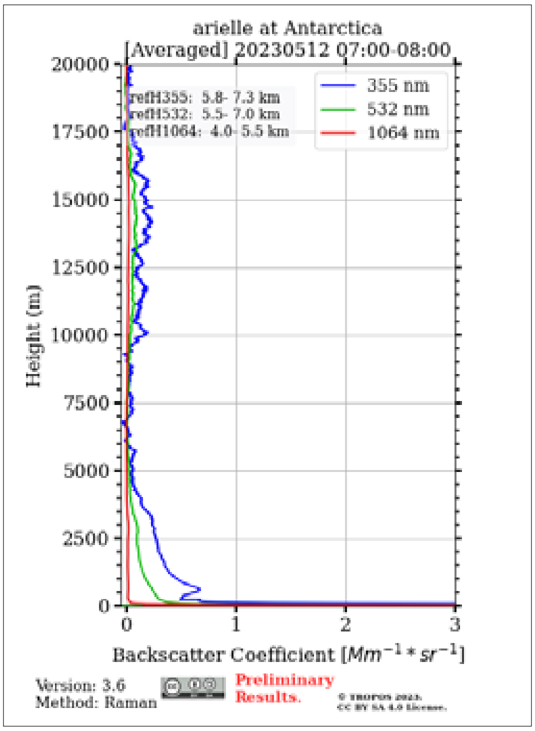

Fig. 4.20.3: A quicklook of the three-wavelength backscatter coefficient profile from aerosol measured above Neumayer Station III with the Raman lidar on 12 May 2023 between 07:00 and 08:00 UTC (https://polly.tropos.de). Two distinct aerosol layers are visible; free-tropospheric aerosol at altitudes up to 6 km and a high-altitude plume from 9 – 18 km height, presumably remnants of the 2022 Hunga Tonga–Hunga Ha'apai eruption in the Tongan archipelago.

Data management

All OCEANET-Atmosphere raw data from this project are stored at the OCEANET-archive 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

- 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)
- 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 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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Engelmann R, Ansmann A, Ohneiser K, Griesche H, Radenz M, Hofer J, Althausen D, Dahlke S, Maturilli M, Veselovskii I, Jimenez C, Wiesen R, Baars H, Bühl J, Gebauer H, Haarig M, Seifert P, Wandinger U, Macke A (2021) Wildfire smoke, Arctic haze, and aerosol effects on mixed-phase and cirrus clouds over the North Pole region during MOSAiC: an introduction. Atmos. Chem. Phys., 21, 13397–13423. https://doi.org/10.5194/acp-21-13397-2021

4.21 ASH – Antarctic Micro Super Pressure Balloons for High Altitude Research

Todd McKinney[1], Nick Perlaky[1] (not in the field), Mike Newchurch[1] (not in the field), Bill Brown[2] (not in the field), Alice Crawford[3] (not in the field)

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[3]GOV.NOAA

Grant-No. AWI_ANT_21

Objectives

The objective of this project is to evaluate the performance of eight low-cost *micro super pressure balloons* (MSPBs), also called pico balloons, in Antarctic conditions. Super pressure balloons float on surfaces of constant density, which enables them to stay aloft for extended periods. MSPBs, similar in size to party balloons, offer a cost-effective alternative to larger super pressure balloons and facilitate a greater understanding of interactions between the lower stratosphere and upper troposphere, floating between altitudes of 9 to 13 kilometers (McKinney 2023). We convert party balloons costing less than 20 US Dollars (18.3 Euro) into MSPBs. These balloons have a max payload of 40-grams. A single person carried all materials for the balloons, except for the helium, to the Antarctic continent in carry-on luggage, underscoring the minimal logistical constraints for these balloon flights.

Fig. 4.21.1: MSPB shortly before launch. Right figure shows one of the WSPR balloon trackers.

Solar-powered WSPR transmitters on the 20-meter (14.09 MHz) band transmiting at 10 and 23 mW were used as trackers on eight of the balloons. WSPR, short for Weak Signal Propagation Reporter, is a communication protocol that enables low-power transmissions to travel long distances via radio frequencies (Taylor, 2022). Balloon transmissions were sent during daytime every 10-minutes, which included data such as latitude and longitude, altitude, solar voltage, satellite lock, and wind speed and direction (calculated from GPS position). As per the work referenced in Hartje et al. (2018), a permanent WSPR beacon and receiver, callsign DP0GVN, was established at *Neumayer Station III* to gain knowledge about radio wave propagation in the ionosphere at Antarctic latitudes. Incorporating WSPR transmitters on these balloons has offered a new perspective on propagation in lower latitudes, supports the objectives of DP0GVN, and enables telemetry capabilities without the need for expensive satellite communication services.

Fieldwork

Eight MSPBs were deployed from *Neumayer Station III* between 13 November 2022 and 23 November 2022. Approximately 0.73 m^3 of *Neumayer Station III* helium was used for the eight launches. Table 4.21.1 shows parameters of the balloons launched. We denote each balloon flight by their call signs which correspond to data uploaded on the public amateur radio database APRS.fi. Balloons were launched when surface wind was low (less than 8 m/s) and there were either no clouds or the cloud depth was less than 0.5 km. The balloons were inflated a day before their scheduled launch. A single individual prepared the balloons, payloads, and conducted the launches.

Tab. 4.21.1: Summary of MSPB flights from *Neumayer Station III*.

Balloon APRS Callsign	Date Range	Flight Duration (day)	Circum-navigations	Latitude Range
K4UAH-3	13 November 2022 – N/A	≈ 64	N/A	N/A
K4UAH-1	16 November 2022 – 14 January 2023	58	5	87.312°S – 43.229°S
W5KUB-114	16 November 2022 – 17 January 2023	61	5	78.438°S – 6.175°S
K4UAH-2	20 November 2022 – 29 December 2022	39	3	86.646°S – 21.938°S
K4UAH-4	20 November 2022 – 12 February 2023	84	7	85.396°S – 22.104°S
K4UAH-6	20 November 2022 – 6 February 2023	78	6	88.479°S – 38.688°S
W5KUB-115	23 November 2022 – 3 March 2023	97	8	88.770°S – 13.313°S
K4UAH-5	23 November 2022	0	N/A	Balloon Leak!

Preliminary (expected) results

In this report, initial observations on balloon performance and data, and propagation results from WSPR transmitters are presented.

Balloon performance and data

All but one of the balloons remained in the air for at least a month and completed a minimum of five circumnavigations around the Southern Hemisphere. Average balloon ascent rates after launch were between 0.8 to 1.1 m/s until achieving a float between 10.8 – 11.1 km AMSL. The ascent rates of the balloons oscillated between -0.2 to 0.2 m/s while floating. The six WSPR balloons performed exceptionally well. Figure 4.21.1 illustrates the flight paths of these six long-duration flights, with the longest balloon remaining aloft for 97 days. The mean zonal wind velocities were between -13.8 m/s and 69.4 m/s, while the meridional velocities were -/+

27.7 m/s. The total wind speeds ranged from 0.5 to 75 m/s. Between latitudes 60°S and 50°S, observations showed that there was a shift from slow-moving polar air masses to faster jets. The wind speed gradients at these heights were steep and could cause rapid acceleration or deceleration of the balloons, enabling them to experience different synoptic-level features.

The latitudes at which the balloons were observed varied considerably. Two of them came within two degrees of the South Pole, while one balloon approached as close as six degrees latitude from the equator. Notably, over time, the balloons were seen to drift further away from Antarctica. The failure of all long-duration WSPR balloons occurred over regions of maritime convection between latitudes 40°S and 10°S. Based on the observation of balloon altitudes in these regions, we believe a sudden increase in balloon altitude can be linked to updraft areas over convection. This rapid change in altitude creates a pressure change within the balloon membranes, leading to leaks and ultimately, the end of the flight.

The K4UAH-5 balloon experienced a leak in its envelope shortly after launch, likely due to quality control issues with the balloon material. The K4UAH-3 balloon was only capable of transmitting data within the line of sight to the station. Once the balloon went beyond the horizon, there was no equipment available over Antarctica to receive and decode its data. Despite not being heard from for a month, the balloon was detected over the station 63 days later, suggesting that it remained in the air and completed several circumnavigations similar to the WSPR balloons.

Out of the 8 balloons that were flown, 7 of them achieved a stable float (88 % success rate) and remained airborne for over a month. We believe this demonstrates the reliability of MSPBs as a cost-effective platform for conducting studies in the Antarctic region.

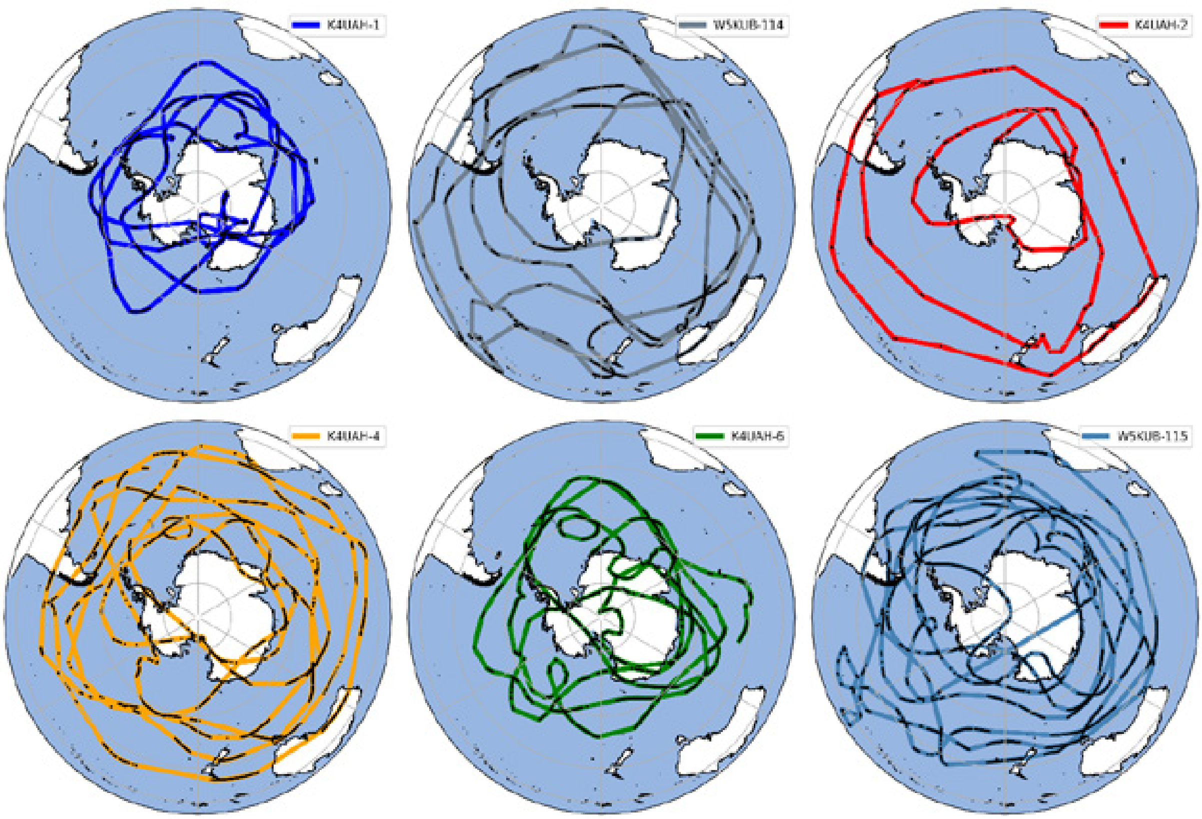

Fig. 4.21.2: Maps showing the trajectories of the six WSPR balloon flights. The black dots over the colored flight trajectories show points when the balloon transmitted a data point.

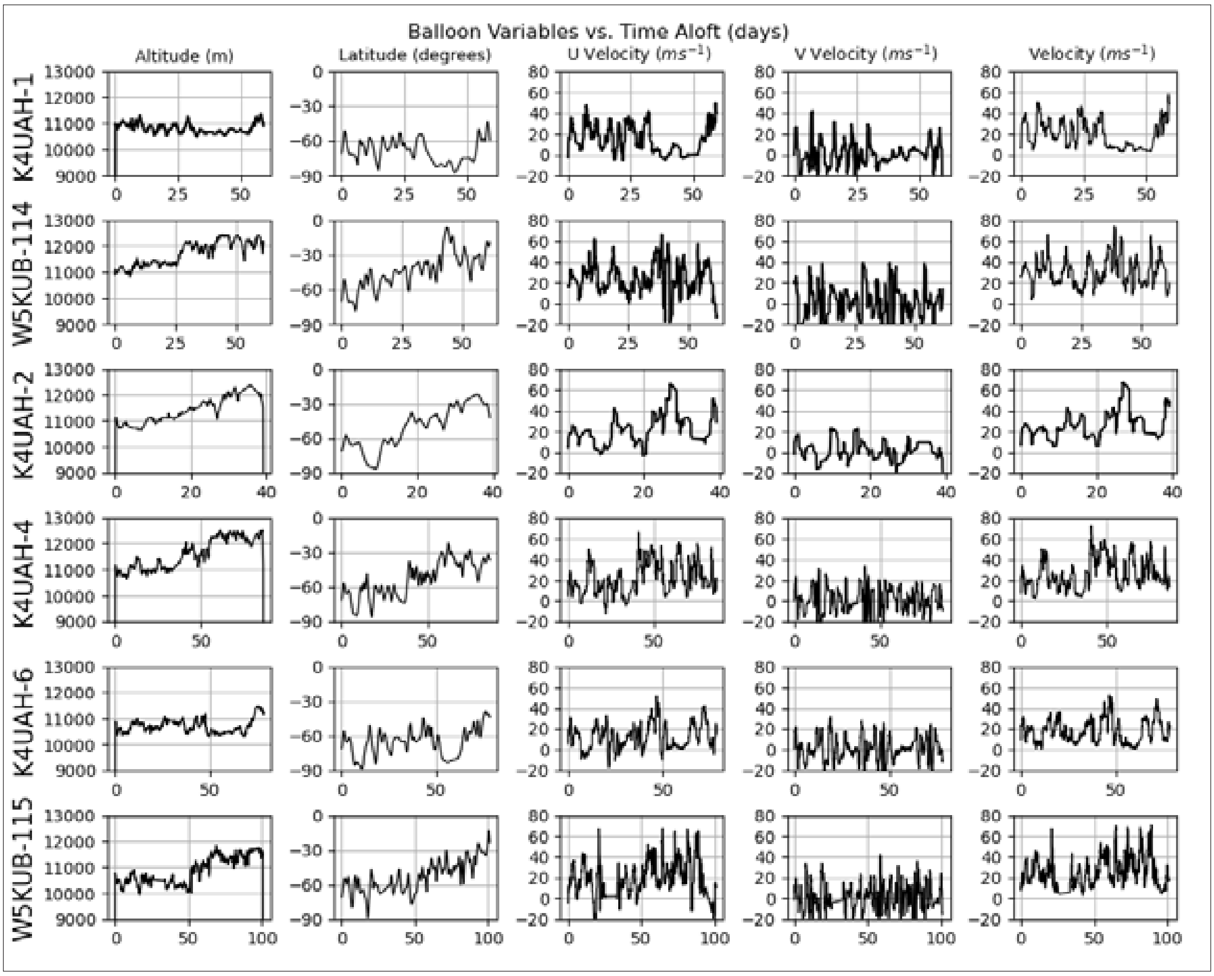

Fig. 4.21.3: Preliminary balloon data plotted vs. days after launch

WSPR Propgation Data

In addition to telemetry data, we present preliminary results of propagation data from the WSPR transmitters. Table 4.21.2 lists parameters of the WSPR transmissions. We denote each balloon flight by their WSPR call signs which corresponds to data uploaded on the public amateur radio website WSPRnet. The number of spots is the amount of uploads to the WSPR network. Mean signal to noise ratios (SNR), mean distances, and max single travel distances are listed. It's worth noting that the maximum signal distance for each balloon exceeded 19,000 km, which is *remarkable* considering the small size and transmit power of each WSPR balloon tracker. To put this into perspective, the great circle distance from the South Pole to the North Pole is approximately 20,014 km; some signals from the WSPR balloon trackers even exceeded the distances achieved by surface WSPR stations that transmit at powers three orders of magnitude higher than the balloons. We believe that this impressive propagation on these balloons is possible is because of two factors:

1. A floating balloon does not have the absorption effects that a surface-level transmitter would normally encounter. When transmitting from the surface, ground clutter or other radio noise can attenuate the signal strength.
2. A transmitter positioned at a higher altitude has a wider field of view, covering a larger portion of the sky from the horizon to the zenith. This is especially beneficial for low solar elevation propagation.

Tab. 4.21.2: Summary of propagation data from the six long duration WSPR balloon flights.

Balloon WSPR Callsign	Number of Spots	Mean SNR	Mean Distance (km)	Max Distance (km)
KN4TPG	5024	-19.3	5037	19030
KW5GP	7050	-17.0	3224	19570
KM4LVC	1994	-16.4	2770	19608
WB8ELK	11165	-18.8	4177	19930
KM4ZIA	12985	-17.3	5808	19837
KD9UQB	20137	-18.9	6188	19879

The locations of the balloons are also presented on Figure 4.21.4 with colour coding indicating the maximum distance and highest SNR achieved for each WSPR grid square. An intriguing aspect of this plot is observing the correlation between the SNR and the location of the balloons, which can be attributed to the positioning of the WSPR network. For instance, the presence of good WSPR reception at *Neumayer Station III* and various networks across Australia lead to higher SNR values when the balloons are in proximity to these regions. Consequently, signals are more likely to take short propagation hops, resulting in higher SNR. It's important to mention that the diversity of the WSPR receiver network worldwide impacts the reception of both short and long distance propagation signals. This is demonstrated in the top plots on Figure 4.21.5, which presents a Spot 2D-Histogram. The x-axis shows latitude and longitude, while the y-axis displays signal travel distance. This initial diagram provides a useful representation of the Southern Hemisphere's WSPR network, indicating which stations based on their location are capable of receiving telemetry signals from Antarctica and surrounding regions.

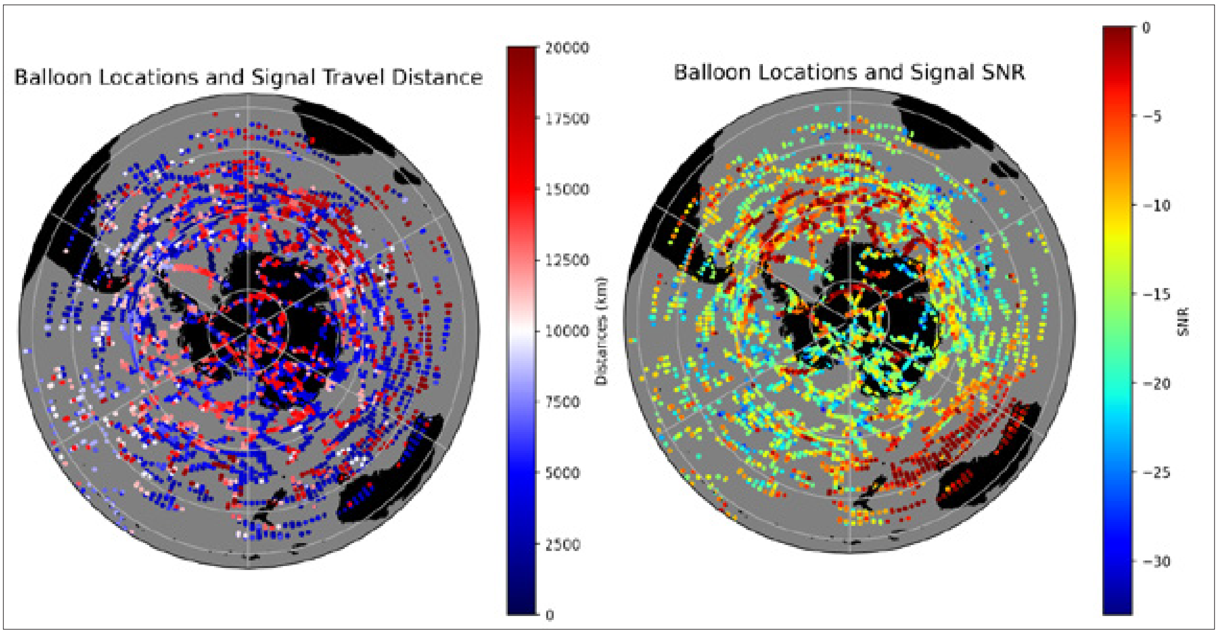

Fig. 4.21.4: Maps depicting the maximum distance and highest SNR obtained for each WSPR grid square, displaying data from all six long-duration WSPR flights. The distance scale features white to indicate the distance between the South Pole and the equator for reference purposes.

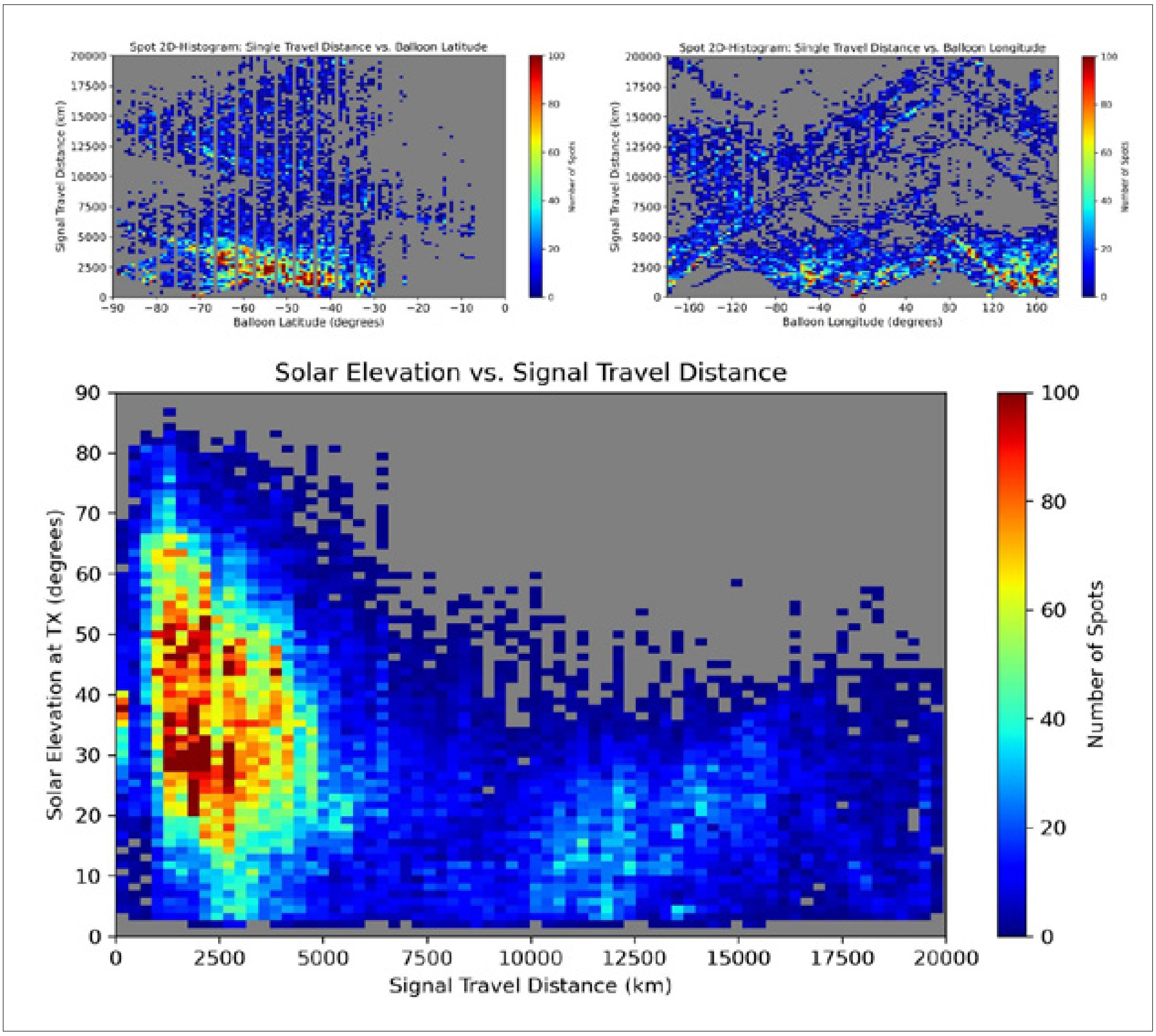

Fig. 4.21.5: Top: Spot 2D-Histogram of signal travel distance vs. balloon latitudes (left) and longitudes (right). Bottom: Spot 2D-Histogram of solar elevation during balloon transmission vs. signal travel distance. For each plot, reds indicate more spots.

As anticipated, there was a correlation observed between the solar elevation angle at the point of the balloon transmissions and the number of spots reported by the WSPR network. In Figure 4.21.5, the lower plot displays the signal travel distance of each balloon transmission, with the y-axis indicating the solar angle at the transmission location. The majority of the spots were found within the distance range of 1,000 to 5,000 km, with solar elevation angles at transmission ranging from 1 to 80 degrees. The distribution's center was at 30 degrees solar evaluation and 1,300 km signal travel distance. It is *noteworthy* that for signals traveling more than 7,000 km, the solar elevation angle had to be below 60 degrees. Additionally, there was a second distribution region centered around 20 degrees solar evaluation and 12,500 km signal travel distance. In cases of long-distance propagation, where signals were transmitted beyond 19,000 km, the solar elevation was consistently below 45 degrees. These correlations merit further investigation in future studies.

Data management

Raw balloon transmission was archived using both amateur radio databases located at WSPRnet (wsprnet.org/) and APRS.fi (aprs.fi/). Data can be found using callsigns found in Table 4.21.1 and 4.21.2. Processed balloon data will later 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.

In all publications based on this expedition, the **Grant No. AWI_ANT_21** will be quoted and the following publication will be cited:

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung. (2016a). *Neumayer III 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.

Conclusions

Based on these initial findings, we are confident in the potential of MSPBs as a valuable tool for cost-effective atmospheric research over Antarctica. We strongly emphasize the importance of developing lightweight and low-cost instrumentation that can be utilized on MSPBs. Standardizing sensors for these balloons will mark the next phase of super pressure balloon research. Moving forward, we intend to deploy more MSPBs equipped with additional sensors and improved telemetry capabilities in both the Northern and Southern Hemispheres for future flights. We hope to fly from *Neumayer Station III* again during future Antarctic summers

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Acknowledgement

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4.22 SnAcc – SNOW Accumulation at *Neumayer Station III*

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Grant-No. AWI_ANT_27

Outline

This report summarizes the measurement campaign led during ANT-Land 2022/23 for the project named "SnAcc". SnAcc was initiated in 2022 through a collaboration between the Alfred Wegener Insitute for Polar and Marine Research (AWI) and the WSL Institute for Snow and Avalanche Research (SLF). The project motivation stems from the substantial snow accumulation observed in winter around the station building, whose management requires important human and fuel resources.

Note that the SnAcc project participant was also taking part to the ANTSI expedition campaign, which was led in parallel during her time in Antarctica.

Objectives

The objectives of the SnAcc project are:

- Assess (qualitatively and quantitatively) the snow accumulation patterns around the Neumayer Station III building in relation to various storm conditions;
- Understand the main factors governing snowdrift formation around structures in the Antarctic environment (building design, wind speed/direction, snow properties);
- Develop a fluid dynamics-based tool for snow transport modeling around Neumayer Station III, improved and validated by field measurements;
- Define appropriate design solutions and snow management techniques for the mitigation of snow accumulation around the *Neumayer Station III* building based on numerical simulations.
- Extend knowledge on snow accumulation to "other" obstacles (e.g., icebergs) to better understand snow accumulation in Antartica in general

Fieldwork

Contrarily to most projects at *Neumayer Station III*, SnAcc investigates the environment in the direct vicinity of the station and not at the sea (i.e., Atka Bay). The main work at the station during ANT-Land 2022/23 was to develop a measuring technique to assess the snow accumulation caused by given storm conditions. For this purpose, the participant employed a terrestrial laser scanner (TLS) from RIEGL® to measure the snow topography before (pre-scan) and after (post-scan) a storm. The difference between the post- and pre-scans gives the snow height distribution for the period between the two measurements, which can be compared to numerical simulations and used for validation purposes.

Fig. 4.22.1: RIEGL VZ® - 6000: operating elements and connectors (RIEGL, 2020)

The TLS technique is widely used for such spatio-temporal applications. It was first applied to snow surfaces by Prokop et al. (2008), who demonstrated its accuracy. A laser scanning device, the RIEGL VZ-6000® (RIEGL, 2020), was developed subsequently to scan cryospheric surfaces (Fig. 4.22.1). The latter is the most suitable to scan the snow topography around *Neumayer Station III*. The activities carried out during field work at the station are summarized in Table 4.22.1. A more detailed description is found subsequently.

Tab. 4.22.1: Activities carried out at *Neumayer Station III* for the SnAcc project during ANT-Land 2022/23.

Activity	Description
A1	Test of the RIEGL® scanning modes for the Neumayer case (point resolution, scanning frequency, scanning pattern, vertical and horizontal angles)
A2	Test with 2 reflector types (cylinder, flat disk) and maximum device-to-reflector distance
A3	Reflector positioning and attachment to the station structure
A4	Scanner and reflector positioning, separately for each face of the building (N, E, S, W). Trade-off between distance from building (survey area) and automatic reflector search
A5	Full 360° scan around *Neumayer Station III*, with 5 different scanning positions. Stitching of points with the RiSCAN PRO software and accuracy check of the method
A6	Test at 2 scanning heights, 1.5m (tripod) and 3m (snow groomer) for shadowing mitigation
A7	Marking of the reflector positions and training documentation for the overwinterers (videos and pictures)

The first activity carried out at *Neumayer Station III* by the participant was to conduct measurements with the RIEGL® scanner at different resolutions, frequencies and angles (A1).

The lower the measurement frequency, the more powerful but also the more time it takes. All these settings require some fine-tuning and have to be clearly defined before starting any scanning survey. The comparison was verified via post-processing with the RiSCAN PRO software (RIEGL, 2016).

After defining those parameters, the participant tested 2 reflector types to use as tie points: a flat reflector disk (5 cm diameter) and a cylinder reflector (10 cm diameter and height). Both kinds are shown in Figure 4.22.2. The distance between scanner and reflector is also important, as the reflecting material is only detected below a fixed range. The maximum distance between scanner and reflector was tested by the participant along with the reflector type (A2).

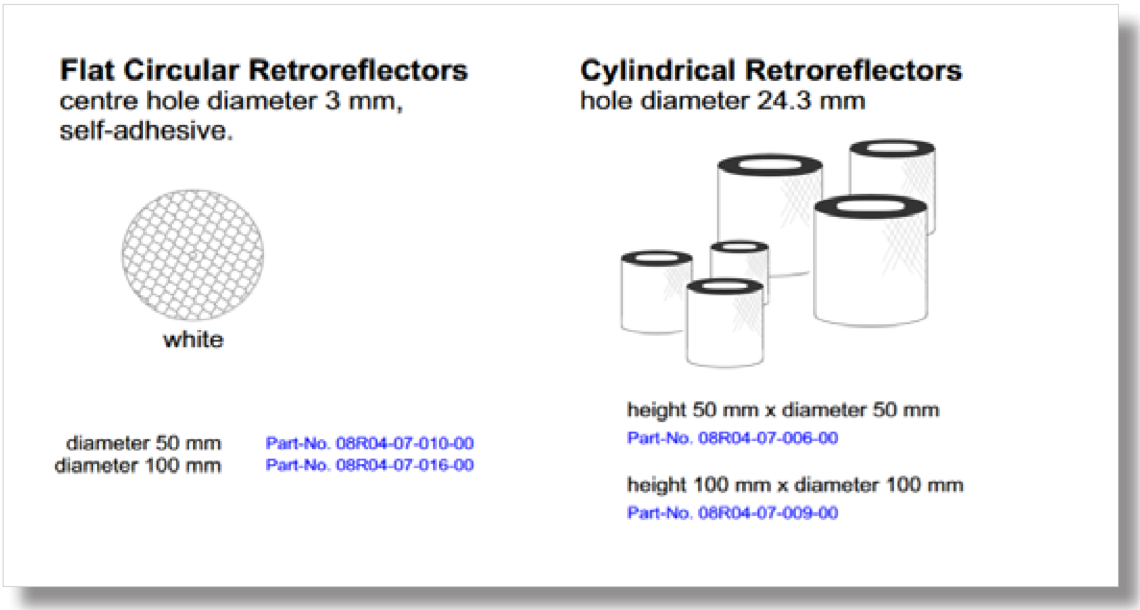

Fig. 4.22.2: Reflector targets used during field work at Neumayer Station III for local scan data registration (RIEGL, 2006). Both flat circular disk reflectors (left) and cylinder reflectors (right) were tested.

A challenge specific to *Neumayer Station III* is that its position is constantly moving, due to its location on the ice shelf. This means that using a global positioning system (GPS) as a reference coordinate system for the scans is not suitable, as it would keep moving over time and the difference between the scans would not be computed at the same grid points. A solution consists in building a local reference system (LRS) based on the station structure itself, which was the third step done by the participant (A3). A local reference system is built by installing reflectors all over the station building, which acts as tie points for the scans taken from different positions. The reflectors should be set such that they are far apart from each other and evenly distributed in the lateral and vertical directions. This limits the measurement errors in the scans far away from the device (large beam footprint). It required important trial and error to define the most appropriate distance between reflectors. Moreover, for safety reasons, the reflectors should be placed on the building in a temporary and easy-to-use manner. This reduces the risk of the wind blowing off the reflectors and damaging surrounding structures. Several attachment systems were explored, among which magnets and reusable cable ties.

Once the scanner and reflector settings were appropriately defined (A1-3), each of the building faces (E-S-N-W) was scanned separately. 4 reflectors were placed per building face; 2 were placed near the ground on the pilars and 2 were on the roof to ensure a good vertical distribution. Several reflector positions were tested, to ensure that they were clearly caught by the scanner placed on the ground. The scanning device was placed at the maximum distance possible from the reflectors to ensure the largest survey area possible (A4). This step was directly followed by the subsequent scanning of the building from 7 different positions in one survey. Placing the scanner at the corners ensures to scan 2 faces simultaneously and reproduce a three-dimensional (3-D) point cloud of the building and its surrounding snow topography (A5). The stitching of all the scans and the quality of the final point cloud were done in the RiSCAN PRO software.

The resulting scans in A4 and A5 showed some important shadowing patterns due to the complex topography. In other words, the laser beam was prevented from reaching the snow surface beyond some terrain variations, leaving holes in the point cloud. Scanning from greater heights has the potential to fix this issue. Therefore, scans of a same surface were perfomed both from a tripod (1.5 m height) and the roof a snow groomer (3 m height). The resulting point clouds were subsequently compared in RiSCAN PRO (A6).

The snow accumulation should ideally be measured during the austral winter, when the human disturbance is the smallest. The summer is less suitable, as the snow surface is constantly altered for logistical purposes (A7). Therefore, the results of all the above-mentioned experiments were summarized in audio-visual and written tutorials for the overwinterers to take over the measurements during their winter stay at the station.

Preliminary (expected) results

Each of the activities described in the section above produced results that were necessary for the establishment of an appropriate measurement method for the snow accumulation around *Neumayer Station III*. The main results drawn from each activity are described hereafter.

- **A1.** The tests showed that a scanning resolution between 0.02-0.0275° for the vertical and horizontal angle was a good trade-off between accuracy and scanning time. Moreover, a frequency of 300 kHz (highest) showed to be appropriate. The horizontal angle start should be set to 0° and its end to 360° (full rotation), while the vertical angle limits are defined with the camera image.
- **A2.** The tests showed that the disk reflectors were not adapted to measurements with a horizontal scanner-to-reflector shift, such as the one performed for the snow distribution assessment around *Neumayer Station III*. Indeed, scans taken from positions with a very obtuse angle relatively to the normal reflector plane did not identify the reflectors, which disables the automatic reflector search and reduces the accuracy of the referencing.
- **A3.** This step showed that placing 2 reflectors on the roof, and 2 reflectors closer to the ground at various pilar heights limited the deviation errors in the point clouds. Note that the reflectors should not be placed directly on top of each other and distributed as evenly as possible in the horizontal direction (e.g., to the extreme left and right pilars). It was found that using magnets to attach the reflectors on the *Neumayer Station III* structure was the easiest, fastest and most reliable method.
- **A4**. The results of this phase, as well as of the following one (A5), are displayed in the pdf file that was sent together with this report (TLS_reflector_positions_2023.pdf). It contains a summary of the reflector positions defined for each building face, as well as their detailed pictures taken in the field. Detailed information for each face can be found at the pages of the file given in Table 4.22.2. Note that there is colour code described in the document, with the best reflector positions (red) and some back-up ones (blue).

Tab. 4.22.2: Pages of the reflector positions for each building face.

Face orientation	**Pages in the file** "TLS_reflector_positions_2023.pdf"
West	4 – 8
South	9 – 12
East	13 – 16
North	17 – 20

- **A5**. The scheme showing the overview of the scanner and reflector positions defined with the results of this phase are also found in the additional document (TLS_reflector_positions_2023.pdf) at pages 2 and 3, respectively. For each position, the scanner should be placed at ~200 m from the building, depending on the topography and laser intensity/frequency.
- **A6**. Some scans were conducted at the East side of the station from both ground and snow groomer heights and compared to each other. It turns out that the scans taken from the snow groomer roof led to less shadowing (larger surface area captured) but were more destructive of the scanned surface (snow groomer tracks). Figure 4.22.3 shows the point clouds of the East side scanned from both heights.
- **A7.** All the above-mentioned results were summarized in text and video tutorials for the station staff to follow while doing the measurements in winter. They can be made available to other AWI members, if necessary.

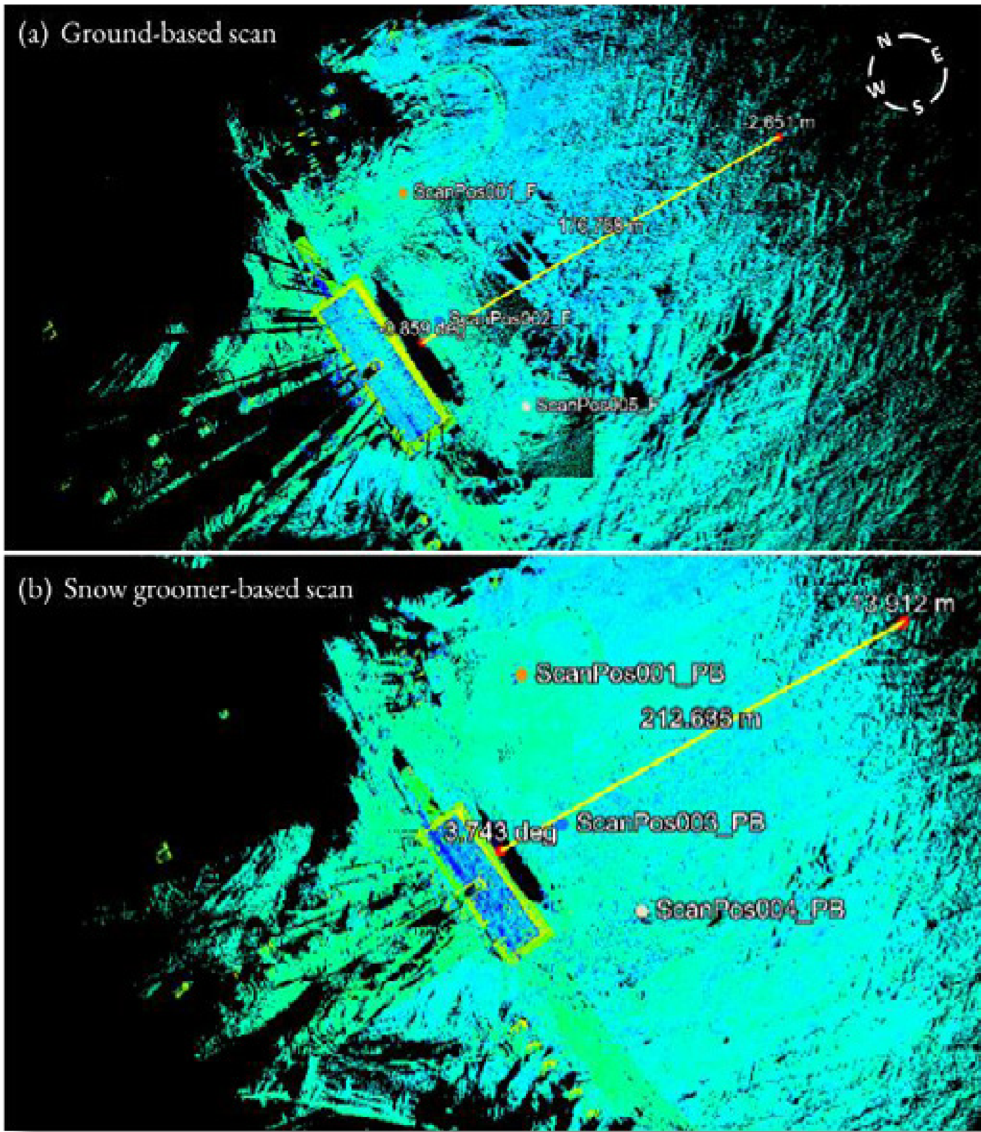

Fig. 4.22.3: Point clouds of the snow surface at the East side of Neumayer Station III. They result from scans taken from three different positions with the device placed (a) at ground height and (b) at snow groomer roof height.

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.

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

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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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4.23 WSPR RADIO Beacon at *Neumayer Station III* for Evaluation of Southern Hemisphere Radio Propagation

Michael Hartje[1] (not in the field), Sören Peik[1] (not in the field)

[1]DE.HS-Bremen

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 2,000 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*.

The project was initially intended to last for one year, but extended to a full 11-year sunspot cycle until 2030. This year, the formerly project leading organization TU München, Prof. Dr. U. Walter has retired. Therefore, the position of the project engineer has changed from U. Walter to M. Hartje. He also introduced his colleague Prof. Dr. Sören Peik, head of the microwave laboratory at Hochschule Bremen, as the co-PI.

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 relative signal-to-noise ratio (SNR) during receiving intervals.

To transform the SNR values from relative to absolute levels, an additional receiver with a calibrated electrical field sensor was installed on the roof of the SPUSO. This offers the opportunity to recalibrate the already existing receiver data of the past and determine the absolute values of noise and signal strength.

Fieldwork

Both, the transmitter and the receivers operate autonomously and are monitored by a remote-control operator in Germany. In case of malfunctions the remote-control operator on duty first elaborates on the problem and, if necessary, contacts a member of the overwintering team for more information. It has been shown, that the excellent team work of remote and on-situ team can solve problems usually within a few minutes.

Updates of the technical equipment are prepared in Germany and shipped to *Neumayer Station III* with *Polarstern*. The summer team on site exchanges the prepared equipment.

Preliminary (expected) results

The following parts are divided into results by the transmitter, operated at the *Neumayer Station III* and the different receivers at the SPUSO.

Transmitter Status

Currently 26 of 30 timeslots per hour are used for transmissions using an RF output power of 5 watts. During the remaining four timeslots the transmitter is silent to allow high sensitivity background noise measurements by the receiver.

Only minor issues were reported during 2022. As shown in Figure 4.23.1 a ten-day outage between 16 October 2022 and 26 October 2022 was caused by a software problem which made the band switching relays inoperable. Otherwise, operation went smooth with just a few short downtimes for maintenance work. A total of 217,934 messages were transmitted resulting in a total of 1,202,161 reception reports from 4,960 distinct receiving stations.

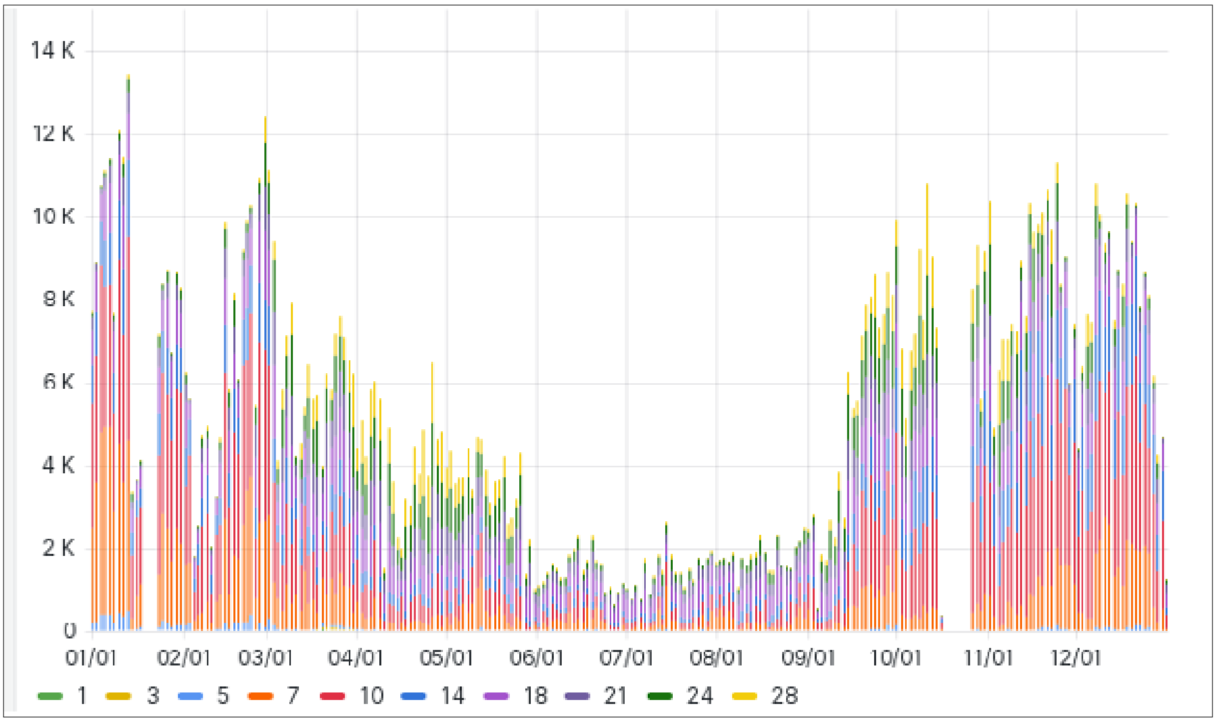

Fig. 4.23.1: Worldwide reported spots form the transmitter during 2022 per day and bands

Measurement results

During 2022 solar activity picked up considerably (Fig. 4.23.2). This came without surprise as it was the third year of solar cycle 25 which started in December 2019. More ionising radiation is now emitted by the Sun, causing an increase in free electron density in all ionospheric regions, foremost the F/F2 region which is the primary means of long-range shortwave communication. Due to the relation between electron density and maximum refracted frequency, higher frequency bands became usable. Over more, as atmospheric noise decreases with frequency, the chance for a signal to get through rises with frequency.

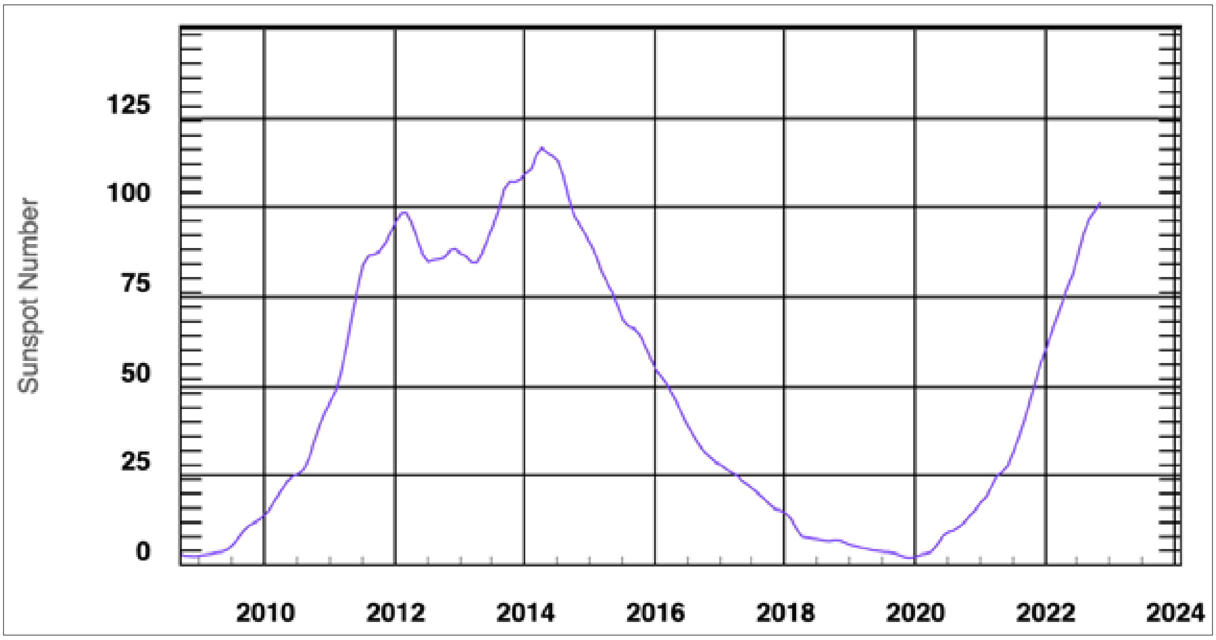

Figure 4.23.2: Development of solar activity for the previous and current cycle (source: NOAA SWPC https://www.swpc.noaa.gov).

This is clearly visible in the number of reception reports (so called „spots") when comparing results obtained in 2021 (Fig. 2.23.3) with results from 2022 (Fig. 2.23.4). The total number of spots has risen by 13 % to over 1.2 million. This is primarily driven by a significant increase in spot count for frequencies above 18 MHz.

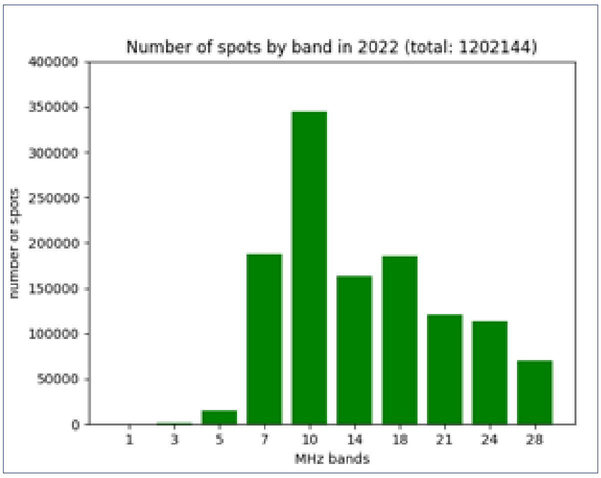

Fig. 4.23.3: Number of spots by band in 2021

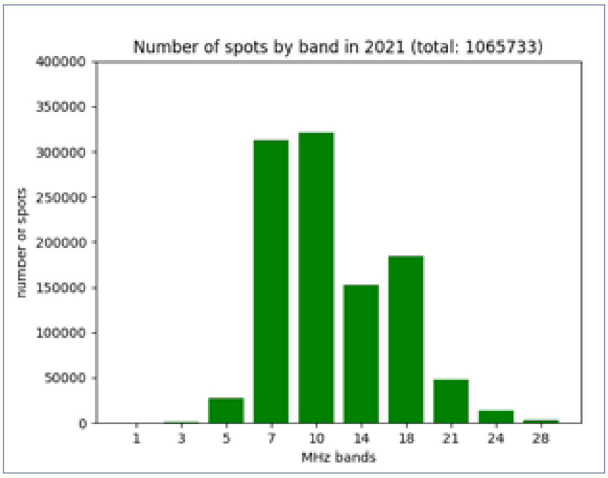

Fig. 4.23.4: Number of spots by band in 2022

While spot counts in the medium bands 10, 14 and 18 MHz remained at nearly the same level the spot count on 7 and 5 MHz shows a distinct drop. This again is caused by rising solar activity. Figure 4.23.5 and 4.23.6 compare the monthly number of spots on the 7 MHz band between 2021 and 2022. While 2022 started with spot counts about the same as one year before (with January 2022 being an outlyer) the spot count dropped significantly towards the end of the year.

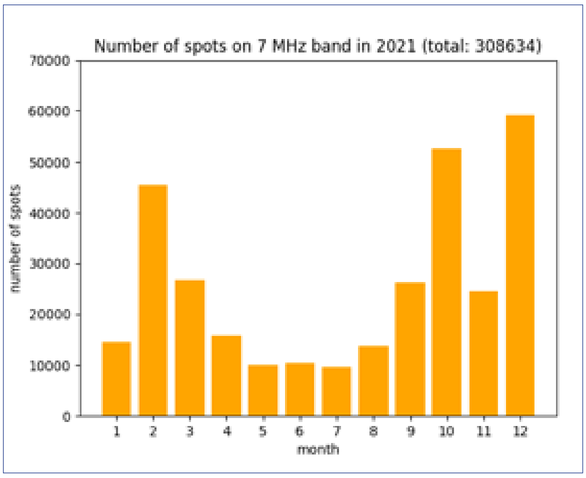

Fig. 4.23.5: Number of spots on 7 MHz throughout 2021

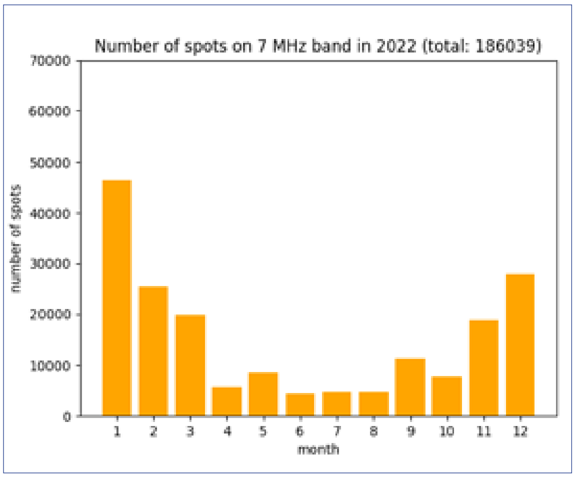

Fig. 4.23.6: Number of spots on 7 MHz throughout 2022 (October count reduced by a 10-day downtime of the transmitter)

More ionising radiation increases free electron in all relevant ionospheric regions, i.e., D, E and F region. While this enables E and F to refract higher frequencies, it also empowers the D region to exert higher attenuation on radio signals passing through this lowest region in about 60 km altitude. This effect decreases with frequency and is therefore most obvious on 7 MHz, the lowest band for which we collected a sufficient number of reception reports.

Figure 4.23.7 shows solar activity during 2021 and 2022 using the monthly average of the 10.7 cm solar flux (solar flux density at a wavelength of 10.7 cm, a convenient proxy of solar activity). It illustrates well the activity increase which caused both the increased spot count on frequencies above 18 MHz and the reduced spot count below 10 MHz.

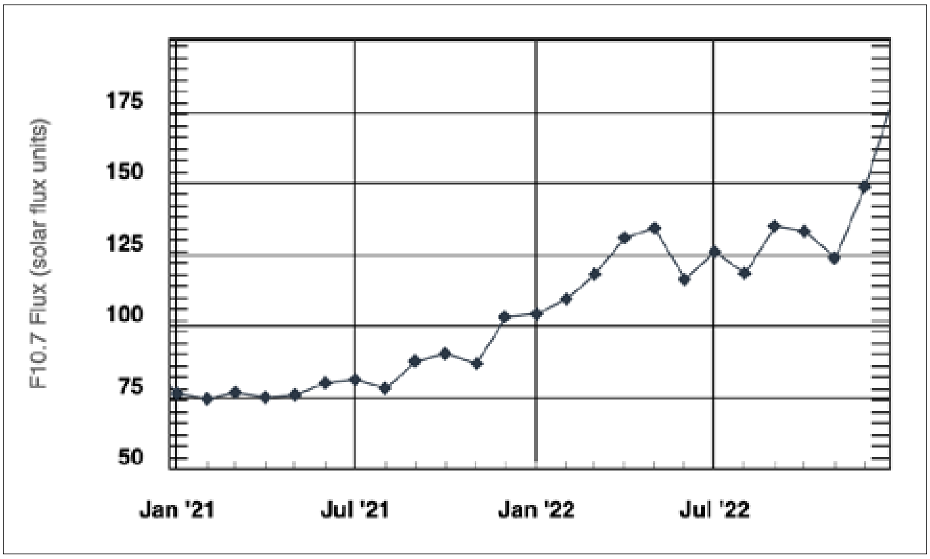

Fig. 4.23.7: Development of solar activity (as expressed by monthly averages of F10.7 cm flux) during 2021 and 2022 (source: NOAA SWPC https://www.swpc.noaa.gov)

The distribution of spots during the days UTC hours over the year 2022 are shown in Figure 4.23.8.

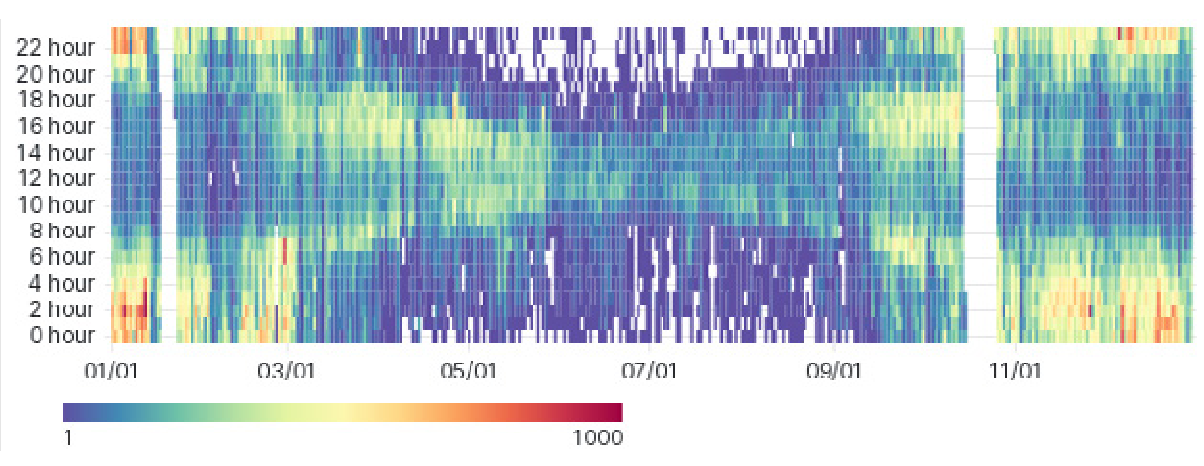

Fig. 4.23.8: Transmitted and world wide reported spots over the year 2022

As shown in Figure 4.23.8, the reported emissions during the polar night (June and July) is limited to the time between 10 and 16 UTC hours of the day. However, during the polar day from November to March, the transmitted spots from *Neumayer Station III* are dominant received during 18 to 06 of the next day.

WSPR-Receivers at SPUSO

The receivers at SPUSO for the reception of worldwide transmitted WSPR-Signals are reported to the international database at wsprnet.org. The so-called spots include the measured signal-to-noise ratio (SNR).

Due to the age of the antenna wire at the larger loop, the antenna wire was broken on the 12 November as can be derived from Figure 4.23.9. Figure 4.23.9 and 4.23.10 shows the received spot numbers per hour over the year 2022. After 12 November only a very few spots are received (dark blue and white area) on the larger loop antenna as shown in Figure 4.23.9, whereas Figure 4.23.10 shows an expected and regular distribution of spot counts over the year and the UTC day time. The spots in Figure 10 are obtained from the smaller loop, which was designed for the higher frequency bands.

Vertical blank areas indicate times where the receiver was not in operation. For example, after a power reset or during power outage. Only in Figure 4.23.9 the blank areas between 6 and 18 UTC after 12 November indicate no received spots due to the broken antenna.

A second receiver on the smaller loop was set up on 16 March. This receiver spot distribution shows different outage times when compared to Figure 4.23.10.

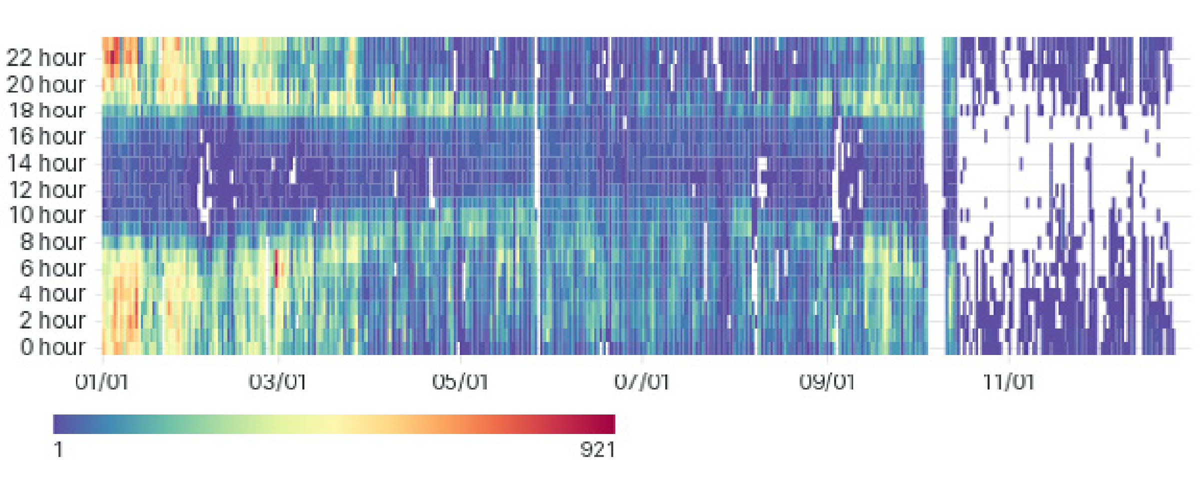

Fig. 4.23.9: At SPUSO received worldwide transmitted spots over the year 2022 on the larger loop antenna.

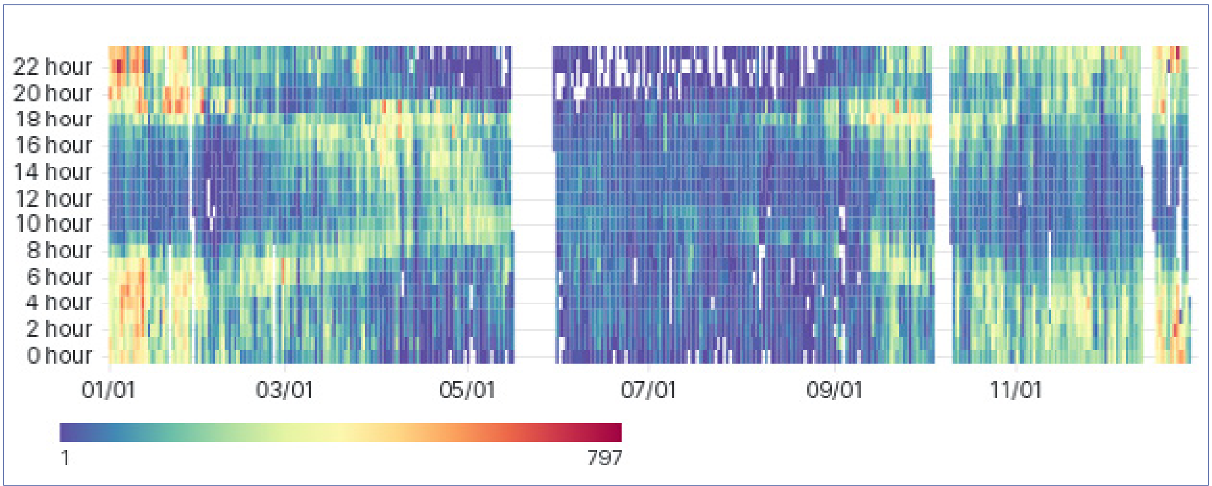

Fig. 4.23.10: At SPUSO received worldwide transmitted spots over the year 2022 on the smaller loop antenna.

As there was at the end of November not enough antenna wire at *Neumayer Station III* available to repair the broken larger loop, we decided to wait for an already planned exchange of the antenna wire during the polar day after delivering of wire with *Polarstern*.

The receivers picked up more than 1,750,000 spots during 2022. The most active transmitting stations received at SPUSO were located as shown in Figure 4.23.11.

Fig. 4.23.11: Most received transmitting stations during 2022

As shown in Figure 4.23.11, the most frequently received transmitting stations in 2022 were in the southern hemisphere. Due to the larger population of stations in the northern hemisphere some well-equipped transmitters could be reported many times as well.

As the receivers get the most active frequency bands 7, 10, 14 MHz on both loops, the higher Frequency bands are observed only on one receiver.

Tab. 4.23.1: Distribution of spots on the higher Frequency bands during 2022

Frequency band / MHz	Number of spots
18	46.666
21	46.291
24	24.738
28	39.430

As shown in Table 4.23.1 there were 157,125 received spots on the higher frequency bands from 18 to 28 MHz. This is a strong indication for better ionosphere propagation due to the increasing solar spot numbers during 2022. For comparison: During the last report period 2021 the receivers picked up 22,000 reports on these frequency bands. /1/

WSPR-Station at *Neumayer Station III* drew world wide attention

The worldwide spread information about the WSPR station at *Neumayer Station III* drew attention by many ham radio operators and in particular some hams at the US University of Alabama at Huntsville in cooperation with National Oceanic and Atmospheric Administration (NOAA).

They started their own project and therefore brought up some drifting balloons to *Neumayer Station III*. Due to a lack of base stations in Antarctica to observe the tracks of the balloons and their measured atmospheric data this project used on short wave transmitted WSPR data to close the communication gap. The measured atmosphere data were encoded and transmitted on a small and very lightweight short wave radio transmitter on the balloon. The receivers at SPUSO picked up the encoded spots and sent them to the wsprnet database.

Figure 4.23.12 shows the geographical distribution during the time between 1 December to the end of December 2022, when several of these balloons where started (see Chapter 4.23). During that time in December, *Polarstern* arrived at Atka Bay. At the Research Vessel *Polarstern* there is a WSPR transmitter, which does show the positions of *Polarstern* in Figure 4.23.12 as well.

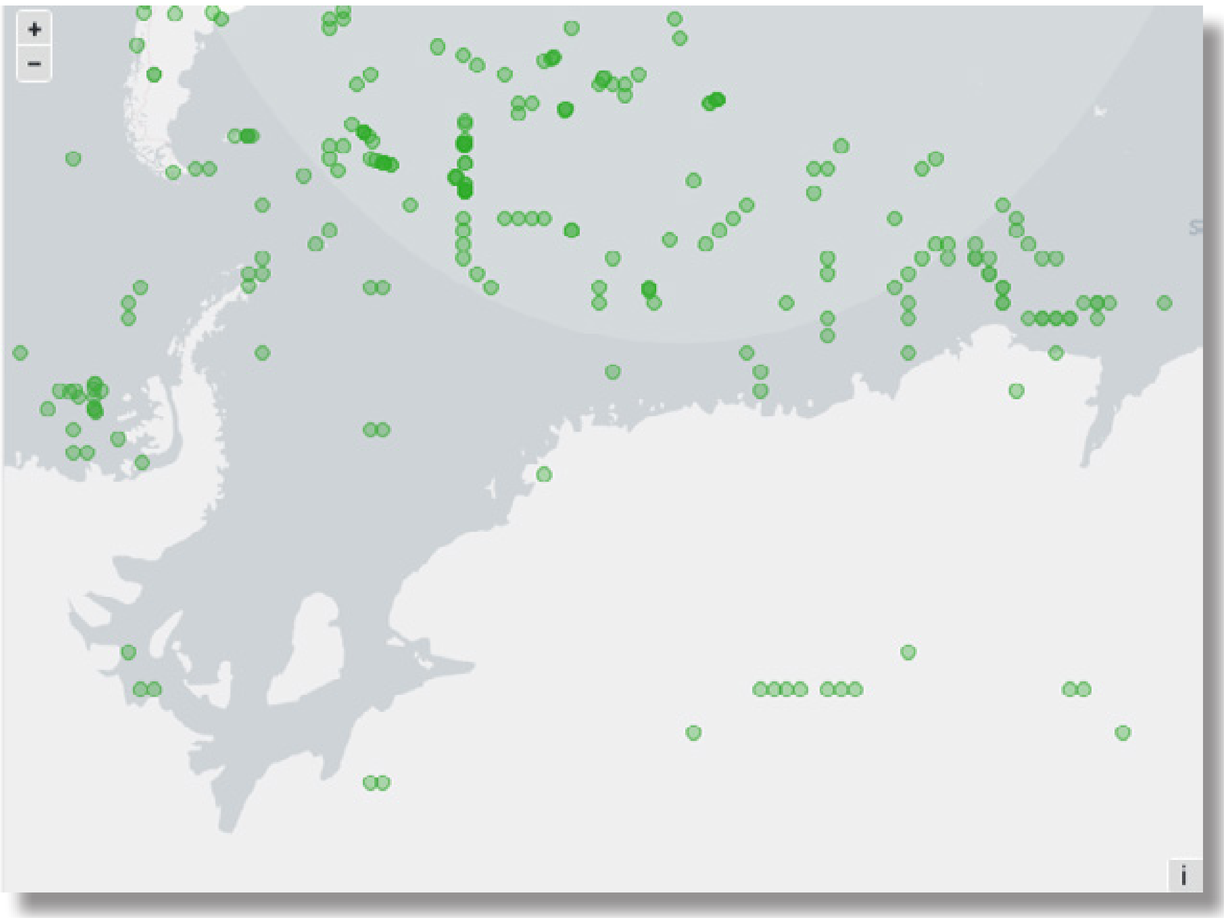

Fig. 4.23.12: Geographical positions of transmitters during December 2022; most of the green dots are showing the positions of drifting ballons and the position of Polarstern using WSPR.

Measurement of the absolute radio noise level

The WSPR-Decoder evaluates the Signal-to-Noise Ratio SNR of the spotted Transmitter relative to the actual noise during the receive time of 112 s. To make these measurements more comparable, it is necessary to determine the absolute noise level continously.

The aim to measure the absolute noise level was realized by a special receiver from 50 KHz to 31 MHz and a separate and calibrated electrical field sensor. This system was recently developed in a separate scientific project with the contribution of the author Michael Hartje. More information was presented in the annual report in 2021/22.

But with the first established sensor at SPUSO, an Antarctic winter storm damaged the antenna. By a great coincidence, the overwintering team found the antenna and sent all parts on one of the first transportation flights to Germany. Then the design engineer, Jörg Logemann, was able to create an improved version from the damage analysis and deliver it in time for the ship's transport with *Polarstern* from Bremerhaven. The repaired antenna was reassembled during the summer season and is still in operation now.

Actual results are presented daily at the website https://www.enams.de. One example of the noise measurement results is shown in Figure 4.23.13.

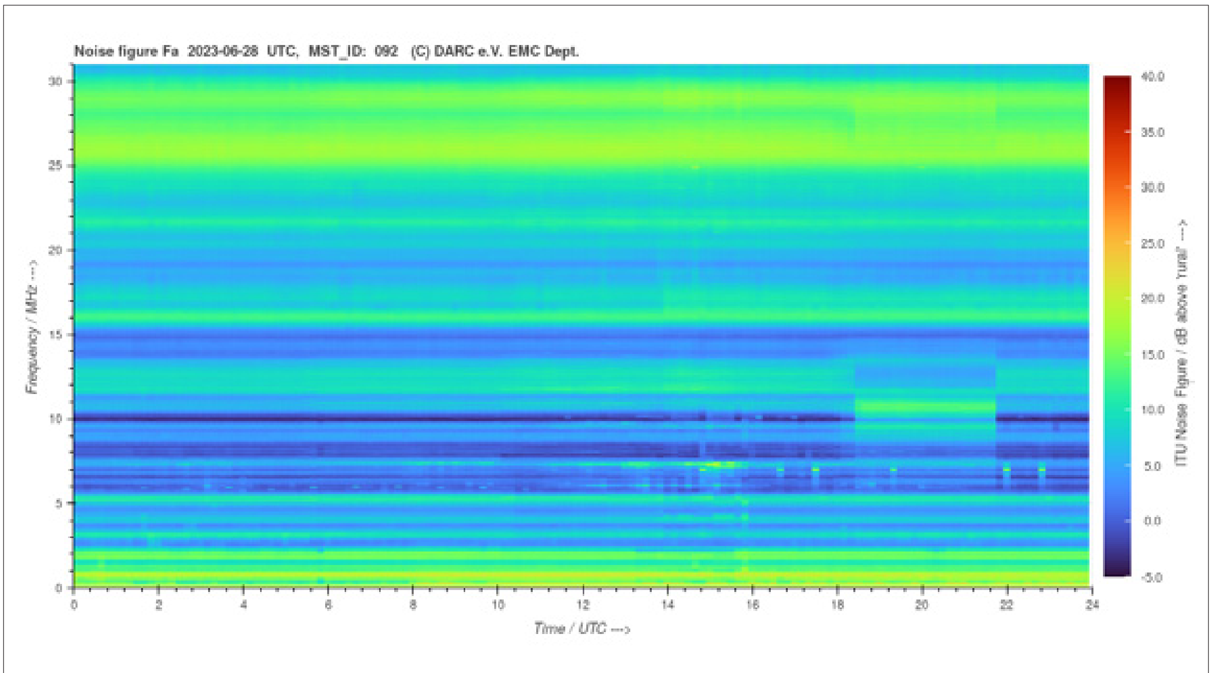

Fig. 4.23.13: Heatmap of the noise measurement at SPUSO based on the ITU class rural

Figure 4.23.13 shows a 24 hour plot of the noise level of 28 June 2023 as a so called "heatmap". The noise level amplitude is indicated by the colour in dB. The "0 dB" refers to the ITU-R P 372 /3/ "rural" environment by the colour "dark blue". For the location at SPUSO a total dark blue heatmap is expected, as the environment is near to "quiet rural", which would be 10 dB below "rural". It is obvious, that in the frequency ranges from 25 to 30 MHz and below 1 MHz shows noise level amplitudes of 15 to 20 dB above "rural" (light green to yellow). As the "industrial" noise level is 10 dB above rural, the measured noise level at SPUSO has to be referred to as "very noisy industrial" environment.

In Figure 4.23.13 we can find a dark blue “line” at 10 MHz, which indicates an amplitude of the noise level about or below rural. But, in the time range from 18:30 to 21:30 on this day, a switched electrical equipment produces additional noise between 8 and 11 MHz very constantly adding 10 dB of noise. Many equal-coloured lines such at 3, 4 and 5 MHz (light green), for example, show a constant behaviour which could be used in an analysis and may assist to identify the noise source.

These first results should be verified by changing the location of the electrical field sensor. The worldwide used enams system shows many examples of much more calm locations even in an industrial environment in the northern hemisphere.

Prospective developments

Solar cycle 25, while still being below long time average, seems to develop a stronger maximum as its predecessor in 2014. Therefore, we expect the development visible in 2022 to continue in 2023. Solar maximum is currently expected to happen during the first half of 2025. We hopefully can catch this time range with our project.

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 2023, about 5,8 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* and on https://www.enams.de.

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

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.

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 played a major role in the drafting the report on the work and propagation interpretation results about the transmitter and the transmitters spot evaluation. Dipl.-Ing. Jörg Logemann developed and improved the active antenna with great enthusiasm. Special thanks go also to Felix Riess, Theresa Thoma, 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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Berichte zur Polar- und Meeresforschung, Bericht Nr. 758/2021 – BzPM_0758_2021. 2021. [Online]. Available: https://epic.awi.de/id/eprint/55241/1/BzPM_0758_2021.pdf pp 42-52.

ITU, RECOMMENDATION ITU-R P.372-15 – Radio noise, ITU, Sep. 2021. [Online]. Available: https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.372-15-202109-I!!PDF-E.pdf

4.24 EDEN ISS

Vincent Vrakking[1], Claudia Philpot[1], Daniel Schubert[1] (not in the field), Paul Zabel[1] (not in the field), Conrad Zeidler[1] (not in the field), Markus Dorn[1] (not in the field), Jess Bunchek[2] (not in the field), Robert Ferl[3] (not in the field), Anna-Lisa Paul[3] (not in the field)

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Grant-No. AWI_ANT_7

Objectives

Sustained human presence in space requires the development of new technologies to maintain environmental control, to manage waste, to provide water, oxygen, food and to keep astronauts healthy and psychologically fit. Bio-regenerative life support systems, in particular the cultivation of higher plants, are advantageous from this regard due to their ability to be employed for food production, carbon dioxide reduction, oxygen production, water recycling, and waste management. Furthermore, fresh crops are not only beneficial for human physiological health but also have a positive impact on crew psychological well-being.

The EDEN ISS project (Zabel et al., 2015) was a 4.5 M€ European Union Horizon 2020 project (reference number: 636501) supported via the COMPET-07-2014 – Space exploration – Life support subprogramme. The project officially started in March 2015 and ended in April 2019 after the completion of a year-long Antarctic deployment phase in which the EDEN ISS greenhouse system was installed and operated in the vicinity of *Neumayer Station III*.

The EDEN ISS consortium was comprised of leading European experts, plus Canadian and US contributors, in the domains of human spaceflight and controlled environment agriculture (CEA). The EDEN ISS scientific advisory board consisted of the top scientists in the field of space greenhouses from Russia, USA, Japan, Italy, and Germany.

The EDEN ISS greenhouse, also called the Mobile Test Facility (MTF), has been designed to provide fresh produce for overwintering crews at *Neumayer Station III* in Antarctica while, at the same time, advancing spaceflight readiness of a number of key plant growth technologies. The greenhouse also serves as a tool to develop operational procedures and select science aims associated with remote plant production. The greenhouse consists of two 20-foot high cube containers, which have been placed on top of an external platform located approximately 400 m south of *Neumayer Station III*. The actual system can be subdivided into three distinct sections:

- Cold porch/airlock: a small room providing storage, crew clothing changing area, and a small air buffer to limit the entry of cold air when the main access door of the facility is utilized.
- Service Section (SES): houses the primary control, air management, thermal control, and nutrient delivery systems of the MTF as well as the full rack ISPR plant growth demonstrator.
- Future Exploration Greenhouse (FEG): the main plant growth area of the MTF, including multilevel plant growth racks operating in a precisely controlled environment.

The design of the EDEN ISS greenhouse is presented in detail by Boscheri et al. (2016); Vrakking et al. (2017) and Zabel et al. (2017).

During the 2018 overwintering period, the EDEN ISS consortium tested essential CEA technologies using an International Standard Payload Rack (ISPR) cultivation system for potential testing on-board the International Space Station (ISS). Furthermore, the FEG was designed with a focus on larger scale bio-regenerative life support systems for planetary surfaces (e.g., Moon, Mars). In addition to technology development and validation, food safety and plant handling procedures were developed and tested in Antarctica. These are integral aspects of the interaction between the crew and plants within closed environments.

Due to the necessity of validating key technologies for space greenhouses under mission relevant conditions and with representative mass flows, the EDEN ISS consortium defined six objectives:

1. Manufacturing a space analogue Mobile Test Facility.
2. Integration and test of an International Standard Payload Rack plant cultivation system for future tests on-board ISS and a Future Exploration Greenhouse for planetary habitats.
3. Adaptation, integration, fine-tuning, and demonstration of key technologies.
4. Development and demonstration of operational techniques and processes for higher plant cultivation to achieve safe and high-quality food.
5. Study of microbial behaviour and countermeasures within plant cultivation chambers.
6. Actively advancing knowledge related to human spaceflight and transformation of research results into terrestrial applications.

Although the project officially ended, the German Aerospace Center (DLR) and the Alfred Wegener Institute agreed to continue operation of the EDEN ISS facility at the *Neumayer Station III* through 2020 and beyond.

Fieldwork

ANT-Land 2022 Neumayer Station III winter season

During the ANT-Land 2022 winter field season, the EDEN ISS greenhouse was not actively operated by the on-site overwintering crew. It remained in a type of hibernation mode. Aside from occasional inspection of the facility, to detect and resolve possible damage, no activities occurred within the Mobile Test Facility.

The reason for not operating the greenhouse throughout the winter season was to limit the effort during the ANT-Land 2022/23 summer season to disassemble the MTF and prepare it for return shipment back to Germany.

ANT-Land 2022/23 Neumayer Station III summer field season

During the 2022-23 summer season, two project members from the German Aerospace Center travelled to Antarctica, to disassemble the EDEN ISS greenhouse and to prepare the containers and project-related components and consumables for transport back to Germany.

A brief, non-comprehensive, overview of the tasks which were carried out during the summer season is presented below:

- Inspection of the greenhouse and its subsystems
- Preparation of inventory lists

- Draining of coolant from the thermal lines
- Removal of externally-mounted components, such as lamps and the CO2 injection system
- Removal of roof-mounted components, such as I-beams, safety railings and the free cooler unit, with assistance from the technical team
- Outreach activities, including a tele-con with Gymnasium Gars and a grow-out of wildflower seeds from the SpaceSeeds project
- Disconnecting and removal of interfaces between the Service Section and Future Exploration Greenhouse containers
- Disassembly of the Command and Data Handling System server PCs
- Packing of loose components and consumables
- Packing of dangerous goods
- Preparing freight documentation for containers and dangerous goods transport
- Disconnecting of main power and data cables from Neumayer Station III to the Mobile Test Facility
- Removal of the greenhouse containers from the raised platform with assistance from the technical team

Stowing of the blue storage container for transport with assistance from the technical team Additionally, the team members took images, measurements and laser scans of two locations within the *Neumayer Station III* which could house a potential future greenhouse, EDEN 2, inside the station.

Preliminary (expected) results

As mentioned previously, the Mobile Test Facility was not operated in 2022 following the final harvest which occurred during the ANT-Land 2021-22 summer season. As such, no further data were gathered during this year to build on the results from the earlier operations phases of the EDEN ISS greenhouse.

Previous results from the EDEN ISS project cover areas ranging from Plant Health Monitoring (Zeidler et al., 2019; Tucker et al., 2020), machine learning and image processing (Nesteruk et al., 2021), the impact of plants on crew well-being (Schlacht et al., 2019), crew time measurements (Zabel et al., 2019), biomass production (Zabel et al., 2020), microbiological measurements (Fahrion et al., 2019), and the ISPR plant cultivation system performance (Boscheri et al., 2019).

Furthermore, additional information on crew time and work load has been presented (Poulet et al., 202; Zeidler et al., 2021), and the possibilities of implementing Augmented Reality to facilitate training and reduce demands on the crew are being investigated (Zeidler and Woeckner 2021).

General experience gained with respect to the greenhouse operations and the performance of the different technical aspects of the design was used, and will be used in the future, to develop the design concept for a greenhouse for the Moon and Mars (Maiwald et al., 2020). With the aim to develop and build an improved greenhouse demonstrator by 2025, the failures and non-optimal design aspects of the EDEN ISS greenhouse will be reviewed, and adjustments will be made to the various systems in order to improve performance and reliability, as well as reduce the amount of crew time needed for nominal and off-nominal operations.

As for the EDEN ISS greenhouse, it will be upgraded and re-outfitted for use in the follow-up project EDEN LUNA. In this project, the greenhouse will be installed near the new LUNA facility at DLR Site in Cologne, which aims to enable simulations of lunar surface missions, and demonstrate semi-closed loop food production with astronauts in the loop.

Data management

All data collected and generated by this project will be published in open access journals and/or submitted to a public database (https://zenodo.org/communities/edeniss).

In all publications based on this expedition, the **Grant No. AWI_ANT_7** 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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Vrakking V, et al. (2022) EDEN ISS. Chapter in Expeditions to Antarctica: ANT-Land 2020/21 Neumayer Station III, Kohnen Station, Flight Operations and Field Campaigns Reports on Polar and Marine Research, Issue 767, pages 64-72, Bremerhaven, Germany, https://doi.org/10.57738/bzpm_0767_2022, ISSN: 1866-3192.

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4.25 GNSS Measurements in Dronning Maud Land to investigate Glacial-Isostatic Adjustment (GIA)

Lutz Eberlein[1], Jölund Asseng[2], Mirko Scheinert[1] (not in the field)

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[2]DE.AWI

Grant-No. AWI_ANT_28

Objectives

Quantifying glacial isostatic adjustment (GIA) in Antarctica is crucial to understand future land and ice-sheet evolution and to correct estimates of ice-mass change from satellite gravimetry (GRACE). A wide range of GIA models have been developed during recent years adopting different modeling approaches. However, substantial differences between GIA model predictions still remain, regarding both, spatial pattern and magnitude of vertical uplift rates as well as the magnitude of the continent-wide GIA mass effect (Whitehouse, 2019). Geodetic GNSS (Global Navigation Satellite System) observations on bedrock provide direct observables to constrain these models. However, the coverage of permanent and campaign GNSS sites is quite different over Antarctica due to the availability of bedrock outcrops and depending on logistic conditions. In central Dronning Maud Land (DML), East Antarctica, our group started GNSS observation campaigns already in the mid-1990s. The coverage was extended to western DML in 2001/02 and 2004/05. Almost all GNSS sites were set up in the mountain range that stretches nearly parallel to the coast, from Heimefrontfjella over Borgmassivet, Orvinfjella to Wohlthatmassivet, over a distance of more than 1,000 km. Whereas for central DML resulting vertical uplift rates could already be inferred, for western DML this is not the case because only the initial observation campaigns were carried out.

The realized GNSS measurements are part of the ongoing project "Investigating glacial-isostatic adjustment on basis of geodetic GNSS observation campaigns in Dronning Maud Land, East Antarctica", funded by the German Research Foundation (SCHE 1426/28-1 and 1426/28-2).

Additionally, two permanently operating GNSS stations were set up, namely at Weigel Nunatak near Kottas Mountains, and at Forstefjell, about 150 km southeast of *Neumayer Station III*. In contrast to campaign sites where only a (long-term) linear trend can be inferred, permanently GNSS recordings allow to also detect periodic signals in coordinate time series (e.g., annual and semi-annual). Both stations are collocated with seismology stations of AWI. The maintenance and data management of both stations was the major task of the field work realized in this season.

Furthermore, to make optimal use of personnel and logistic efforts further tasks were coordinated with other research projects and realized as following:

- Maintenance of seismology stations of AWI Geophysics at Weigel Nunatak, SVEA and Forstefjell;
- Maintenance of the permanently operating GNSS station at SVEA (Sweden)

Fieldwork

To use synergies in the best way, the field group was made up of Lutz Eberlein (PI's group at TU Dresden) and Jölund Asseng (AWI Geophysics). The field work was temporally split into two parts. First, there was a three-day activity at Forstefjell. Second, a longer field campaign was realized heading to the measurement sites situated in the Heimefrontfjella (see overview map, Fig. 4.25.1).

a) Work at Forstefjell

From 25 to 27 December 2022, two Toyota Hilux cars and a trailer were used to drive to Forstefjell, a nunatak located approximately 200 km (driving distance) away from *Neumayer Station III*.

An already known route was followed (as used in 2019/20). At the site Forstefjell a maintenance of both the permanent GNSS site FOP1 (Fig. 4.25.2) and of the seismometer was carried out. At the GNSS station, two defective wind generators (dismantled in 2021 and February 2022) were replaced. Additionally, all data could be downloaded and saved. At the seismometer station, also a data download was accomplished.

b) Work at Heimefrontfjella

Between 30 December 2022 and 10 January 2023, by means of two Toyota Hilux and a PE mat (Carsledge) the two participants drove from *Neumayer Station III* to the Heimefrontfjella area. In the field, a tent served as overnight accommodation. At the Swedish summer station *SVEA* the existing hut could be used for accommodation. At the site Weigel Nunatak, the maintenance of the permanent GNSS station KOP1 (Fig. 4.25.3) and the seismometer station were carried out from 1 to 3 January 2023. All recorded data were downloaded, the wind generator was replaced and the station was upgraded by installation of satellite communication.

From 3 to 7 January the group stayed at *SVEA*. The GNSS point Steinnaben (STEI) was also occupied for this time (Fig. 4.25.4). In *SVEA*, the seismometer and the GNSS station of the Swedish Antarctic Program were maintained. In addition to downloading the data, this included the re-location of the batteries (from outside into the interior of the hut) and the connection of a satellite communication to the seismometer.

The return journey from *SVEA* to *Neumayer Station III* was accomplished including an additional visit to Forstefjell. Here, work was carried out (9 January 2023) which could not be fulfilled during the first visit (25 to 27 December). These included the re-location of the seismometer sensor and the installation of satellite communication for the GNSS station.

We could use a fuel depot which was set up near Weigel Nunatak in the 2021/22 season. The entire route was carried out according to waypoints already known from previous field campaigns and traverses.

For both work topics (a) and (b) a total travel distance of approximately 1,600 km per vehicle was accomplished. As a positive outcome from the logistical point of view it has to be stated that it is not only possible to utilize the two Toyota Hilux Arctic trucks to realize the ride and transport along the traverse up to Heimefrontfjella but that this can be accomplished in an effective way, both in terms of a minimum number of participants and of temporal and logistic efforts (especially fuel consumption). Due to the shorter set-up time and higher cruising speed, this type of traverse is much more flexible than a “classic” sledge traverse (see also Fig. 4.25.5).

Preliminary (expected) results

All GNSS data will to be analysed at the home institution (post-processing) since precise orbit and clock data as well as observational data of permanent stations of the International GNSS Service are to be incorporated. From the processing we expect to infer precise coordinates (with an accuracy of 2 to 5 mm) and coordinate change rates (with an accuracy of 1 to 2 mm/a).

It turned out, that there was a failure in the power system at KOP1. Therefore, data was recorded only for about 15 days right after the initial setup in January 2020. Because since that time no visit could have been realized, the maintenance only could be done in this field season. Starting in January 2023 the station KOP1 successfully records data again.

At FOP1 the data acquisition has been quite successful with more than 800 recorded observation days since installation in January 2020 (Fig. 4.25.6 for a preliminary analysis).

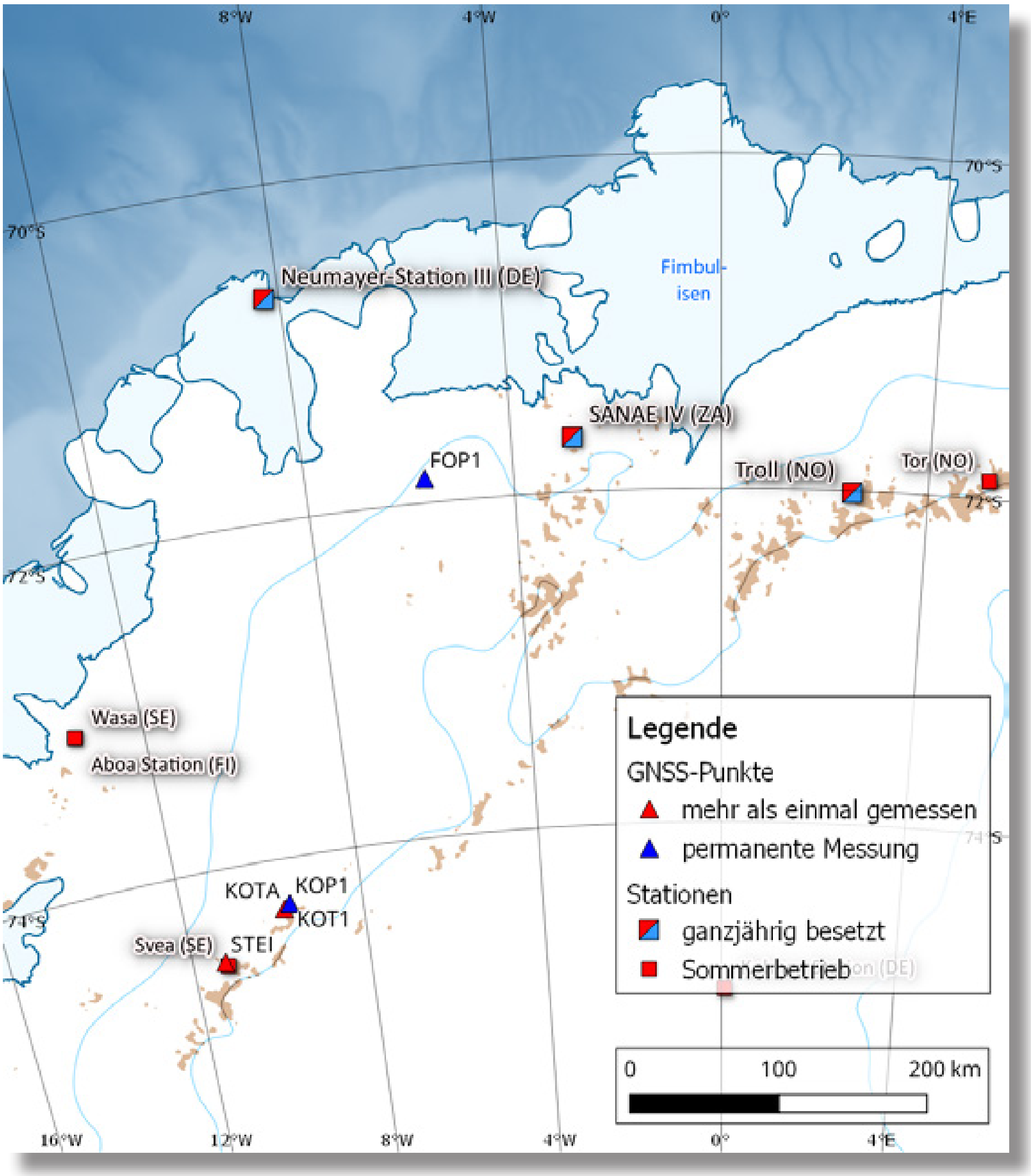

Fig. 4.25.1: Overview map of the working area with Neumayer Station III, the permanent GNSS sites at Forstefjell (FOP1) and Weigel Nunatak (KOP1), and further sites in the Heimefrontfjella; the site KOTA was not observed during the 2022/23 field campaign.

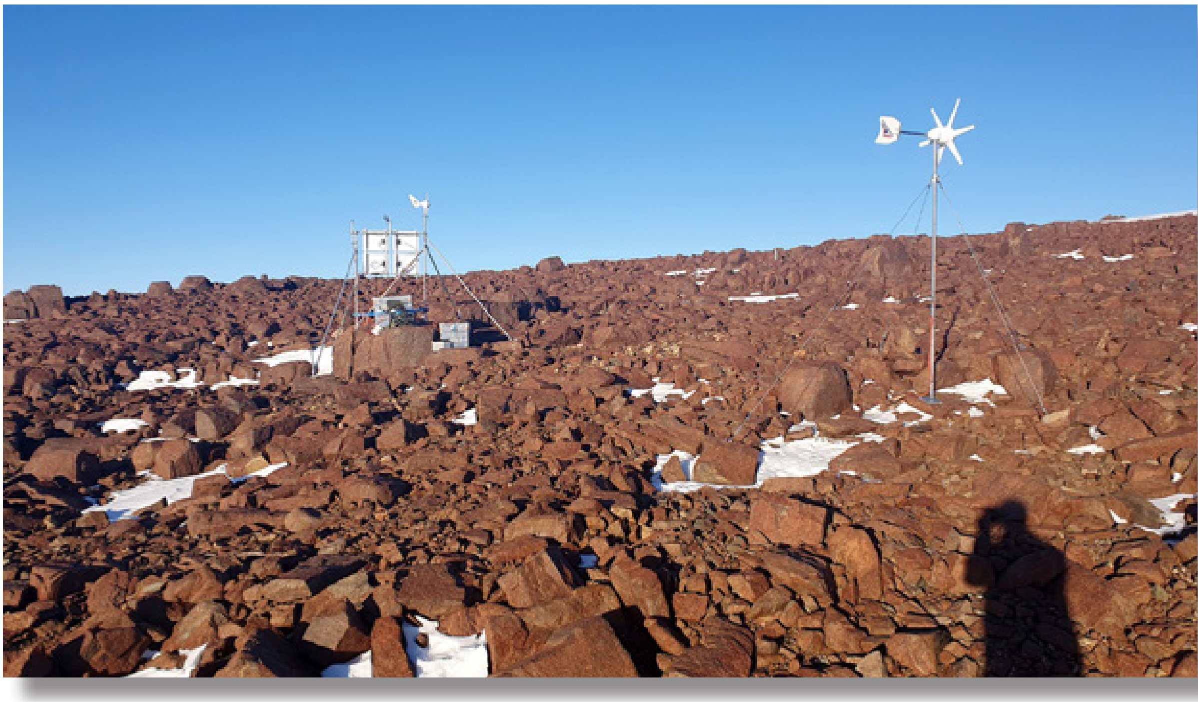

Fig. 4.25.2: Setup of the permanent GNSS station FOP1 at Forstefjell.

Fig. 4.25.3: Setup of the permanent GNSS station KOP1 at Weigel Nunatak (Kottas Mountains).

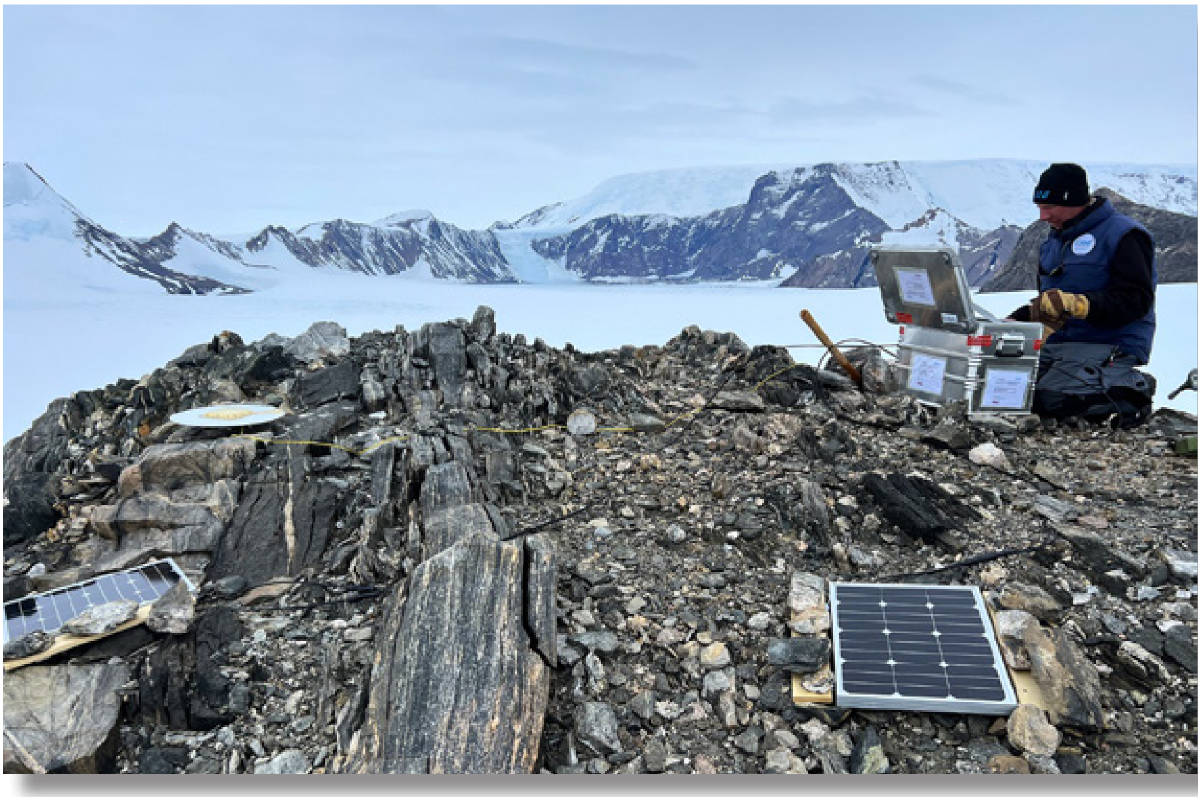

Fig. 4.25.4: Setup of GNSS campaign station STEI at Steinnabben (in the vicinity of the Swedish summer station SVEA, Heimefrontfjella).

Fig. 4.25.5: Usage of Toyota Hilux Arctic Truck together with PE mat. At the PE mat, the tent was temporarily set up for overnight accommodation.

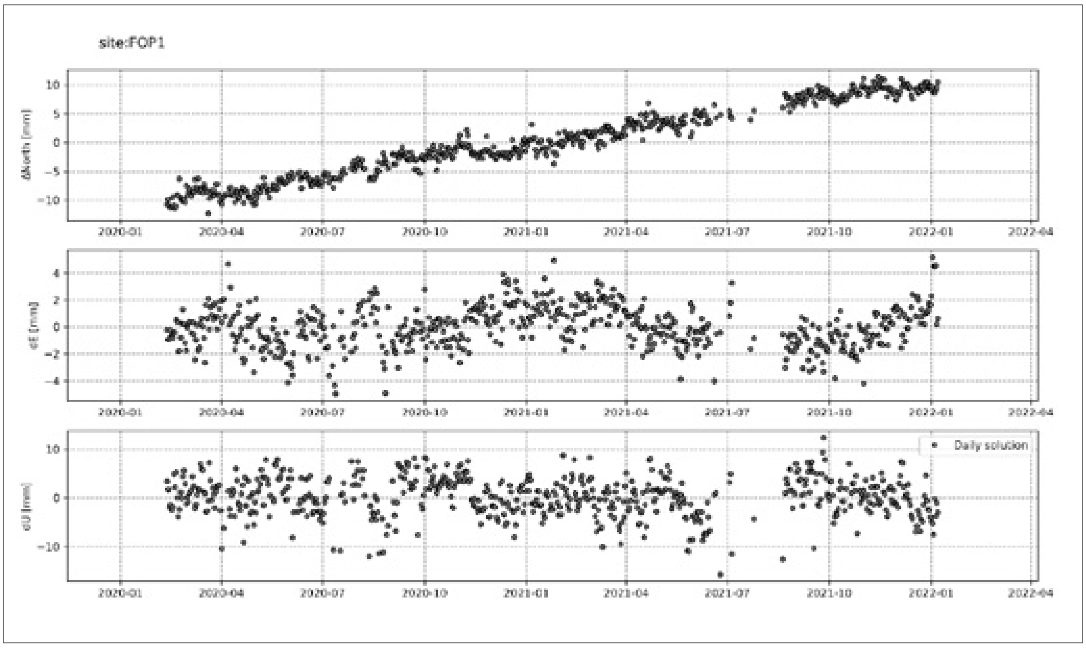

Fig. 4.25.6: Preliminary processing of the GNSS data observed at the permanent site Forstefjell (FOP1) from 02/2020 to 01/2022, resulting time series for the coordinate components north (top), east (middle) and up (bottom panel).

Data management

Original (raw) GNSS data will be archived at the GNSS database of TU Dresden in conjunction with the SCAR GNSS Database. Final data (processed results) 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 in conjunction with a scientific publication. By default, the CC-BY license will be applied.

In all publications based on this expedition, the **Grant No. AWI_ANT_28** 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.

4.26 TRIPLE-IceCraft – a Retrievable Electro-Thermal Drill to access Subglacial Lakes and Oceans

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[1]DE.RWTH
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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 of several hundred meters of thickness 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.

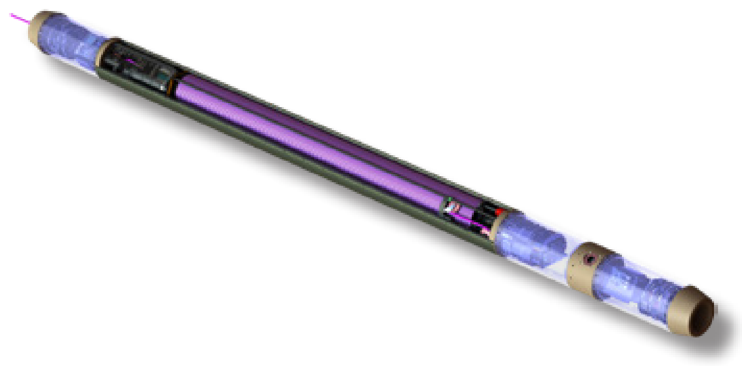

Fig. 4.26.1: Technical drawing of the modular setup of the TRIPLE-IceCraft melting probe

The main objective of the test campaign in February 2023 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. In collaboration with the PALAOA project (Klinck et al., 2016), we prepared the deployment of hydrophones into the ocean below the Ekström Ice Shelf using the melted holes. For this test campaign, we integrated a camera payload module into the TRIPLE-IceCraft system to collect visual data of the icy sidewalls of the hole. We also tested the sonar-based acoustic forefield reconnaissance system (FRS) within the project TRIPLE-FRS (Heinen et al., 2021). This system is designed to detect obstacles in the ice as well as the boundary between ice and water 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.

Fieldwork

We started by commissioning the field station within a container close to *Neumayer Station III* near the radome. The container houses diesel generator and power electronics and is used as a workspace for the team during the test campaign. The next step was to prepare the operations and to integrate the sonar-based FRS and the payload camera module into TRIPLE-IceCraft. During this integration we also re-tested the individual components of the IceCraft, to ensure that each component was still working correctly. We encountered only minor issues that likely arose from transportation, which could be addressed. During testing of the probe's inner winch system, we encountered a low friction issue between the melting probe's cable and the traction sheave, resulting in an unstable climbing behaviour. We addressed it by assisting the climbing up with an external winch, reducing the total load on the cable. As a final acceptance test we drilled a test hole until the full length of the probe had entered into the ice. With the successful completion of these pre-tests, the TRIPLE-IceCraft and all other equipment was transported to the deployment site.

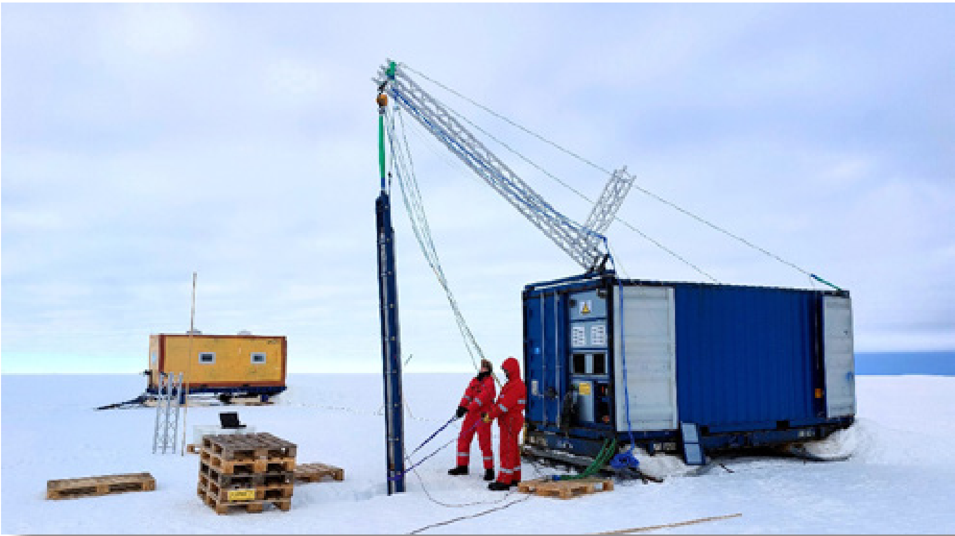

Fig. 4.26.2: Deployment of the TRIPLE-IceCraft Melting Probe

The position of the site was chosen by 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. The probe, and the payloads, the FRS and the camera module, worked fine for the first meter of melting. We achieved a melting speed of up to 3,5 m/h. 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 was draining out of the boreholes. After reaching a depth of about 11 m, we lost the communication link to one of the probe's subsystems. 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.

After the retrieval the communication link could be re-established and the TRIPLE-IceCraft was prepared for another test. We used the existing 11 m hole and the probe lowered itself into it. During the descent the camera module was recording. After reaching the bottom of the hole, the FRS and the front heating elements were started. A final depth of 25 m was achieved. The probe returned to the surface, while recoiling the cable into the probe.

After the completion of the final test, the probe's traction sheave with the gearbox was extracted for returning it via air freight for further examination and improvement. The launch setup was disassembled and stored with all other equipment in the container for overwintering.

Preliminary (expected) results

The TRIPLE-IceCraft melting probe showed a very good system stability. All heating systems at the melting tips and the sidewall worked fine. The probe achieved a high melting speed of up to 3,5 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). Based on this data we started to validate the system and its melting behaviour in more detail. Despite encountering the friction issue during the test, the TRIPLE-IceCraft was successfully deployed and reached a depth of 25 m. The issue was identified and the traction sheave with the gear unit was dismounted and shipped to Germany for further analysis and improvement. The deployment of PALAOA hydrophones was not possible, since the probe did not penetrate the whole ice shelf. The camera payload module performed well, and the data collected provide insights on the layering of the firn and the behaviour of the melting probe. The FRS was operated successfully. The functionality was validated by recording reflection with an air transducer. During the drilling campaigns no reflectors were identified within the ice, since the ice water boundary was not yet within the range of the system.

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 users. The sonar-based forefield reconnaissance system (FRS) recorded data during the in-air validation 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.

References

Heinen D, et al. "The TRIPLE Melting Probe - an Electro-Thermal Drill with a Forefield Reconnaissance System to Access Subglacial Lakes and Oceans". In: OCEANS 2021: San Diego – Porto. OCEANS 2021: San Diego – Porto. Sept. 2021, pp. 1–7. https://doi.org/10.23919/OCEANS44145.2021.9705999

Klinck H, Kindermann L, Boebel O, (2016). PALAOA: The Perennial Acoustic Observatory in the Antarctic Ocean—Real-Time Eavesdropping on the Antarctic Underwater Soundscape. In: Au, W., Lammers, M. (eds) Listening in the Ocean. Modern Acoustics and Signal Processing. Springer, New York, NY. https://doi.org/10.1007/978-1-4939-3176-7_8

4.27 SEAEIS – Seals and Cryobenthic Communities at the Ekström Ice Shelf

Horst Bornemann, Henning Schröder, Christoph Held DE.AWI

Grant-No. AWI_ANT_25

Outline

SEAls and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) apply biologging technologies for studying the foraging ecology of Weddell seals with a direct link to the investigation of cryobenthic invertebrate communities beneath the Ekström Ice Shelf at Atka Bay. Incidences of cryobenthic communities beneath ice shelves are rare and recent discoveries. Combined seal- and ROV-borne imagery and novel sampling technologies led to the discovery of a cryobenthic isopod community (*Antarcturus* cf. *spinacoronatus* Schultz, 1978; Wägele, 1987), being attached head-down to the underside of floating shelf ice at Drescher Inlet (Riiser-Larsen Ice Shelf) at depths of around 80 – 150 m (Watanabe et al., 2006; Bornemann et al., 2016). These "hanging gardens" may represent a food horizon where seals could benefit from a local hotspot of high biologic activity. The presence of isopod aggregations explained a multimodal distribution of the seals' dive depths known from earlier investigations at Drescher Inlet, and could probably also be indicative for increased abundances of seals in Areas of Ecological Significance (AES) at the interface between shelf and sea ice. However, the question whether the aforementioned findings are representative for the far-ranging high Antarctic ice shelves or even unique remains open, and factors contributing to AES and their stability over time are largely unexplored. Therefore, we proposed a synoptic field study at Atka Bay (*Neumayer Station III;* Alfred-Wegener-Institut 2016a), where earlier deployments of satellite-linked data loggers also showed a mode in the distribution of bottom times spent at water depths corresponding to the underside of the floating shelf ice, thus supporting the hypothesis of ice shelf associated foraging.

Objectives

SEAEIS focuses on the foraging ecology of Weddell seals (*Leptonychotes weddellii*) and shelf-ice associated cryobenthic communities. Data obtained from seal-borne 3D-multi-channel data loggers and cameras during earlier expeditions to the Drescher Inlet in 2003/2004 (PS65) and 2015/2016 (PS96) documented that Weddell seals dived along the steep cliffs of the shelf ice and made foraging excursions under the ice shelf (Liebsch et al., 2007; Watanabe et al., 2006; Bornemann et al., 2016). The seal-borne images and dive data led to the discovery of a hitherto unknown cryobenthic community of marine invertebrates, presumably isopods (Antarcturidae, Austrarcturellidae), and potentially anthozoans (*Edwardsiella* spp., *cf.* Daly et al., 2013), being attached head-down to the underside of the floating ice shelf at depths of around 130 – 150 m (Watanabe et al., 2006) and also at around 80 m (Bornemann et al., 2016). These "hanging gardens" may represent an attractive food horizon, where seals could benefit from a local hotspot of high biological activity. These particular findings also explain the trimodal distribution of dive depths of Weddell seals known from earlier investigations during PS65, PS48, PS34, PS20, PS17 (Plötz et al., 2005; 1999; 1997; 1994; 1991). A synoptic field study at Atka Bay (*Neumayer Station II*) during austral spring 2008 also showed a bimodal distribution in dive depths and feeding events of Weddell seals with an increased feeding rate likely on smaller prey items in the pelagic realm (Naito et al., 2010). A number of seals undertook dives to shallower depths between 70 and 80 m close to the ice shelf edge and along an iceberg stranded inside the Atka Bay, and supported our hypothesis of shelf ice associated foraging (Naito et al., 2010).

Most recent underwater video-footage taken during a re-assessment at Drescher Inlet during PS96 in combination with ANT-Land 2015-2016 showed that the cryobenthic isopod crustaceans populate the underside of floating shelf ice in dense aggregations (average: 25 adults/m^2), and at different life stages. The filter-feeding crustaceans could be identified as *Antarcturus* cf. *spinacoronatus*. Molecular barcoding demonstrates that (1) males, ovigerous females and juveniles sampled from the cryobenthic community belonged to the same species, thus proving that the population under the shelf ice is self-sustained and (2) that the same species occurs in nearby benthic communities, albeit abundances on the seabed are about 5 orders of magnitude lower. The aggregations of juveniles concentrated inside depressions of the scallop textured shelf ice underside, with adults on ridges. This suggests the importance of hydrographic conditions across the scallop structure in association with melting ice surfaces. Microturbulences may bring plankton particles within reach of juveniles (<1 cm). Data from earlier expeditions show that Weddell seals feed in depths corresponding to the occurrence of the cryobenthic isopods (70 – 150 m), possibly feeding on the isopods themselves or their associated fish fauna (Plötz et al., 2001).

The question whether or not these findings are representative for the extensive Antarctic ice shelves in general still remains open. Though the seals' diving behaviour at the Drescher Inlet indicates active foraging in a locally attractive feeding spot, the factors contributing to this hotspot of enhanced food availability and its stability over time are largely unexplored. In particular questions towards species composition, horizontal extent and nutrient supply of the fauna inhabiting the underside of the ice shelf are still open and call for additional investigations to further our understanding of bentho-pelagic coupling processes. We therefore initiated another synoptic study at Atka Bay to investigate the underside of the floating ice shelf tongue of the Ekström Ice Shelf with instrumented "camera-seals" and an ROV to be deployed from sea ice.

Physical environment – bathymetry and hydrography

The Atka Bay is an approximately 25 x 20 km shallow embayment in the Ekström Ice Shelf. The thickness of the ice shelf along the outer bay contours increases from about 80 m to about 200 m in a southerly direction within the first 5 km. The flow velocity of the shelf ice tongue in this area is about 100 – 150 m per year. In the southern part of the bay, the ice shelf is grounded (Atka ice rise), and the grounding line is just under 100 km inland at Halvfarryggen (*cf*. Arndt et al., 2013; BSH 2009; Dorschel et al., 2023). The sea ice in the bay is generally about 1 – 3 m thick, sometimes with snow accumulations of up to several meters, while some patches in the southernmost corners may remain with multi-year sea ice that can increase to several meters in thickness. In the area of the western shelf contour, snow deposits of the sea ice reach the level of the ice shelf. At the time of the sojourn, a consolidated sea ice surface can be assumed to completely fill the bay and extend to the coastal polynia. Below the sea ice, aggregations of plate ice may extend down to 20 m water depth (*cf*. Günther et al., 1999; Thomas et al., 2001), an observation that was in line with our own during this expedition. Water depths within the bay range from 120 – 275 m (*cf*. Wegner 1981; Schenke et al., 1997; BSH 2009; Dorschel et al., 2023;) with even shallower parts in the Southwestern part of Atka Bay (Aurelia crack approx. 75 m water depth, see Tab. 4.27.2). Water temperatures are around -1.9°C with an increase in summer to -1.5°C within the upper 100 m water column.

Biological environment – benthos

The benthos encountered on the shelf in the near and far vicinity of Atka Bay near *Neumayer Station III* belongs predominantly to the suspension feeder community, characterized by bryozoans, sponges, tunicates and soft corals. In terms of biomass the area represents one of the richest communities in the Southern Ocean and provides microhabitats for an equally rich associated fauna of crustaceans, polychaetes, echinoderms, and mollusks. In areas deeper than 250 m, species numbers decrease significantly; in contrast, areas at depths less than 100 m are far more exposed to the effects of iceberg groundings, and consequently are characterized by a "patchwork" of recolonization stages dominated by different pioneer species (J. Gutt pers. comm.).

Biological environment – fish fauna and evertebrates

The fish fauna in the marine area off Atka Bay is dominated by the pelagic schooling fish *Pleuragramma antarctica*; other species of the families Nototheniidae, Channichthyidae, Bathydraconidae, Artedidraconidae and others as well as krill (*Euphausia* spp.), gelatinous plankton and amphipods are present (*cf*. Günther et al., 1999). There is also evidence for a possible evertebrate fauna beneath the ice shelf (Naito et al., 2010), as well as a record of hydrozoans in the platelet ice (Galea et al., 2016).

Biological environment – emperor penguins and seabirds

The population size of the Atka Bay emperor penguin (*Aptenodytes forsteri*) colony in 2018 was estimated to be about 26,000 individuals (Zitterbart et al., 2019). As early as the beginning of December, chicks hatched early in the season lose their down feathers and are abandoned by their parents. Late-hatched chicks continue to feed until the end of December. After that, the colony disintegrates. By mid-December, the formerly consolidated breeding colony of emperor penguins was divided into several groups that disperse along, and in some cases on the western shelf of the bay. In addition to the emperor penguins, small number of Adélie penguins (*Pygoscelis adeliae*) occurred, as well as skuas (*Catharacta maccormicki*), giant petrels (*Macronectes spp*.), Antarctic petrels (*Thalassoica antarctica*), snow petrels (*Pagodroma nivea*), and Wilson's storm petrels (*Oceanites oceanicus*).

Biological environment – seals and whales

Weddell seals (*Leptonychotes weddellii*) are common in Atka Bay, and their local population size has been determined for the first time for the western half of Atka Bay during a 2018 combined satellite remote sensing and aircraft campaign. Including those encountered on the offshore pack ice areas, 140 seals were encountered. The number of Weddell seals determined within the fast ice area within the bay was 120 (Bornemann et al., 2019). At about the same time as the planned work on the sea ice began around mid-November, the birthing phase for Weddell seals ended. Set groups, as elsewhere, consist mostly of about 5 – 10 females, each with one pup (Reijnders et al., 1990), which is nursed for 5 – 6 weeks. Late-born pups are weaned around mid-December. The potential presence of lactating mother seals and their pups are therefore expected to continue into December (*cf*. van Opzeeland et al., 2010). During periods of ice breakup, small numbers (individuals) of crabeater seals (*Lobodon carcinophaga*), and possibly leopard seals (*Hydrurga leptonyx*) and Ross seals (*Ommatophoca rossii*), may linger in the bay area for a few hours to a few days. The presence of these species has been documented by the PALAOA acoustic observatory at Atka Bay (van Opzeeland et al., 2010). Also associated with sea ice breakup, humpback whales (*Megaptera novaeangliae*), killer whales (*Orcinus orca*), minke whales (*Balaenoptera bonaerensis*), and Arnoux's beaked whales (*Berardius arnouxii*) have been observed in the marine area off Atka Bay; the presence of some of these and other species has been documented by the PALAOA acoustic observatory at Atka Bay (Schall & van Opzeeland 2017; Filun et al., 2017; Thomisch et al., 2016; van Opzeeland et al., 2013) and in the vicinity off the bay (*cf*. Menze et al., 2016a; Menze et al., 16b).

Fieldwork

Summary and itinerary

The SEAEIS team prepared for the expedition with a 5-day self-isolation in Bremerhaven and travelled via Hamburg (27 October 2022), Oslo (27 – 28 October 2022), Accra (28 October 2022) and Cape Town (29 October 2022) with NPI-F1 (Boeing 757, Iceland Air) to the Norwegian research station *Troll* (30 October – 2 November 2022) and arrived at *Neumayer Station III* with a subsequent feeder flight with the DC-3 Basler *Mia* on 2 November 2022.

The good weather conditions made it possible to carry out a reconnaissance of the sea ice areas of the Atka Bay immediately after arrival. In the course of several reconnaissance trips by Skidoo and Nansen sledge along the tidal cracks of the sea ice and in the vicinity of grounded icebergs, about 80 adult Weddell seals were counted in Atka Bay, which was still completely covered by sea ice. These were mainly female seals with their pups, which were set before the arrival of the SEAEIS team. The animals initially aggregated in groups of 10 – 15 mother-pup pairs at the cracks, some of which separated by more than 10 km to each other. After weaning, the group size of these aggregations increased to sometimes more than 50 animals towards the end of December when the break-up of the fast ice began. Seal species other than Weddell seals were not encountered on the bay ice.

Beyond Atka Bay, another study site was considered to be established further west in the vicinity of the Kvitkuven ice cap near Rampen (Riiser-Larsen Ice Shelf) with the support of the Finnish research station *Aboa* (73°02’S - 13°24’W) at the end of the campaign. However, this could not be implemented as planned, as the Finnish collaboration partners could not offer support during the planned period due to logistical and personnel limitations and hence suggested the requested stay and associated ice camp under their direction be postponed to a subsequent season. A previously requested collection of sample material on the ice by the Finnish station team also did not take place for the aforementioned reasons. For a future, temporally separated mission via *Aboa*, a new request would be made on our part in due course.

Work on the sea ice continued until 4 January. On 10 January 2023, access to the sea ice was restricted for safety reasons in view of the anticipated ice break-up. The SEAEIS team then dealt with data inventory and processing and left *Neumayer Station III* on 25 January 2023 via a feeder flight with DC-3 Basler *Polar 5* to the Norwegian *Troll* Station, from where the return flight to Cape Town was made on 26 January 2023 with NPI-F4 (Boeing 737 Max 8, Smartwing Airlines).

Skidoo operation

The SEAEIS team visited the seals on the sea ice and the ROV deployment sites with two skidoos, to each of which one or two sledges with expedition equipment including emergency equipment were attached. Over the entire project period, the SEAEIS team spent a total of about 350 hours on the ice on 53 working days and covered about 2,000 km by skidoo. As a rule, the trips started during the morning hours (UTC) and lasted until the late afternoon/early evening hours in order to ensure the probability of encounter according to the seals’ diurnal rhythm when searching the sea ice. Figure 4.27.1 shows an example of the distances travelled to the work sites (with trivial designations) within Atka Bay. Table 4.27.1 shows the corresponding quantity structure of the travel distances and the duration of the work assignments on the ice.

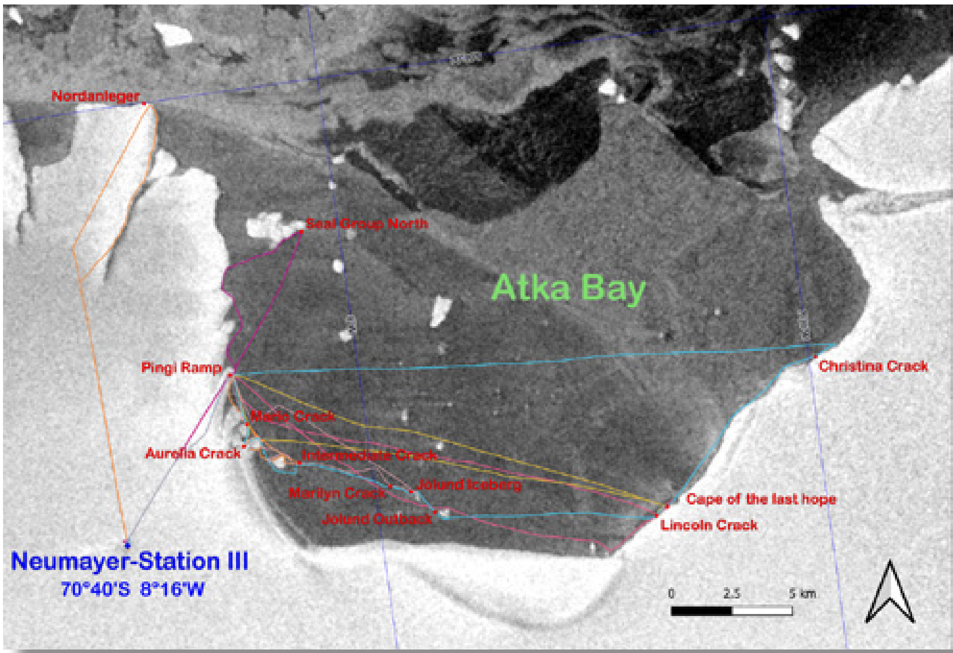

Fig. 4.27.1: Map of Atka Bay and the locations visited during the Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) project of the ANT-LAND 2022/23 expedition at Neumayer Station III from 2 November 2022 – 25 January 2023. The place names given are trivial designations that only serve to facilitate orientation for the expedition participants. Image: Sentinal 1, 11_S1_EW_HH_sub_20221111T204907_202211T205011_sentinal_highres_50.tiff; modified and GPS data implemented by Henning Schröder, AWI)

Tab. 4.27.1: Data on the total skidoo deployments and distances covered during the Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) project of the ANT-LAND 2022/23 expedition at *Neumayer Station III* from 2 November 2022 – 25 January 2023. The place names given are trivial designations that only serve to facilitate the orientation of the expedition participants.

Visit	Date	Time (Start)	Time (End)	Latitude	Longi-tude	Distance	Destination
[No]	[yyyy-mm-dd]	[hh:mm]	[hh:mm]	[deg]	[deg]	[km]	[trivial #]
01	2022-11-04	11:30	19:00	-70.63150	-8.13850	22	Aurelia Crack
02	2022-11-05	11:00	17:30	-70.63150	-8.13850	28	Aurelia Crack
03	2022-11-06	10:00	17:30	-70.62735	-7.49177	85	Christina Crack
04	2022-11-07	09:00	14:30	-70.65715	-7.95748	45	Jölund Iceberg
05	2022-11-08	09:30	17:00	-70.63150	-8.13850	28	Aurelia Crack
06	2022-11-11	10:00	18:00	-70.63150	-8.13850	28	Aurelia Crack
07	2022-11-12	09:00	16:00	-70.63150	-8.13850	28	Aurelia Crack
08	2022-11-13	13:00	20:15	-70.63150	-8.13850	28	Aurelia Crack
09	2022-11-15	16:30	21:00	-70.55275	-8.03352	40	Seal group north
10	2022-11-16	10:00	15:00	-70.55275	-8.03352	40	Seal group north

Visit	Date	Time (Start)	Time (End)	Latitude	Longi-tude	Distance	Destination
[No]	[yyyy-mm-dd]	[hh:mm]	[hh:mm]	[deg]	[deg]	[km]	[trivial #]
11	2022-11-16	15:00	19:30	-70.63150	-8.13850	28	Aurelia Crack
12	2022-11-17	10:30	14:00	-70.62366	-8.13093	28	Intermediate Crack
13	2022-11-17	14:00	20:00	-70.50132	-8.18883	40	Nordanleger
14	2022-11-19	11:00	16:00	-70.63150	-8.13850	28	Aurelia Crack
15	2022-11-19	16:00	19:30	-70.65715	-7.95748	43	Jölund Eisberg
16	2022-11-20	10:30	17:30	-70.63150	-8.13850	28	Aurelia Crack
17	2022-11-22	11:30	13:00	-70.63150	-8.13850	28	Aurelia Crack
18	2022-11-22	13:00	19:00	-70.63150	-8.13850	28	Aurelia Crack
19	2022-11-23	10:50	14:30	-70.62366	-8.13093	28	Mario Crack
20	2022-11-24	10:15	13:30	-70.63150	-8.13850	28	Aurelia Crack
21	2022-11-24	16:30	22:00	-70.63150	-8.13850	28	Aurelia Crack
22	2022-11-26	09:30	21:00	-70.63150	-8.13850	28	Aurelia Crack
23	2022-11-27	10:30	12:30	-70.60506	-8.13958	12	Pingi Ramp
24	2022-11-29	09:00	22:00	-70.62735	-7.49177	09	Christina Crack
25	2022-11-30	10:30	19:00	-70.63150	-8.13850	28	Aurelia Crack
26	2022-12-03	14:30	21:00	-70.63150	-8.13850	28	Aurelia Crack
27	2022-12-04	09:30	16:00	-70.62735	-7.49177	57	Lincoln Crack
28	2022-12-05	09:30	18:00	-70.67800	-7.69233	57	Lincoln Crack
29	2022-12-06	09:30	21:00	-70.67800	-7.69233	58	Lincoln Crack
30	2022-12-09	09:30	20:00	-70.67540	-7.67912	58	Cape of Last Hope
31	2022-12-10	09:30	11:30	-70.63150	-8.13850	28	Aurelia Crack
32	2022-12-12	14:30	19:00	-70.63150	-8.13850	28	Aurelia Crack
33	2022-12-13	11:30	15:00	-70.63150	-8.13850	28	Aurelia Crack
34	2022-12-13	16:00	21:00	-70.66567	-7.93433	50	Jölund Outback
35	2022-12-14	11:45	19:30	-70.63150	-8.13850	28	Aurelia Crack
36	2022-12-15	11:00	21:30	-70.67540	-7.67912	58	Cape of Last Hope
37	2022-12-17	10:30	19:30	-70.62735	-7.49177	85	Christina Crack
38	2022-12-18	09:30	21:30	-70.67540	-7.67912	42	Cape of Last Hope
39	2022-12-20	13:15	22:30	-70.65715	-7.95748	43	Jölund Iceberg
40	2022-12-21	15:30	19:30	-70.63150	-8.13850	28	Aurelia Crack
41	2022-12-22	10:30	19:30	-70.67540	-7.67912	58	Cape of Last Hope

Visit	Date	Time (Start)	Time (End)	Latitude	Longi-tude	Distance	Destination
[No]	[yyyy-mm-dd]	[hh:mm]	[hh:mm]	[deg]	[deg]	[km]	[trivial #]
42	2022-12-23	10:30	16:00	-70.67540	-7.67912	58	Cape of Last Hope
43	2022-12-25	13:30	21:00	-70.67540	-7.67912	58	Cape of Last Hope
44	2022-12-26	15:30	17:30	-70.62366	-8.13093	28	Intermediate Crack
45	2022-12-27	07:00	08:30	-70.50132	-8.18883	40	Nordanleger
46	2022-12-27	08:30	19:30	-70.50132	-8.18883	40	Nordanleger
47	2022-12-28	09:30	19:00	-70.67540	-7.67912	58	Cape of Last Hope
48	2022-12-30	11:00	19:30	-70.63150	-8.13850	28	Aurelia Crack
49	2022-12-31	09:30	16:30	-70.67540	-7.67912	58	Cape of Last Hope
50	2023-01-01	13:30	17:30	-70.67540	-7.67912	85	Christina Crack
51	2023-01-02	09:30	21:30	-70.67540	-7.67912	58	Cape of Last Hope
52	2023-01-03	11:30	18:30	-70.63150	-8.13850	38	Marylin Crack
53	2023-01-04	09:30	18:30	-70.63150	-8.13850	43	Jölund Iceberg

Work on Weddell seals

For the purpose of instrumentation with video-camera loggers, the seals needed to be anaesthetized following the methods as described in Bornemann et al. (1998) and Bornemann & Plötz (1993). Drugs were initially administered intramuscularly (i.m.) by remote injection using blowpipe darts. Follow-up doses were usually given intramuscularly by direct manual i.m. injection or in rare cases intravenously. The seals were immobilized using a ketamine/xylazine combination that was complemented by diazepam if necessary (see https://doi.org/10.1594/PANGAEA.955098 for the dose regime involved the aforementioned drugs). Depending on the course of the immobilisation, dosages were individually adjusted and complemented by the same drugs to maintain or extend the immobilisation period on demand. Atipamezol was used to reverse the xylazine component in the xylazine/ketamine immobilisation. Doxapram was exclusively reserved for the necessity to stimulate breathing in a case of a finally irreversible apnoea, where mechanical obstructions of the upper airways could be excluded. The length and girth of each seal was measured. All procedures were carried out pursuant to the SCAR Code of Conduct for Animal Experiments, and were approved by the German Federal Environmental Agency (Umweltbundesamt) and the Federal Agency for Nature Conservation (Bundesamt für Naturschutz) under the German acts implementing the Protocol of Environmental Protection to the Antarctic Treaty and the Convention for the Conservation of Antarctic Seals.

During the ice work from 2 November 2022–4 January 2023, a total of 7 Weddell seals were immobilised (anaesthetized) in order to deploy infrared underwater video cameras (Little Leonardo, Japan; *cf*. Naito et al., 2013; Watanabe et al., 2006; 2003) in order to track their foraging behaviour visually during the course of the study and to investigate the seals' under shelf ice foraging excursions and to take samples; 4 of the aforementioned seals were adult, non-lactating females and 3 were adult male seals (see Tab. 4.27.2). Figure 4.27.2 shows a Weddell seal with camera logger.

Fig. 4.27.2: Weddell seal with infrared camera logger as part of the Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) project of the ANT-LAND 2022/23 expedition at Neumayer Station III from 2 November 2022 – 25 January 2023 (Photo: Horst Bornemann, AWI).

All immobilisations in the area of the seals' resting places were without any particular findings and showed the broad spectrum of individual reactions to the doses of the preparations used. Except for seal numbers 05, 06 and 07, all other animals were anaesthetized several times at intervals between 3 and 15 days between deployments. A total of 17 immobilisations were administered (see Tab. 4.27.2). In two cases, a sufficiently deep anaesthesia could not be induced. Here, the work was not pursued further and therefore no sampling or instrumentation was carried out.

The immobilisations lasted on average 1:07 hours (period between first injection to induce and last injection to reverse the immobilisation) including a standardised observation time of at least 20 minutes after the first injection until the anaesthesia took full effect and plus a standardised observation time of at least 20 minutes after the last injection until awakening from the anaesthesia. The total time including the follow-up observation time was 1:27 hours on average (Tab. 4.27.3).

After the aforementioned time period, all animals recovered sufficiently from anaesthesia and reacted adequately to environmental stimuli. None of the animals went into the water within this period. Data could be recorded from four of the seals fitted with infrared underwater cameras after recovery of the devices. In two cases, the devices remained on the animal as the devices could not be recovered during the phase of incipient sea ice break-up. The gauze mat used to attach the camera loggers will fall off the animals' hair at around February, limiting the period during which the gauze mats and cameras remain on the animals to a maximum of another 6 – 8 weeks after the end of the project.

Information on the place and time of the work performed on the animals, the duration of anaesthesia, the total duration of the examination, size and sex of the animals as well as the equipment with infrared camera loggers are summarised in tables (see Tab. 4.27.2, 4.27.3 and 4.27.4).

Tab. 4.27.2: Data on immobilisations of 7 adult Weddell seals (*Leptonychotes weddellii*) within the project Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) of the ANT-LAND 2022/23 expedition at *Neumayer Station III* from 2 November 2022 – 25 January 2023.

Weddell seal			DateTime	Latitude	Longitude	Length	Girth
[No]	Sex	Procedure	[yyyy-mm-ddThh:mm]	[deg]	[deg]	[mm]	[mm]
01	M	1	2022-11-08T11:02	-70.63150	-8.13850	2590	2010
01	M	2	2022-11-11T12:00	-70.63150	-8.13850	2590	2010
02	M	1	2022-11-17T11:47	-70.62366	-8.13093	2630	2100
01	M	3	2022-11-21T11:22	-70.63150	-8.13850	2590	2010
02	M	2	2022-11-23T11:30	-70.62366	-8.13093	2630	2100
01	M	4	2022-11-26T11:05	-70.63150	-8.13850	2590	2010
01	M	5	2022-11-30T12:02	-70.63150	-8.13850	2590	2010
02	M	3	2022-12-05T10:40	-70.63150	-8.13850	2630	2100
03	F	1	2022-12-06T10:39	-70.67540	-7.67912	2860	1960
03	F	1	2022-12-13T17:22	-70.66567	-7.93433	2860	1960
04	M	1	2022-12-18T12:17	-70.67540	-7.67912	2460	1710
02	M	4	2022-12-20T14:29	-70.63150	-8.13850	2630	2100
04	M	2	2022-12-22T12:56	-70.67540	-7.67912	2460	1710
04	M	3	2022-12-28T11:35	-70.67540	-7.67912	2460	1710
05	F	1	2023-01-03T12:45	-70.63667	-8.11983	n.a.*	n.a.*
06	M	1	2023-01-03T15:05	-70.63667	-8.11983	n.a.*	n.a.*
07	F	1	2023-01-03T15:45	-70.63667	-8.11983	n.a.*	n.a.*

*F = female M = male * no sufficient immobilization n.a. = not available*

Tab. 4.27.3: Data on immobilisation, sampling and instrumentation of 7 adult Weddell seals (*Leptonychotes weddellii*) as part of the Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) project of the ANT-LAND 2022/23 expedition at *Neumayer Station III* from 2 November 2022 – 25 January 2023.

Seal	Immobilisation	Procedure	Sampling				Device
No	[hh:mm]	[hh:mm]	Blood	Vibrissae	Hair	Faeces	[#]
01	01:43	2:03		xx	x		IR-CAM
01	00:57	1:17				X	IR-CAM
02	02:03	2:23	x	x	x		IR-CAM
01	00:41	1:01	x				IR-CAM
02	01:00	1:20					IR-CAM

Seal	Immobilisation	Procedure	Sampling				Device
No	[hh:mm]	[hh:mm]	Blood	Vibrissae	Hair	Faeces	[#]
01	01:03	1:23					IR-CAM
01	01:06	1:26					*
02	00:30	0:50					IR-CAM
03	01:23	1:43	x	x	x	X	IR-CAM
03	01:00	1:20				X	*
04	01:06	1:26		x	x	X	IR-CAM
02	01:01	1:21					*
04	00:54	1:14					IR-CAM
04	01:00	1:20					IR-CAM
05	01:15	1:35					IR-CAM
06	**	**					**
07	**	**					**
Mean	01:07	01:27					

*IR-CAM = Infrared-camera logger   * = only retrieval of IR-CAM   ** = depth of immobilisation unsufficient*

Tab. 4.27.4: Data on collections of faecal samples within the project "Seals and cryobenthic communities at the Ekström Ice Shelf" (SEAEIS) of the ANT-LAND 2022/23 expedition at *Neumayer Station III* from 2 November 2022 – 25 January 2023.

Sample	Seal	Date	Latitude	Longitude
No	Nr.	[yyyy-mm-dd]	[deg]	[Grad]
01	01	2022-11-12	-70.63150	-8.13850
02	xx	2022-11-16	-70.55275	-8.03352
03	xx	2022-11-29	-70.64090	-8.07673
04	xx	2022-11-29	-70.65715	-7.95748
05	01	2022-11-29	-70.67800	-7.69233
06	02	2022-11-30	-70.63150	-8.13850
07	02	2022-12-05	-70.63150	-8.13850
08	03	2022-12-13	-70.63150	-8.13850
09	xx	2022-12-06	-70.67800	-7.69233
10	xx	2022-12-06	-70.67800	-7.69233
11	03	2022-12-13	-70.65715	-7.95748
12	xx	2022-12-13	-70.66567	-7.93433
13	xx	2022-12-14	-70.63150	-8.13850
14	xx	2022-12-17	-70.67540	-7.67912
15	xx	2022-12-17	-70.67540	-7.67912
16	04	2022-12-18	-70.67540	-7.67912

xx = seal not known from our immobilisation scheme (see Tab. 4.27.3)

Making of ice holes

In the course of the campaign, 10 deployment sites for the ROV were explored, of which only three could eventually be used for ROV deployments. The others could not be used because of too thick ice or floes that had been pushed over each other or because the underwater topography was too unclear. In all cases, holes were made in the ice with hand saws (“Fin saw”) and the ice holes were kept open and maintained as needed in the course of the ROV deployments (see Fig. 4.27.3). Another deployment site was accessed from the ice shelf. The highly compacted platelet ice floating in the ice holes was removed with buckets (“Schlagpütz”) and a scoop. Depending on the thickness of the ice and the thickness of the platelet-ice layer, it took three people about one to three days to create an ice hole on a crack in the immediate vicinity of the ice shelf edge. However, the success of the subsequent ROV deployment depends on the fact that underwater ice pressing with multi-layered uplift of floes has not occurred in the course of sea ice formation, that the further aggregation of platelet ice at the once opened ice hole is low or that larger accumulations can be bypassed with the ROV. These conditions can only be determined empirically, which repeatedly led to the abandonment of previously painstakingly created ice holes for potential ROV deployments. At a distance of about 50 – 100 m from the ice shelf edge, these would be much safer for deploying, manoeuvring and recovering the submersible as well as setting up the ROV control station and winch, and would be more promising in terms of the expected data yield. At this distance from the ice shelf edge, however, the consolidated sea ice is about 3 m thick. The underlying platelet ice aggregations accumulate to about 7 m, and in individual cases platelet ice thicknesses of up to 16 m have been observed in the eastern part of Atka Bay. Such ice thicknesses cannot be managed without special mechanical equipment with an adequate amount of work and time to deploy a ROV. The creation of ice holes at a greater distance from tidal cracks would also make it possible to use equipment that is lowered into the water column in the manner of a plumb bob (CTD, fish traps, fishing rods, hydrophones). In the course of the SEAEIS campaign, the use of these devices often failed because they could not be directed past a protruding foot of the ice shelf or grounded icebergs or the frozen platelet ice fringes, but came to rest on top of them.

Particularly against the background of future systematic, comparative sampling along different depth horizons of the ice shelf of Atka Bay and neighbouring inlets, the availability of mechanical equipment at *Neumayer Station III* would be desirable in order to be able to collect and analyse data and samples on a sufficient scale. This is the only way to determine with the necessary statistical precision which species occur under the ice shelf and what their spatial distribution looks like (patchiness, abundance, estimated total biomass, etc.). Both are indispensable for modelling the carbon cycle in order to be able to meaningfully determine the magnitude of the cryobenthos in the carbon and energy flux. The collection of invertebrate samples and fish for a genetic investigation of the cryobenthic species inventory is essential to investigate species identity, phylogenetic position and population genetic links in comparison with conspecifics from the adjacent benthos. For future time series and potential deployments of underwater robotics and landers, it would be indispensable to have the appropriate equipment for an efficient creation of ice holes available on site. Figure 4.27.3 illustrates work and gear to create an ice hole. The future assistance of drilling hardware would permit establishing holes a bit farther away from tidal cracks and thus grounded icebergs or shelf ice cliffs, thereby improving the work safety and permitting systematic surveys independent of the existence of conveniently located and sized tidal cracks.

Fig. 4.27.3: Set-up of the working site to create an ice hole (Photo: C. Held, AWI).

ROV setup

Two BlueROV (bluerobotics, US) were assembled and customized by Geo-Engeneering.org., Bremen and IGP Meerestechnik, Hamburg, Germany, used in varying technical configurations (Tab. 4.27.5). One of the ROVs was originally considered redundant as back up in case of critical damages.

Due to transport complications on the part of the transporting airline, the ROV had to be stored in Oslo until the NPI-F2 flight. Despite the contrary results of a preliminary inspection and corresponding coordination, the airlines did not complain about safety concerns regarding the lithium-ion batteries belonging to the ROV until immediately before departure. It was therefore necessary to redesign the battery configuration during the journey from *Troll Station*. The implementation was done in coordination with the design office of IGP in Bremen and the AWI workshop in Bremerhaven, while 200 alternative batteries (form factor 18650) were bought through AWI's Logistics and Research Platforms in Bremerhaven and Meihuizen Agency in Cape Town and flown to *Troll Station* together with the spare parts with NPI-F2 as hand luggage of newly incoming expedition participants, while the ROV was still waiting in Oslo. The ROV reached *Neumayer Sta*tion *III* on 12 November 2022 with a cargo flight of the Basler DC-3 Mia and was modified the following day to accommodate the new batteries, rebalanced in a water basin in the station's climate control centre and successfully tested during an initial deployment. However, the alternative battery concept previously developed for the ROV had to be abandoned again, as increased contact resistances between the batteries due to the design led to massive heat generation during several ROV deployments, which considerably limited the ROV's operational safety. To avoid damage to the ROV, the battery concept was reconsidered again. For this purpose, the main tube of the spare ROV was adapted as a battery compartment for the lithium polymer batteries to operate a drone from the *Neumayer Station III* inventory. These had only half the capacity of the original ROV batteries, but up to four dive missions of up to 90 minutes with one of the drone batteries each were possible in succession. The greatly decreased battery capacity did, however, severly limit the ROV's ability to pump water samples for environmental DNA as the complicated underwater topography made returning to the ice hole with enough battery power to disentangle the cable etc. mandatory. The energy consumption of the pump in combination with the weaker replacement battery only allowed relatively short distances to be travelled and a smaller number of water samples to be taken before having to abandon the mission and return to the ice hole.

The entire setup consists of two up to three racks of which the technical equipment combined different constellations as outlined in Table 4.27.5. The Full HD ROV video camera (1920 x 1080) in the front transmitted the signal to the control laptop on the surface via the tether and was recorded there and one GoPro Hero 8 camera (4K), which recorded locally on a micro SD card. The cameras were complemented by up to three parallel green laser points providing reference scales of 10 by 10 cm on the videos. Illumination is ensured by four white LED lights (each 1,500 lumen, colour temperature 5,700 Kelvin) in the front and one dive lamp (BigBlue VTL800P) wich was occasionally used to amplify illumination for the cameras. Two versions of a mini-dredge and sampling box, a so-called slurp gun, in different versions, were attached to the underside and front side of the ROV respectively to obtain invertebrate specimens for *post hoc* morphological and genetic investigations. Water samples for environmental DNA were taken by means of a revolver valve and pump, samples stored into secretion bags. Setting out and retrieval of the ROV was achieved manually, and spooling of the 450 (4 x twisted pair) and 600 m (1 x twisted pair) alternating ROV cables was done by a hand winch, which was placed on a sledge or the back of a skidoo next to the ice hole. Some of the dives of the ROV turned out to be close or even beyond its operational technical specifications, and hence required intensive technical support and maintenance before and after each dive. As a result, several dives needed to be aborted prematurely due to various technical malfunctions. The successful dive operations under the ice shelf provided high resolution footage and samples of the under-shelf ice community at depths between 0 and 155 m. Table 4.27.5 provides all data on the deployments of ROV and its customized technical specifications.

Sonars were not used for navigation, since the ROV could be driven under visual control between the deployment sites at the tide gaps to and along the contours of the ice walls due to the good visibility conditions (visibility under water 40 m and more). Figures 4.27.4a and 4.27.4b illustrate the ROV at one of the ice holes and the cockpit setup to manouvre the ROV remotely.

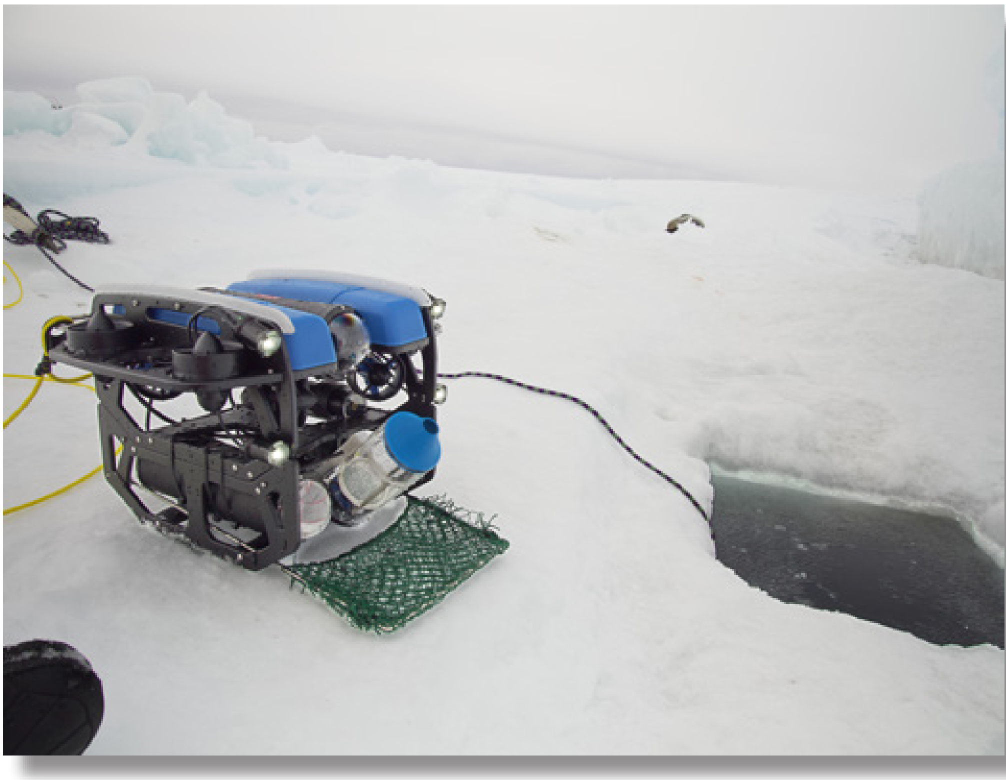

Fig. 4.27.4a (top) and b (bottom): ROV setup (top) at on of the ice holes showing the sledge-mounted cockpit (bottom) as part of the Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) project of the ANT-LAND 2022/23 expedition at Neumayer Station III from 2 November 2022 – 25 January 2023 (Photos: Christoph Held and Aurelia Hölzer).

Tab. 4.27.5: For further information please see the end of the chapter

ROV operation and cryobenthic work implementation

The SEAEIS team conducted ROV operations on a regular basis at 3 deployment sites on the southwestern and eastern shelf ice contour of Atka Bay and on a grounded iceberg, as well as on the shelf ice edge in the area of the *Polarstern* mooring site “Nordanleger” and was able to secure extensive video and sample material (see Fig. 4.27.1 for locations).

On the southwestern contour, an ice hole was created at a tidal crack (“Aurelia Crack”) in the southern corner of Atka Bay, regularly visited and kept open over the course of the campaign. During 24 ROV missions, 35 dives of about 1–1.5 hours, each were conducted at depths between 30 and 70 m along the flanks of the grounded and decaying iceberg. The occurrence of ice fish, ctenophores, amphipods and isopods, the surface structure of the ice and the benthos, which was visibly disturbed at this location by the influence of icebergs, were documented. Here, fishing rods or fish traps were laid out, hydrophones were deployed and the Weddell seal males were instrumented with camera loggers. Blood, vibrissae, hair and faecal samples were collected in order to map the diving behaviour and diet of the animals in the context of the topography and fauna documented with the ROV. The sea ice team working at *Neumayer Station III* at the same time documented the hydrographic conditions of the water column with a CTD.

Following several days of preliminary explorations, further ice holes were created downwind of an iceberg stranded in Atka Bay (“Jölund Iceberg”) and on the eastern ice shelf contour of Atka Bay. The ROV site at the iceberg was abandoned after three deployments with five ROV dives, as it was not possible to collect further samples beyond the fish found there and along the jagged ice walls. At this site, the ROV succeeded in filming Weddell seals under the ice hole.

After operations on the eastern ice shelf contour of Atka Bay had been explored on the basis of satellite images by the sea ice team and in the field in order to test and deploy several sites for potential ROV, a series of new ice holes was made at a more recent break-off point of the ice shelf (“Cape of the Last Hope”). ROV dives in this section on the eastern side of the bay confirmed that the ice shelf forms a floating tongue at this location, reaching down to about 80 m water depth. The seabed is at about 170 m water depth and has an undisturbed benthos rich in species as expected for the region, with dense occurrences of bryozoa, sea cucumbers (Holothuroidea), glass sponges (Hexactinellida), fish and squid. By the end of the campaign, 11 ROV deployments with a total of 30 dives along and below the ice shelf had been carried out at this site. Various samplings yielded live catches of isopods (*Antarcturus* spp.), amphipods (Lysianassidae, Eusiridae) and icefish (*Pagothenia borchgrevinki*), which were documented photographically and preserved or frozen for later molecular biological analyses. In the vicinity of this ROV deployment site, two Weddell seals were fitted with camera loggers.

A particularly impressive and important dive under the ice shelf was made after preliminary reconnaissance in the area of the “Nordanleger”. Here, the ROV was manoeuvred over the ice shelf edge with a PistenBully crane and along the steeply sloping ice walls in 69 m water depth about 200 m inland from the ice shelf edge and sample material was collected (amphipods, ice fish). In contrast to the aggregations of platelet ice within Atka Bay, some of which reached down to 40 m water depth, the shelf ice in the area of the northern jetty was free of plate ice.

Deployment of fish traps, fishing rods and hydrophones

Fish traps and fishing rods were deployed at the ROV sites and other selected seabed sites. Two passive hydrophones (Soundtrap STD202, https://www.oceaninstruments.co.nz/, serial numbers 1074548783 and 1073766446) were deployed together with the fish traps and rods to record data on sound pressure levels of scavenging crustaceans in the wild at a distance of approximately 1 m.

Preliminary (expected) results

Work on Weddell seals

In total, five seals were fitted several times with a total of 24 camera loggers, of which 20 camera loggers could be retrieved. The camera loggers yielded a total of 219 gigabytes of infrared video recordings, 14 megabytes of dive depth data and 1,500 megabytes of acceleration data records. In addition to the imaging information, the infrared camera logger data obtained includes data on the animals' diving depth, acceleration measurements during swimming and feeding, and water temperature, and helps to supplement and update previous assumptions about the animals' underwater foraging. Table 4.27.6 provides the entire information for all camera deployments and retrievals. In addition, two vibrissae as well as hair, faeces and blood samples were collected from each of the seals 01 – 04 (Tab. 4.27.3, 4.27.4). Blood samples were centrifuged, separating blood serum from cellular compoments, and divided into a total of 16 redundant blood and 21 blood serum samples, which were preserved or frozen together with the hair samples and further collected faecal samples (n = 14) for later molecular biological and food ecological analyses.

Tab. 4.27.6: For further information please see the end of the chapter

ROV operation and cryobenthic work implementation

A total of 41 ROV missions with 74 dives in different technical configurations of the ROV combined with numerous samplings at the four locations recorded about one terabyte of video material in diving depths between 0 and 155 m water depth (Tab. 4.27.7). In addition, depths as to which platelet layers of ice and meteoric ice as a result of platelet ice aggregation beneath shelf ice were reached, the surface structure of the ice and the benthos on the seafloor were documented.

Documentation of ROV-borne samples

In addition to the video footage taken during the ROV dives, all specimen sampled by ROV and fish traps (see below) were photographed and preserved for later analyses. Figure 4.27.5 examplifies a selection of taxa from Atka Bay. All images were taken with an Olympus OM1 digital camera equipped with a 60 mm f 2.8 macro lens using one or two Olympus FL300 flash units for illumination, occasionally also a constant LED light source (BigBlue VTL800P) was used for this purpose. Due to an unforeseen interruption of the cooling chain during transportation, all samples that were to be kept frozen, were exposed to temperatures of up to +10°C for a period of approx. 24 h and therefore thawed. It remains to be proved what consequences that had for the integrity of the samples and the feasibility of the planned downstream analyses.

Deployment of fish traps, fishing rods and hydrophones

With ROV and fish trap, 3 samples with ice fish (*Pagothenia borchgrevinki*), 4 samples with isopods of the genus *Antarcturus*, 1 sample with isopods of the genus *Aega*, 18 samples with amphipods of the families Lysianassidae, Eusiridae, and 1 sample each with bristle worms (Polychaeta), brittle stars (Ophiuroidea), leeches (Hirudinea), ribbon worms (Nemertea) of unknown genus as well as 25 water filtration samples for environmental DNA studies (eDNA) and preserved or frozen for later molecular biological analyses (*cf*. Tab. 4.27.7).

Fig. 4.27.5: Selected representatives of ice-associated fauna collected with the ROV in Atka Bay during the 2022/23 SEAEIS campaign. From top left to bottom right: Amphipoda, Pteropoda, Aega antarctica*,* Antarcturus cf. spinacoronatus, Pagothenia borchgrevinki*, Polychaeta. Images not to scale. (Photos: Christoph Held, AWI)*

Tab. 4.27.7: ROV deployments within the Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) project of the ANT-LAND 2022/23 expedition at *Neumayer Station III* from 2 November 2022 – 25 January 2023. Deployments were counted separately if ROV configuration, deployment location or date changed.

ROV	Date	Time	Time	Latitude	Longitude	Dives	Samples	
		Start	*End*					
No	*yyyy-mm-dd*	*hh:mm*	*hh:mm*	*[Deg]*	*[Deg]*	*[n]*	*Species*	*No [n]*
01	2022-11-13	16:46	17:54	-70.63150	-8.13850	1		
02	2022-11-16	13:41	14:01	-70.55275	-8.03352	1		
03	2022-11-16	16:37	17:28	-70.63150	-8.13850	1		
04	2022-11-19	13:00	14:37	-70.63150	-8.13850	1		
05	2022-11-20	13:43	15:47	-70.63150	-8.13850	1		
06	2022-11-22	13:46	14:15	-70.63150	-8.13850	1		
07	2022-11-22	15:50	16:23	-70.63150	-8.13850	1		
08	2022-11-24	11:42	12:39	-70.63150	-8.13850	1		

ROV	Date	Time	Time	Latitude	Longitude	Dives	Samples	
		Start	*End*					
No	*yyyy-mm-dd*	*hh:mm*	*hh:mm*	*[Deg]*	*[Deg]*	*[n]*	*Species*	*No [n]*
09	2022-11-24	17:35	20:23	-70.63150	-8.13850	3		
10	2022-11-26	13:09	14:34	-70.63150	-8.13850	2		
11	2022-11-26	14:46	16:04	-70.63150	-8.13850	1		
12	2022-11-26	16:47	17:35	-70.63150	-8.13850	1		
13	2022-11-26	17:57	19:27	-70.63150	-8.13850	1	A	<15
14	2022-11-29	11:44	12:54	-70.65715	-7.95748	1		
15	2022-11-29	13:54	15:08	-70.65715	-7.95748	1		
16	2022-11-29	19:22	19:34	-70.67800	-7.69233	1		
17	2022-11-30	14:12	15:17	-70.63150	-8.13850	1		
18	2022-11-30	16:37	17:35	-70.63150	-8.13850	1		
19	2022-12-03	16:25	17:32	-70.63150	-8.13850	1		
20	2022-12-03	18:08	19:49	-70.63150	-8.13850	1	I, A	1, 3
21	2022-12-09	14:23	15:15	-70.67540	-7.67912	1		
22	2022-12-09	15:54	17:07	-70.67540	-7.67912	1		
23	2020-12-12	16:40	17:00	-70.63150	-8.13850	2		
24	2022-12-13	13:00	14:00	-70.63150	-8.13850	3		
25	2022-12-14	13:20	14:00	-70.63150	-8.13850	1		
26	2022-12-14	14:05	18:00	-70.63150	-8.13850	3	A	2
27	2022-12-15	14:30	17:20	-70.67540	-7.67912	3		
28	2022-12-17	14:30	17:35	-70.67540	-7.67912	2		
29	2022-12-18	13:50	18:40	-70.67540	-7.67912	3		
30	2022-12-20	17:30	20:20	-70.65715	-7.95748	3	F	1
31	2022-12-21	17:15	18:15	-70.63150	-8.13850	1	F	1
32	2022-12-22	13:30	14:50	-70.67540	-7.67912	1	A	1
33	2022-12-23	13:05	13:40	-70.67540	-7.67912	1		
34	2022-12-25	14:30	18:55	-70.67540	-7.67912	7	I, A, F	1,4,1
35	2022-12-27	12:35	16:30	-70.50132	-8.18883	2	A, F, M	4,1,1
36	2022-12-28	12:55	16:55	-70.67540	-7.67912	4	I, P	2,2
37	2022-12-30	13:40	16:15	-70.63150	-8.13850	2	I, A, S	1, 1,1
38	2022-12-31	11:20	14:45	-70.67540	-7.67912	3	A	5
39	2023-01-02	12:55	19:05	-70.67540	-7.67912	4	I, P, A, W	1,2,1,16
40	2023-01-03	16:35	17:15	-70.63150	-8.13850	1	W	1
41	2023-01-05	10:20	13:00	-70.63150	-8.13850	3	W	6

A = Amphipods
I = Isopods
F = Fishes
M = Molluscs
P = Polychaet worms
S = Nemertid worms
W = Environmental DNA (eDNA)

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, and will be attributed to a consistent project label denoted as "Marine Mammal Tracking" (MMT). By default, the CC-BY license will be applied.

Species barcodes derived from genetic analyses will be deposited in the barcode of life database (www.barcodeoflife.org) and BOLD database and linked to from the SEAEIS project page in PANGAEA.

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_25** 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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Tab. 4.27.5: Technical configurations of the ROV within the Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) project of the ANT-LAND 2022/23 expedition at *Neumayer Station III* from 2 November 2022 – 25 January 2023. Deployments were counted separately if ROV configuration, deployment location or date changed.

ROV	Date	Time Start	Time End	Latitude	Longitude	Racks	Laser	Lamps	Additional lamps	Additional Cams	Sampling dredge	Sampling slurp gun model	Cable	Comment
[#]	[yyyy-mm-dd]	[hh:mm]	[hh:mm]	[Deg]	[Deg]	[n]	[n]	[n]	[#]	[Type]	[Model No.]	[Model No.]	[#]	[#]
1	2022-11-13	13:00	20:15	-70.63150	-8.13850	2	3	4					thin	Test dive, small batteries
2	2022-11-16	10:30	15:00	-70.55275	-8.03352	2	3	4					thick	Labyrinth ice flows, contact lost, premature termination
3	2022-11-16	15:00	19:00	-70.63150	-8.13850	2	3	4					thin	Contact lost, premature termination, battery fire
4	2022-11-19	10:30	17:30	-70.63150	-8.13850	2	3	4					thick	Succesful dive, with Aurelia,warm batteries, contact deficencies
5	2022-11-20	10:30	17:30	-70.63150	-8.13850	2	3	4					thick	Succesful dive
6	2022-11-22	11:30	13:00	-70.63150	-8.13850	2	3	4				1	thin	Contact lost, premature termination, battery concept discontinued
7	2022-11-22	13:00	19:00	-70.63150	-8.13850	2	3	4					thick	Contact lost, premature termination, batteries hot, battery concept using small batteries discontinued
8	2022-11-24	10:15	13:30	-70.63150	-8.13850	2	3	4			1	1	thick	Test dive, drone batteries, too strong current velocity, premature termination, batteries ok
9	2022-11-24	16:30	22:00	-70.63150	-8.13850	2	0	4			1	1	thick	Succesful dive
10	2022-11-26	13:00	13:30	-70.63150	-8.13850	2	0	4			2	2	thin	Modification of sampling gear
11	2022-11-26	14:30	16:00	-70.63150	-8.13850	2	0	4			2	2	thick	Contact lost, premature termination
12	2022-11-26	16:30	18:00	-70.63150	-8.13850	2	0	4			2	2	thick	Succesful dive
13	2022-11-26	18:30	20:00	-70.63150	-8.13850	2	0	4			2	2	thick	Succesful dive, ROV temporarily entangled
14	2022-11-29	11:45	13:00	-70.65715	-7.95748	2	3	4				1	thick	Succesful dive
15	2022-11-29	14:00	15:00	-70.65715	-7.95748	2	3	4				1	thick	Succesful dive, seal on screen
16	2022-11-29	19:00	20:00	-70.67800	-7.69233	2	3	4				1	thick	Labyrinth ice flows, premature termination
17	2022-11-30	14:00	15:30	-70.63150	-8.13850	2	3	4		Gopro		1	thick	Succesful dive, Aurelia Crack 2; new setup; 3 racks
18	2022-11-30	16:30	18:00	-70.63150	-8.13850	2	3	4		Gopro		1	thick	Succesful dive, Aurelia Crack 1
19	2022-12-03	16:00	17:30	-70.63150	-8.13850	3	3	4		Gopro, Side cam		3	thick	Succesful dive, Aurelia Crack 1

20	2022-12-03	18:00	19:30	-70.63150	-8.13850	3	3	4		Gopro, Side cam		3	thick	Succesful dive, Aurelia Crack 1
21	2022-12-09	14:25	15:15	-70.67540	-7.67912	3	3	4		Gopro, Side cam			thick	Succesful dive, start through the seals‘ platelet tunnel
22	2022-12-09	15:50	16:35	-70.67540	-7.67912	3	3	4		Gopro, Side cam		3	thick	Lights start flickering, premature termination
23	2020-12-12	16:40	17:00	-70.63150	-8.13850	3	3	4		Gopro			thick/ thin	Lights start flickering, premature termination
24	2022-12-13	11:30	15:00	-70.63150	-8.13850	3	3	4		Gopro			thick	ROV shaking; thrusters query; premature termination
25	2022-12-14	11:45	14:00	-70.63150	-8.13850	3	3	4		Gopro			thick	Succesful dive
26	2022-12-14	14:05	16:25	-70.63150	-8.13850	3	3	4		Gopro		3	thin	Succesful dive
27	2022-12-15	11:00	21:30	-70.67540	-7.67912	3	3	4	Dive Lamp	Gopro		3	thin	ROV dive sensor query; premature termination
28	2022-12-17	10:30	19:30	-70.67540	-7.67912	3	3	4		Gopro		3	thin	Succesful dive, new dive sensor, seal on screen
29	2022-12-18	10:30	21:30	-70.67540	-7.67912	3	3	4		Gopro		3	thin	Succesful dive
30	2022-12-20	13:15	22:30	-70.65715	-7.95748	2	0	4		Gopro		4	thin	Lights start flickering, premature termination; Fish trap entangled
31	2022-12-21	15:30	19:30	-70.63150	-8.13850	2	2	2	Dive Lamp	Gopro		4	thick	Succesful dive, new setup, 2 racks
32	2022-12-22	10:30	19:30	-70.67540	-7.67912	2	2	2	Dive Lamp	Gopro		4	thick	Lights start flickering, premature termination
33	2022-12-23	10:30	16:00	-70.67540	-7.67912	2	2	4	Dive Lamp	Gopro		4	thick	Lights start flickering, premature termination
34	2022-12-25	13:30	21:00	-70.67540	-7.67912	2	2	4		Gopro		4	thick	Succesful dive
35	2022-12-27	8:30	19:30	-70.50132	-8.18883	2	2	4		Gopro		4	thick	Succesful dive
36	2022-12-28	9:00	19:00	-70.67540	-7.67912	2	2	4		Gopro		4	thin	Succesful dive
37	2022-12-30	11:00	19:30	-70.63150	-8.13850	2	2	4		Gopro		4	thin	Succesful dive; slow reaction of ROV
38	2022-12-31	9:30	16:30	-70.67540	-7.67912	2	2	4		Gopro		4	thick	Succesful dive
39	2023-01-02	9:30	21:30	-70.67540	-7.67912	3	2	4		Gopro		4	thick	Succesful dive
40	2023-01-03	11:30	18:30	-70.63150	-8.13850	3	2	4		Gopro		4	thick	Succesful dive
41	2023-01-05	9:30	18:30	-70.63150	-8.13850	3	2	4		Gopro		4	thick	Succesful dive

Tab. 4.27.6: Deployment and retrieval information for all seal camera loggers used on Weddell seals (*Leptonychotes weddellii*) within the Seals and cryobenthic communities at the Ekström Ice Shelf (SEAEIS) project of the ANT-LAND 2022/23 expedition at *Neumayer Station III* from 2 November 2022 – 25 January 2023.

Event	DateTTime deployment	Latitude	Longitude	Location	Procedure	DVL	Date Start	Time Start	Loggertimer	Depth trigger	Deployment	Date Retrieval	Video	Depth	Acceleration
[#]	[yyyy-mm-ddThh:mm]	[Deg]	[Deg]	[#]	[n]	[ID]	[yyyy-mm-dd]	[hh:mm]	[h]	[m]	[#]	[yyyy-mm-dd]	[GB]	[MB]	[MB]
NEU2022_wed_a_m_01	08.11.2022T11:02	-70,63150	-8,13850	Aurelia Crack	1	20018	2022-11-08	08:27	48	50	Head; left; not initiated	2022-11-12	0.00	0.00	0.00
						20019	2022-11-08	08:35	72	20	Head; right	2022-11-12	10.82	0.80	84.00
NEU2022_wed_a_m_01	12.11.2022T12:00	-70,63150	-8,13850	Aurelia Crack	2	19005	2022-11-12	08:05	36	20	Head; left	2022-11-21	7.26	0.80	84.70
						20017	2022-11-12	08:12	60	20	Head; right	2022-11-21	10.30	0.81	83.80
NEU2022_wed_a_m_02	17.11.2022T11:47	-70,62366	-8,13093	Intermediate Crack	1	20020	2022-11-17	09:23	36	20	Head; left	2022-11-23	11.42	0.73	83.80
						22026	2022-11-17	09:29	60	20	Head; right	2022-11-23	18.64	0.73	84.70
NEU2022_wed_a_m_01	20.11.2022T11:22	-70,63150	-8,13850	Aurelia Crack	3	20018	2022-11-20	09:00	36	20	Head; left	2022-11-26	11.70	0.79	79.70
						20019	2022-11-20	09:11	60	20	Head; right	2022-11-26	10.10	0.79	80.40
NEU2022_wed_a_m_02	23.11.2022T11:30	-70,62366	-8,13093	Intermediate Crack	2	19005	2022-11-23	09:00	36	20	Head; left	2022-12-05	9.17	0.82	83.80
						20017	2022-11-23	09:05	36	20	Head; right	2022-12-05	11.04	0.82	84.20
						20028	2022-11-23	09:10	36	20	Head; underneath jaw	*			
NEU2022_wed_a_m_01	26.11.2022T11:25	-70,63150	-8,13850	Aurelia Crack	4	20020	2022-11-26	08:28	36	20	Head; right	2022-11-30	13.12	0.80	82.30
						22026	2022-11-26	08:37	36	20	Head; underneath jaw	2022-11-30	15.84	0.80	84.70
NEU2022_wed_a_m_02	05.12.2022T10:40	-70,63150	-8,13850	Aurelia Crack	3	20018	2022-12-05	08:03	36	20	Head; left	2022-12-20	11.00	0.80	84.40
						20019	2022-12-05	08:06	60	20	Head; right	2022-12-20	0.01	0.08	0.08
NEU2022_wed_a_f_03	06.12.2022T10:39	-70,67800	-7,69233	Lincoln Crack	1	20020	2022-12-06	08:04	36	20	Head; left	2022-12-13	13.46	0.79	84.00
						22026	2022-12-06	08:08	60	20	Head; right	2022-12-13	13.31	0.80	83.90
NEU2022_wed_a_m_04	18.12.2022T12:17	-70,67540	-7,67912	Crack of Last Hope	1	19005	2022-12-18	08:25	36	20	Head; left; far ahead	2022-12-22	9.74	0.80	82.90
						20017	2022-12-18	08:28	60	20	Head; right; far ahead	2022-12-22	12.56	0.76	82.30
NEU2022_wed_a_m_04	22.12.2022T12:56	-70,67540	-7,67912	Crack of Last Hope	2	20020	2022-12-22	08:24	36	20	Head; left; far ahead	2022-12-28	13.50	0.73	83.40
						22026	2022-12-22	08:32	60	20	Head; left; far ahead	2022-12-28	16.14	0.73	84.50
NEU2022_wed_a_m_04	28.12.2022T11:35	-70,67540	-7,67912	Crack of Last Hope	3	19005	2022-12-28	08:30	36	20	Head; right; far ahead	*			
NEU2022_wed_a_f_05	03.01.2023T12:45	-70,63667	-8,11983	Marylin Crack	1	20017	2023-01-02	07:47	36	20	Head; left	*			
						20020	2023-01-02	07:53	60	20	Head; right	*			

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

Aurelia Hölzer[1], Peter Fröhlich[1], Anette Küster[2] (not in the field), Jan Koschorreck[2] (not in the field)

[1]DE.AWI
[2]DE.UBA

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).

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:

1. 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.

2. 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.

3. 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*. Five abandoned eggs from the emperor penguin colony in Atka Bay were collected and brought to *Neumayer Station III*, and then transported 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). To keep the cold chain as constant as possible, the sampled eggs were stored in the cold room of *Neumayer Station III* during the entire storage period. To determine the developmental status of the eggs, the frozen eggs were scanned/x-rayed at *Neumayer Station III*. The eggs were stored and transported in a transport box with a built-in temperature sensor included at a constant temperature between -20 °C and -25 °C.

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-und polyfluoralkyl substances (PFAS). Further sampling of emporer 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:

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.

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

Dreyer et al. 2019. Recent findings of halogenated flame retardants (HFR) in the German and Polar environment. Environmental Pollution253 (2019) 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. 2020, 54, 16, 9958–9967.

4.29 ISO-ANT – Water Vapour Isotope Research in the Antarctic

Melanie Behrens, Saeid Bagheri Dastgerdi (not in the field), Maria Hoerhold (not in the field), Martin Werner (not in the field)

DE.AWI

Grant-No. AWI_ANT_29

Objectives

Stable isotopes of water are fundamental for the understanding of the modern hydrological cycle and key parameters for the reconstruction of past climate changes, e.g., from Antarctic ice cores. For several decades, related isotope research projects were focussed on snow and ice samples as end member products of the hydrological cycle, only. Vapour measurements in the field were most difficult to perform. Since very recently, the isotopic composition of water vapour can be measured with necessary precision by commercially available light-weighted cavity-ring-down spectrometers (CRDS). The CRDS allow that the isotopic content of the water vapour in the air can be analysed directly under *in-situ* conditions on any place or platform almost autonomously, thus also at remote stations in the Arctic or Antarctic.

The overall goal of the project Iso-Ant, funded by the Helmholtz Climate Initiative Regional Climate Change (REKLIM), is a first-time detailed detection and description of the isotopic composition of water vapour transported to the vicinity of AWI's *Neumayer Station III*. In combination with correspondent isotope measurements on board of *Polarstern* and the well-established long-term isotope measurements of snow samples from *Neumayer Station III*, these new isotope measurements will allow a unique simultaneous data set of $H_2^{18}O$ and HDO directly above the ocean surface and after transport to the Antarctic continent. Observational data will be paired with complementing climate simulations using atmospheric circulation models enhanced by explicit water isotope diagnostics. Combined analyses of model results and measured data will provide an improved basis to understand Antarctic climate variability and its imprint in firn and ice cores.

Fieldwork

During the campaign ANT-Land 2016-17 a CRDS instrument was successfully installed at *Neumayer Station III*. Since the installation of the instrument, automatic, continuous isotope analyses of the atmospheric water vapour at *Neumayer Station III* in Dronning Maud Land, Antarctica, have been conducted. As the Iso-Ant project finished in early 2022, the instrument was deinstalled during the field season of ANT-Land 2022/23. For this task, the project member Melanie Behrens travelled to *Neumayer Station III*. The deinstallation included a final calibration of the instrument, a controlled shut down of all electronic components as well as the disassembly, packing and shipping of all parts to AWI Bremerhaven (Fig. 4.29.1). After consultation with Holger Schmithüsen, head of the Meteorological Observatory at *Neumayer Station III*, the heated air inlet from the roof of the station to the instrument was not removed, but will be used for other air measurements in the future.

Preliminary (expected) results

Combining the results of isotopic measurements in vapour with meteorological data and climate simulations using two versions of an atmosphere general circulation model with explicit isotope diagnostics (ECHAM5-wiso, ECHAM6-wiso) and with ERA-5 reanalyses data enable a unique quantitative assessment of the isotopic signature of the Antarctic water cycle.

As the CRDS instrument has been run without larger disruptions until the deinstallation of the instrument, six complete years of continuous measurements of water vapour isotopic composition at *Neumayer Station III*, Antarctica, could be achieved within the Iso-Ant project. This is a very successful outcome of the project and the measurements are by far the longest continuous vapor isotope data series at any Antarctic station, so far. The first 2-year period from February 2017 to January 2019 has already been published (Bagheri Dastgerdi et al., 2021). Isotope variations at *Neumayer Station III* could be characterized on a seasonal and synoptic time scale variations and their link to meteorological weather conditions established. The key drivers of isotope changes are local temperature and specific humidity, which affect $\delta^{18}O$ and δD in vapour at *Neumayer Station III* on the different timescales. Eastward winds bring warmer and more enriched vapour, while southerly winds bring colder and more depleted vapour. On some occasions, $\delta^{18}O$ changes without temperature changes due to wind shifts could be detected. No seasonal pattern in d-excess is found, but d-excess correlates inversely with specific humidity more than temperature, especially under cloudy skies in summer. High uncertainty in winter CRDS measurements reduces the confidence in the retrieved data during this season and a vapor isotope analyzer capable of performing precise measurements at lower humidity values would be needed for improving this instrumental deficit.

Analyses of the remaining data is a still ongoing combined effort of the AWI sections Paleoclimate Dynamics and Glaciology. One goal will be to combine the CRDS vapour isotope data of the Iso-Ant project with isotope measurements performed at water samples of cold traps collect at the Neumayer Air Chemistry Observatory since 1995. Such combination will result in a climatological highly important vapour data series covering the last 30 years. First analyses of both data series show a promising agreement during the overlapping period 2017-2022 (Fig. 4.29.2). As the Iso-Ant project also revealed a strong link of $\delta^{18}O$-δD and temperature-$\delta^{18}O$ slopes of water vapour and snow samples taken near the station, a combined analyses of vapour and snow measurements focusing on water cycle changes at *Neumayer Station III* during the last decades seams feasible.

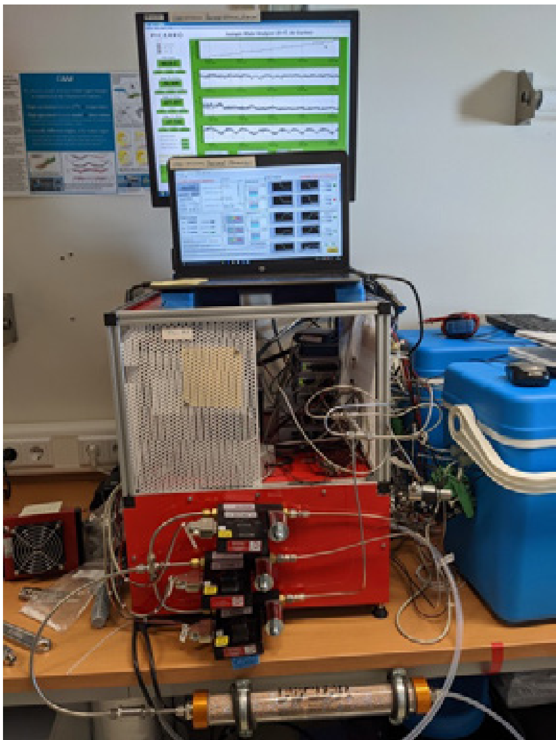

Fig. 4.29.1: Iso-Ant water vapour CRDS analyzer and instrumental setup before deinstallation in November 2022 (photo taken M. Behrens, AWI).

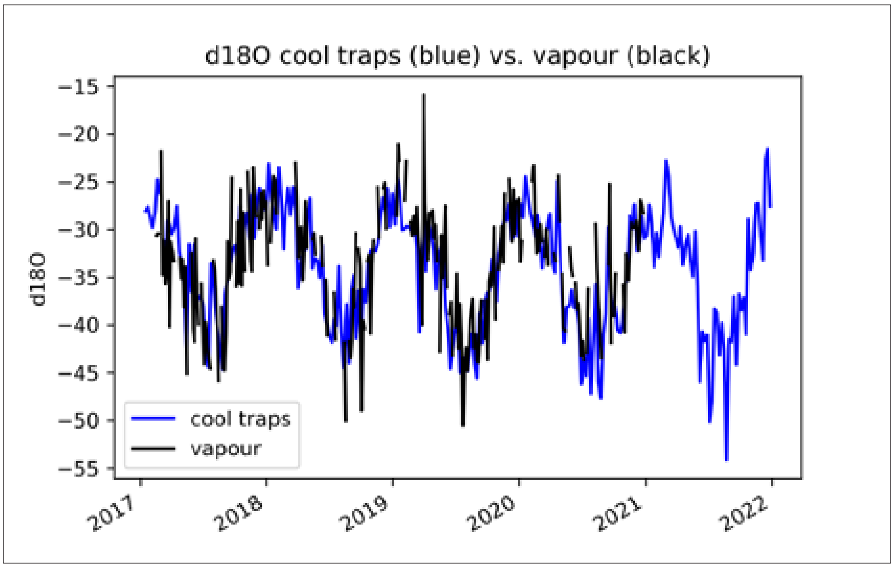

Fig. 4.29.2: Isotope δ¹⁸O variations measured at water samples collected from cold traps (blue line) and measured directly in vapour (black line) at Neumayer III Station during the years 2017-2022 (unpublished figure by M. Hoerhold and M. Behrends, AWI, 2023).

Data management

Environmental data of this study is archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de). By default, the CC-BY license will be applied.

This research was funded by the Helmholtz Climate Initiative REKLIM (Regional Climate Change), a joint research initiative of the Helmholtz Association of German Research Centres (HGF).

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_29** will be quoted and the following publication will be cited:

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.

References

Bagheri Dastgerdi S, Behrens M, Bonne J-L, Hörhold M, Lohmann G, Schlosser E, Werner M (2021) Continuous monitoring of surface water vapour isotopic compositions at Neumayer Station III, East Antarctica. The Cryosphere, 15, 4745-4767. https://doi.org/10.5194/tc-15-4745-2021

5. ANT-LAND 2022/2023 – OTHER SCIENTIFIC ANT-LAND PROJECTS WITH AWI PARTICIPATION

5.1	**BEOI 2022/2023** **Start and End:** **Christchurch**	**17 November 2022 –** **04 February 2023**	**Chief scientist: Frank Wilhelms** **Coordinator: Frank Wilhelms**
5.2	**ITGC-GHOST 2022/23** **Start and End:** **Christchurch**	**04 November 2022 –** **22 January 2023**	**Chief scientist: Coen Hofstede** **Coordinator: Olaf Eisen**
5.3	**FISP-AIR 2022/23** **Start and End:** **Punta Arenas**	**18 December 2022 –** **03 January 2023**	**Chief scientist: Daniel Steinhage** **Coordinator: Christine Wesche**
5.4	**Polar Connection 2022** **Start and End:** **King George Island**	**12 November 2022 –** **30 November 2022**	**Chief scientists: Simeon Lisovski and Ulrike Herzschuh** **Coordinator: Simeon Lisovski**
5.5	**SIGMA-I 2022/2023** **Start and End:** **Rio Gallegos**	**18 December 2022 –** **09 March 2023**	**Chief scientist: Kerstin Jerosch** **Coordinator: Kerstin Jerosch**

5. OTHER SCIENTIFIC ANT-LAND PROJECTS WITH AWI PARTICIPATION

5.1. BEOI 2022/2023 – Beyond EPICA Oldest Ice Core

Frank Wilhelms[1], Giuditta Celli[2], Andrea De Vito[3], Romain Duphil[4], Markus Grimmer[5], Romilly Harris-Stuart[6], Matthias Hüther[1], Florian Krauß[5], Gunther Lawer[1], Johannes Lemburg[1], Martin Leonhardt[1], Robert Mulvaney[7], Saverio Panichi[3], Michele Scalet[3] and Julien Westhoff[8], Olivier Alemany[2] (not in the field), Steffen Bo Hansen[8] (not in the field)

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[7]UK.BAS
[8]DK.PICE

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 zweiten Saison ist ein Bohrfortschritt bis zu 1310 m unter idealen Bedingungen. Die Gewinnung des Eiskerns, der die meteorologische 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 die Fertigstellung der Bohr- und Kernbeschreibungsinfrastruktur vor Ort sowie über den Beginn und den Verlauf der Tiefbohrung während der Feldkampagne 2022/23 bis zu einer Tiefe von 808,47 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 second season is production drilling beyond to 1,310 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 success of the Beyond EPICA Oldest Ice project. We report the completion of the drilling and logging infrastructure on site, and the inception and progression of the deep drilling operation during the 2022/23 field campaign, down to a depth of 808,47 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 first deep drilling season 2022/23, where the coring advanced to 808.47 m.

Fieldwork

The main group left middle Europe on 15 November 2022 and spent a quarantine between 17 – 21 November 2022 in Methven in New Zealand. On 21 November 2022 we departed Christchurch (NZ) to *Mc Murdo Station* (USA) by Italian LC-130H and immediately proceeded by Basler BT-67 to *Mario Zucchelli Station* (IT). After another quarantine between 21 – 23 November 2022 and waiting for favourable weather conditions the main group went by Basler BT-67 to *Dome Concordia Station* (IT/FR) on 29 November 2022 and proceeded after two days of high-altitude acclimatisation to the Little Dome C drilling camp. This resulted in 49 days (3 December 2022 – 20 January 2023) of available time for the drilling operation on site.

Fig. 5.1.1: Alignment of the core extraction table and electrical wiring of the FED (fluid extraction device).

For the next seven days we completed the installation of the drilling and logging infrastructure (3 – 10 December 2022). When we opened the core buffer, we recorded a temperature of approximately –40 °C inside. After opening the roof of the drill tent, to be able to erect the drill tower, we observed some direct sunlight on the logging table. We avoided this unfavourable setting for the ice core by re-arranging shades for the next days and finally found an arrangement that avoids direct sunlight at any time of the day.

First, we finished identified items from last season, as e.g., changing a coupling between the winch motor and the gear box, laying out grids to avoid slipping in the drill area, mounting the core-logging support-structure in the drill area and a back-up in the core storage. The recorded temperature in the core storage area for this period was as low as –48 °C. Further, we replaced the well head of the slush-pan with a better optimized design. Next, we had the tower and the winch operational and completed the electrical installations for the ventilation, the heated cabins and the weatherport drill tent. We set up the chip collection and processing system and furthered the core-logging table, including the fluid extraction device (FED). For preparation of getting past the lower end of the casing into the deep drilling hole, we mounted the mechanical section of the nominal 2 m-core-length-drill and mounted the EGRIP electronics after soldering a custom electrical adaptor plug for the connection to the mounted anti-torque. In parallel, we put the chips melter and sucking device (“the pig”) operational. For modification into a sieve and a slush collection pan by welding, we took decommissioned well heads to *Concordia Station*. In preparation of controlling the drill, we mounted the EGRIP surface control. The drill string extraction winch was mounted and we equipped it with a stronger battery. We positioned the core trough mounts with a laser alignment system and fixed the tables to the floor. To demonstrate the pulling strength of the winch, we performed a pull test on the tower and calibrated the load cell. The winch pulled on the topmost layer to 1,764 daN, as measured with a load-cell. For optimized core and drill-handling we re-arranged the position of the workshop cabin in the trench. The core buffer was upgraded with some plastic curtains to further reduce air exchange when the door is open. After cleaning out boxes, stuffing up our stocks, e. g. with core boxes, arranging the electronic and mechanical workshop, installation of a chips spinner we moved from *Concordia station* and oiling and creasing of the winch we had put the last missing bits operational to start with the deep drilling operation.

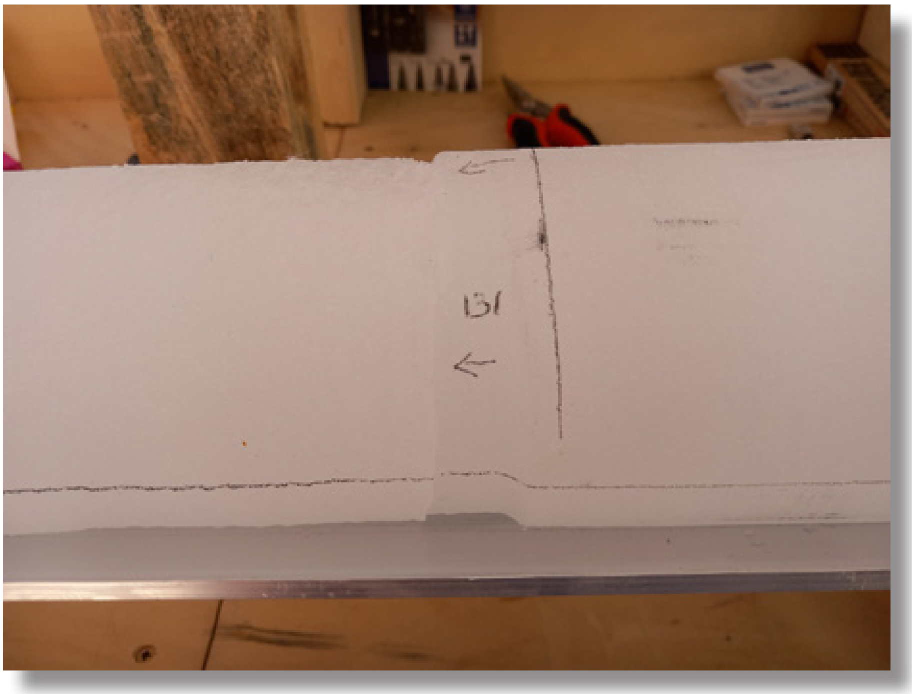

Fig. 5.1.2: Smooth fit of the core from the pilot hole to the deep core

Initially, we had envisaged up to two weeks for this operation, as significant items scheduled already in the season before had to be completed. Due to the exceptionally favourable skill profile and previous drilling experience of the team we could parallelize jobs and complete the missing preparations in just one week.

On 11 December 2022 we had the drill ready to start penetrating with the deep drill (129.7 mm outer diameter and 98 mm core diameter) past the interface of the casing hole into the deep hole. The casing hole had been drilled with the IGE shallow drill with a hole diameter of 144 mm and a core diameter of 101 mm, where about 1 m of core had been left at the bottom of the hole to provide centring of the deep drill. The deep drill reamed over the core stump at the bottom and went, concerning the core quality, smoothly into the new deep hole. In terms of penetration, we had a few lost runs, while adjusting the antitorque blades to the varying hole diameter and ensuring low inclination over the transition to the narrower hole. The next day we prepared the 3 m-nominal-core-length-drill and repaired the chip melting system. On 13 December 2022 we passed into the new hole with the 3 m drill and over the next week further optimised the handling routines for the drill on the surface. Over the next days we established a typical run length beyond 2.5 m. From 16 December 2022 core processing at *Concordia Station* started. We further optimised the mechanical tuning of the drill and switched between the EGRIP and the BE-OI equipment, as we observed high power consumption of the down-hole unit despite an optimised mechanical setting of the drill. On 17 December 2022 we had to terminate a run due to very high power consumption and back on the surface observed that the electronics section idled very noisily. We disassembled the electronics towards identifying the problem in detail. As we were aware that for the EGRIP electronics spares had not been provided, we immediately started assembling the partly finished BE-OI electronics. The next day we faced the totally broken gearbox of the EGRIP electronics and started to arrange the transport of a spare from Europe. In parallel we had assembled the BE-OI electronics. The crucial question was if a fully implemented control of the down-hole microcontroller would be required or if we could record the power for drilling from the powermeter of the DC power supply at the surface.

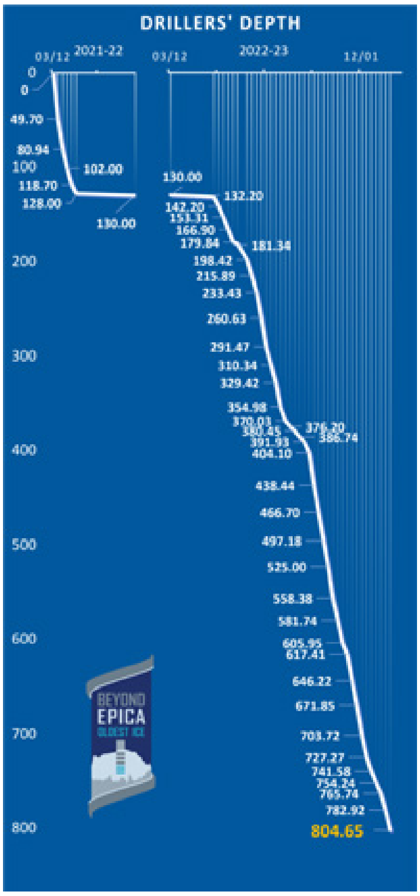

Fig. 5.1.3: The penetration in drillers depth in m on the ordinate versus date on the abscissa

On 19 December we tested the system successfully and went into stable drilling with about 2.5 m long runs in a stable drilling mode. The next day we went into a two-shift operation between about 08:00–24:00. The daily core production ramped up from about 17 m to up to 30 m on a full day. The principal limitation of the BE-OI electronics was having no control about antitorque rotation. On 26 December 2022 we scheduled a major maintenance of the drill system and changed the faulty inverter of the deep drilling winch, re-arranged the alignment of the logging infrastructure, started overworking supports of the tower and switched to an updated version of the drill surface electronics. On 27 December we mounted a differently parameterized down-hole drill electronics, motivated by the idea to gain penetration speed especially towards the end of each run by having slightly more power to move the cuttings easier in the almost filled-up drill. After opening the exchanged electronics, that had been running for a good week, we observed slight leakage and decided to tight the O-rings of the plugs harder when mounting in the future.

With the second electronics our luck of the last week also left us and we were challenged with high power consumption after short penetration, often with no indication of penetration. First, we were not sure whether we had anti-torque rotation, but after two days of problems we decided on 30 December 2022 to switch back to the other electronics kit we had dried and overworked in between. In the electronics that troubled us the past days we found a significant amount of drill liquid. This demonstrates again, that stable electronics is essential for drilling, as in the retrospective the electronics was not working properly and it exhibited a behaviour that also could have been anti-torque rotations, which could be due to wrong setting of the leaf springs in the anti-torque. With the wet electronics it is obvious, that the problem was not due to a wrong mechanical tuning. Till 1 January 2023 we tuned the anti-torque and together with the stable electronics got the drilling into stable operation again, with daily productions of up to 34 m. Processing of the ice core stopped at 217 m for the season. as the roof of the cold trench at Concordia station collapsed and left the processing area unusable. On 8 January 2023 we switched to a new downhole unit with an upgraded program on the electronics that had been wet, but we faced again power problems and switched back to the other kit, which brought us back to stable core production of up to 31 m. In parallel we tested mechanical configurations and prepared the nominal 4 m-core-length version of the drill. On 11 January 2023 we mounted and tested the EGRIP electronics, after the spare gear sent from Europe had arrived at Little Dome C. From about 12 January 2023, we started the documentation and packing of the drill equipment for a fast close down, once drilling operations to be ceased. On 15 January we switched to the EGRIP electronics for logging the inclination of the hole. After observing problems to start the EGRIP electronics at the bottom of the hole, we switched back to the BE-OI electronics. We opened the EGRIP electronics, overworked a ferrite in the top plug and successfully tested it at low temperatures in the core-store. After we had logged the inclination of the hole with the BE-OI electronics and verified it is in a good range below 2.5°, the motor of the BE-OI electronics was frozen and had collected ice, we switched to the EGRIP electronics on 17 January 2023. After de-freezing and getting the ice out, the BE-OI electronics worked again.

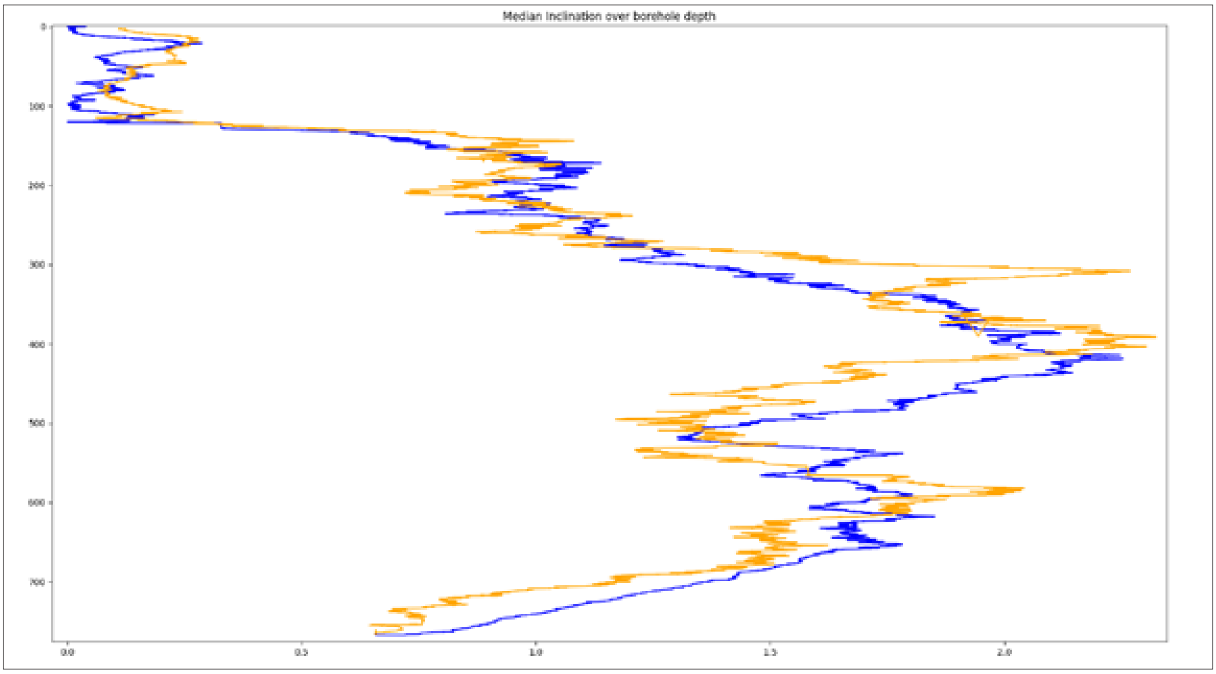

Fig. 5.1.4: Plot of the running median of the previous 200samples @ 300ms interval over depth, blue marks the way down and orange the way up. X axis inclination in degree, Y axis depth in meter

As the EGRIP electronics worked stable, we finished the season with the initial set-up and for the last two runs mounted the nominal 4 m core-length drill. After one run that terminated after 3.88 m due to anti-torque slip, we finished the season with a slightly harder adjusted anti-torque leaf spring with 4.54 m core, which is the maximum that fits into the core barrel. We finished the season at a loggers depth of 808.47 m and a drillers depth of 804.65 m due to logistic constraints, as no more core boxes were in camp anymore.

We could maintain stable drilling with the BE-OI electronics. However, for both the EGRIP and the BE-OI electronics we would desire slightly more power at the end of the run. We will access the BE-OI electronics intermediate circuit capacitance and possibly will modify it during envisaged runs on a motor test stand. With slightly more power we envisage 4.5 m runs with the longer version of the BE-OI drill at penetration speeds of more than 2 mm s^{-1}.

After the end of drilling, we had the 19 January 2023 to pack down everything, tune the liquid level and winter the tents.

The main group moved from Little Dome C to *Concordia Station* on 20 January 2023 and the rear guard followed the next morning 21 January 2023. On 23 January 2023 a first group departed toward *Mario Zucchelli Station* to sort cargo and check the –50 °C reefer container for the transport of the ice cores. The rest of the group followed 3 days later. We waited at *Mario Zucchelli Station* till 4 February 2023 to move to *McMurdo Station* by Basler BT-67 and proceed immediately to Christchurch by United States C-17. On 6 February we moved by commercial flight back to Europe and arrived on 7 February 2023.

Fig. 5.1.5: Group photo: 800 m – end of production drilling (18.03.2023) back row from left to right: Martin Leonhardt, Florian Krauß, Gunther Lawer, Johannes Lemburg, Matthias Hüther, Michele Scalet, Frank Wilhelms, front row from left to right: Robert Mulvaney, Romilly Stuart-Harris, Saverio Panichi, Andrea De Vito, Julien Westhoff, Markus Grimmer

For the definition of the original milestone to 1,310 m for the second season, 60 days on-site were estimated with 7 days to open up and 4 days to close down the drilling infrastructure. A penetration of 170 m per week during the 7 weeks of drilling advances the 120 m of the casing to the envisaged 1,310 m at optimal conditions. We had 49 days on site and needed 7 days to get the first core, but about 17 days in total to get fully operational and 2 days to close down. Over the 40 days of drilling, we advanced about 680 m, which is an average of 120 m per week for the entire period, but e. g. 175 m per week maintained over the first two weeks of January, when we reached a stable mode without interruptions by e. g. holidays, logging etc. The demonstrated 4.5 m coring capability and increase of the travel speed in the hole from 0.8 to 1.2 m s^{-1} after penetrating beyond the brittle zone, give the prospect of maintaining good advancement during the coming season.

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 and according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de). within two years after the end of the expedition at the latest. By default, the CC-BY license will be applied.Any other data will be submitted to an appropriate long-term archive that provides unique and stable identifiers for the datasets and allows open online access to the data.

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

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

5.2 ITGC-GHOST 2022/23

Coen Hofstede[1], Ole Zeising[1], Florian Koch[1], Elizabeth Case[2], Catrin Thomas[4], Sridhar Anandakrishnan[3], Andy Smith[4], Olaf Eisen[1] (not in the field)

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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), gravity, magnetotellurics, autonomous phase sensitive-radar (ApRES) and ground-based radar (RES). This information will help to predict the contribution of Thwaites Glacier, that rests on a bed well below sea level, to global sea level rise. AWI's task in GHOST 2022 was to record one long seismic reflection profile of the centerline of Thwaites Glacier using a seismic vibrator (Envirovib, EV, Eisen et al., 2015) as a source and a 1,500 m long, 60 channel, snowstreamer for recording. The seismic profile gives us the topography and structure of the subglacial bed. With the reflection coefficient (R) of the ice-bed contact, derived from the shot records, we can identify the subglacial material and, in the case of sediment, it's water saturation.

Fieldwork

4 November 2022: Florian Koch, Ole Zeising and Coen Hofstede arrived, with other GHOST team members, at the United States Antarctic research station *McMurdo* (MCM). From MCM we travelled to the summer camp WAIS-Divide (WSD) where our equipment had overwintered over the last four years due to COVID. Most equipment was stored in Zarges boxes on berms but the EV overwintered in a Weatherhaven tent. WSD opened up late, on 7 December due to COVID and bad weather. Due to this delay our field plans were restricted to RES, ApRES, passive seismics and active vibrator seismics: The AWI team, having its own traverse, collected a 208 km long,10-fold, seismic profile along the centerline of Thwaites Glacier (Fig. 5.2.1). Elizabeth Case joined the traverse, and collected ApRES data along the centerline every 500 – 1,000 m.

The survey area of Thwaites Glacier is divided into ten sequential, 20 km long, 10 km wide boxes (Fig. 5.2.1), box 1 being the most downstream. Originally the entire GHOST team would move from box to box, doing all geophysical measurements per box, one box every week but due to the mentioned delays, we restricted ourselves to one long centerline profile through the center of the boxes.

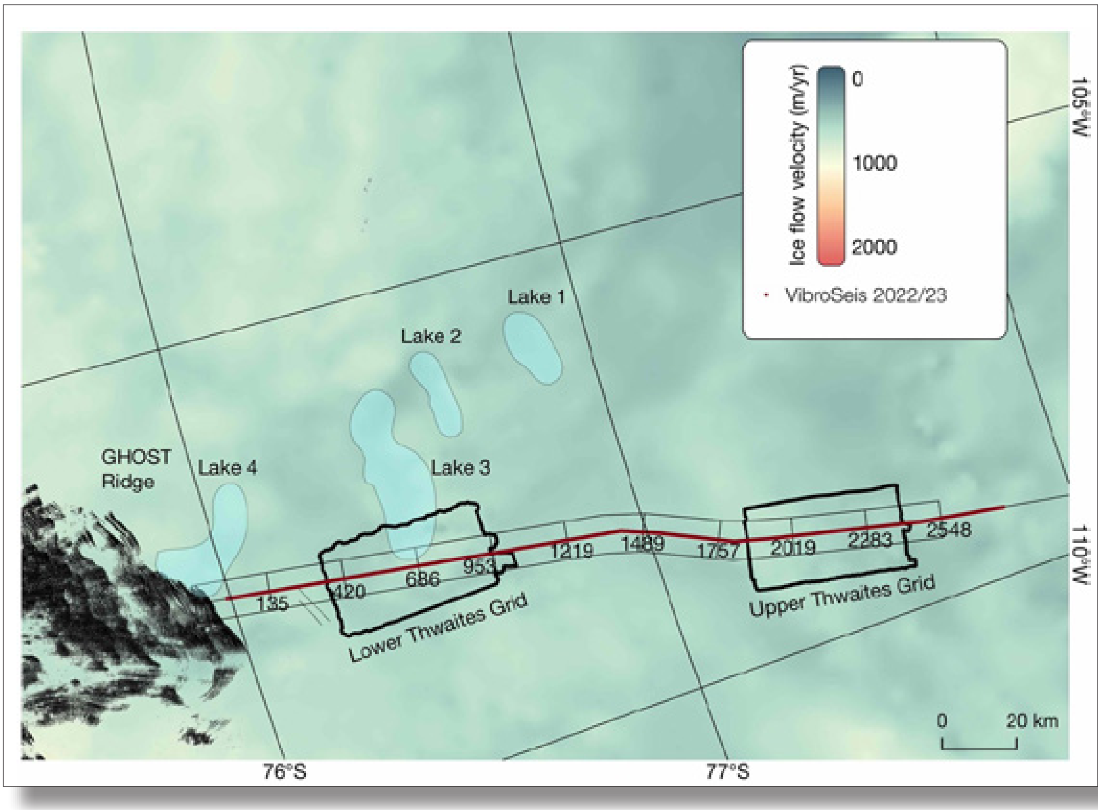

Fig. 5.2.1: The survey boxes of Thwaites Glacier and the recorded seismic centerline profile (red). The area of the black curved shadowy lines on the bottom right side is the crevasse zone, partly covering box 1. Two big crevasses cross the lower (west) side of box 2. At the left (southern) border of each box is the seismic shot point number along the centerline.

The AWI-BAS traverse team consisted of two PistenBullies (PB's), each pulling a "train" (Fig. 5.2.2). The first train, the accommodation train, consisted of a caboose having a kitchen and a small work shed, and one PE sled with two fuel bladders and two sleeping tents. The second train, the recording train, consisted of a Lehmann sled with all the seismic equipment, including the snowstreamer on a winch, the PE sled with the EV. When in operation we towed the 1,500 m snow streamer behind the EV.

Details on the daily operation, use of spare parts, maintenance, etc. are available in a separate report, but will not be reproduced here for brevity.

Fig. 5.2.2: The two PB trains during the traverse. On the left is the recording train with the EV, the Lehmann sled with the snowstreamer and spares and the PB. On the right we see the accommodation train with the sleeping tents and caboose (Photo: Ole Zeising).

Timeline WSD:

14 December:	Florian and Coen were the first group to fly to WSD. Here, they prepared the EV, replaced parts, checked the accumulator and air pressure, greased fat nipples, performed an oil change and fixed the EV on a custom-made PE sled.
23 December:	The rest of GHOST team arrived at WSD at night.
24 December:	The AWI-Team deployed the streamer, connected it to the seismographs (Geometrics GEODES) in the cabin of the EV. We tied the towing clamp of the snowstreamer with two Dyneema ropes to the rear corners of the PE sled to prevent the streamer from rotating. While recording during the traverse, a skidoo was towed at the left (port) corner and streamer on the right (stbd) corner with a second rope from the towing clamp to the rear center of the PE sled.
25 December:	Maneuvering the recording train with deployed streamer to a starting position of a test line. A maneuvering speed of 6 km/h is fine for U-turns or normal turns in steps of 12.5º/km. We recorded a 5 km, 10-fold testline. During this testline we recorded correlated data. This correlated data had poor quality; some correlation noise was present throughout the record.
27 – 30 December:	Traversed 406 km downstream with two PB trains to box 1, the starting point of the centerline.
31 December:	Deployed streamer in the morning and start recording data after lunch.

Table 5.2.1 shows the timeline, location, and production of the 208 km recorded seismic reflection profile during the traverse. We travelled upstream starting 813 meters above sea level (m.a.s.l.) climbing up to 1,368 m.a.s.l. recording approximately 20 km/day. Of the 14 field days, we lost 2.5 day due to bad weather. On those days the wind picked up to at least 15 knots and snow started drifting. With snow drift the data becomes too noisy immediately so the data acquisition was halted.

Tab. 5.2.1: A summary of the first shot of all recording days, their position, surface height (m.a.s.l.) and total distance recorded.

Shot	Date	Longitude (°)	Latitude (°)	Height (m)	Distance (m)
1	31 December 2022	-107.563164	-75.9907	813.45	0
173	1 January 2023	-107.629311	-76.106655	873.50	12902.78
401	2 January 2023	-107.718265	-76.260371	976.29	30008.06
445	3 January 2023	-107.735822	-76.29004	957.22	33309.14
727	4 January 2023	-107.849356	-76.480241	1024.00	54468.22
1025	5 January 2023	-107.973198	-76.681199	1103.43	76823.13
1283	6 January 2023	-108.083291	-76.855159	1156.06	96180.09
1580	7 January 2023	-108.333018	-77.048173	1185.57	118467.63
1847	8 January 2023	-108.655998	-77.214939	1202.06	138489.08
2020	10 January 2023	-108.779541	-77.329967	1262.42	151489.17
2326	11 January 2023	-108.986179	-77.533638	1279.63	174418.59
2476	12 January 2023	-109.090072	-77.633558	1297.08	185672.89
2483	13 January 2023	-109.09389	-77.638347	1308.66	186207.10
2770	13 January 2023	-109.238101	-77.831814	1368.47	207727.74

Preliminary (expected) results

Here we present the band-pass (10 – 200 Hz) filtered, depth converted, 208 km stack (Fig. 5.2.3). Note that the depth is simply derived from the two-way traveltime (TWT) and P-wave velocity of ice (assumed 3,750 m/s) and is not accurate below the bed. We've converted depth below the ice surface to a height in m.a.s.l. and displayed the ice surface slope. The most striking features we annotated in the section.

Generally returning features in all sections:

- Englacial reflections, throughout all sections but varying in strength. We see strong englacial reflections on the left side, fading out after km 10, returning at km 160 – 180. They usually form when there is a shift in preferred crystal orientation in the ice which is usually related to a changing stress regime.
- Blocky structures having leeward stratification and diffraction hyperbolas on the stoss side. Although premature at this stage these features are sometimes identified as crag-and-tail features or flutes (Alley et al., 2021). These have been found offshore at Thwaites (Nitsche et al., 2016) and also in the lower and upper Thwaites grids (Fig. 5.2.1) by swath radar (Holschuh et al., 2020).
- Basins occur in various sizes along the profile. The largesst one lies at km 90. It is some 20 km long and 110 m deep. The basins clearly have been deposited over the existing bed(rock). They lack the clear stratification of the crag-and-tail features.

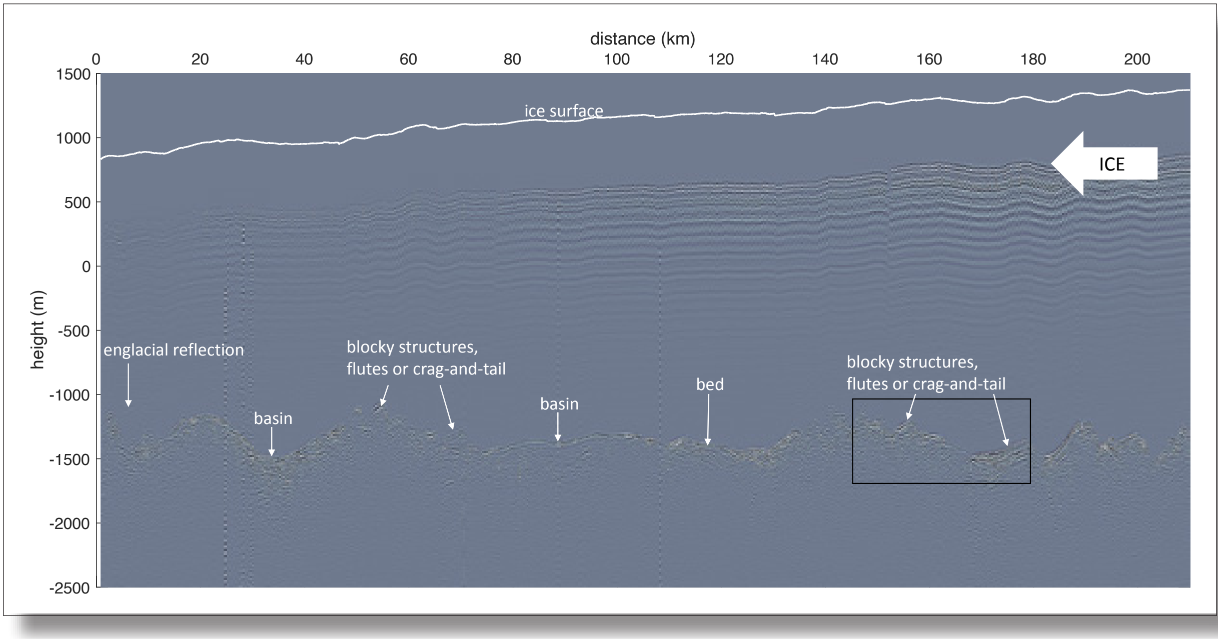

Fig. 5.2.3: Throughout the 208 km profile we see blocky structures identified elsewhere as flutes or 'crag-and-tail' features. We see englacial reflections some 200 m above the bed on the far-left side, fading out and reappearing at km 160–180. We see several basins, a large one, 20 km long, 110 m deep, at km 90. The inset box, also showing these blocky structures, has been surveyed before by Muto et al. (2019).

Outlook

The data still needs considerable processing 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(θ) is calculated. At the ice-bed interface R(θ) 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).

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.

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_31** 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, Hofstede C, Diez A, Kristoffersen Y, Lambrecht A, Mayer C, Blenkner R, Hilmarsson S, On-ice vibroseis and snowstreamer systems for geoscientific research, Polar Science, Volume 9, Issue 1, 2015, 51-65, https://doi.org/10.1016/j.polar.2014.10.003

Holschuh N, Christianson K, Paden J, Alley R B & Anandakrishnan S (2020). Linking postglacial landscapes to glacier dynamics using swath radar at Thwaites Glacier. Geology, 48, 268–272. https://doi.org/10.1130/G46772.1

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Nitsche FO, Larter R D , Gohl K, Graham AGC and Kuhn G (2016): Crag-and-tail features on the Amundsen Sea continental shelf, West Antarctica / Dowdeswell J, Canals M, Jakobsson M, Todd B, Dowdeswell E and Hogan K (editors) , Geological Society London Memoirs, 46 , pp. 199-200. https://doi.org/10.1144/M46.2

5.3 FISP-AIR 2022/2023

Mario Hoppmann[1], Daniel Steinhage[1],
Hartmut Hellmer[1] (not in the field),
Angelika Humbert[1] (not in the field),
Markus Janout[1] (not in the field),
Holger Schmithüsen[1] (not in the field),
Tore Hattermann[2] not in the field),
Keith Nicholls[3] (not in the field)

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Grant-No. AWI_ANT_32

Outline

The FISP-Air campaign took place between 18 December 2022 (departure from Punta Arenas, Chile) and 3 January 2023 (arrival at Punta Arenas) to service and retrieve data from meteorological, glaciological and oceanographical instrumentation deployed on Filchner Ice Shelf as part of the joint German-British-Norwegian project FISP/FISS in 2016. The field work was supported by the company Antarctic Logistics & Expeditions (ALE), running a seasonal camp at Union Glacier and operating an intercontinental airlink between a blue ice landing strip near the camp and Punta Arenas, Chile. This camp, situated in the Ellsworth Mountains, served as a base for further Twin Otter flights to the work area on the Filchner-Ronne Ice Shelf. From 6 planned sites, 4 could be visited and the maintenance/retrieval work was done as planned. The two northern sites could not be reached within the set timeframe due to persistent low clouds over the fuel cache on Berkner Island and/or the field sites on the Filchner-Ronne Ice Shelf.

Tab 5.3.1: Site overview

Site	Latitude	Longitude	Arrival time (UTC)	Departure time (UTC)
Union Glacier Base Camp	79° 45.474' S	082° 52.501' W	18 Dec 2022 20:30	03.01.2023 15:30
SFG_East (= SFG1)	82° 21.846'S	045° 38.377' W	25 Dec 2022 17:00	25 Dec 2022 20:20
SFG_West (= SFG2)	82° 21.750'S	045° 43.723' W	25 Dec 2022 20:30	26 Dec 2022 17:00
FSE2	81° 04.140' S	040° 47.280' W	31 Dec 2022 16:20	01 Jan 2023 13:30
FSW1	80° 25.985' S	044° 25.034' W	01 Jan 2023 14:00	02 Jan 2023 20:30
FNE1	78° 30.000' S	037° 14.520' W	not visited	
FNE2	78 °30.660' S	038° 04.260' W	not visited	

Tab. 5.3.2: Summary of work at the different sites.

Site	Summary of work
SFG_East (=SFG1)	Fully retrieved pRES and GPS equipment from >3 m depth
SFG_West (=SFG2)	Fully retrieved pRES equipment from >3 m depth

Site	Summary of work
FSE2	Dug out (but did not raise) mooring site, checked battery status, updated logger firmware, swapped SD cards, downloaded missing data from all Microcats, reset Microcats to UTC, tested new setup locally, verified remotely with Tore Hattermann (NPI), cleaned site.
FSW1	Dug out mooring site, checked battery status, repaired mooring cable, backed up SD cards, downloaded missing data from all Microcats, reset Microcats to UTC, tested new setup locally, verified remotely with Tore Hattermann (NPI) cleaned site.
	Checked (but did not retrieve) weather station and wind turbine, raised lower sensors, solar panels, and batteries, cleaned site.
FNE1	not visited
FNE2	not visited

Objectives

Since their installation in 2016, the four oceanographic moorings at sites FNE1, FNE2, FSW1 and FSE2 have been transmitting their Microcat and Aquadopp data on a daily basis via the iridium satellite service. Through the course of the years however, several technical issues have arisen that have led to data gaps and affected general functioning of several of the moorings.

The standard maintenance of the moorings includes the replacements of memory cards in the logger and raising the equipment on site (electronics, battery and solar panel. Since April 2022, none of the moorings was fully operational. Thus it, was decided to replace data logger, update firmware and if necessary, repair broken cables as well as to download data from the instruments. The latter requires several hours on site.

The two sites in front of Support Force Glacier (SFG) were not revisited and raised for four years for various reasons. Based on accumulation readings made in the past, markers at both sites would be buried by austral season 2023/23. Thus, the instruments and data had to be retrieved in this season.

Work in the field

Site FSW1:

Mooring FSW1 (BAS-type logger, IMEI 300234061031800) was installed in January 2016, and has reliably provided data since then. The surface logger and batteries are presumably in good condition. The present issue however was that, although the data logger itself was still reporting engineering data, no valid instrument data came in for all instruments starting on 17 January 2022, the day of the last service. Thus, it was assumed that the inductive data cable, presumably at the transition from the steel mooring wire to the flexible copper cable that connects to the logger, was broken when uplifted.

The cable was broken as expected and could be repaired on site. Afterwards, the logger could be reconnected to the modem cable and data were downloaded from the SBE37IMP Microcat instruments. The download lasted ~6 hours, and was done without further problems. The instruments were set to UTC and restarted. As planned, no Aquadopp data were downloaded. After a final verification of the repaired instrument, the snow pit with electronics and battery was closed and the site cleared. The surface instruments were not raised, as the last service was only done a few months before.

In addition to the mooring, an automatic weather station (AWS) has been operational at FSW1 since 2016, providing reliable data throughout. But the AWS was not uplifted for several years. The sensor arm was raised and the batteries were uplifted for an easier maintenance in the upcoming year.

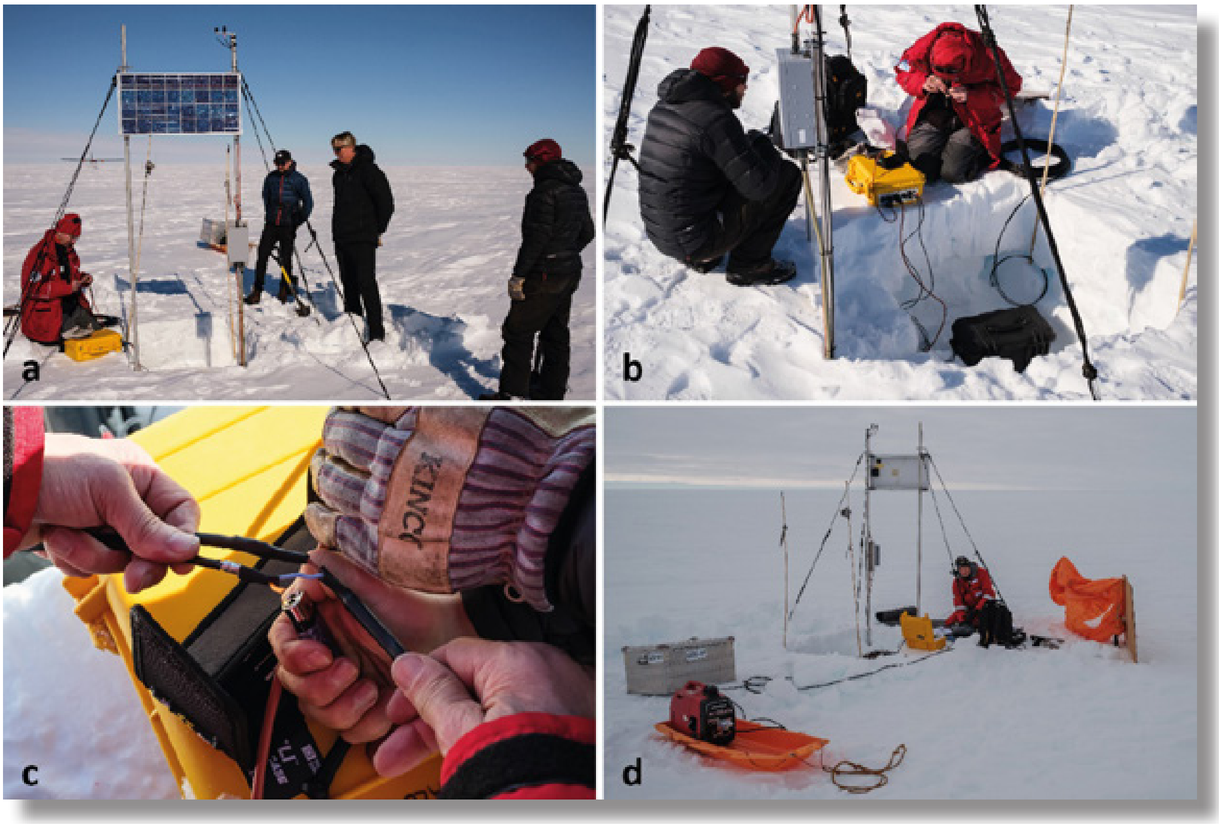

Fig. 5.3.1: Service of the oceanographic mooring at site FSW1. a-c) Retrieval of the data logger to fix the broken mooring cable; d) data download of the SBE37IMP Microcats via the inductive modem link.

Fig. 5.3.2: Service of the weather station at site FSW1. Left: Site overview at time of arrival; right: site overview after maintenance and overnight camp.

Site FSE2:

Mooring FSE2 (BAS-type logger, IMEI 300234061032780) was also installed in January 2016, but has suffered from several issues during its operational time. During the last service, both SD cards in the data logger were found to be unreadable. The logger also seemed unresponsive, which most likely was caused by a damaged firmware. Thus, a new firmware was uploaded and the logger successfully reanimated. The SD cards were swapped for new ones.

Furthermore, the missing SBE37IMP Microcat data between 2019 and 2022 were downloaded from the instruments via the inductive modem link. The data download was done over night and took ~15 hours. No further problems occurred. The instruments were re-set to UTC and restarted. As planned, no Aquadopp data were downloaded. After a final verification of the repaired instrument, the snow pit with electronics and battery was closed and the site cleared. The surface instruments were not raised, as the last service was only done a few months before.

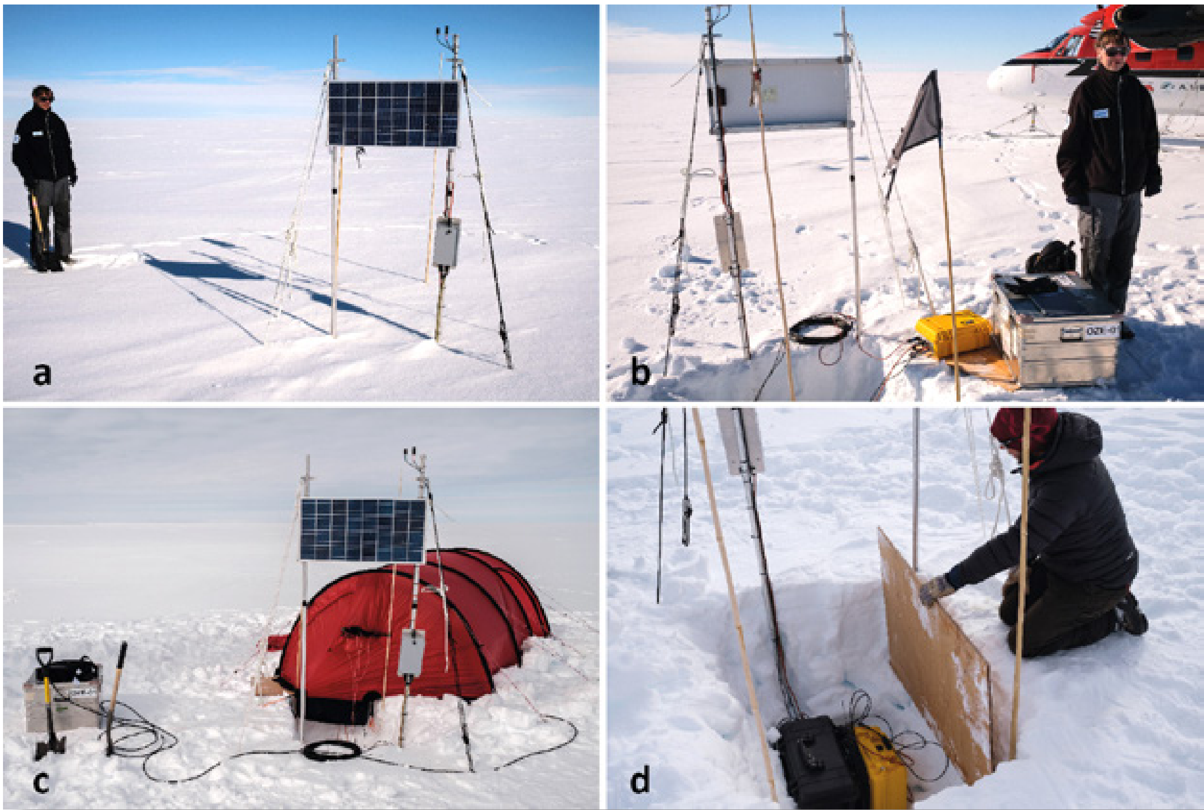

Fig. 5.3.3: Service of the oceanographic mooring at site FSE2. a) Condition at arrival; b) retrieval of the data logger to fix the firmware issue; c) data download of the SBE37IMP Microcats via the inductive modem link during an overnight stay. d) closing of lid within the snow pit after service was done.

Sites SFG East and West:

In front of Support Force Glacier (SFG) two ApRES stations were set-up in austral season 2015/16 approximately 2 km apart. The stations were raised whenever possible once per season, last time in January 2019. To support the retrieval, the positions of the stations were calculated based on flow velocities from satellite data by Niklas Neckel, AWI.

Both stations were by going to the estimated locations. At SFG East a wind turbine was partly sticking out. After location of the solar panel stand of the station, the electronics and batteries could be located, dug out and uplifted from > 3 m below the surface. Solar panel stand nd wind turbine were removed from the field, too.

At SFG West, a station with an ApRES only, a bucket placed on a beam in the foundation of the earlier removed wind turbine was sticking out. Eveything could be retrieved similar to the other station from > 3 m depth.

Fig. 5.3.4: Retrieval of equipment at site SFG_East. a) The wind generator still sticking out; b) the equipment was buried beneath 3-4 m snow, was dug out manually.

Overview of flights

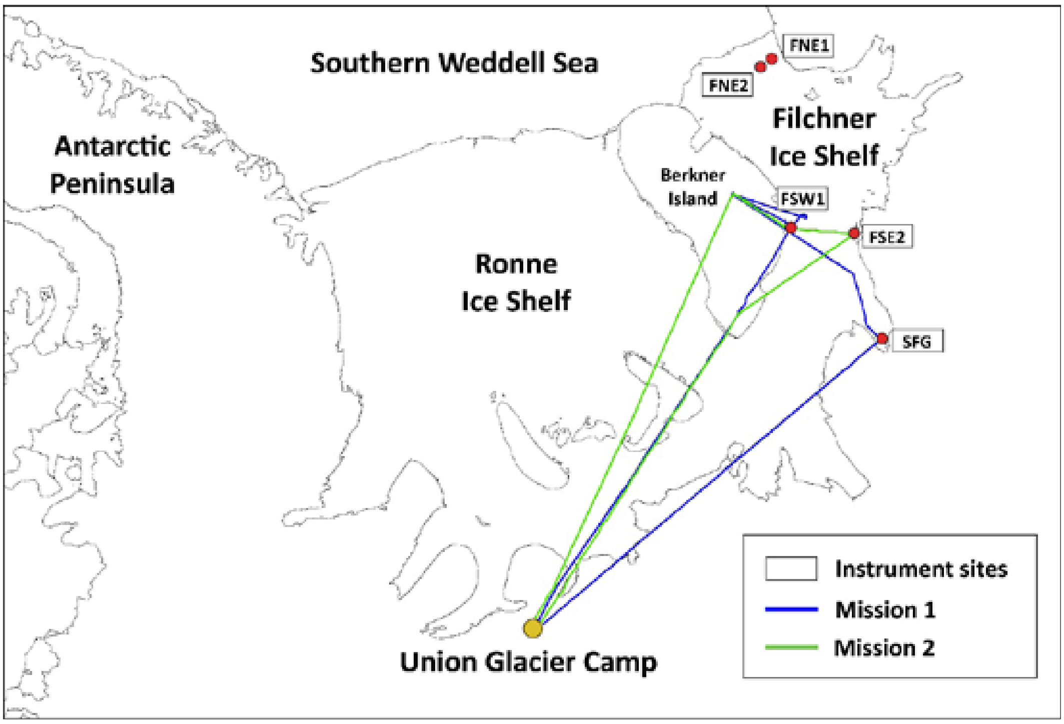

Fig. 5.3.5: Map of the Filchner-Ronne Ice Shelf area, depicting relevant points of interest and flight trajectories during the 2 missions.

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.

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_32** 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.

5.4 PolarConnection 2022

Grant-No. AWI_ANT_33

Überblick und Expeditionsverlauf

Simeon Lisovski DE.AWI

Die Expedition KingGeorge2022 ist die erste von mehreren geplanten Expeditionen nach King George Island (Südliche Shetlandinseln, Antarktis), die sich mit der Besiedelung der Flora und Fauna in der Vergangenheit 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 (Fig. 5.4.1). In der kurzen Zeit konnten wir zwei Projekte mit den folgenden Zielen erfolgreich umsetzen:

1. Die Gewinnung kurzer Sedimentkerne aus zwei Seen, sowie aus einer mit Wasser gefüllten Senke innerhalb einer Pinguinkolonie.
2. Das Fangen und Beproben (Blut, Abstriche) von ankommenden und brütenden Zugvögeln.

Die gewonnen Daten werden zum einen Erkentnisse zum zeitlichen Verlauf der Besiedlung von Vegetation, Seevögeln und Viren der letzten 10 – 15000 Jahre liefern. Sogenannte ancient DNA und RNA wird aus den Sedimentkernen extrahiert und sequenziert, um die Artenzusammensetzungen verschiedener Zeitperioden rekonstruieren zu können. Des Weiteren konnten die Blutproben und Abstriche der Seevögel bereits auf Vogelgrippe spezifische Antikörper und auf akute Infektionen mit Vogelgrippe untersucht werden. Mit Blick auf die derzeitige anhaltende Epidemie von Vogelgrippe (H5N1) in Wildtieren und den damit verbundenen hohen Sterberaten hatte diese Analyse vorrang. Die Ergebnisse und Beobachtungen zeigen, dass der pathogene Stamm H5N1 in der Brutsaison 2022/23 nicht nach King George Island gelangt ist. Vorhandene H5 spezifische Antikörper, konnten jedoch in mehrern Individuen und Arten nachgewiesen werden, und ein Eintrag von Vogelgrippeviren nach King George Island und in die gesamte Region der Antarktischen Halbinsel ist anzunehmen. Insbesondere der mögliche Eintrag und zeitliche Verlauf von H5N1 Infektionen sowie die Konsequenzen für Seevögelkolonien auf den Südlichen Shetlandinseln sollte in den nächsten Jahren besonders aufmerksam dokumentiert und verfolgt werden.

Verlauf der Landexpedition

Am 12. November erreichten wir Fildes Peninsula mit dem chilenischen Schiff *AquilesAP-41.* Die Besatzung der uruguaynischen Station *Base Científica Antártica Artigas,* wo wir für den gesamten Expeditionszeitraum untergekommen waren, nahm uns sehr freundlich auf. Da alle Seen auf Fildes und Ardley noch mit Eis bedeckt und daher für unser Schlauchboot unzugänglich waren, konzentrierten wir uns in den ersten zwei Wochen auf das Fangen und Beproben der Seevögel. In dieser Zeit liefen wir einen Großteil beider Inseln ab, um Proben zu sammeln. In der letzten Woche zogen wir kurze Sedimentkerne aus zwei teilweise eisfreien Seen. Zudem konnten wir eine Probe aus einer mit Wasser gefüllten Senke in einer Pinguinkolonie gewinnen. Am 30. November flogen wir mit einem Transportflugzeug der uruguayanischen Armee zurück nach Punta Arenas (Chile).

Summary and Itinerary

This expedition KingGeorge2022 is the first of several planned expeditions to King George Island (South Shetland Islands, Antarctica) to focus on the past colonization of the flora and fauna, and the associated diversity of viruses and contaminants. The South Shetland Islands at the tip of the Antarctic Peninsula have a particularly high diversity of breeding seabirds, arriving from a wide range of regions from within the world's oceans to breed on the ice-free islands and peninsulas. Our work focused on Fildes Peninsula and Ardley Island (Fig. 5.4.1). The latter is accessible from Fildes at low tide. Despite the short expedition we were able to successfully implement two projects with the following objectives:

1. The recovery of short sediment cores from two lakes, and from a water-filled depression within a penguin colony.
2. The capture and sampling (blood, swabs) of arriving and breeding migratory birds.

The data obtained will provide insights into the past 10 – 15,000 years of colonization pattern of vegetation, seabirds, and viruses. Ancient DNA and RNA will be extracted from the sediment cores and sequenced to reconstruct the species composition of different time periods. Furthermore, the blood samples and swabs from seabirds could already be analyzed for avian influenza specific antibodies and for acute infections with avian influenza viruses. In view of the current ongoing epidemic of avian influenza viruses (H5N1) in wildlife and the associated high mortality rates, this analysis had priority. Results and observations indicate that the H5N1 pathogenic strain did not reach King George Island during the 2022/23 breeding season. However, H5 specific antibodies could be detected in several individuals and species, and the entry of avian influenza viruses to King George Island and the entire Antarctic Peninsula region via migratory birds is likely. In particular, the possible introduction and dynamic of H5N1 infections, as well as the consequences for seabird colonies on the South Shetland Islands, should be documented and monitored in the upcoming breeding seasons.

Itinerary

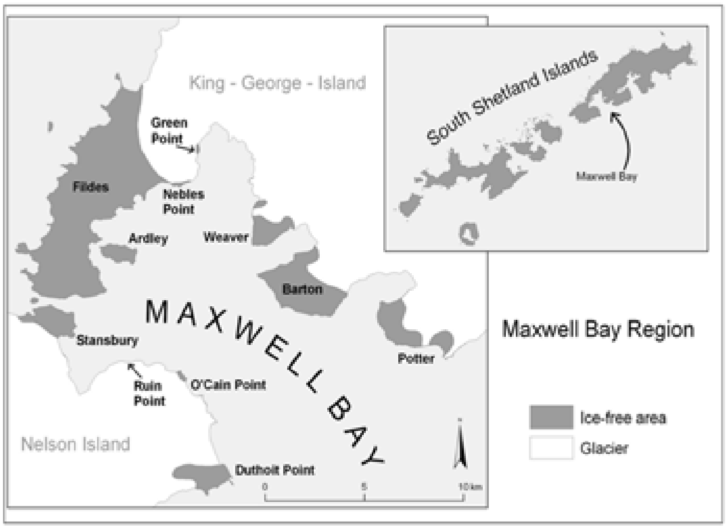

Fig. 5.4.1: King George Island, Shetland Islands, Antarctica. Fieldwork was carried out on Fildes Peninsula and Ardley Island.

On 12 November we arrived at Fildes Peninsula with the Chilean ship *Aquiles AP-41*. The crew of the Uruguayan station *Base Científica Antártica Artigas*, where we stayed for the whole expedition period, welcomed us. Since all lakes on Fildes and Ardley were still covered with ice, and therefore inaccessible to our inflatable boat, we concentrated on catching and sampling seabirds within the first two weeks.

During this time, we walked much of both islands to collect samples. During the last week, we took short sediment cores from two partially ice-free lakes. In addition, we were able to collect a sample from a water-filled depression in a penguin colony. On 30 November we flew back to Punta Arenas (Chile) on a Uruguayan Army transport airplane.

Past Colonization of Flora and Fauna and associated Viruses on King George Island, Antartica

Ulrike Herzschuh, Simeon Lisovski DE.AWI

Objectives

Studies have shown that past colonization patterns and population dynamics (of penguins) can be inferred from sediment core analyses. Notably the lake on Ardley Island has proven to be suitable to get long-term sediment cores (>10,000 – 15,000 years) and identify penguin guano, bacterial diversity and measure the presence and content of various elements (Li et al., 2006; Roberts et al., 2017). Other lakes have been sampled on King George Island providing information on seal population and mercury influx over time (Sun et al., 2006). We aimed to build on these studies and extent our knowledge on the colonization patterns using state-of-the-art molecular methods. Recent advances in computational analysis and the development of new bioinformatic tools (such as Kraken2) and pipelines 25-27, pave the way for shotgun sequencing of environmental DNA (Bálint et al., 2018), which allows the investigation of a broad range of organisms, from non-living viruses to mammals and plants within one single experiment (Ahmed et al., 2018; Murchie et al., 2021). Applied to sedimentary and soil ancient DNA, it has the potential to provide, at least partially, an ecosystem view and snapshots of past environments (Courtin et al., 2021).

In this project, we specifically aim to identify colonization pattern of seabirds on the ice-free areas of Fildes Peninsula and Ardley Island and how this alters viral and bacterical communities.

Fieldwork

The conditions for lake sediment sampling during November were expected to be challenging, since the lake ice becomes too unstable to collect samples through a drilled whole in the ice, but access to the lakes with a boat is still limited. However, during the last week of our expedition, we managed to manouver our small invlatable rubber boat onto two lakes of interest and collected two short cores from both lakes (22-EN-4001, 22-EN-4002, see Tab. 5.4.1 and Fig. 5.4.2 – 5.4.3). In addition, and mainly to derive a calibration sample with high probability of DNA/RNA from seabirds and accociated viruses and bacteria, we collected two samples from a small water filled depression sourrounded by penguin colonies (22-EN_4003, see Tab. 5.4.1 and Fig. 5.4.2 – 5.4.3).

Tab. 5.4.1: Short sediment cores taken during the expedition on Fildes Peninsula and Ardley Island using a gravity corer (12 cm diameter).

CoreID	Date	Location	Lon	Lat	Core length
22-EN-4001-1	26.11.2022	Fildes	-58.94	-62.19	22 cm
22-EN-4001-2	26.11.2022	Fildes	-58.94	-62.19	24 cm
22-EN-4002-1	27.11.2022	Lake YY, Ardley	-58.93	-62.21	40 cm
22-EN-4002-2	27.11.2022	Lake YY, Ardley	-58.93	-62.21	50 cm
22-EN-4003-1	29.11.2022	Ardley	-58.91	-62.21	27 cm
22-EN-4003-2	29.11.2022	Ardley	-58.91	-62.21	22 cm

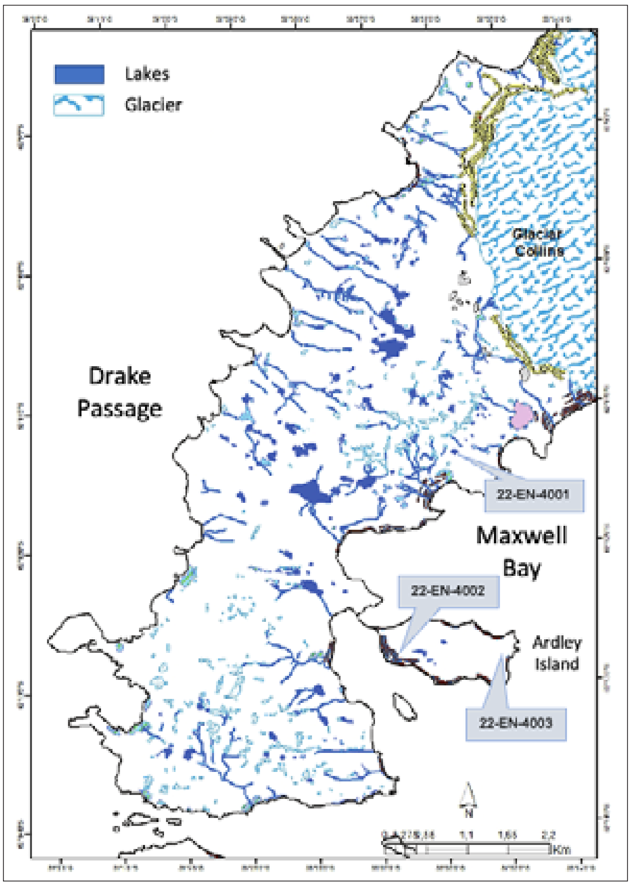

Fig. 5.4.2: Lake sediment core sampling locations on Fildes Peninsual and Ardley Island.

Fig. 5.4.3: Left: Ulrike Herzschuh taking a small sediment core (22-EN-4003). Right: Simeon Lisovski preparing the boat and corer to derive short sediment core in Lake YY (22-EN-4002) on Ardley Island (Photos: Simeon Lisovski, Ulrike Herzschuh)

Expected results

In the second half of 2023, we plan to subsample all cores: taking small samples across the entire core, representing different depths and sediment ages. Subsampling must be done under extremely clean conditions in a separate laboratory to avoid contamination with (e.g., environemtnal) DNA. Samples will be defided into three samples: 1) age analyses via e.g., C^{14} methods, 2) DNA/RNA extraction, 3) long-term storage. To optimize our laboratory and analythical pipeline, we will start with the short cores from the lake sourrounded by breeding penguins, brown skuas and southern giant petrels. Afterwards we will analyse the age of samples from the other cores, extract DNA/RNA to be sequenced. After matchup with reference databases, we will derive occurance of taxonomic units that will allow us to reconstruct species diversity (incl. plants, animals, bacteria, viruses) and community assampleges over time.

Data management

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).

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

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The Origin and Diversity of Viruses transported to King George Island via Migratory Birds

Simeon Lisovski[1], Ulrike Herzschuh[1]
Anne M. Günther (not in the field)[2]

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[2] DE.FLI

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 Antarctics 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 and 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 and 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 deseases.

The major objectives of this project and for the initial fieldwork expedition to King George Island (Fildes Peninsula and Ardley Island) were 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. 5.4.2 for information on species and numbers) by hand, a casher, or a baited snare. 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 pharyngial 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). Fieldwork was carried out with the permit to enter the special protected areas of Fildes Peninsual (ASPA No. 125) and Ardley Island (ASPA No. 150), issued by the Umweltbundesamt (94033-213). Catching techniques and sampling of birds were also approved by the Umweltbundesamt (94033-213).

Fig. 5.4.4: Simeon Lisovski while taking a pharyngial swab (right) and a blood sample (left) from a Brown skua (Stercorarius antarcticus) on Fildes Peninsula, King George Island, Antarctica (Photo: Ulrike Herzschuh).

Tab. 5.4.2: Number and species caught during the expedition to collect blood samples and swabs.

Species	**Scientific name**	**Numbe of blood samples**	**Number of swabs**
Adelie Pengiun	*Pygoscelis adeliae*	25	25
Gentoo Penguin	*Pygoscelis papua*	25	25
Chinstrap Penguin	*Pygoscelis antarcticus*	25	25
South Polar Skua	*Stercorarius maccormicki*	30	30
Brown Skua	*Stercorarius antarcticus*	30	30
Southern Giant Petrel	*Macronectes giganteus*	15	15

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, there was concern that the virus will arrive in Antarctica during the 2022/23 breeding season. Observations (also from other places) did not show any signs of acute infections and it is very likely that, together with Australia, this particular virus clate did not yet spread across the two southernmost continents. The analysis of the swab samples also showed that **none of the sampled individuals had an acute infection of any influenza A virus**. However, the serum samples were also tested for Avian Influenza Virus Antibodies. The results show that individuals from almost all sampled species had past exposure and infections with this group of viruses. Most interestingly, at least one individual of the Gentoo Penguin, South Polar Skua, Brown Skua and likely the Southern Giant Petrel showed H5 specific antibodies. This indicades that those individuals were in contact to Avian Influenza Virus strains with high potential for pathogenicity (like the H5N1 subtype).

Tab. 5.4.3: Avian Infleunza Virus seroprevalence of individuals and species sampled during the expedition (NP = Unspesific Influenza A Nukleoprotein).

Species	NP-positive	NP-negative	% NP-positive	H5-positive	% H5-positive
Adelie Penguin	2	21	9,5	0	0
Gentoo Penguin	4	18	22,2	1	5,6
Chinstrap Penguin	8	22	36,4	0	0
South Polar Skua	2	30	6,7	1	3,3
Brown Skua	18	33	54,6	1	3,0
Southern Giant Petrel	1	21	4,8	(1)	(4,8)

Further analysis and research agenda

Using the already extracted RNA, we plan to run full virome analyses (Cobbin et al., 2021) to quantify the diversity of viruses within and among the sampled species. These results will also provide first clues on the general origin of the viruses and via which routes and species pathogens might be transported into Antarctica.

In the future, we plan to combine individual tracking technologies with individual virus diversity to establish emeprical migration networks and quantify the global connectivity of King George Island and the consequences regarding virus transport as well as within and among species transmissions of potential pathogens. Ultimately, and following this approach, we aim to get a better understanding of the role of migratory seabirds and Antarcitca in the global dynamic of wildlife disease dynamics.

Data management

Raw data information and results will be submitted to an appropriate long-term archive upon first pulication of the results, providing 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_33** will be quoted.

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Logistics support

Name	Description
Institute Antarctico Uruguayo (IAU)	Logistical support (organisation of transport to/from King George Island), invitation to stay at the Base Científica Antártica Artigas on Fildes Peninsula during the expedition, logistical support during the expedition
Institute Antarctico Chileno (INACH)	Logistical support (transfer from Punta Arenas to King George Island with *Aquiles AP-41*)
Dirk Mengedoht (@AWI)	Logistical support (organisation of transport opportunities)
Josefine Weiss, Jan Kahl (@AWI)	Logistical support (organisation of air freight)

5.5 SIGMA-I 2022/2023

Kerstin Jerosch[1], Grit Steinhöfel[1] (not in the field), Camila Neder[2]

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Grant-No. AWI_ANT_34

Überblick und Expeditionsverlauf

Im Fokus der ANT-Land-SIGMA-I Expedition (Dezember 2022 – März 2023) stand die Untersuchung der marin-terrestrischen Übergangszone der West-Küsten der antarktischen Halbinsel, um detaillierte Information über die Lebensräume von sieben Gletschern von King George Island zu gewinnen, die durch sedimentbeladene Schmelzwasserabflüsse beeinflusst werden. Von den antarktischen Forschungsstationen *Carlini, Escudero* und *Arctowski* aus setzten wir eine Multispektralkamera auf einer DJI P4 Multispectral ein, um die Prozesse zu erfassen, die bei der Umwandlung einer stark gestörten, glazial beeinflussten in eine stabilere und vielfältigere Landschaft ablaufen. Unbemannte Luftfahrzeuge (UAVs) können zu bevorzugten Zeiten unter den Wolken fliegen und Daten mit einer Auflösung im Zentimeterbereich erfassen, wodurch eine bedeutende Lücke zwischen den bestehenden Möglichkeiten der Fernerkundung (vor Ort, aus der Luft und per Satellit) geschlossen wird. Ziel der Kampagne war (i) die georeferenzierte Kartierung der marinen Gletscherabflussgebiete (Plumes) von sieben Gletschern, (ii) die Analyse der Beziehungen zwischen Luft- (multispektrale) und Wasserdaten (Salzgehalt, Temperatur, Trübung, SPM, TOC, Geochemie, Phytoplankton), um die Multispektral-Daten zu kalibrieren, (iii) Erfassung von Erosionsprozessen wie periglazialen Bächen an unvergletscherten Küsten, die durch SPM-Eintrag direkt mit Veränderungen im marinen Ökosystem verbunden sind (Bereitstellung und Lieferung von Sediment und gelösten Stoffen von der Küste), und (iv) Kartierung der Auswirkungen auf die Sediment- und Landschaftsstabilität durch opportunistische Vegetationssukzession in entgletscherten Gebieten. ANT-Land-SIGMA-I trägt zum PoF IV Unterthema 4.2 bei und wurde vom AWI und dem EU-Projekt CoastCarb (Marie Curie Action RISE, Research and Innovation Staff Exchange, H2020-MCSA-RISE 872690) finanziert. Die Expedition wurde logistisch vom Argentinischen Antarktis-Institut (IAA), dem Chilenischen Antarktis-Institut (INACH) und dem Institut für Biochemie und Biophysik der Polnischen Akademie der Wissenschaften (IBB-PAS) für Aufenthalte in den antarktischen Forschungsstationen *Carlini, Escudero* und *Arctowski* unterstützt.

Summary and Itinerary

The campaign ANT-Land-SIGMA-I (December 2022 – March 2023) focused on the marine/terrestrial transition zone at Westantarctic Peninsula (WAP) coasts and to gain detailed insides in the distribution and character of habitats influenced by sediment-loaded meltwater runoff in front of 7 glaciers at King George Island. From the Antarctic scientific stations *Carlini, Escudero* and *Arctowski*, we used a multispectral camera on a DJI P4 multispectral to baseline the processes involved in transforming a highly disturbed, glacially influenced to more stable and diverse landscape. Unmanned Aerial Vehicles (UAVs) can fly under clouds at preferred times, capturing data at cm resolution, filling a significant gap between existing *in situ*, airborne and satellite remote sensing capabilities. The campaign aimed for (i) georeferenced mapping of marine glacial outflow areas (plumes) of in front of seven glaciers, (ii) analyzing the relationships between air- (multispectral) and water-born (salinity, temperature, turbidity, SPM, TOC, geochemistry, phytoplankton) data for calibration purposes, (iii) surveying erosional processes such as periglacial creeks at unglaciated coasts, which are directly linked to changes in the marine ecosystem (provision and delivery of sediment and solutes from the shore) by

SPM, TOC, discharge volume measurements, and (iv) mapping implications for sediment and landscape stability by opportunistic vegetation succession in deglaciated areas.

ANT-Land-SIGMA-I contributes to PoF IV subtopic 4.2 and was funded by AWI and the EU project CoastCarb (Marie Curie Action RISE, Research and Innovation Staff Exchange, H2020-MCSA-RISE 872690). The expedition has been logistically supported by the Argentine Antarctic Institute (IAA), Chilean Antarctic Institute (INACH), and Institute of Biochemistry and Biophysics, Polish Academy of Sciences (IBB-PAS) for research stays at the Antarctic scientific stations *Carlini, Escudero* and *Arctowski*.

Air-born Investigation of sediment-rich Glacial Meltwater Plumes and Sediment Delivery from the Shoreline of recently deglaciated Coasts at King Georg Island, Antarctica

Kerstin Jerosch[1], Grit Steinhöfel[1] (not in the field), Camila Neder[2]

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Objectives

ANT-Land-SIGMA-I 2022/2023 aimed to spatially assess and quantify glacial meltwater discharge in front of seven glaciers in Maxwell and Admiralty Bay at King George Island (Fig. 5.5.1) and with that to serve for a better understanding of the importance of glacier melt in terms of habitat change. The increase of suspended particulate material (SPM) resulting from glacier retreat, changes in glacial activity, ice melting, freshwater discharge) is one of the most important effects of climate change in the Antarctic marine coastal zone. Surface waters at the West Antarctic Peninsula (WAP) have warmed up and are predicted to warm further in the future. Increased concentration and extend of SPM triggered by glacier retreat are known as the potential causal factor shaping the overall benthic communities. Filter-feeder dominated macrobenthic communities are known for fine sand areas with little glacial disturbance, while scavenger and opportunistic feeder dominated communities, in contrast, are present where frequent ice scouring and high concentrations of SPM induce mortality in fauna inhabiting muddier sediments (e.g., Sahade et al., 2015; Breackman et al., 2021). Even marcoalgae, the main source of biomass and carbon transfer to the ecosystem, experience a habitat shift due to a reduced light availability (e.g., Quartino et al., 2013; Jerosch et al., 2019). Hence, the higher sedimentation rates induce a significant habitat change for sessile species in particular.

Targets of ANT-Land-SIGMA-I 2022/2023 were

- georeferenced mapping of marine glacial outflow areas (plumes) of in front of seven glaciers,
- analysing the relationships between air- (multispectral) and water-born (salinity, temperature, turbidity, SPM, TOC, geochemistry, phytoplankton) data for calibration purposes,
- surveying erosional processes such as periglacial creeks at unglaciated coasts, which are directly linked to changes in the marine ecosystem (provision and delivery of sediment and solutes from the shore) by SPM, TOC, discharge volume measurements,
- mapping implications for sediment and landscape stability by opportunistic vegetation succession in deglaciated areas.

The air-born Unmanned Aerial Vehicles (UAVs) and water-borne data taken at four bays in Maxwell and Admiralty Bay at King George Island will be analysed to assess the different extents and contents of SPM in the bays and its effect on the planktonic and benthic communities. The air-born survey further supports the attempt to extrapolate our existing detailed knowledge of SPM discharge and transport at Potter Cove (Jerosch et al. 2018; Neder et al. 2022) to wider areas such as the coasts of King George Island or the WAP, since airborne UAV data has major potential to be embedded in operational monitoring programmes and can form useful links between satellite and in situ observations (De Keukelaere et al., 2023).

Fieldwork

A station consisted of an about 2 h UAV missions with a DJI Phantom 4 multispectral (blue, green, red, red edge, and near infrared bands and a DJI Inspire 2 (high resolution Zenmuse X5s with a standardized Red-Green-Blue colour model (sRGB)). The missions were immediately followed by *in situ* CTD and turbidity measurements using a SBE 19plus V2 CTD with an auxiliary ECO NTU turbidity sensor from a zodiac inside the recorded area (Fig 5.5.1). Niskin bottles were used for water sampling at the water surface and at 10 m depth. The RTK positioning and the D-RTK 2 Mobile Station provided high precision georeferencing and an independent flight planning system controlled via the DJI GO4 App.

Fjord or meltwater samples were filtered for quantitative determination of suspended sediment/particles and organic carbon at AWI (1 sample ≙ a 0.7 μ glass fiber filters incl. filtrate in aluminum foil). Further, fjord or meltwater samples were taken for geochemical studies (1 sample ≙ 200 ml filtered, acidified water in PET bottle). We collected rock samples for geochemical studies (1 sample ≙ 1 fist-sized rock) and fjord water samples for analysis of phytoplankton communities (1 sample ≙ 50 ml filtered water, 3% formalin-diluted).

Preliminary (expected) results

The campaign ANT-Land-SIGMA-I focused on the marine/terrestrial transition zone at WAP coasts and to gain detailed insides in the distribution and character of habitats influenced by sediment-loaded meltwater runoff at King George Island. Based at the scientific stations Carlini (DNA-IAA, ARG), Escudero (INACH, CL), and Arctowski (IBB-PAS, PL) 23 UAVs DJI Phantom 4 multispectral / DJI Inspire 2 missions have been launched. They were deployed from land in front of seven glaciers in Maxwell and Admiralty Bay, King George Island: Collins Harbour –Polar Friendship Glacier, Marian Cove – Moczydlowski Glacier, Potter Cove – Fourcade Glacier, Goulden Cove – Zalewski Glacier, Anse Hervé – Dera Icefall, Suszczewski Cove – Ecology Glacier, Lussich Cove – Krak Glacier. The sites were reached either via zodiak or by foot. The flight missions lasted about 60 min per UAV, and at 80 – 120 m altitude (depending on wind conditions) covered an area of about 400 x 400 m. Per mission 450 – 1,500 photographs were taken. The GNSS Mobile Station and the DJI TimeSync system ensure precise position data and centimeter-accurate measurements in real time. UAV technology will allow the observation of ice phenomena that prevent this type of analysis or interfere with its results. High-resolution photographs given by the Zenmuse X5s camera on the DJI Inspire 2 UAV, we will be able to identify and quantify shapes and colours of glacial discharges as well as the recognition of plumes, due to its natural RGB colour model (Wójcik et al. 2019). Further, MapEO water data processing workflow will be used, that deals with the complexities of observing water surfaces and retrieves water-leaving reflectance and water quality products like turbidity and chlorophyll-a (Chl-a) concentration. We therefore expect georeferenced products such as water-leaving reflectance, turbidity, suspended sediments, Chl-a, proved by *in situ* measurements. During the campaign, UAVs have been successfully used even in the unfavourable weather conditions and harsh climate of polar regions (Lehmenhecker & Wulff 2013; Wójcik et al., 2019; Blash & Moorman 2020). Their use in scientific research in

Antarctica offers many benefits to science and if used responsibly, may be less invasive than other research techniques, offering a rich source of new scientific data.

Temperature, salinity, and turbidity measurements were carried out inside the UAV mission areas applying 125 CTD deployments. Multispectral sensors of the DJI P4 Multispectral UAV will be used for the analysis of water turbidity. Red wavelengths are applicable for identifying values representing low-turbidity and medium-turbidity waters (<70 FNU) and for identifying red and white sediments in water. High turbidity in water correlates with longer wavelengths such as Red Edge and Near Infrared. Additional fjord surface (95) and 10 m depth (19) water samples were taken for SPM/TOC and geochemistry of filtered particles, isotope of dissolved substances and phytoplankton biodiversity. Furthermore, two meltwater streams at Potter Cove were sampled for SPM/TOC the volume of meltwater was investigated over time by 25 current measurements, width and depth cross sections of two meltwater streams at Potter Cove (Tab. 5.5.1). At the bases *Carlini* and *Arctowski*, we looked at implications landscape stability by opportunistic vegetation succession in deglaciated areas (Fig. 5.5.2).

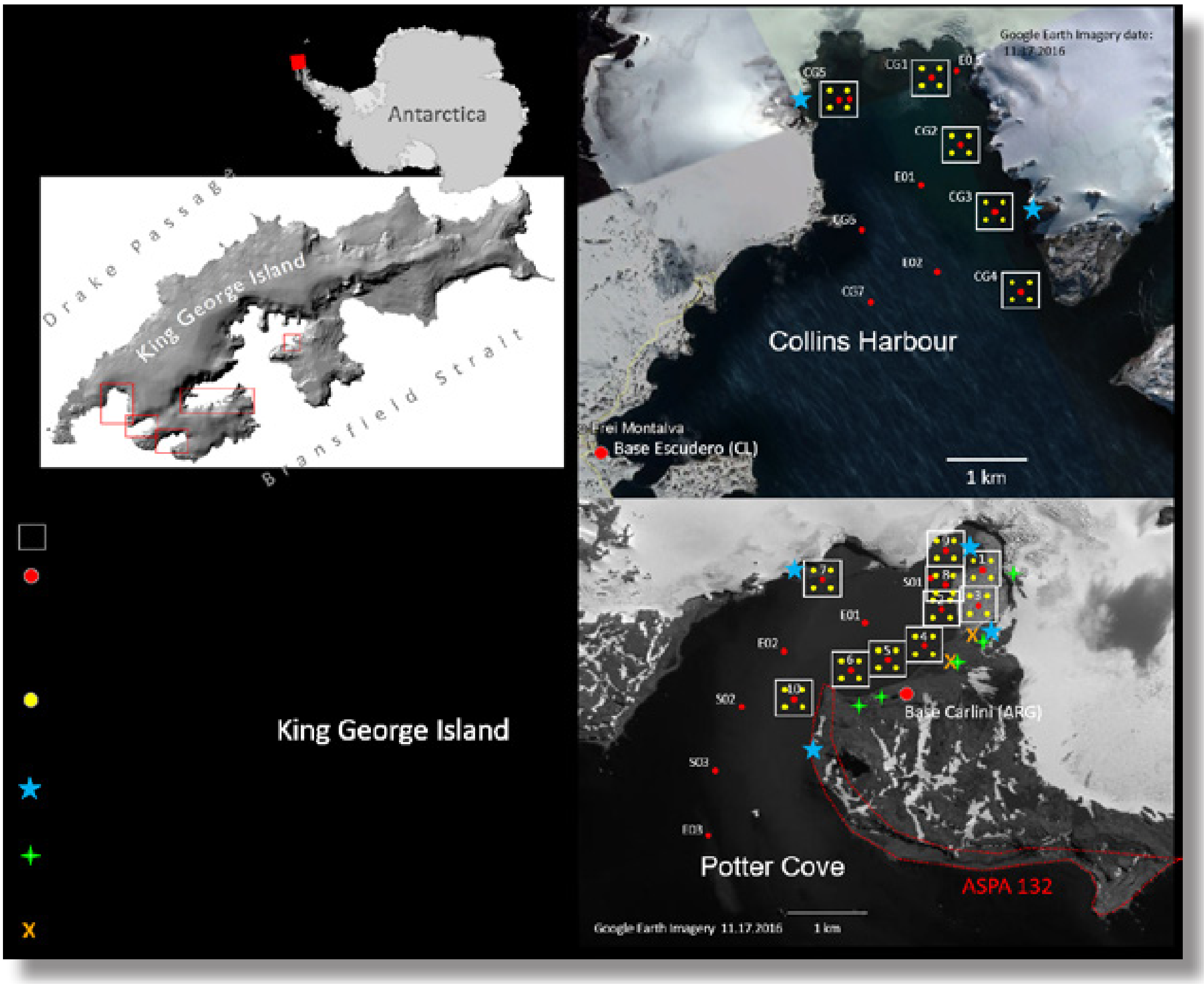

Fig. 5.5.1: ANT-Land-SIGMA-I study areas in Maxwell and Admiralty Bay, King George Island. Exemplaarym eta data collection in front of Polar Friendship Glacier at Collins Harbour and Fourcade Glacier at Potter Cove.

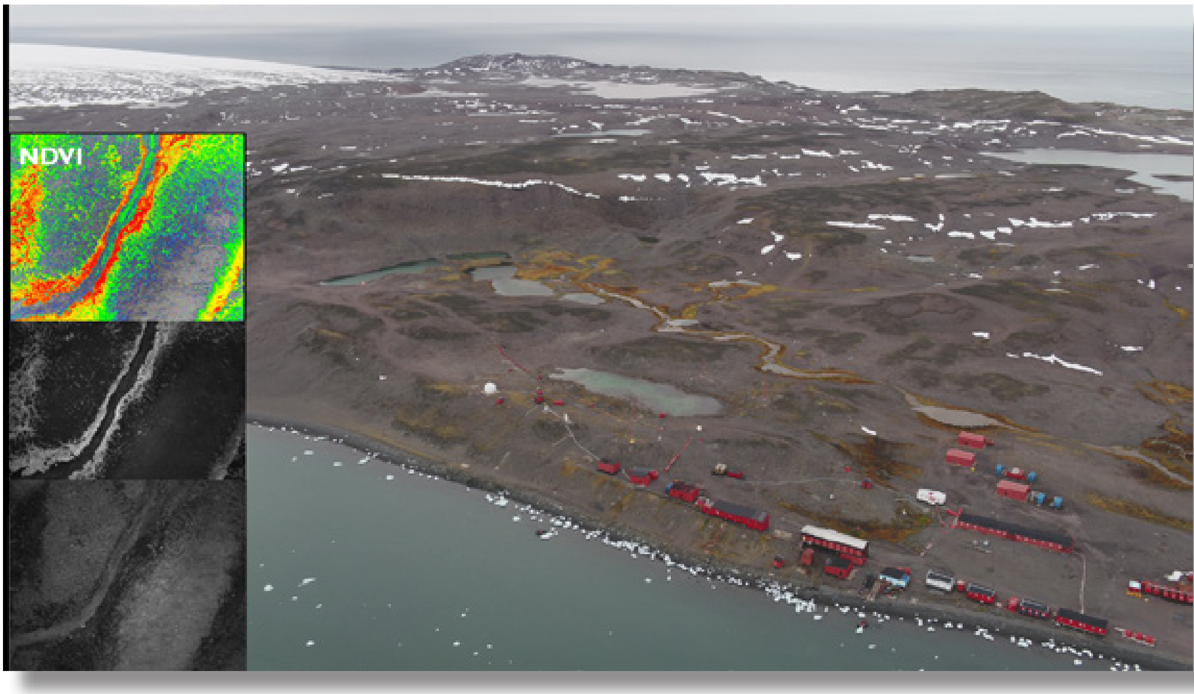

Fig. 5.5.2: Opportunistic vegetation succession in deglaciated areas at Carlini Station. The colours represent the Difference Vegetation Index (NDVI). NDVI values range from -1.0 to 1.0, with negative values indicating clouds and water, positive values near zero indicating bare soil, and higher positive values of NDVI ranging from sparse vegetation (0.1 – 0.5) to dense green vegetation (0.6 and above) (Photo: K. Jerosch)

Tab. 5.5.1: Sampling during ANT-Land-SIGMA-I (12/2022 – 03/2023).

Objective	Sample type	No of samples
phytoplankton biodiversity	fjord water	63
isotopy of dissolved substances	fjord and meltwater	69
geochemistry	rocks	29
SPM, TOC & geochemistry	filtered particles of fjord & meltwater (total)	205
SPM/TOC	meltwater streams (only)	64
CTD-turbidity	sensors	125
hydrological discharge	currents & volume of meltwater streams	25
UAV missions	multispectral & RGB imagery	23

Data management

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

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

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In all publications based on this expedition, the **Grant No. AWI_ANT_34** will be quoted.

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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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