ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

767
2022

Berichte
zur Polar- und Meeresforschung
Reports on Polar and Marine Research

Expeditions to Antarctica: ANT-Land 2021/22 Neumayer Station III, Kohnen Station, Flight Operations and Field Campaigns

Edited by

Christine Wesche and Julia Regnery
with contributions of the participants

HELMHOLTZ

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

Die Berichte zur Polar- und Meeresforschung enthalten Darstellungen und Ergebnisse der vom AWI selbst oder mit seiner Unterstützung durchgeführten Forschungsarbeiten in den Polargebieten und in den Meeren.

Die Publikationen umfassen Expeditionsberichte der vom AWI betriebenen Schiffe, Flugzeuge und Stationen, Forschungsergebnisse (inkl. Dissertationen) des Instituts und des Archivs für deutsche Polarforschung, sowie Abstracts und Proceedings von nationalen und internationalen Tagungen und Workshops des AWI.

Die Beiträge geben nicht notwendigerweise die Auffassung des AWI wider.

Herausgeber
Dr. Horst Bornemann

Redaktionelle Bearbeitung und Layout
Susan Amir Sawadkuhi

Alfred-Wegener-Institut
Helmholtz-Zentrum für Polar- und Meeresforschung
Am Handelshafen 12
27570 Bremerhaven
Germany

www.awi.de
www.awi.de/reports

The Reports on Polar and Marine Research are issued by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) in Bremerhaven, Germany, succeeding the former Reports on Polar Research. They are published at irregular intervals.

The Reports on Polar and Marine Research contain presentations and results of research activities in polar regions and in the seas either carried out by the AWI or with its support.

Publications comprise expedition reports of the ships, aircrafts, and stations operated by the AWI, research results (incl. dissertations) of the Institute and the Archiv für deutsche Polarforschung, as well as abstracts and proceedings of national and international conferences and workshops of the AWI.

The papers contained in the Reports do not necessarily reflect the opinion of the AWI.

Editor
Dr. Horst Bornemann

Editorial editing and layout
Susan Amir Sawadkuhi

Alfred-Wegener-Institut
Helmholtz-Zentrum für Polar- und Meeresforschung
Am Handelshafen 12
27570 Bremerhaven
Germany

www.awi.de
www.awi.de/en/reports

Titel: Neumayer-Station III
Foto: Christine Wesche, AWI

Title: Neumayer Station III
Photo: Christine Wesche, AWI

Expeditions to Antarctica: ANT-Land 2021/22 Neumayer Station III, Kohnen Station, Flight Operations and Field Campaigns

Edited by
Christine Wesche and Julia Regnery
with contributions of the participants

Please cite or link this publication using the identifiers

https://hdl.handle.net/10013/epic.17995ca9-421f-4d92-a084-370008bae349

https://doi.org/10.57738/BzPM_0767_2022

ISSN 1866-3192

ANT-Land 2021/22

05 November 2021 – 24 February 2022

Neumayer Station III, Kohnen Station, Flight Operations and Field Campaigns

Field Operations Manager
Christine Wesche

Coordinators
Julia Regnery and Christine Wesche

Contents

1.	Überblick und Expeditionsverlauf	3
2.	Weather Conditions during ANT-Land 2021/22 at *Neumayer Station III*	5
3.	Station Operations	8
	3.1 Technical Operations	9
	3.2 General Flight Operations	11
	3.3 Ship Operations	12
	3.4 Reduction of *Neumayer Station III* Carbon Footprint	12
4.	*Neumayer Station III*	18
	4.1 Long-term Air Chemistry Observations at *Neumayer Station III*	*18*
	4.2 The Geophysical Observatory	24
	4.3 The Meteorological Observatory at *Neumayer Station III*	*28*
	4.4 CTBTO – IS27 Infrasound Station	30
	4.5 Antarctic Fast Ice Network (AFIN)	34
	4.6 SPOT – Single Penguin Observation and Tracking Heading	40
	4.7 Ocean Acoustics – PALAOA	47
	4.8 Neuromayer – Neurophysiological Changes in Human Subjects during Long-duration Overwintering Stays at *Neumayer Station III* in Antarctica	49
	4.9 Consequences of Longterm-Confinement and Hypobaric Hypoxia on Immunity in the Antarctic Environment at the *Concordia* and *Neumayer* Station *III* (CHO$_2$ICE @ *Neumayer*)	51
	4.10 WSPR RADIO Beacon at *Neumayer Station III* for Evaluation of Southern Hemisphere Radio Propagation	53
	4.11 VACCINE (Variation in Antarctic Cloud Condensation Nuclei (CCN) and Ice Nucleating Particle (INP) Concentrations at *Neumayer Station III*	60
	4.12 EDEN ISS	64
	4.13 ISO-ANT – Water Vapour Isotope Research in the Antarctic	73
	4.14 MARE – Monitor the Health of the Antarctic using the Emperor Penguin as a Sentinel	76

4.15 MICA-S – Magnetic Induction Coil Array – South 82

4.16 MIMO-EIS – Monitoring Melt where Ice Meets Ocean – Continuous Observation of Ice-Shelf basal Melt on Ekström Ice Shelf, Antarctica 85

4.17 GrouZE – Grounding Zone of the Ekström Ice Shelf – Geophysical Characterization with GPS, Seismology and Magnetotelluric 90

4.18 Remelt Radar – Determining Ice Shelf Rheology and Ocean Induced Melting across Timescales 94

4.19 GNSS-Reflecto-/Refractometry 99

4.20 SLIFT: Microstructural and Mechanical Properties of Snow used to lift *Neumayer Station III* *103*

4.21 ZeroPolAr – Incentives for a Zero-Pollution Ambition for Antarctica 105

5. *Kohnen Station* *108*

5.1 Kottaspegel 2021/22 108

5.2 FIDEMEKO2 110

6. Flight Campaigns 113

7. Other Scientific Projects with AWI Participation 114

7.1 Beyond EPICA – Oldest Ice Core 114

APPENDIX 120

A.1 Teilnehmende Institute / Participating Institutes 121

A.2 Expeditionsteilnehmer:innen / Expedition Participants 125

A.3 Logistische Unterstützung, Überwinternde / Logistics Support, Wintering Team 126

1. ÜBERBLICK UND EXPEDITIONSVERLAUF

Christine Wesche DE.AWI

Nach wie vor beeinflusste die CoV-2 Pandemie die Vorbereitung und Durchführung der Sommersaison 2021/22. Trotz vorhandener Impfstoffe galt als oberstes Ziel die Ausbreitung des Virus auf dem Kontinent zu vermeiden, was im Rahmen des Councils of Managers of National Antarctic Programs (COMNAP) und des Dronning Maud Land Air Network (DROMLAN) international beschlossen wurde. Nichtsdestotrotz sollte an einer nahezu normalen Saisonplanung festgehalten werden, um den Wissenschaftler:innen und Techniker:innen so viel Zeit wie möglich für ihre Feld- und Wartungsarbeiten zu geben.

Man entschied sich in der Vorbereitung die Luftbrücke zwischen Kapstadt, Südafrika und der Antarktis eingeschränkt zu nutzen – dies bedeutete, Wissenschaftler:innen und Techniker:innen nach einer 14-tägigen Hotelquarantäne in Kapstadt mit Charterflügen in die Antarktis zu bringen. So konnte die Saison wie gewohnt Anfang November 2021 beginnen. Auf dem Rückweg wurde auf international genutzte DROMLAN Flüge zurückgegriffen, da dies aus pandemischer Sicht die Virus-Ausbreitung innerhalb der Antarktis nicht mehr beeinflusst. Die Sommersaison 2021/22 endete am 20. Februar 2022 mit der Abreise der letzten Sommergäste.

Initial waren drei Interkontinentalflüge geplant, die insgesamt 60 Personen (inkl. des 42. Überwinterungsteams) im Verlaufe des Sommers zur *Neumayer-Station III* bringen sollten. Während der Quarantänezeit der zweiten Gruppe der Sommergäste kam es jedoch zum Ausbruch der Omikron-Welle und die Quarantänezeit dieser Teilnehmer:innen wuchs auf 38 Tage an, da sich einige von ihnen in der Quarantäne infizierten. Außerdem entschieden sich einige Teilnehmer:innen ihre Reise abzubrechen, was zur Folge hatte, dass Projekte wiederholt verschoben werden mussten, darunter auch die Flugkampagne der *Polar5*. Zusätzlich entschied man sich, auf den dritten Interkontinentalflug in die Antarktis zu verzichten, sondern *Polarstern* für den letzten Personentransport zu nutzen. Hierfür wurde der Fahrplan der *Polarstern* angepasst und die Reisenden auf das 42. Überwinterungsteam beschränkt, was zur Folge hatte, dass weitere wissenschaftliche Projekte in die folgende Saison verschoben werden mussten.

Insgesamt konnten trotz der Schwierigkeiten Feldkampagnen stattfinden und wissenschaftliche Daten vor Ort gesammelt werden. Neben den Langzeitmessungen konnten zwei geophysikalische Traversen zur Gründungslinie, die jährlichen Arbeiten zur Untersuchung der Vitalität der Kaiserpinguinkolonie in der Atka-Bucht, sowie kleinere wissenschaftliche Projekte durchgeführt werden. Durch die reduzierte vorherige Saison blieben einige technische Arbeiten liegen, die in dieser Saison nachgeholt werden mussten. So wurden alle Außenanlagen zweifach erhöht, um die Akkumulation der letzten beiden Jahre auszugleichen und den Betrieb der Anlagen zu gewährleisten. Außerdem wurde die *Kohnen-Station* auf dem Plateau geöffnet und dringend notwendige technische Arbeiten durchgeführt, um die Station selbst und den wissenschaftlichen Trench zu erhalten. Auf dem Landweg zwischen der *Neumayer-Station III* und der *Kohnen-Station* wurden wiederkehrende Akkumulationsmessungen durchgeführt sowie an der *Kohnen-Station* Messgeräte gewartet.

In den nachfolgenden Kapiteln wird ein Überblick über das Wettergeschehen sowie die Technik und Logistik während der Sommersaison gegeben. Anschließend werden die jährliche Wartung der Observatorien und weitere wissenschaftlichen Projekte an der *Neumayer-Station III* und *Kohnen-Station*, sowie andere Feldkampagnen unter der Beteiligung des AWIs beschrieben.

SUMMARY AND ITINERARY

The CoV-2 pandemic continued to influence the preparation and implementation of the 2021/22 summer season. Despite the availability of vaccines, the primary goal was to avoid the spread of the virus on the continent, which was decided internationally within the framework of the Council of Managers of National Antarctic Programs (COMNAP) and the Dronning Maud Land Air Network (DROMLAN). Nevertheless, a near-normal seasonal schedule was to be maintained to give the scientists and technicians as much time as possible for their field and maintenance work.

In preparation, it was decided to make limited use of the airlift between Cape Town, South Africa, and Antarctica, which meant that scientists and technicians would be brought to Antarctica by charter flights after a 14-day hotel quarantine in Cape Town. This allowed the season to begin as usual in early November 2021. On the way back, internationally used DROMLAN flights were used, as from a pandemic point of view this no longer affects the virus spread within Antarctica. The 2021/22 summer season ended on 20 February 2022 with the departure of the last summer guests.

Initially, three intercontinental flights were planned to bring a total of 60 people (incl. the 42nd wintering team) to *Neumayer Station III* during the summer. However, during the quarantine period of the second group of summer guests, there was an outbreak of the Omikron wave and the quarantine period for these participants grew to 38 days as some participants became infected while in quarantine. In addition, some participants decided to abort their journey, which meant that projects had to be repeatedly postponed, including the *Polar5* flight campaign. In addition, it was decided to forego the third intercontinental flight to Antarctica, but to use *Polarstern* for the last passenger transport. For this purpose, the schedule of *Polarstern* was adjusted and the number of passengers was limited to the 42nd wintering team, which meant that further scientific projects had to be postponed to the following season.

Overall, despite the difficulties, field campaigns could take place and scientific data could be collected in the field. In addition to the long-term measurements, two geophysical traverses to the foundation line, the annual work to investigate the vitality of the emperor penguin colony in Atka Bay, as well as smaller scientific projects could be carried out. Due to the reduced previous season, some technical work was left undone and had to be made up for this season. For example, all outdoor facilities were raised twice to compensate for the accumulation of the last two years and to ensure the operation of the facilities. In addition, the *Kohnen Station* on the plateau was opened and much needed technical work was carried out to maintain the station itself and the scientific trench. Recurrent accumulation measurements were carried out on the land route between *Neumayer Station III* and *Kohnen Station*, and measuring equipment was maintained at *Kohnen Station*.

In the following chapters, an overview of the weather pattern as well as the technology and logistics during the summer season is given. Subsequently, the annual maintenance of the observatories and other scientific projects at *Neumayer Station III* and *Kohnen Station*, as well as other field campaigns with the participation of the AWI, are described.

2. WEATHER CONDITIONS DURING ANT-LAND 2021/22 AT NEUMAYER STATION III

Not in the field: Holger Schmithüsen DE.AWI

After a comparably cold and stormy winter 2021 the overall weather situation at *Neumayer Station III* during ANT-Land 2021/22 was mostly normal in terms of the basic meteorological parameters listed in Table 2.1. The first two months of the season were rather windy with various low pressure systems passing by north of *Neumayer Station III*. From December until 12 February working conditions were mostly fine. In December this period was interrupted by higher winds and precipitation for little more than a week. Another shorter interruption was encountered during the second half of January. Starting on 12 February only few days were left with good outdoor working conditions.

Statistically, the parameters shown in Table 2.1 during ANT-Land 2021/22 are mostly within one standard deviation of their long-term mean values. An exception to that is the low air pressure in December, which is closer to the two standard deviation boundary. Furthermore, White-out was less frequent during the entire season compared to the long-term average for this time of the year. Particularly, in November only 11 % of the observations made reported White-out, and in January even as few as 3 %.

Concerning snow accumulation (Figs. 2.1 and 2.2) there were three relevant events of accumulation during ANT-Land 2021/22. The most prominent event was the low-pressure system influencing *Neumayer Station III* in mid December. This event brought a wealth of snowfall to *Neumayer Station III*, connected with rather low north-easterly winds. As a result from that, an extraordinary snow accumulation was detected during this time. Some of this accumulation was compensated by rather strong ablation in early 2022. The two other accumulation events in the second half of November and towards the end of the season were not as pronounced. Nevertheless, all three events contributed to the persistent snow accumulation around *Neumayer Station III*.

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 2021	**-9.5°C** (-9.8 ± 1.4)°C	**981.3 hPa** (984.5 ± 4.5) hPa	**8.8 m/s** (9.4 ± 1.6) m/s	**11%** (23 ± 12)%
December 2021	**-5.6°C** (-4.8 ± 0.8)°C	**978.7 hPa** (987.3 ± 5.6) hPa	**7.6 m/s** (7.3 ± 1.4) m/s	**19%** (17 ± 10)%
January 2022	**-3.7°C** (-4.1 ± 1.0)°C	**986.1 hPa** (989.2 ± 4.0) hPa	**6.6 m/s** (6.6 ± 1.2) m/s	**3%** (12 ± 8)%
February 2022	**-8.0°C** (-8.1 ± 1.5)°C	**985.1 hPa** (987.0 ± 3.7) hPa	**7.6 m/s** (7.6 ± 1.5) m/s	**8%** (14 ± 9)%

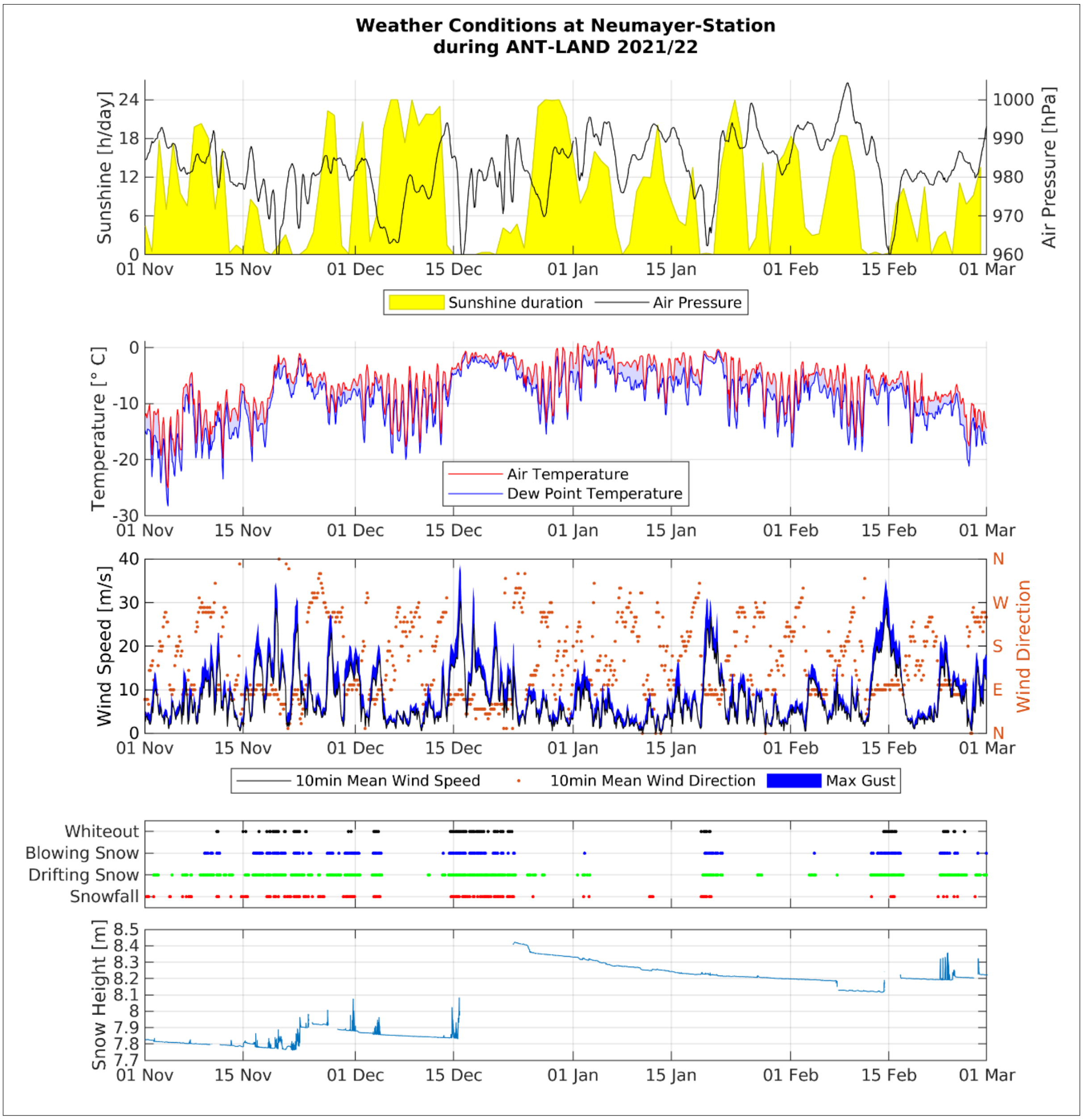


Fig. 2.1: Weather conditions at Neumayer Station III during ANT-Land 2021/22

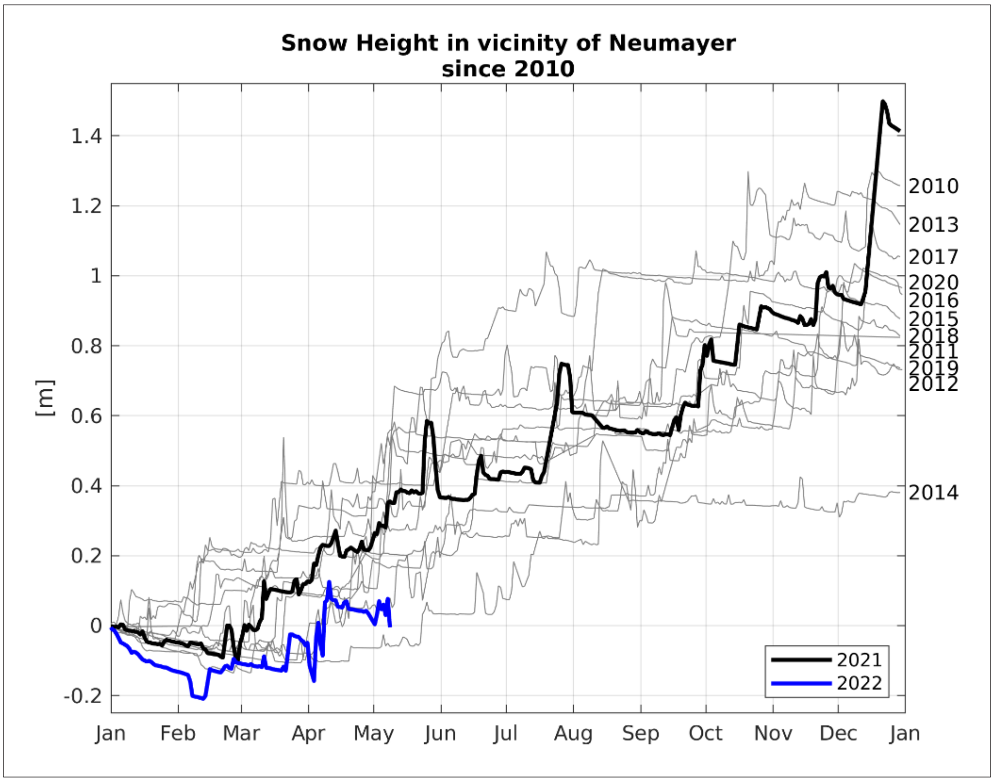


Fig. 2.2: Snow height measured in the vicinity of Neumayer Station III with sensor "Jenoptik SHM30" from 2010 until May 2022. Most recent data are shown in blue, accumulation of 2021 in black, earlier years in grey. All data shown here are relative to the snow height at the beginning of the respective year. Since October 2011 the measurements are conducted near the Spuso (1,500 m south of Neumayer Station III), before the instrument was mounted at the meteorological mast about 300 m south-east of the main station building.

3. STATION OPERATIONS

Christine Wesche DE.AWI

Still under the influence of the CoV-2 pandemic, the summer season 2021/22 needed to be adjusted to the changing conditions. To avoid the introduction of the virus to Antarctica, several precautionary measures were taken. Every participant had to be fully vaccinated and a 14-day quarantine with three PCR tests prior to the deployment were mandatory. The quarantine was conducted in a pre-selected hotel in Cape Town, as it was decided to use Cape Town as the gateway city to Antarctica, by using AWI dedicated flights for inbound passengers.

The season started on 4 November 2021 with the arrival of the first scientists and technicians to maintain the station. With the arrival, a series of low-pressure systems influenced the weather significantly and made outdoor work nearly impossible during the first weeks. Nevertheless, two station liftings were successfully performed until Christmas, together with a few stations of the infrasound array.

The departure of the overland traverse to *Kohnen Station* was also delayed by the weather, so they could only set off on 24 November 2021 and reached *Kohnen Station* nine days later.

On 19 December 2021, MV *Malik Arctica* was close to the Atka Bay, but the sea-ice conditions as well as stormy weather prevented the start of ship's operations. On 27 December 2021, the second group of summer personnel arrived with a delay of 26 days at *Neumayer Station III*. Due to a positive COVID case during hotel quarantine, the initial 14-days had to be extended significantly, to prevent the introduction of the virus to the station. The second group was accommodated in a camp next to the station for three more days and were allowed to actively participate in everyday stations life after a negative antigen test.

Finally, on 28 December 2021, ship operations could start with the offloading of containerized supply goods, new tracked vehicles (Pistenbullys and a heavy lifting crane) and fuel bunkering. First return freight was loaded to the ship during the three days period. Right after finishing the offloading of the ship, the stowing of return freight container started and ended with the loading of waste containers, return freight containers and old tracked vehicles (Pistenbullys and smaller heavy lifting crane) on 7 January 2022, which marked the end of the main supply of *Neumayer Station III*.

Shortly before Christmas, it was decided to cancel the third dedicated intercontinental flight between Cape Town and Antarctica and to bring only the 42nd wintering team onboard *Polarstern* to the *Neumayer Station III*, no further summer personnel was transported to Antarctica. The Omicron variant of the CoV-2 virus hit the entire world and the course of the season had to be adopted to it. *Polarstern* departed Cape Town on 6 January 2022 with direct course to *Neumayer Station III*. On 17 January 2022, the ship was in helicopter distance to the station and five helicopter flights were performed to send the wintering team and their luggage over to their new home. Immediately after arrival, the handover phase between the old and the new team started and ended with the official handover on 5 February 2022 and the 41st wintering team left *Neumayer Station III* on 11 February 2022.

After maintaining the station technique and the scientific trench at the plateau station, *Kohnen Station* was closed on 24 January 2022 with the departure of the technicians. After six days of travelling, the team arrived safely at *Neumayer Station III*. During the operation of the station, a few small scientific projects were conducted, including the installation of a new automatic weather station.

At *Neumayer Station III*, the remaining work at the station was done until the 20 February, when the last summer guests departed towards Cape Town.

3.1 Technical Operations

Not in the field: Thomas Matz DE.AWI

In the short summer season 2020/21, only urgently needed work was carried out at *Neumayer Station III* due to the pandemic and some of this work was reduced in scope. Fortunately, routine maintenance work could be resumed in full or made up for, albeit at considerable additional expense in some cases in season 2021/22.

Prior to the start of the season, preparatory activities were again performed by the wintering team before the first summer guests arrived. Storage and functional containers were transported from the winter storage to the station for the summer operation. The 1,500 m long landing strip, which is made of snow, was groomed by the technicians of the wintering team prior to the first transiting aircraft.

After the technical summer staff arrived, maintenance work could immediately start. Due to the higher snow accumulation near *Neumayer Station III*, significantly more work was required to be done at the external stations and for terrain maintenance. In the winter storage facility with its many heavy-duty sleds, storages and tank containers, significantly more work had to be done to clear the snow and reposition the sledges and containers for the upcoming winter.

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.

Station maintenance works and repairs

In the months of November and December, which were still characterised by bad weather, two station elevations could be carried out as planned. The 26th station elevation started on 6 November 2021 and was finished after ten days. As the station was lifted twice within a summer season, the 27th station elevation started on 2 December 2021 and was completed on 12 December 2021. In total, the *Neumayer Station III* was lifted nearly 2.4 m (without settling in the snow).

On the station roof, air scoops of the air conditioning intake and the smoke extraction system were replaced with new more stable scoops, additionally repair work on the associated workshop was performed.

Besides many other extensive maintenance works on the station, such as replacement of a diesel engine of the cogeneration units, inspection of the bolted connections of the steel structure and the facade elements of the station and its structure was done by an external inspection engineer. During the first half of the season, the two-yearly inspection of the technical equipment was carried out by an external inspection engineer from DNV.

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 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 twice. Usually, these outdoor structures were raised only once every two years, however, this was not done last year due to the short season.

To buffer short-term failures in the electrical supply, an independent power supply was installed in the air chemistry observatory, to which the magnetic observatory was also connected.

The measuring fields of the infrasound array could also be elevated. Routinely, this lifting takes place every year. Due to time constraints, it could not be performed last season. In the meantime, the measuring equipment was at a depth of about three meters.

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.

The antenna field of the WSPR-radio beacon at the air chemistry observatory, the scientific measurements at the meteorology field station, as well the „library in the ice“ were lifted.

The wind energy plant was elevated for 2 m and maintained. New cables were laid from the plant to the vehicle hall at *Neumayer Station III*, as the reserves of the old cables had been used up by the annual station increases.

IT and communication

A new weather satellite-receiving antenna was erected on the roof of the balloon-filling hall.

In the station, PC’s were replaced and software renewals were carried out. Work was carried out on the dedicated satellite line, the telephone system and the network structure. In December, the bandwidth of the leased line was increased. A new Iridium system was installed as a backup system. Outside the station, elevation work was carried out on the antenna systems.

Vehicle engineering

A new 50 tons crawler crane from the manufacture Sennebogen was delivered with the ship’s supply at the end of December. It replaces the weaker 20 tons crane, which has now served well for over 10 years.

In terms of the Pistenbully vehicle fleet, seven new 300 Polar vehicles arrived with the ship and replaced the vehicles of the 240/260 and 300 series. The old vehicles were returned to Germany. All Pistenbully were maintained by a mechanic of the manufacturer, supported by station personnel.

The inventory of heavy-duty sleds for transporting 20 ft containers was increased by 10 units. Among other things, they replace 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.

Both Arctic Truck vehicles had to be taken out of service during the summer season due to massive chassis damage. A repair will be done by a mechanic of the company Arctic Truck in the season 2022/23.

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. In case of extensive damages, the sledges will be exchanged.

Kohnen Station

The summer station was opened via a vehicle traverse coming from *Neumayer Station III* in early December. Along the way, cargo for the Swedish Antarctic programme was transported and in agreement with the Swedish partner, made available for pickup along the route to the Kottas Mountains.

With the commissioning of the *Kohnen Station*, a broken drinking water pipeline below the station had to be repaired, which was not planned.

For logistic operations, the runway was prepared and other infrastructure needed for summer operations was built.

Extensive maintenance was performed on the *Kohnen Station* and also on the scientific drill trench, but also terrain maintenance around the station and the roof of the trench.

The diesel engine at the station was routinely replaced. Meanwhile, the station was supplied by an external genset from outside the station. Another genset in the 10 ft container served as a backup unit.

The platform of the *Kohnen Station* with its 16 legs was calibrated for inclination and then the entire platform station was raised.

A stair tower made of scaffolding elements was installed in the drill trench, as well as a hatch for craning loads across all levels.

The snow load on the upper second roof of the trench was reduced by using a snow blower and a Pistenbully. Several braces were installed in the trench so that both roof levels will hold until 2023–24. At that time, construction of a third roof above the existing two is planned to transfer loads and keep the trench and its borehole accessible for the EPICA campaign.

On 24 Januaryv 2022, the work was done and the *Kohnen Station* was closed. The technical team arrived safely at *Neumayer Station III* after six days of travel.

3.2 General Flight Operations

Christine Wesche DE.AWI
Not in the field: Thomas Matz

During season 2021/22, flight operations were, apart from precautionary measures to avoid the spreading of CoV-2 within the stations, nearly back to normal. Inbound intercontinental flights were used exclusively by AWI and only three flights between Cape Town and Wolf's Fang Runway were panned. With the omicron wave arriving in November 2021 in South Africa, the third flight was cancelled and the last group was moved by *Polarstern* to *Neumayer Station III*. Most of the departing personnel was transported via *Novo Runway* with shared DROMLAN (Dronning Maud Land Air Network) flights. Apart from the exclusive flights, the feeder flights were shared with DROMLAN members. Face masks were mandatory on every flight to prevent infection.

Besides the transportation of personnel, a few cargo flights for the Finnish Antarctic Programme were supported.

About 5 km north of *Neumayer Station III*, a skiway of White Desert was established 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 take place due to increased tourist traffic.

3.3 Ship Operations

Christine Wesche DE.AWI
Not in the field: Thomas Matz

This season, a chartership was used for the main supply of *Neumayer Station III*. MV *Malik Arctica* (Royal Arctic Lines) loaded freight in Bremerhaven in mid-November 2021 and arrived in Cape Town to load 16 tank containers. The ship departed Cape Town on 09.12.2021 and sailed directly towards *Neumayer Station III*. On 17 December 2021, there was first telephone contact with the ship. Unfortunately, the weather and sea-ice conditions did not allow for an immediate discharge. After the wind shifted to the south, the sea-ice conditions improved and a polynya formed off the north jetty. It was agreed that discharge would begin at 8:30 UTC on 28 December 2021. During three days, a total of 25 freight and reefer containers, seven new Pistenbully, a heavy-duty crane, timber for maintenance work at the scientific drill trench at *Kohnen Station*, ten pieces of general cargo as well as 301,320 litres of Arctic Diesel and 60,160 litres of Jet-A1 were bunkered to the stations tank containers. On 7 January 2022, the loading of the return freight and waste containers was performed and MV *Malik Arctica* returned to Bremerhaven via Cape Town on 12 February 2022.

Besides the main supply of the station, the 42nd wintering team was bought close to the ice shelf edge by *Polarstern* on 17 January 2022. As soon as the ship was within flight distance of the helicopters, five flights were performed between the ship and the station. *Polarstern* also performed a second call at Atka Bay in mid-March to routinely exchange medical equipment between the station and the ship, after the summer season was finished.

3.4 Reduction of *Neumayer Station III* Carbon Footprint

Not in the field: Michael Hartje[1], Peter Köhler[2] (Logistics) [1]DE.HS-Bremen
[2]DE.AWI

Objectives

Neumayer Station III with all its facilities and personnel is a central element of German polar research and enables year-round research operations.

In order to modernise energy production and integrate more renewable energy sources into the supply, a semester project has been set up together with the AWI in 2018 at the Hochschule Bremen City University of Applied Sciences in the master’s programme Sustainable Energy and Environment Systems (ZEUS). The aim was to survey potential and develop proposals on how to achieve the goal of a more regenerative and lower-energy supply for the needs at *Neumayer Station III*. This is to pursue the goal of achieving a lower carbon footprint through the operation of *Neumayer Station III*.

The semester project has concluded with a report of more than 300 pages. Based on meteorological data and known consumption data from 2007 to 2017, the studies examined, among other things, the energy benefits of:

- PV system and its contribution
- Thermal solar plant and possible contribution
- heat pump with the heat reservoir water under the ice
- low-energy fresh water production by desalination of sea water
- different wind turbines and their contribution
- electrical storage
- waste utilisation, possibly thermal
- evaluation of an optimal mix of the above sources
- Energy supply to remote stations.

Development of a PV test plant

In order to gradually achieve the goal of a large-scale PV system, a PV test system was developed, built, tested and shipped from the extensive results of the master project in 2019 for integration into the electrical grid of *Neumayer Station III*.

To analyse the mechanical loads on the mounted solar panels and to optimise the mounting options, sensors were placed on and behind the panel to measure

- air pressure
- temperature
- air humidity

Sensors used:

- Acceleration – 3 axis accelerometer
- Position – 3 axis gyroscope
- Pressure – analog load sensor measurement.

At sampling rates of up to 100 Hz, the mechanical movement of the centers of the panels in wind can be measured and analysed. The aim is to detect vibrations that could promote a possible fatigue failure of the fastening, leading to personal injury or property damage in the surrounding area. Local wind speeds will be determined from comparative analysis of the air pressures of differently oriented panels. It is expected that different measurement results will be found on the windward and leeward sides of the panels. These measurements should therefore be carried out on all mounting sides (east, north, west).

Work in field

Due to the pandemic, assembly has only been possible in the 2020/21 season and only in parts. An electrical fault when continuing the assembly in season 21/22 has further delayed the project. Thus, since the 20/21 season, 4 of the existing 12 solar panels, as shown in Figure 3.4.1 (intermediate status with 2 panels), have been mounted on the east side of *Neumayer Station III*.

Another panel was laid out horizontally in the station to record the frequency spectrum of the vibrations from *Neumayer Station III* as a reference. The special measurement equipment for this has been put into operation and is working reliably so far. At intervals of 10 minutes, vibration measurements are recorded 3-axis with gyroscope and accelerometer for 1 minute each and stored as a short-term spectral estimate (method according to Welch) in a database at *Neumayer Station III*.

The air pressure, temperature and humidity measurements are sent as a local mean value of each measuring point once per minute to a database server (InfluxDB) developed for this purpose in Bremerhaven. For the presentation a website with the tool Grafana was developed and put into operation. The website can be reached at the URL "nm3-solar.awi.de".

The measurement technology prepared and tested in Bremen could be connected and put into operation on site. The solar panels have been electrically tested with short circuit and open circuit load.

The vibrations and the difference of the air pressures in front of and behind the panel can be seen as a function of the wind speed.

Fig. 3.4.1: Two mounted solar panels on the east side of Neumayer Station III

Preliminary (expected) results

After the strong wind events with up to 100 kn, an immediate inspection of the installed panels with a cherry picker was possible at the end of August 2021. Mounting brackets and panels did not show any changes compared to the time of installation and made a safe impression on the inspectors.

An example should show the possibilities of the introduced measuring technique:

21 July 2021 was a day with increasing strong wind from the east.

Figure 3.4.2 shows the course of the measured wind speeds (PANGAEA) at a height of 10 m above the hour of the day with the 1-min average and the peak value. The wind direction was constant during this time.

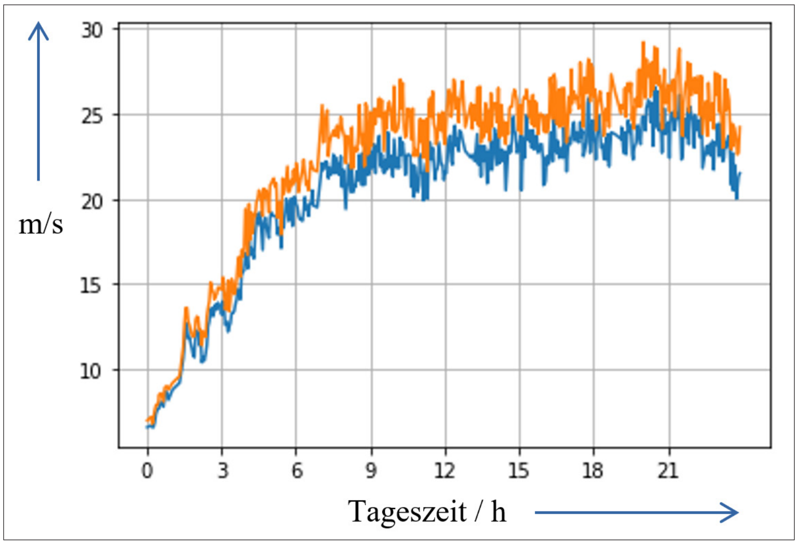


Fig. 3.4.2: Wind speed H10 (mean and peak speed) at 21.7.21 from 0 – 24 h; the time history of the sensors inside the station at 22:21 is shown in Fig. 3.4.3.

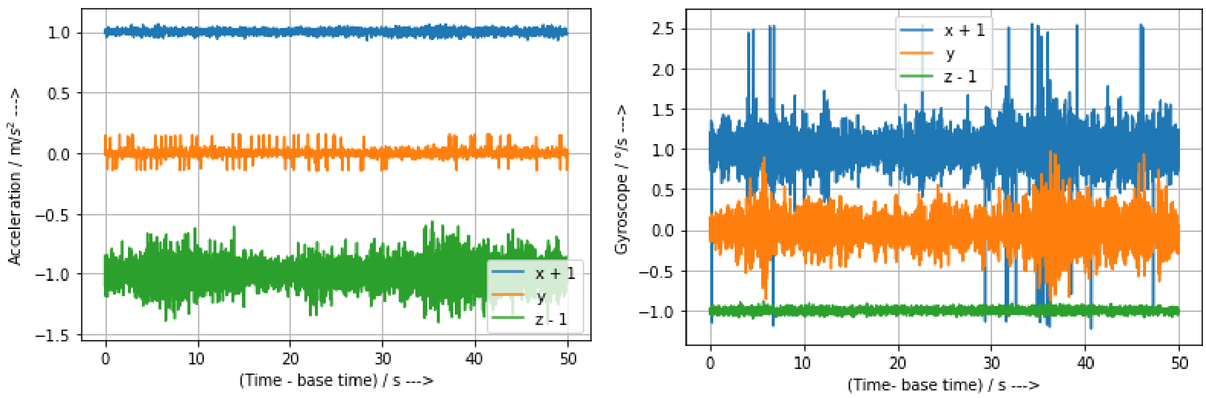


Fig. 3.4.3: Accelleration (left) and Gyroscope (right) of each 3 axes offset by + / – 1 units at 22:21

For the time histories shown in Figure 3.4.3 on the left and right, the histories for the directions X and Z were offset by "+" and "–" 1, respectively. In order to condense the time histories and to determine characteristic contents, a "power density spectrum" is calculated from them and shown in Figure 3.4.4.

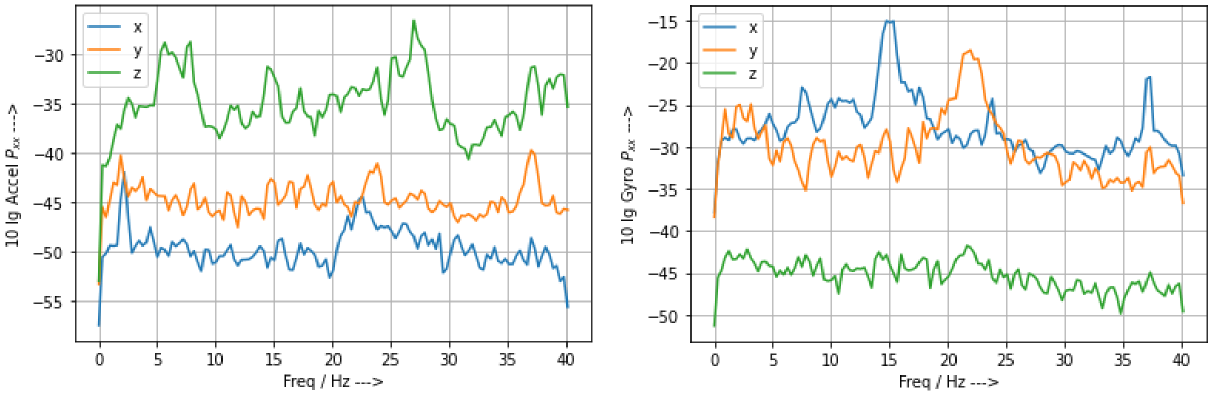


Fig. 3.4.4: Plot of the power density spectra of the time histories at 22:21 from Fig. 3.4.3 over the frequency up to 40 Hz

Furthermore, the measurements are repeated every 5 minutes, so that 288 measurements are collected locally in a GnuDB database over the course of the day. With Figure 3.4.5, the event can be displayed in the form of a daily heat map in a waterfall representation. The 3 axes are displayed one below the other.

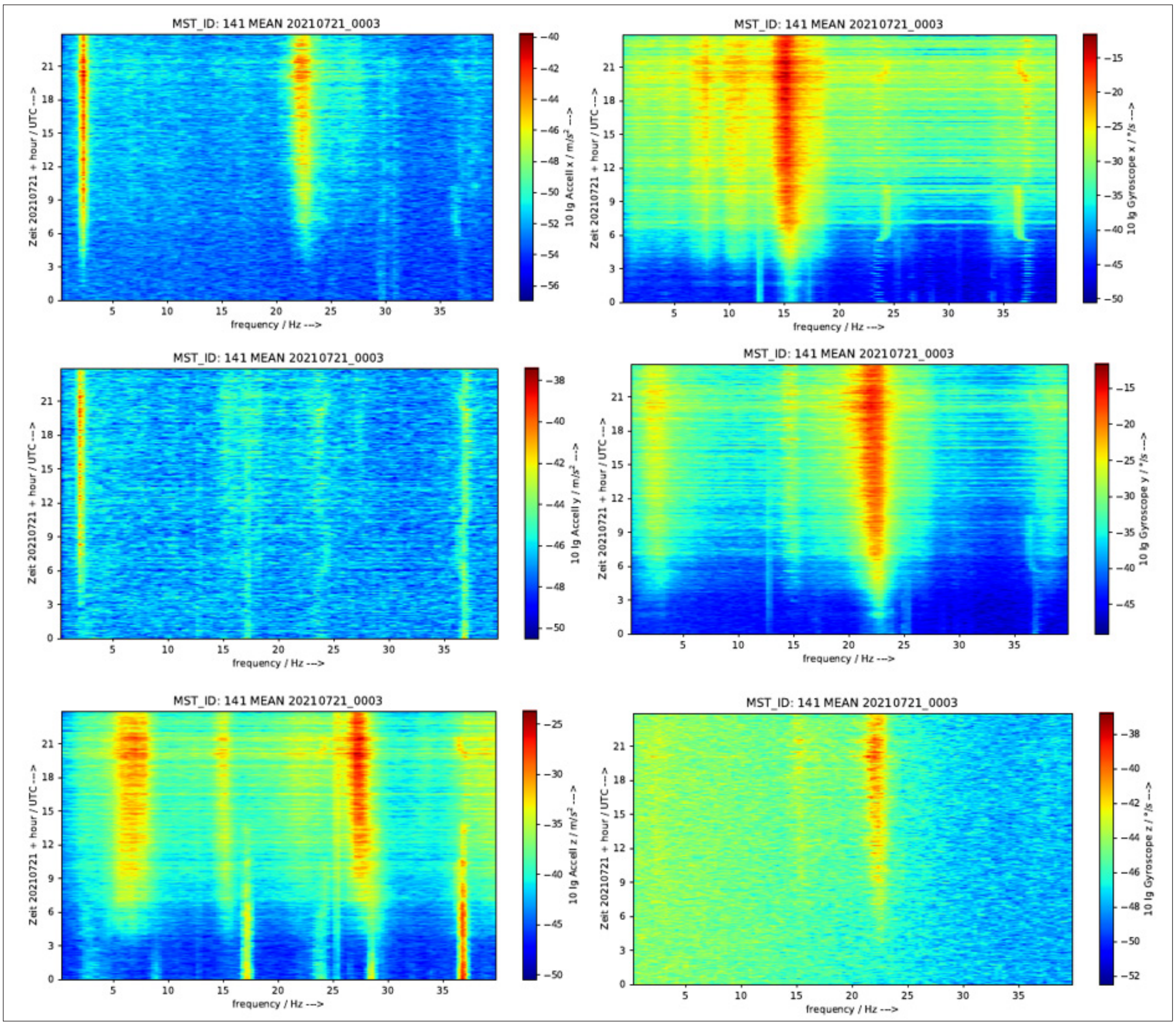


Fig. 3.4.5: Plot of power density spectrum in waterfall display as a function of time of day, left column: Accellerometer, right column: Gyroscope Lines: x, y, z

Figure 3.4.5 impressively documents how, with increasing wind speed from 3 o'clock and more strongly from 6 o'clock, frequency components in the low-frequency range up to 40 Hz arise and increase in intensity, whereas the components at 17 and 36 Hz disappear in strong winds.

Similar measurement results are available for the sensors applied to the panels, but are not shown here due to space limitations. However, it can be seen that the power density spectra on the panel are much quieter, do not show individual frequency components as clearly, i.e. show fewer resonant spots. From about 8 p.m. on that day, however, they show broadband excitation with high amplitudes.

By comparing air pressures on a surface, the incoming wind speeds can be determined. Figure 3.4.6 shows the differences in air pressures in front of and behind the panel.

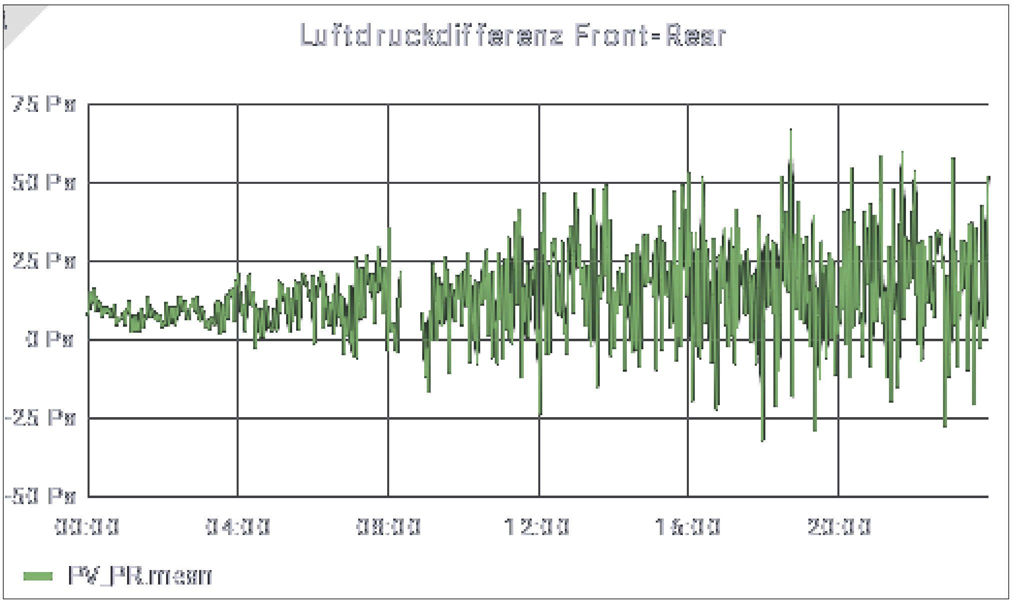


Fig 3.4.6: Difference of air pressures in front of and behind the panel in the diurnal cycle (here an excerpt from the website)

As Figure 3.4.6 shows, pressure differences of up to 70 Pa have occurred. It is clearly visible that the pressure in front of the panel is higher than behind the panel. – On other days, up to 100 Pa = 1 hPa have been measurable. In principle, this pressure difference can be used to determine the wind velocities of the horizontally approaching air. The investigations will be continued when the panels and the associated measuring equipment have been installed and commissioned on all planned sides of the building.

A danger for the reliability of the panel mounts cannot yet be derived from these short investigations and can rather be negated at present.

4. NEUMAYER STATION III

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

Rolf Weller[1] (not in the field), Linda Martina Orth[1], Hannes Keck[1]; Olaf Eisen[1], Silvia Henning[2] (not in the field)

[1]DE.AWI
[2]DE.TROPOS

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 Station III* 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 characterised, we can use such records to derive information about climate, composition and chemistry of the paleo-atmosphere. The *Neumayer Station III* 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 air-chemist or meteorologist is responsible for the observatory.

Part I Atmospheric measurements: Aerosol and trace gases

Work in field

Once again, due to Corona pandemic only a restricted summer season was practicable, but we succeeded in completing all necessary work to run the observatory for another year without cutback. Apart from the usual maintenance work in and around the observatory, we successfully installed within the scope of the project REBCASA (Investigating the Radiative Effect due to Black Carbon by combining Atmospheric and Snow measurements in Antarctica, PI: Andreas Herber, AWI) a new instrument, a Single Particle Soot Photometer with extended range (SP2xr). This instrument quantifies refractory carbon in aerosol particles. The method is based on measuring single particle incandescence and scattering with a Nd-YAG laser at 1,064 nm. 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. The measurements started at 5 January 2022. 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. BC deposition can lead to earlier snow melt by reducing the surface albedo. The radiative forcing caused by BC in the atmosphere and in the snow has still one of the largest uncertainties within all components of radiative forcing. 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 in Dronning Maud Land before.

The project VACCINE (Variation in Antarctic cloud condensation nuclei (CCN) and ice nucleating particle (INP) concentrations at NEumayer Station) managed by the Institute for Tropospheric Research (TROPOS, Leipzig. PI: Silvia Henning) in cooperation with the AWI (started in December 2019) will be continued for another over wintering period. We will link these data with regional meteorology and the chemical composition of the sampled aerosol particles for identifying sources of INP and CCN. The scientific background of this project addresses the fact that Polar Regions have a strong global impact on climate conditions but the crucial aerosol – cloud – climate interaction is poorly understood, especially in the Southern Ocean realm. For further information and first, preliminary results, see separate contribution by Silvia Henning (Chapter 4 and 11).

Concerning technical issues, we installed a new uninterruptible power supply. This was necessary because the old one broke down during a serious blizzard event with so far never observed peak wind velocities > 200 km/h on 13 August 2021. In December and January, 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 over-winterer Hannes Keck, arriving at *Neumayer Station III* on 17 January 2022. In spite of the short training period (just 4 weeks), Hannes Keck took on the responsibility for the Air Chemistry Observatory thanks to the competent and dedicated instruction by Linda Ort.

Preliminary (expected) results

We completed an in-depth evaluation and validation of the established long-term observations (LTO) in January 2022, except the chemical analyses of the aerosol filter samples which are completed in April. Like in previous years, the outcome of this subsequent analysis revealed the high quality of the measured time series comprising

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

with generally negligible data gaps, occasionally caused by short temporary instrumental problems or routine service operations.

Concerning BC and the new REBCASA project, long-term observations from *Neumayer Station III* are available for this climate relevant aerosol component. Up to now, we could not verify any significant trend based on our continuous BC time series, started in 1999. Figure 4.1.1 shows part of the time series measured with the more reliable Multi Angle Absorption Spectrometer (MAAP). There is a clear seasonality of the measured BC concentration with a broad maximum around October/November each year. The source region of BC at *Neumayer Station III* are biomass burning regions in South America. This could be shown in a previous publication, supported by trace element and air mass trajectory analysis (Weller et al. 2013). Apart from this, we observed a strong correlation with the biomass burning oxalic acid, measured as oxalate-anion in our aerosol-sampling programme at *Neumayer Station III* (Fig. 4.1.2; Legrand et al. 2021).

In combination with aerosol scattering coefficient data from our integrating Nephelometer measurements, we calculated single scattering albedo of the aerosol, which was close to 1.0 (mean ± std: 0.994 ± 0.011).

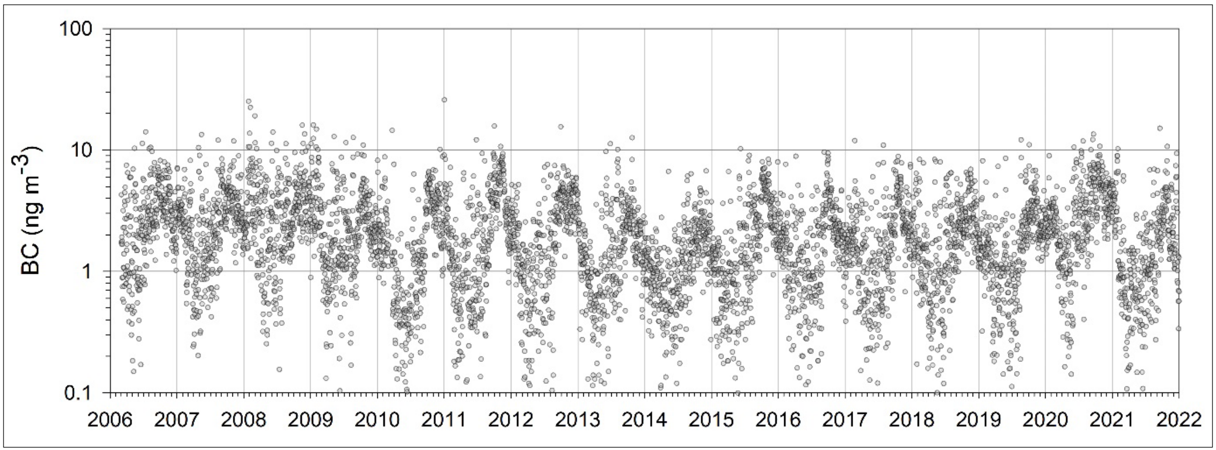


Fig. 4.1.1: Time series of BC concentrations measured at Neumayer Station III with the MAAP from 2006 through 2021. The shaded area marks the period of the setup of Neumayer Station III, which was prone to much higher local BC-contamination. Note, that the BC data shown were rigorously cleaned from local contamination, which is possible considering wind direction and particle concentrations (for details see Weller et al. 2013). However, this was somewhat problematic during the strong local impact caused by Neumayer Station III construction. Presented data are daily medians based on the originally data taken in 1-minute intervals.

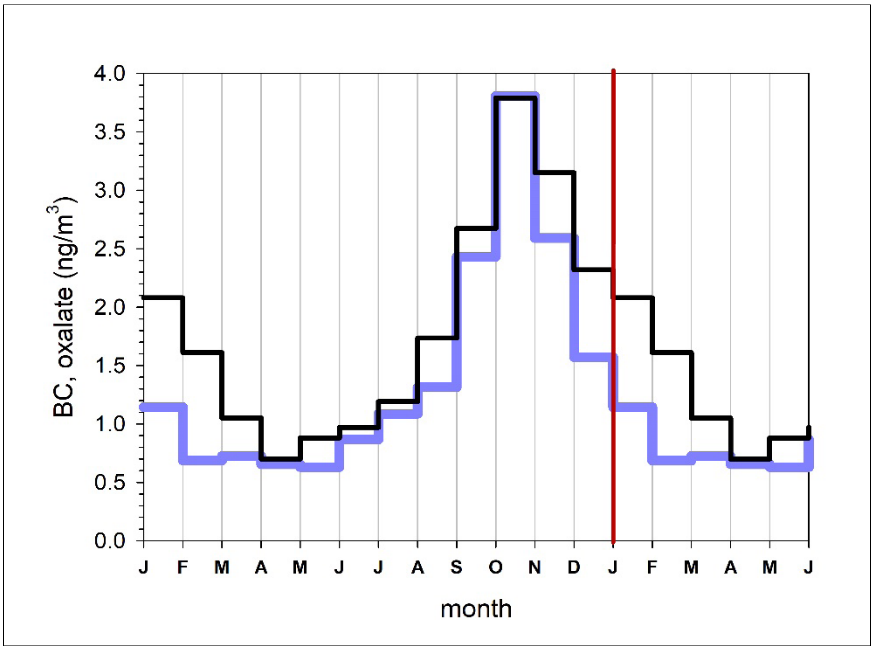


Fig. 4.1.2: Seasonality (monthly means based on daily medians) of BC (black line) and oxalate (blue line), based on 9 years of continuous observation. Note that the graph comprises 18 months starting from January to accentuate the seasonal maxima without cease (red vertical line marks the turn of the year).

Data management

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

- PANGAEA: after chemical analysis of the aerosol filter samples, the entire 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). By default, the CC-BY license will be applied.
- GAW: https://ebas-data.nilu.no/default.aspx.

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 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:

Weller R, Minikin A, Petzold A, Wagenbach D and König-Langlo G (2013): Characterization of long-term and seasonal variations of black carbon (BC) concentrations at Neumayer, Antarctica, Atmospheric Chemistry and Physics, 13, pp. 1579-1590. https://doi.org/10.5194/acp-13-1579-2013

Part II Snow accumulation and glaciological studies

Work in field

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 2021 the snow surface accumulation measurements at the Pegelfeld Süd reached its 30-year anniversary (Fig. 4.1.3). This is an important milestone, as it corresponds to what is typically considered a climate period. The Pegelfeld Süd has been initiated at the *Georg-von-Neumayer Station* and kept in operation during *Neumayer Station II* and continued with the opening of *Neumayer Station III*. With start of the operation of Spuso III a new stakefield, Spuso III, was also put into operation, with measurements now available since 2009 (Fig. 4.1.3). Although the stake field is advected with ice shelf by about 150 m/a, it can nevertheless be considered a reliable proxy for the seasonal, interannual and decadal changes of snow accumulation. First analyses on the raw, uncorrected time series do not indicate any significant change in annual snow accumulation, which corresponds basically to 1 m/a on average. Notably, the year 2021 shows the highest amount of annual accumulation over the 30-a time span, based on the uncorrected data.

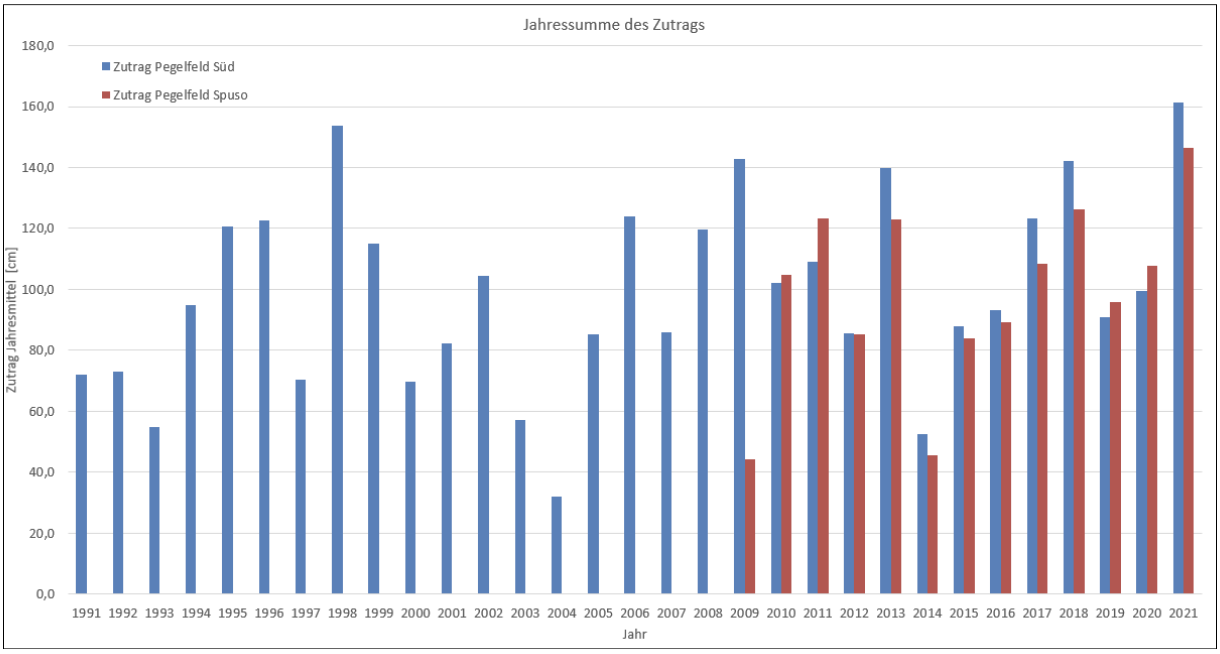


Fig. 4.1.3: Time series of snow accumulation at Pegelfeld Süd (blue) and Pegelfeld Spuso III (red)

A monthly analysis of snow accumulation at Spuso III based on weekly measurements (Fig. 4.1.4) moreover indicates that the monthly accumulation in December in the years 2020 and 2021 has been the highest once on record for the spring period (December, January, February) for the time period 2009 – 2021. While December normally is a month with very little accumulation and in fact often net erosion, 2020 and 2021 accumulation is even an order of magnitude higher the previously recorded values. Whether the record accumulation and the shift in seasonality are persistent features or just extreme values cannot be concluded at this stage, but will be the subject of ongoing analysis in the meteorological and oceanographic context. In any case this time series shows the extraordinary value of long-term observations, especially in times of climate change.

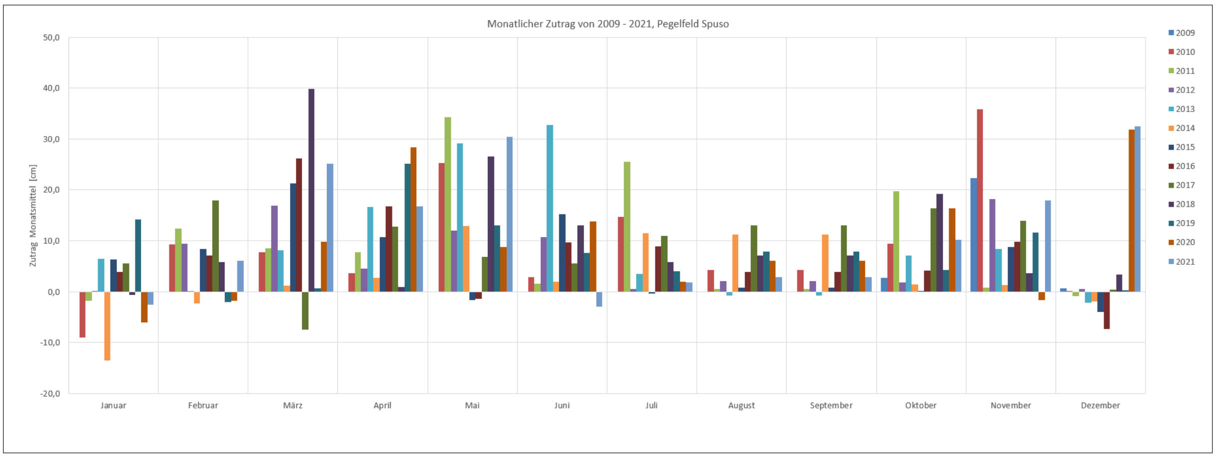


Fig. 4.1.4: Distribution of monthly snow accumulation over years at Pegelfeld Spuso III

Data management

Density and stake readings are currently quality checked, compiled and uploaded to the PANGAEA repository. Moreover, metadata of the density measurements have been uploaded to the metadata data base sensor.awi.de.

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 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

Weller R, Minikin A, Petzold A, Wagenbach D and König Langlo G (2013): Characterization of long term and seasonal variations of black carbon (BC) concentrations at Neumayer, Antarctica, Atmospheric Chemistry and Physics, 13, https://doi.org/10.5194/acp-13-1579-2013.

Weller R, Schmidt K, Teinilä K and Hillamo R (2015): Natural new particle formation at the coastal Antarctic site Neumayer, Atmospheric Chemistry and Physics, 15 (19), https://doi.org/10.5194/acp-15-11399-2015.

Legrand M, Weller R, Preunkert S and Jourdain B (2021): Ammonium in Antarctic aerosol: Marine biological activity versus long-range transport of biomass burning, Geophysical Research Letters, 48, https://doi.org/10.1029/2021GL092826.

4.2 The Geophysical Observatory

Tanja Fromm[1], Benita Wagner[1],
Alicia Rohnacher[1], Timo Dornhöfer[1],
Lorenz Marten[1], Louisa Kinzel[1,2]
Not in the field: Jölund Asseng[1],
Alfons Eckstaller[1], Jürgen Matzka[3]

[1]DE.AWI
[2]DE.Uni-Bremen
[3]DE.GFZ

Objectives

The Geophysical Oobservatory 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. The temporarily installed network of twelve seismic stations in the vicinity of *Neumayer Station III* completes the number of stations operated in 2021 (see Fig. 4.2.1, inset). These stations, which were set up during the first quarter of 2020, allowed further investigations in ice dynamics. The network has been decommissioned in austral spring of 2021 and replaced by the GrouZE network around the Ekström Ice Shelf grounding zone in the summer season 2021/2022 (see Chapter 4.17). Other unattended seismographic broadband stations record data at logistically feasible locations (see Fig. 4.2.1).

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, two 3-component fluxgate sensors recording directional changes (FGE and STL) and high frequency induction coils for ionosphere research (MICA-S, see Chapter 4.19). 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 Ekström Ice Shelf dynamics. During the winter of 2021 we increased the sample rate of the receiver to 50 Hz and added support for GLONASS and Galileo.

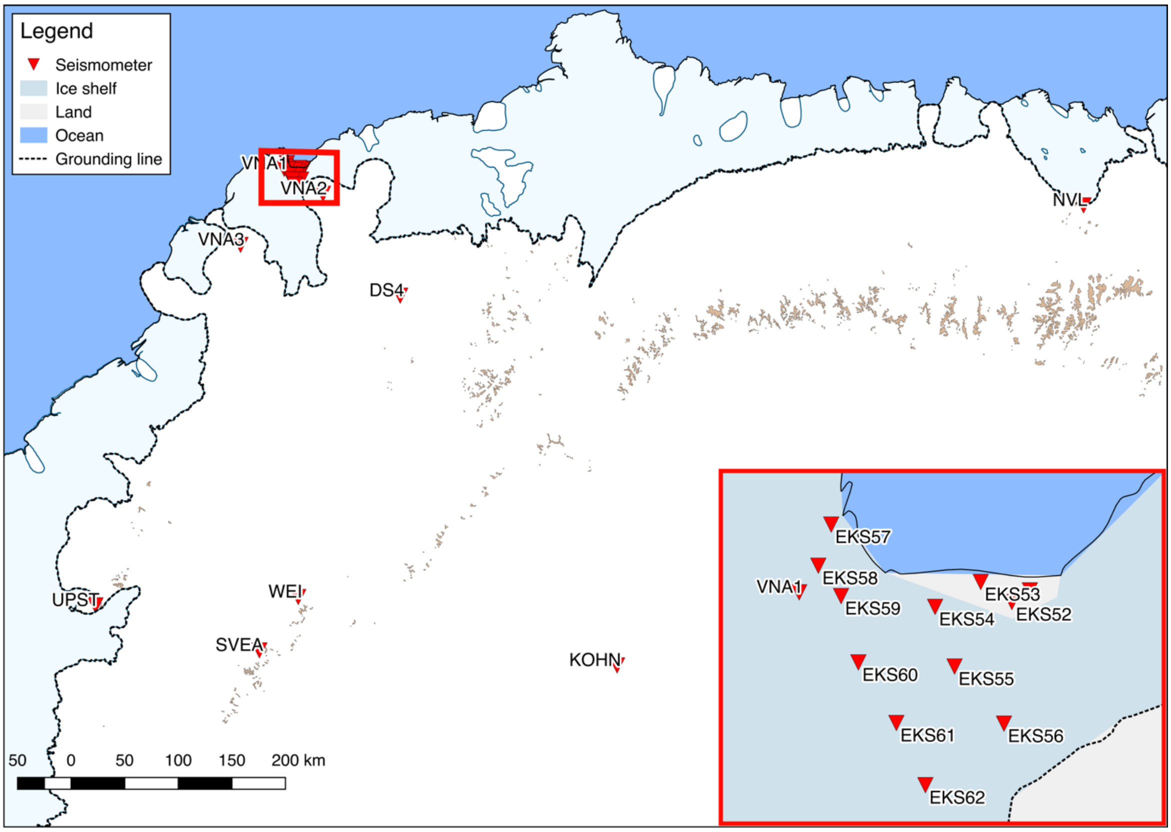


Fig. 4.2.1: Map showing the active seismometer stations in Dronning Maud Land of the AWI network during 2021. The red inset shows the location of the temporary seismometer installation east of Neumayer Station III.

Work in field

During the winter of 2021, the twelve stations of the temporary network “EKS” east of *Neumayer Station III* were checked frequently. Between September and November 2021, the EKS network was brought back from the field for maintenance and preparation for the GrouZE project. In the Antarctic summer season 2021/2022, maintenance work was done at the permanent stations VNA2 and VNA3. The GrouZE network was deployed and the seismic station at *Kohnen Station* was visited and repaired by station personnel.

The station DS4 at Forstefjell was visited in January 2022, and a problem with the data acquisition device was diagnosed. A repair in the field was not possible. The station NVL at *Novolazarevskaya Station* was visited in February 2022. WEI, SVEA, and UPST were not serviced this season.

During the summer season 21/22, we started to integrate an automated machine learning model into the earthquake picking workflow. We implemented a model to automatically refine rough picks in order to reduce the picking workload. First tests were done and will be continued during winter 2022.

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 12 August 2021 a magnitude 8.1 earthquake close to the South Sandwich Islands was recorded. This major event led to a series of aftershocks and increased the 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 30,499 phase arrivals were picked during the year 2021. Phase picks of 2,210 earthquakes were associated with earthquakes listed in international catalogues. In addition, 6,353 regional/local earthquakes were located (Fig. 4.2.2).

2. The total magnetic field intensity decreased by 45 nT from a mean of 38,077 nT at 01-01-2021 to a mean of 38,032 nT at 12-31-2021. This decrease is the net effect of the regional weakening of the Earth magnetic field in the South Atlantic Magnetic Anomaly and the change of the remanent crustal magnetic field, due to *Neumayer Station III* moving with the ice shelf (Fig. 4.2.3).

3. During 2021, *Neumayer Station III* moved 154.7 metres from (8:16:54.40ºW, 70:39:51.49ºS) to (8:16:57.56ºW, 70:39:46.61ºS)

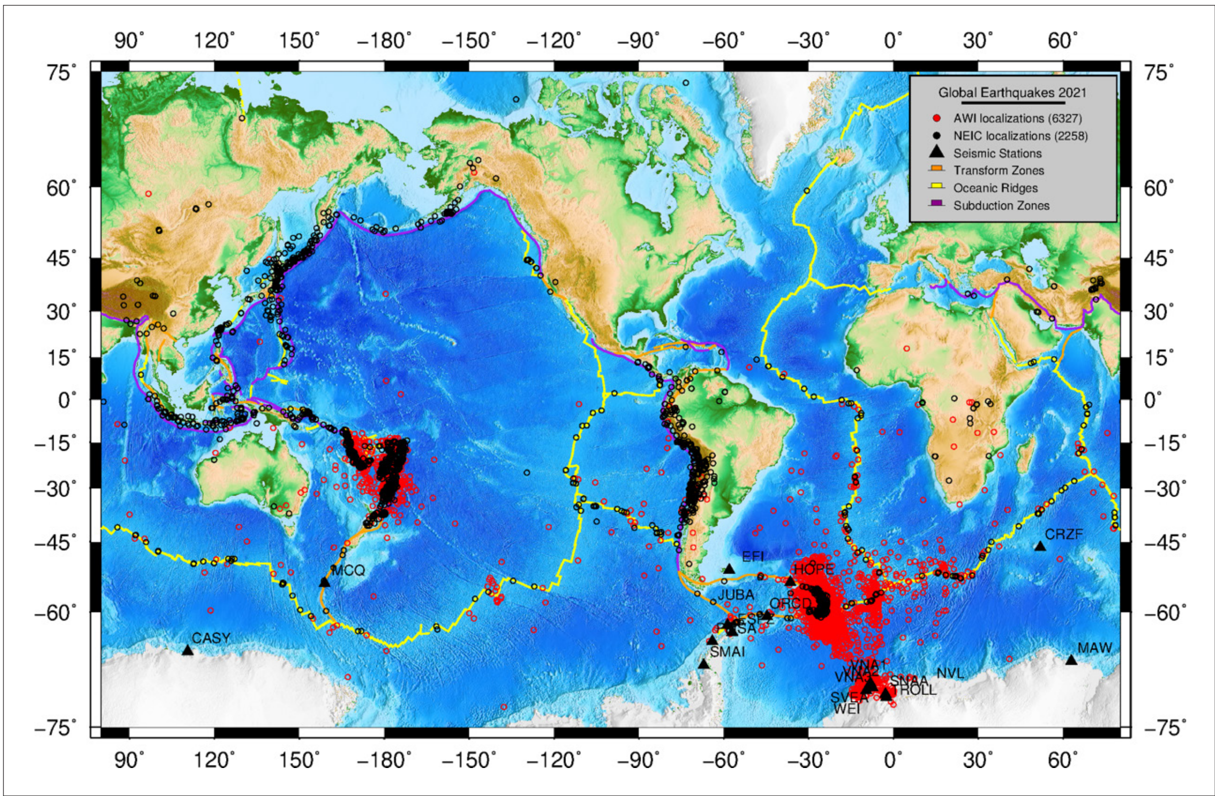


Fig. 4.2.2 Map showing seismic events recorded by the AWI network in 2021

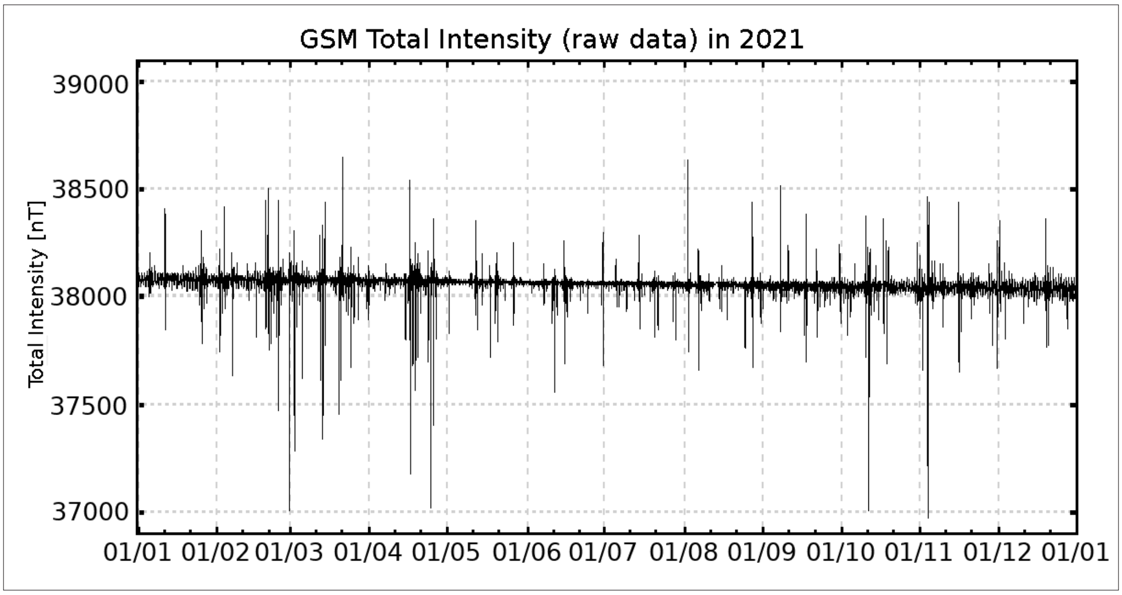


Fig. 4.2.3: Total Intensity of the geomagnetic field at Neumayer Station III, recorded by the Overhauser GSM-19

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 (http://www.isc.ac.uk).
- Data from the geomagnetic observatory can be accessed via INTERMAGNET (https://intermagnet.github.io) and SuperMAG (http://supermag.jhuapl.edu)
- GPS data in Rinex format are available on request.

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

In all publications based on this expedition the 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

Aster RC, Winberry JP (2017) Glacial seismology. Reports on Progress in Physics, 80(12), 126801, https://doi.org/10.1088/1361-6633/aa8473.

Eckstaller A, Müller C, Ceranna L & Hartmann G (2006) The Geophysics Observatory at Neumayer Stations (GvN and NM II) Antarctica. Polarforschung 76 (1-2), 3–24, https://epic.awi.de/id/eprint/17194/.

Fromm T, Eckstaller A & Asseng J (2018) The AWI Network Antarctica – Alfred-Wegener Institute, Germany. Summary of the Bulletin of the International Seismological Centre, 22-36, 2309-236X, https://doi.org/10.5281/zenodo.1156983.

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.

4.3 The Meteorological Observatory at *Neumayer Station III*

Not in the field: Holger Schmithüsen DE.AWI

The Meteorological Observatory at *Neumayer Station III* 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. Due to the pandemic situation the summer maintenance of the observatory was heavily limited to the most urgent tasks during ANT-Land 2021/22.

Objectives

The Meteorological Observatory at *Neumayer Station III* 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.

Work in field

In the field season 2021/22 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

This handing over was not attended by a long-term member of the observatory as in other years due to the pandemic situation. A minimum of maintenance and service of all observatory facilities was carried out by the staff on site. Remote support from the long-term staff in Bremerhaven was provided as far as possible.

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

- AWS Søråsen: not serviced due do shortage of staff; it is expected that the station will remain above the surface for another year, even though measurements will be thoroughly affected
- AWS Halfvarryggen: serviced as planned
- AWS *Kohnen Station*: newly erected station in 2021/22; the work on site was carried out by members of the logistics and glaciology department

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. Due to the pandemic situation, the forecasting service was provided from Cape Town, South Africa and Hamburg, Germany. Weather observations at *Neumayer Station III* for the DROMLAN community were provided as usual.

Data management

Data of the observatory are 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 will be 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 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.

4.4 CTBTO – IS27 Infrasound Station

Torsten Grasse[1](not in the field), Mathias Hoffmann[1](not in the field), Timo Dornhöfer[2], Lorenz Marten[2], Alicia Rohnacher[2], Benita Wagner[2]

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

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 the *Neumayer Station III* (Fig. 4.4.1). It consists of nine elements (Fig. 4.4.2) each equipped with a microbarometer and a data acquisition systems (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 the *Neumayer Station III*. IS27 went operational 2003.

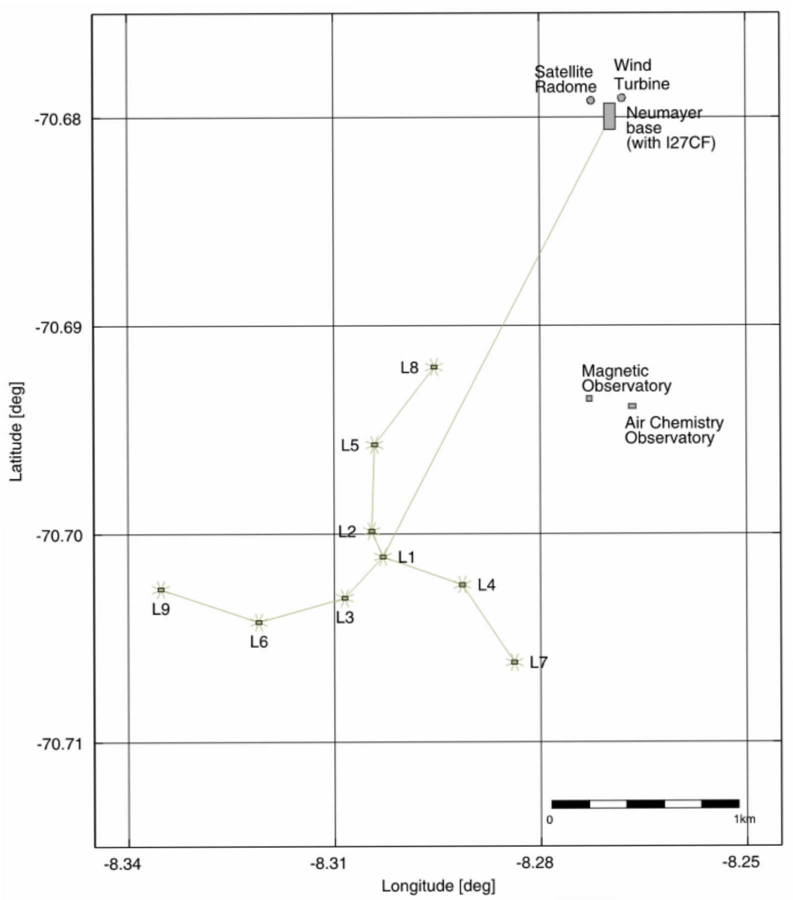


Fig 4.4.1: Map showing the location and layout of the Infrasound Array IS27 with reference to Neumayer Station III (Grafik: Inge Glinsmann / AWI)

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

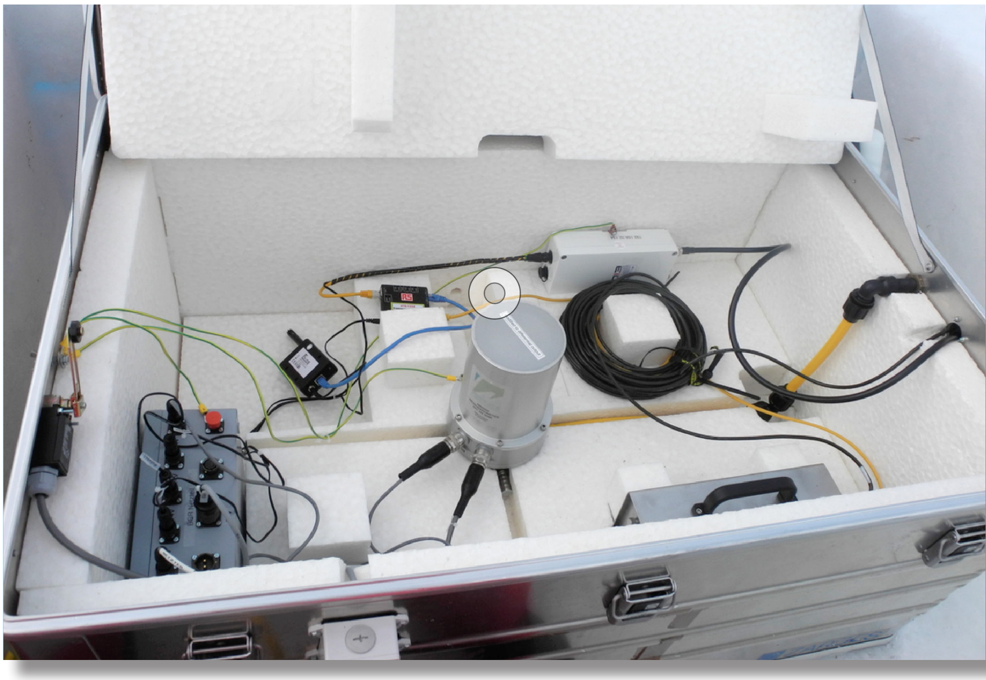


Fig. 4.4.3 The insulated field-box contains the microbarometer (in the middle), data acquisition system as well as the power supply and a communication unit.

Work in field

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.

Once again this year's maintenance work was canceled due to the corona pandemic. Nevertheless, the nine elements could be recovered from 2 m snow depth and were repositioned on the surface. Remote support was available all the time to keep data quality as high as possible.

Preliminary (expected) results

Data availability and quality for year 2021 met the requirement set by the CTBTO. All data were qualified for data processing at CTBTO.

For waveform-data from IS27 contributed to several recently conducted atmospheric research studies please refer to the list of publications.

Data management

Archived data as well as real-time infrasound data and metadata are publicy available. It can be obtained from BGR via FDSN-Webservice (https://eida.bgr.de/info)

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.

List of publications

Hupe P, Ceranna L, Le Pichon A, Matoza RS, Mialle P (2022) International Monitoring System infrasound data products for atmospheric studies and civilian applications. Earth System Science Data Discussions, 2022, 1-40, https://doi.org/ 10.5194/essd-2021-441.

Pilger C, Ceranna L and Bönnemann C (2017) Monitoring Compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT), Contributions by the German National Data Center, Schweizerbart Science Publishers, Stuttgart, Germany, 2017. ISBN 978-3-510-96858-9

Hupe P, Ceranna L, Pilger C, Le Pichon A, Blanc E, & Rapp M (2019) Mountain-Associated Waves and their relation to Orographic Gravity WavesMeteorologische Zeitschrift, https://doi.org/10.1127/metz/2019/0982

Hupe P, Ceranna L, Le Pichon (2019) A How Can the International Monitoring System Infrasound Network Contribute to Gravity Wave Measurements? Atmosphere 2019, 10, 399. https://doi.org/:10.3390/atmos10070399

Hupe P, Ceranna L & Pilger C (2018) Using barometric time series of the IMS infrasound network for a global analysis of thermally induced atmospheric tidesAtmospheric Measurement Techniques, 11(4), 2027–2040. https://doi.org/10.5194/amt-11-2027-2018

De Carlo M, Hupe P, Le Pichon A, Ceranna L, & Ardhuin F (2021) Global microbarom patterns: A first confirmation of the theory for source and propagation. Geophysical Research Letters, 48, e2020GL090163. https://doi.org/10.1029/2020GL090163

Pilger C, Ceranna L, Ross JO, Le Pichon A, Mialle P, and Garcés M A (2015) CTBT infrasound network performance to detect the 2013 Russian fireball event. Geophys. Res. Lett., 42, 2523– 2531. https://doi.org/10.1002/2015GL063482.

Le Pichon A, Ceranna L, Pilger C, Mialle P, Brown D, Herry P and Brachet N (2013) The 2013 Russian fireball largest ever detected by CTBTO infrasound sensors, Geophys. Res. Lett., 40, 3732– 3737, https://doi.org/10.1002/grl.50619.

Le Pichon et al. (2019) Infrasound Monitoring for Atmospheric Studies, https://doi.org/10.1007/978-3-319-75140-5; https://www.springer.com/gp/book/9783319751382

Hupe, Patrick (2019) Global infrasound observations and their relation to atmospheric tides and mountain waves. Dissertation, LMU München: Faculty of Physics, https://edoc.ub.uni-muenchen.de/23790/; https://doi.org/10.5282/edoc.23790; **URN**: urn:nbn:de:bvb:19-237904

Pilger & Ceranna BGR Report 2018, Titelstory „Lauschen für den Frieden“ https://www.bgr.bund.de/DE/Gemeinsames/UeberUns/Taetigkeitsbericht/taetigkeitsbericht_node.html

Le Pichon et al., 2019, Infrasound Monitoring for Atmoshperic Studies, https://link.springer.com/book/10.1007/978-1-4020-9508-5

4.5 Antarctic Fast Ice Network (AFIN)

Stefanie Arndt[1] (not in the field), Paul Ockenfuß[1], Marcel Nicolaus[1] (not in the field), Christian Haas[1], (not in the field) Markus Janout[1] (not in the field)

[1]DE.AWI

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 programme on the fast ice of Atka Bay, Antarctica. This work contributes to the international Antarctic Fast Ice Network (AFIN), which was initiated as legacy project under the International Polar Year (IPY) and is set out to establish an international network of fast-ice monitoring stations around the Antarctic coastline. The monitoring programme at *Neumayer Station III* started in 2010 (Arndt et al. 2020).

Work in field

During the season 2021, the sea ice conditions in Atka Bay have been again rather challenging as ice remained in the bay (see Fig. 4.5.1). On the one hand, an approximately 5 km wide strip along the west coast of the ice shelf has remained in the bay for several years. In addition, a large part of the fast ice formed last year has not broken up, but has remained in the bay. However, this situation offered the opportunity to work on the fast ice during the *Polarstern* expedition PS124 in March 2021 and to deploy, among others, a Snow Buoy, an ice mass balance buoy, and an ocean buoy (Haas et al. 2021). This location was regularly visited by the overwintering team as part of the AFIN programme to conduct manual validation measurements (see below).

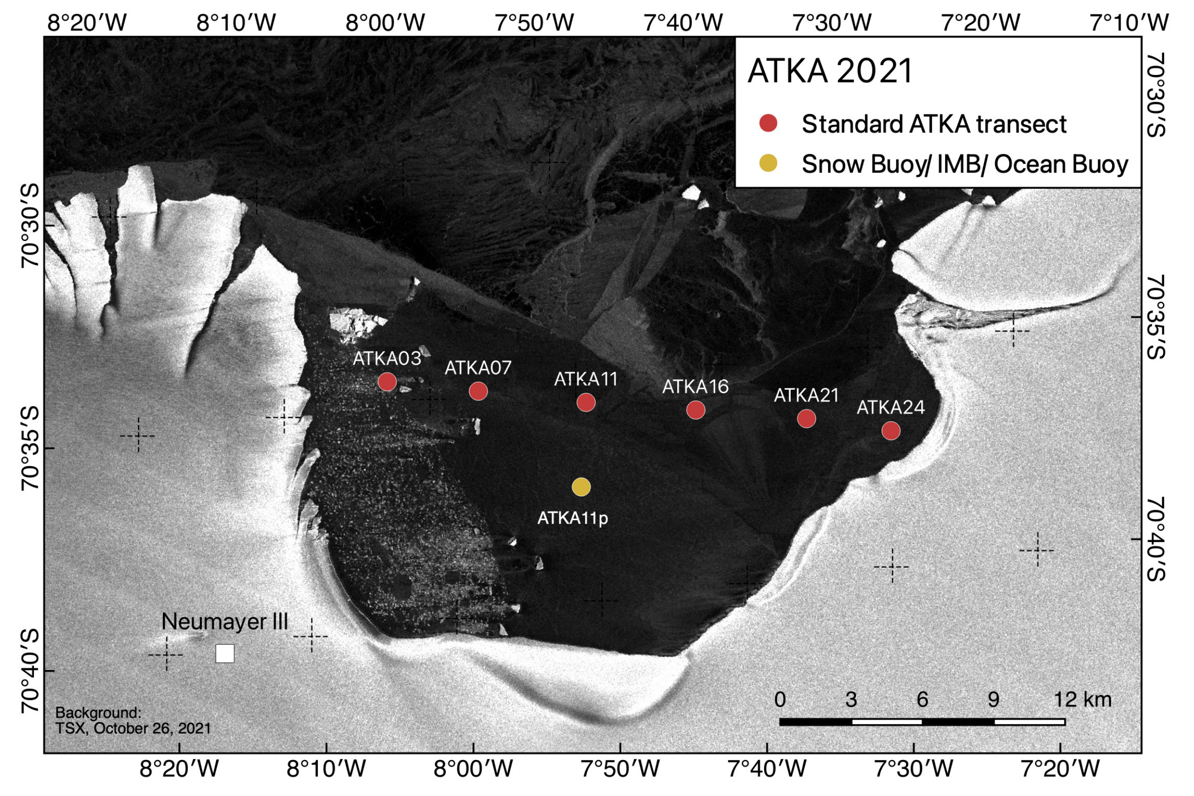


Fig. 4.5.1: Overview on the measurement sites in Atka Bay *for the season 2021; ATKA03-24 denote the routinely measurement sites of AFIN. Numbers (03-24) state the distance to the western shelf ice edge (E-W transects). In addition, the location of buoys installed in* Atka Bay *in March 2021 as part of the PS124 expedition is marked (yellow dot). This point correlates with the sampling site ATKA11p of previous measurements. The background of the map shows a TerraSAR-X image recorded on 26 October 2021.*

(1) Manual measurements of sea ice and snow thickness

Manual measurements of sea ice and platelet ice thickness, freeboard, and snow depth (drillings and stake measurements) were repeated along a 25-km-long transect across Atka Bay once per month (Fig. 4.5.1). As in the previous years, 6 fixed sampling sites have been revisited monthly between annual formation and break up to obtain the mentioned measurements. In addition, sampling site ATKA11p was sampled regularly for control measurements on the buoys deployed there.

First sea-ice, platelet ice and snow thickness measurements were carried out 24 May 2021. Since entering the sea ice was not yet safe in the entire bay, only a first sampling site (ATKA03) of the route could be worked on. Afterwards, in total, 4 series of the entire transect could be conducted. Due to various iceberg passes that also cracked parts of the fast ice, the sea ice east of ATKA11 was closed in mid-October. From then until the end of the year another 3 transects between ATKA03 and ATKA11 could be performed. On these surveys, ATKA11p was additionally approached for corresponding measurements close to the deployed autonomous systems (see below). Last measurements were performed on 30 December 2021. The fast ice was closed by 15 January 2022 due to crack widening in the southern part. Beginning of February, the fast ice area broke up and drifted off the bay. Table 4.5.1 summarizes all mentioned manual measurements.

Tab. 4.5.1: Overview of all manual sea ice and snow thickness measurements along the standard transect and ATKA11p; the ATKA sites correspond with the sampling sites in Figure 4.5.1.

Date	ATKA03	ATKA07	ATKA11	ATKA16	ATKA21	ATKA24	ATKA11p
May 24, 2021	X						
Jun 29, 2021	X	X	X	X	X	X	
Jul 29, 2021	X	X	X	X	X	X	
Sep 08, 2021	X	X	X	X	X	X	
Oct 06, 2021	X	X	X	X	X	X	
Nov 08, 2021	X	X	X				X
Dec 07, 2021	X	X	X				X
Dec 30, 2021	X	X	X				X

(2) Electromagnetic sea ice thickness measurements

In addition to the manual sea-ice and snow thickness measurements, a ground-based electromagnetic induction device GEM (Geonics Limited, Mississauga, Ontario, Canada) was operated measuring total sea-ice thickness (sea ice thickness plus snow depth). Due to logistical reasons, GEM transect measurements only started in October and were then also conducted once a month. Table 4.5.2 summarizes all conducted GEM measurements.

Tab. 4.5.2: Overview of sea-ice thickness measurements with the electromagnetic induction sounding system (GEM)

Date	GEM
Oct 08, 2021	X
Nov 12, 2021	X
Dec 02, 2021	X
Dec 29, 2021	X

(3) Vertical water profiling below the fast ice

In order to measure the water mass properties in the vertical water column, a Conductivity-Temperature-Depth (CTD) sensor suit was lowered through a drilled hole at ATKA16. All measurements including the number of casts are summarized in Table 4.5.3.

Tab. 4.5.3: Overview of water profiles with the CTD; the number in brackets indicates the number of down-casts of the CTD.

Date	CTD (casts)
Nov 29, 2021	X (1)
Dec 07, 2021	X (2)
Dec 30, 2021	X (2)

(4) Deployment of autonomous ice tethered platforms (buoys)

In order 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. 4.5.1) on 7 July 2021: One Ice Mass Balance buoy (IMB) deriving the sea-ice growth as well as one Snow Buoy measuring the snow accumulation over the course of the year. During the breakup of the bay, unfortunately, both systems have been damaged. Thus, the IMB stopped transmitting data on 18 January 2022, and the Snow Buoy on 20 January 2022.

Regarding the buoys at ATKA11p deployed on 17 March 2022 as part of *Polarstern* expedition PS124, the following can be noted: The IMB had technical problems from the beginning and could not record any data. The Snow Buoy and ocean buoy, however, measured reliably. Due to heavy snow accumulation this summer season, the Snow Buoy was dug out, sawed out and raised during the last measurements on 30 December 2021. After the breakup of the fast ice in Atka Bay, the systems drifted with the ice regime into the Weddell Sea. The Snow Buoy tipped over and stopped sending data on 12 February 2022. The ocean buoy is expected to have moved into the water in the meantime and continues to float here.

Snow thickness 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 period, the Snow Buoy was lifted once (27 July 2021) to avoid a complete coverage in snow.

Preliminary (expected) results

Figure 4.5.2 summarizes all snow, sea ice and platelet ice thickness measurements as well as the observed freeboard over the season. Although the ice in the west of the bay has not broken out by the end of the previous season, the platelet ice accumulation under the fast ice was as usual. On average the annual accumulation between ATKA03 and ATKA11 amounted to 3.85 ± 0.39 m while highest accumulation rates were measured at ATKA07 with 4.19 ± 0.30 m. Excluding the old ice at ATKA03, the fast ice and snowpack show annual maximum thickness values of 2.03 ± 0.11 m and 0.80 ± 0.04 m, respectively, by the end of December, which are comparable to those of previous years.

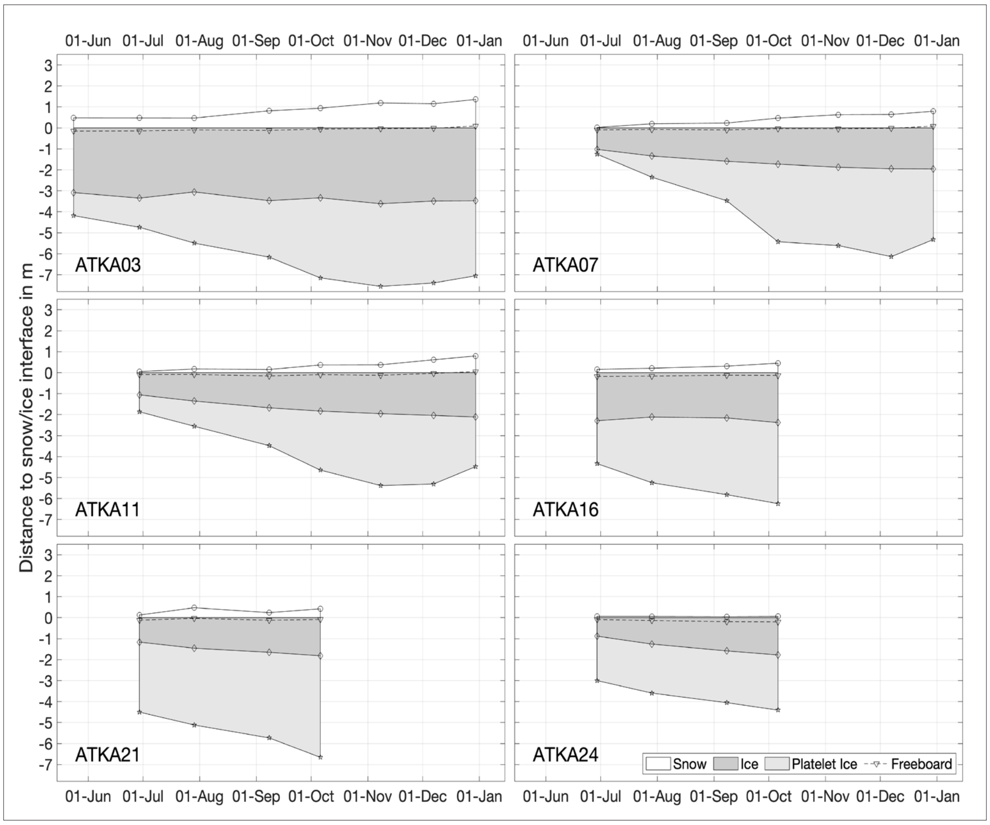


Fig. 4.5.2: Overview of all manual snow depth, sea ice and platelet ice thickness as well as freeboard measurements for the 6 ATKA points along the standard W-E transect (Fig. 4.5.1) in 2021

Figure 4.5.3 shows the snow accumulation of the deployed Snow Depth Buoy 2020S55 (at ATKA11) for the time period from 7 July 2021 to 20 January 2022. 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 mid-September and late September, repeated heavy snowfall accumulated an additional 20 cm of new snow for each event. In mid-October, another strong wind event apparently dispersed the snow from this, causing a decrease of 10 cm in snow depth at the Snow Buoy location. The snow accumulation was then rather constant until mid-December. Afterwards, an enormous snowstorm added about half a meter of new snow in December, causing the buoy to be almost completely snowed in. Shortly before the break-up of the fast ice, another snowdrift blew off another 20 cm, resulting in an average snow depth of about 90 cm at the Snow Buoy location by mid-January 2022.

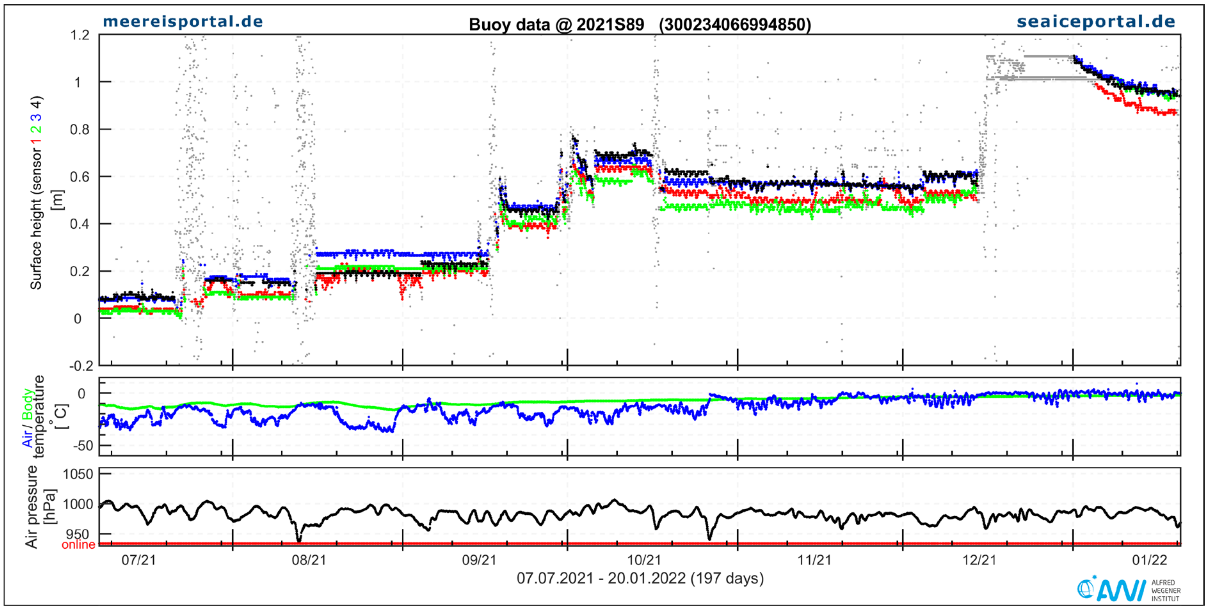


Fig. 4.5.3: Time series of snow accumulation along with respective meteorological conditions for Snow Buoy 2021S89, deployed on 7 July 2021 at ATKA11 (Fig. 4.5.1).

GEM and CTD data will be only processed at a later stage.

Data management

All manual drilling measurements are already post-processed 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 three months. By default, the CC-BY license will be applied

The sea ice thickness data from electromagnetic measurements will be released following final processing after the field season ANT-Land 2021/2021 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 Programme 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 the field expedition, the Grant No. 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

Arndt S, Hoppmann M, Schmithüsen H, Fraser AD, and Nicolaus M (2020), Seasonal and interannual variability of landfast sea ice in Atka Bay, Weddell Sea, Antarctica, The ryosphere, 14, 2775-2793, https://doi.org/10.5194/tc-14-2775-2020.

Haas C, Arndt S, Peeken I, Eggers SL, and Neudert M (2021) Chapter Sea Ice Geophysics and Biogeochemistry in: The Expedition PS124 of the Research Vessel POLARSTERN to the Weddell Sea in 2021, Berichte zur Polar-und Meeresforschung= Reports on polar and marine research.

4.6 SPOT – Single Penguin Observation and Tracking Heading

Daniel Paranhos Zitterbart[1,2], Alexander Winterl[1],
Aymeric Houstin[1], Céline Le Bohec[3,4]
Not in the field: Sebastian Richter[1], Ben Fabry[1]

[1]DE.FAU
[2]EDU.WHOI
[3]FR.CNRS
[4]MC.CSM

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. 4.6.1) specifically designed to operate in Antarctic conditions.

Fig. 4.6.1 SPOT penguin observatory in 2021

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 behaviour can only be observed during the coldest and darkest months, with wind speeds up to 150 km/h and temperatures as low as -50° C. Therefore, the observatory needs to be, autonomous and remotely controllable, as well as require little maintenance. As emperor penguins do not build nests, and incubate their single egg on their feet, the whole colony can move within an area of several km^2. To observe such a large area, we installed 7 stationary wide-angle cameras for panoramic overview images, and a steerable 29 megapixel camera mounted on a pan-and-tilt unit as well as a long wave thermal imaging camera. Both, the thermal and the colour camera, are equipped with a telephoto lens for either high-resolution images, stitched panoramic images, or video recordings of the colony.

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

Work in field

Data collection throughout the winter 2021 went without major problems. During one massive storm with sustained winds of up to 49 m/s in mid August 2021, one of the SPOT wind turbines and the SPOT weather sensor was damaged (Fig. 4.6.2). During the August 2021 strom, the majority of the emperor penguin colony also moved from the land-fast sea ice, to the ice-shelf (Fig. 4.6.3), up to 1 km "in-land", and moved out of sight of the observatory.

Fig. 4.6.2: SPOT wind turbine damaged during a heavy storm in August 2021

Fig. 4.6.5:
Top: High-resolution panoramic images of the whole Atka Bay colony created on 8 October 2021;

Bottom: Cut-out enlargement from the middle part (red frame) of the panoramic images

Fig. 4.6.3: During the strong storm in August 2021, the emperor penguin colony moved from the sea ice to the ice shelf. The container storage can be seen in the background of the colony.

Overview cameras recording the position and density of the colony were operational throughout the year and collected a total of 323,717 minutes of data throughout the year (Fig. 4.6.4).The high-resolution RGB camera was operational throughout the year and recorded images on demand when daylight, penguin's position were favorable and the power reserves of SPOT observatory enough. We recorded during 127 days a total of ~4,712 minutes distributed over the whole year. 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 2019/2020. A total of ~4,964 minutes of thermal imaging data was recorded during 128 days. To count emperor penguins and to study their reorganization processes on a colony scale level, we acquired a total of 121 gigapixel size panoramic images throughout 2020. An example is provided in Figure 4.6.5.

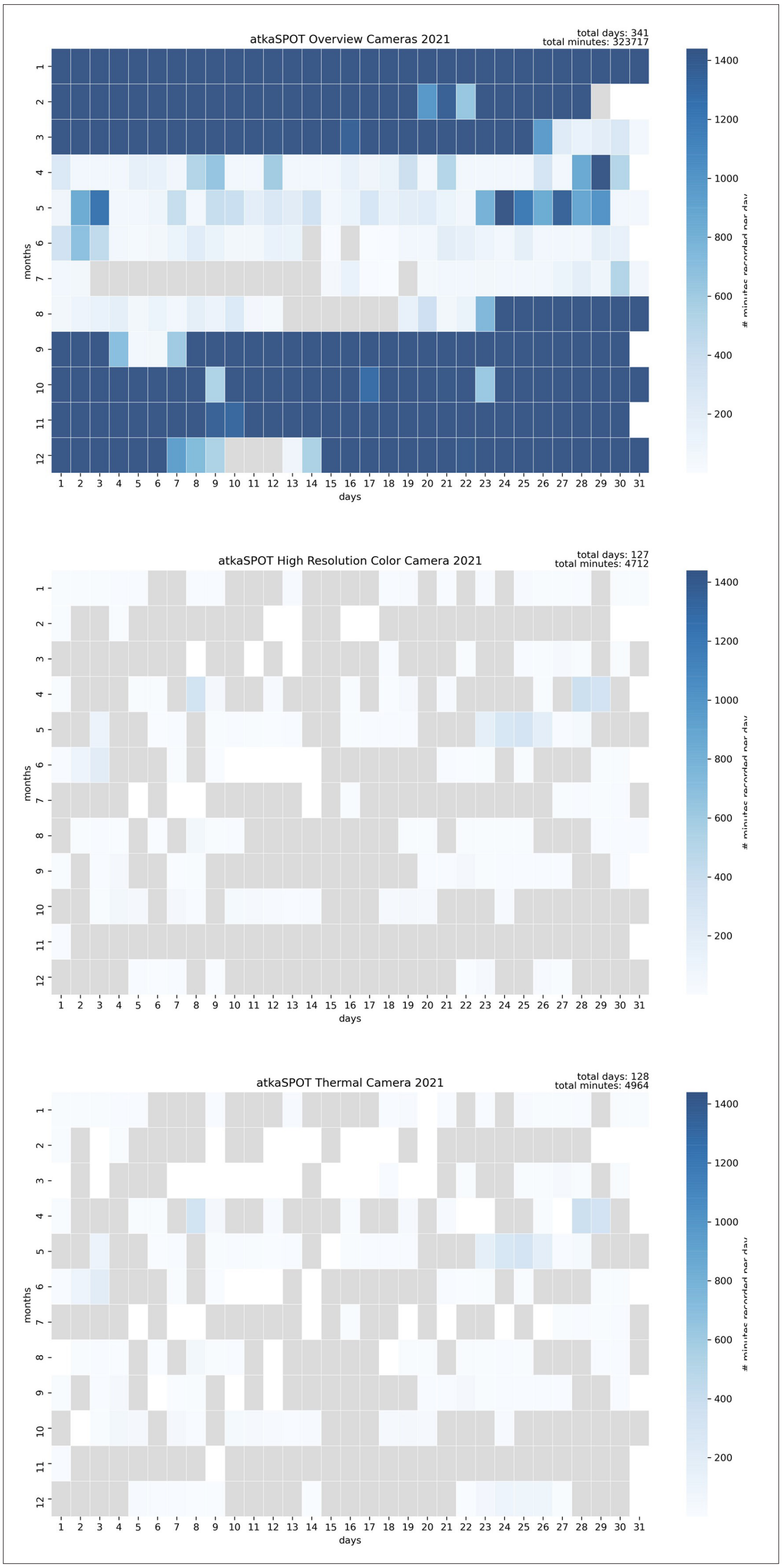


Fig. 4.6.4: Data collection overview. Minutes per day data collected of the respective camera system: Overview cameras (top), high-resolution colour camera (middle), and thermal imaging camera (bottom).

During the summer field season (ANT-Land 2021/22), normal maintenance were was conducted on the SPOT observatory. We replaced the heated windows for the camera that were not functional anymore due to normal wear, installed a new weather station and replaced the isolation for the electronics within spot. In January 2022, SPOT was moved approximately 150 m further north, where a high sastrugi had formed over the winter allowing for an increased elevation by 3 m.

Preliminary (expected) results

We have been operating SPOT now for 9 breeding seasons with increasing success, which is reflected in annual operation time and data collected. Whilst during the first 2 years we had hardware failure of different components, this has not occurred since the winter of 2015. The operation is conducted completely remotely with support from the Overwinters in case it is needed. 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 penguins abundance assessments (*Larue et al. 2022, in prep*).

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 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

Dell AI, Bender JA, Branson K, Couzin ID, De Polavieja GG, Noldus LPJJ, Pé Rez-Escudero A, Perona P, Straw A, Wikelski M & Brose U (2014). Automated image-based tracking and its application in ecology.

Gerum RC, Richter S, Fabry B & Zitterbart DP (2016). ClickPoints : an expandable toolbox for scientific image annotation and analysis (T. Poisot, Ed.). Methods in Ecology and Evolution.

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.

Kucera TE & Barrett RH (1993). THE TRAILMASTER? CAMERA SYSTEM FOR DETECTING WILDLIFE. Source: Wildlife Society Bulletin, 21, 505–508.

Lynch TP, Alderman R & Hobday AJ (2015). A high-resolution panorama camera system for monitoring colony-wide seabird nesting behaviour (H. Schielzeth, Ed.). Methods in Ecology and Evolution, 6, 491–499.

Newbery KB & Southwell C (2009). An automated camera system for remote monitoring in polar environments. Cold Regions Science and Technology, 55, 47–51.

Richter S, Gerum R, Schneider W, Fabry B, Le Bohec C, Zitterbart DP (2018) A remote-controlled observatory for behavioural and ecological research: A case study on emperor penguins, Methods in Ecology and Evolution, 9(5), 1168-1178.

Zitterbart DP, Richter S, Spiekermann G, Behrens LK, Regnery J, Fontes RP, Hänssler T, König-Langlo G, Weller R & Fabry B (2014). Short Note Are environmental factors responsible for changed breeding behaviour in emperor penguins?

Zitterbart DP, Wienecke B, Butler JP & Fabry B (2011). Coordinated movements prevent jamming in an emperor penguin huddle. PLoS ONE, 6, e20260.

4.7 Ocean Acoustics – PALAOA

Not in the field: Stefanie Spiesecke, Olaf Boebel, Elke Burkhardt, Karolin Thomisch, Ilse van Opzeeland DE.AWI

Objectives

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.

Field work

During the supply of the *Neumayer Station III* from 28 December 2014 until 31 December 2014, an aluminum box, containing modified Sonovault electronics, was installed at the position of the former PALAOA container. It was recessed into the snow and covered with a wooden board and some snow. The box (80 cm x 60 cm x 60 cm) included a Reson input module EC6073 for the active hydrophone (Reson TC4032) and a SonoVault electronics module, similar to those used in the moored recorders. For the power supply, four 90 Ah, 12 V batteries were included, two connected in row for each, the active hydrophone and the recording electronics. The battery setup was changed later in 2015 to batteries two in a row and those rows in parallel, supplying both, the hydrophone and the recording electronics. Storage capacity is 4.4 TB (35 x 128 GB SDXC). With a sampling rate of 96 kHz at 24 bit and a file size corresponding to of 600 s (10 min) the PALAOA system was expected to hold recording capacities for up to 6 months. Servicing was provided by the overwintering team of *Neumayer Station III*. However, based on the experience from the team at *Neumayer Station III*, a servicing interval of approx. 3 months proved to be necessary. The responsible person at *Neumayer Station III* is the current radio officer.

Maintenance of the PALAOA observatory

In early 2021, a bug-fixed GPS box for the in-field time synchronization of the electronics was delivered. Data following the exchange of February 2021 has the correct time stamp logged in the file header and in the filename. For details refer to report on ANT-Land 2019/2020.

For PS129 it was intended to calibrate the hydrophone and recording equipment using a frequency generator attached to the calibration input on the EC6073 input module. However, on 20 March 2022 and later on 23 March, when approaching the shelf with *Polarstern*, it seemed as if the hydrophone cable was ending at the shelf-ice edge. A helicopter flight to the PALAOA site on 23 March 2022, confirmed this suspicion. 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.

- On 23 March 2022, i.e. approximately one month after PALAOA's hydrophone break-off and immediately prior to removing its recording box the latter's location was determined by handheld GPS as 70.502781°S 008.205716°W.

Batteries and electronics were exchanged on the following dates:

In 2021:

- 11 Febuary 2021
- 29 April 2021
- 30 July 2021
- 08 November 2021
- 29 December 2021

In 2022:

- 09 Febuary 2022:

Hydrophone break-off:

- 27 Febuary 2022 08:16

Recovery of electronics and final data

- 23 March 2022

Data management

Tapes with data from 2021/2022 have arrived in Bremerhaven in March 2021 and were copied into the OZA project folder on the Isilon Server. An additional backup will be made on the OZASRV1. A fix for the WRNO (GPS Week Number Rollover) problem, which occurred in 2019 and is still present in the first two months of 2021, will be applied. Pre-processing of data and analysis will then be performed.

Passive acoustic data will be made accessible through the OPUS.aq webpage 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.

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 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.

4.8 Neuromayer – Neurophysiological Changes in Human Subjects during Long-duration Overwintering Stays at *Neumayer Station III* in Antarctica

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

[1]EDU.UPenn
[2]DE.Charite
[3]DE.MPIB-Berlin
[4]EDU.Pitt
[5]GOV.NASA

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 Polar Institute for Polar and Marine Research and several international partners, including Charite, Ludwig Maximilian University of Munich, the University of Pennsylvania, Harvard and NASA.

Work in field

Data has been collected in crew members at *Neumayer Station III* as part of ANT-Land 2018/19, 2019/20, 2020/21, and 2021/22, and is currently collected in 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 overwintering have been successfully completed. Pre-mission data collection for the 42nd overwintering campaign was accomplished in November 2021. In-mission data collection for this crew is currently ongoing at *Neumayer Station III*.

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 programmes. 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 AWI and the Grant No. will be quoted in all publications.

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

Maestripieri D, Lilienfeld SO (2016). Using the NIMH Research Domain Criteria (RDoC) in human and nonhuman primate research. Psychophysiology 53(3): p. 367-371.

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

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.

4.9 Consequences of Longterm-Confinement and Hypobaric Hypoxia on Immunity in the Antarctic Environment at the *Concordia* and *Neumayer* Station *III* (CHO$_2$ICE @ *Neumayer*)

Not in the field: Alexander Choukér, Matthias Feuerecker — DE.Med.Uni-Muenchen

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 with 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-Maximilians-University of Munich (Department of Anesthesiology) aims to investigate on *Neumayer Station III*

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

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

Work in field

For the winterover-season 2021, after a baseline data collection in the fall of 2020, the examinations of all ten subjects started on the station in February 2021 to run the CHOICE@*Neumayer* observation in a monthly period over the winter. The study has been completed by 8 subjects and ended by the last time point in March 2022 (due to COVID regulation it was split into 3 days) 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. From the former years' data we conclude in a preliminary and very recent publication in Biomedicines (IF 6.1) that overwintering can trigger or modulate hypersensitivity immune answers to different degrees in isolated and confined conditions. To analyze these effects in a controlled way and with longer exposition, conditions of the German station *Neumayer Station III* and the French-Italian *Concordia Station* (3,200 m above sea) were included.

About one third of the 39 participants displayed specific IgEs against pollen. In most individuals, kinetics showed a reduction in the specific IgE at the time about nine months after deployment to Antarctica. Five participants had the highest specific IgE levels after returning to the "normal" world. The examination of the specific IgE relative to house dust mites and storage mites showed different kinetics. Six out of 10 had the highest specific IgE concentrations at the inner Antarctic measurement time point. These data corresponded well to the general situation in the stations. At the stations themselves, there were almost no pollen particle load, especially at *Concordia*. In summary we found that the first line of immune defense, the microbiome and related to this stress events, indicating the role of the environmental challenge on the one hand (so being confined and stressed), will also allow us to bridge these phenomena to other immune dysregulations as reported (e.g., viral reactivations). The data gathered here and the possibly underlying immunological mechanisms add another element to this understanding of complex immune responses, though the exact causes of these sensitizations can only be answered in a speculative way. As initially described, this special Antarctic environment leads to significant changes distinct immunological pathways. These findings and with previous findings and currently ongoing studies are helping to demonstrate that exposition of healthy humans to the physically challenging extreme environment of Antarctica can affect stress and immune related health condition. The identification of these and more adverse effects from confinement conditions allows not only the overwintering crew to be better prepared, but also to design feasible countermeasures that will help support Antarctic crews and also space travelers during exploration class missions in the future. During their mission and, often less investigated though as important, after the return to the “normal” world, e.g. back in Europe.

Data management

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

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

Feuerecker M, Strewe C, Aumayr M, Heitland Tim, Limper U, Crucian B, Baatout S, Choukér A (2022) One Year in the Extreme Isolation of Antarctica-Is This Enough to Modulate an “Allergic” Sensitization? Biomedicines 2022 Feb 15;10(2):448. https://doi.org/10.3390/biomedicines10020448.

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

Not in the field: Michael Hartje[1], Ulrich Walter[2]

[1]DE.HS-Bremen
[2]DE.TUM

Objectives

The objective of this project is to gain more knowledge about the propagation of radio waves in the ionosphere at Antarctic latitudes at frequencies between 100 kHz and 50 MHz. This is achieved by about 2,000 amateur radio stations (also known as “ham radio”) spread across the globe. These stations transmit beacon signals and/or receive them from other stations, generating so-called “spots”. These spots are reported to an open web-based database system, also known as “WSPR-Net”. The beacon messages use a standardized format named “propagation reporter protocol”, which was developed and introduced in 2008 by physicist and Nobel Laureate Joe Taylor, amateur radio call sign K1JT. Because seasonal propagation situations south of the tropic of Capricorn 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 now is planned to be extended to a full 11-year sunspot cycle, i.e., until 2030. The project is funded by the two primary research institutes, as well as by DARC (German Amateur Radio Club) and is also supported by several private individuals highly dedicated to amateur radio and to research projects. The receivers are operating autonomously with special decoder programmes reporting the relative signal-to-noise ratio (SNR) during receiving intervals.

To convert the signal-to-noise-ratio (SNR) to absolute values, an additional receiver with a calibrated electrical field sensor has been installed on the roof of the “SPUSO”. This offers the opportunity to recalibrate the prior receiver data and determine the absolute values of noise and signal strength.

Work in field

During one of the Antarctic winter storms in 2021, the active antenna that had been installed in February 2021 was destroyed. It was sent for repair to the design engineer Jörg Logemann in Germany. It was reinstalled on SPUSO in February 2022, showing the expected functionality. However, first signals revealed a very noisy environment, which could not be linked to a source. As no such noise was received at the radio station at *Neumayer Station III*, it was assumed that the noise must be from SPUSO itself. Due to the limited time available during that summer season, the noise source could not be determined.

Since the dual-channel receiver for the active antenna on one channel was damaged in the spring of 2021, the receiver (Redpitaya) has now been replaced.

As shown in Figure 4.10.1 a new low-noise dual channel RF preamplifier with 6 isolated power outputs was installed. This makes it possible to connect the two large loop antennas with up to 6 receiver inputs without feedback. Since no suitable products were available on the market, this had to be newly developed and assembled in 2021. The fully tested device was installed in the SPUSO in February 2022. With the new power preamplifier, the 3 WSPR receivers at SPUSO could now be connected in a matched configuration.

The new preamplifier also allows the adapted connection of a new KiwiSDR. The KiwiSDR is only accessible via the internal intranet. It is a software defined radio for the entire short-wave spectrum and is controlled via a web interface. It is intended to be a secure alternative receiving site for radio reception on the entire shortwave spectrum at *Neumayer Station III* and uses the existing loop antennas at the SPUSO for this purpose.

The KiwiSDR also displayed the interfering signals observed with the other receiving equipment at SPUSO even when running on battery power.

Fig. 4.10.1: New dual channel power preamplifier with 10 termination resistors in front of the open chassis

Preliminary (expected) results

In 2020 the antenna and transmitter at *Neumayer Station III* were partially damaged by an electrostatic discharge, caused by a broken ground connection. In 2021 there were no such events, so that transmitter operation was uninterrupted. We were therefore able to collect a complete year of data for the first time. This turned out to be “just in time“, as solar activity picked up considerably during 2021, indicating that Solar Cycle 25 was gaining momentum (see Fig. 4.10.2). The project aims to collect data over at least one full solar cycle (i.e. about 11 years).

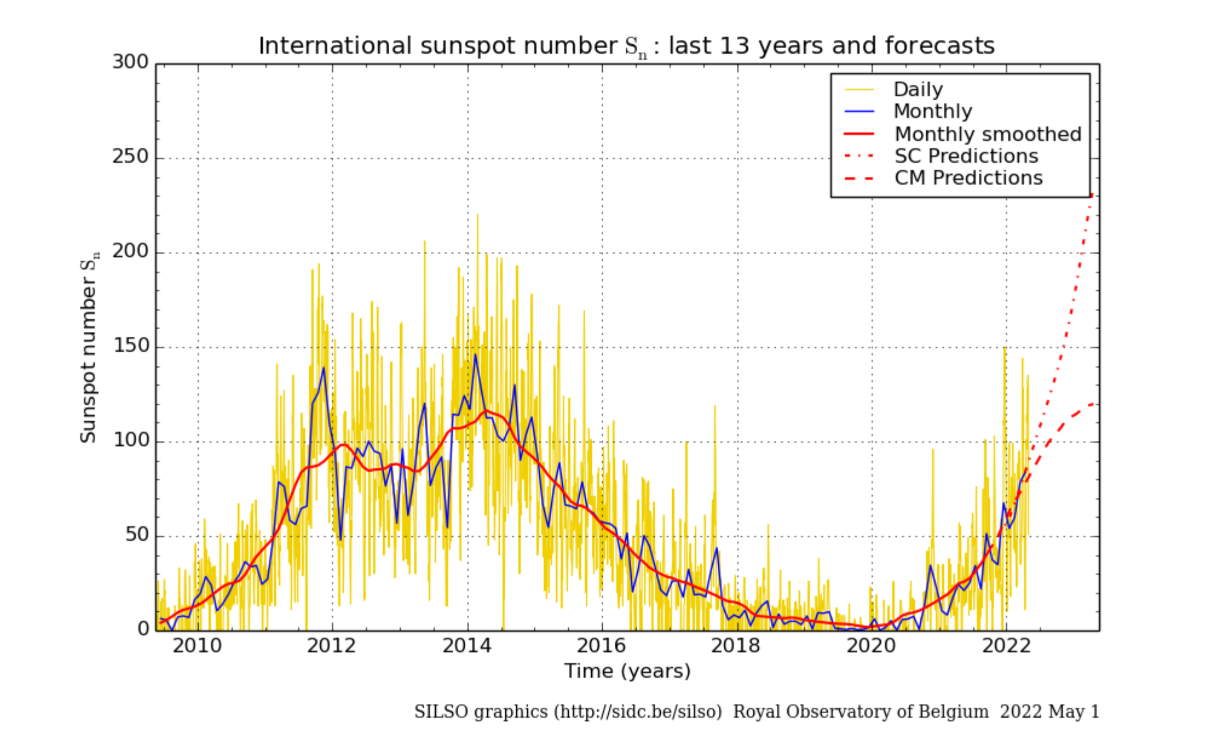


Fig. 4.10.2: Status and Prediction of the Sunspot numbers S_n

During 2021 the transmitter sent about 262,000 beacon messages, which generated 536,410 reception spots by 2,368 receiving stations across the globe. Broken down by frequency bands, the distribution is as expected for the still young solar cycle:

Tab. 4.10.1: Obtained Spots from the Transmitter at *Neumayer Station III*

Frequency [MHz]	Band [m]	Number of reports
1.83	160 m	24
3.57	80 m	282
5.36	60 m	10,134
7.04	40 m	146,886
10.14	30 m	205,164
14.07	20 m	68,474
18.11	17 m	66,767
21.07	15 m	25,561
24.93	12 m	10,365
28.07	10 m	2,741
50.03	6 m	12

During the coming years, we expect increasing numbers of reports on frequency bands above 10 MHz.

This data set will provide the opportunity to analyse significant space weather phenomena. Late on 3 November 2021, a shockwave from solar wind reached the Earth. It was caused by three subsequent coronal mass ejections which left the sun on the 1 and 2 November. The influx of charged particles into the magnetosphere led to moderate to severe disturbances in the geomagnetic field, a so called “magnetic storm“. The plots in Figure 4.10.3 from the magnetometer operated at *Neumayer Station III* show the onset of the event on the 3 November at about 21:00 UTC and its subsequent quieting until noon UTC on the next day.

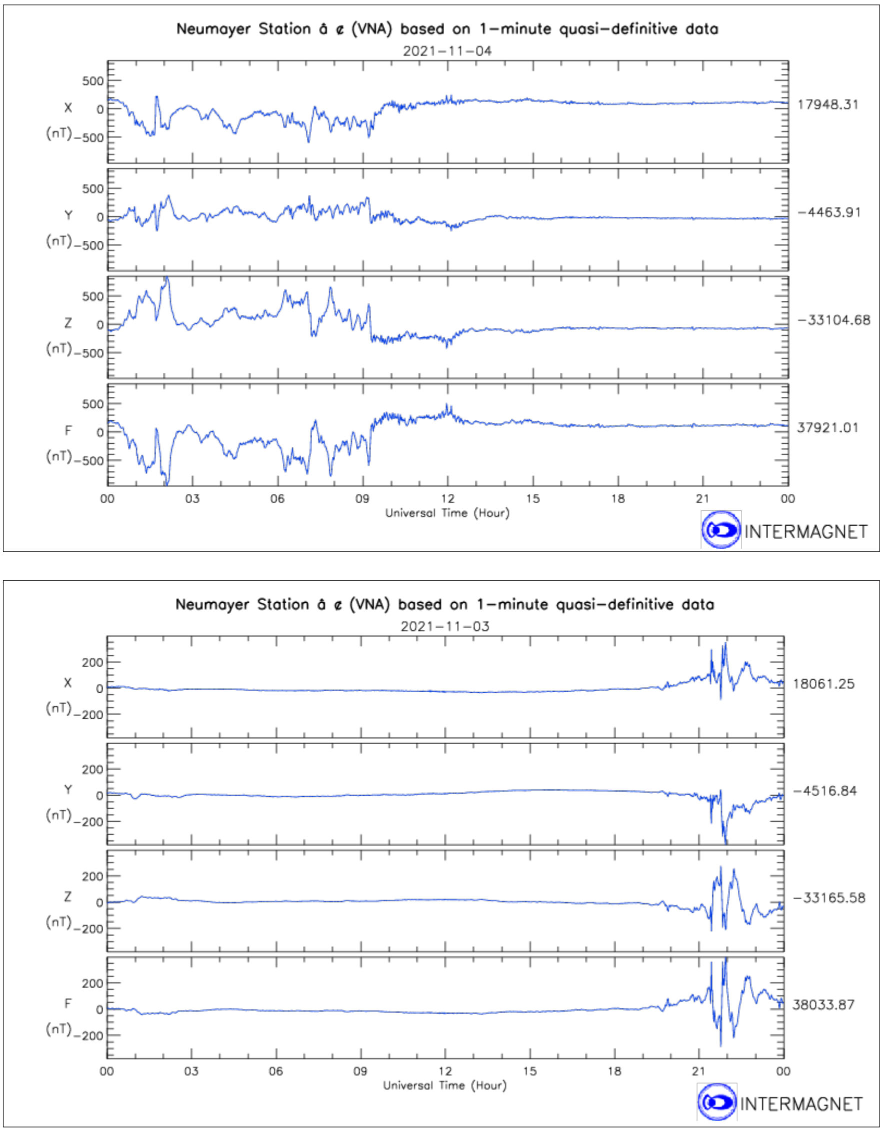


Fig. 4.10.3: Magnetometer plots at Neumayer Station III from 3 November to 4 November 2021

Such events affect shortwave radio propagation in a very peculiar way. During the first hours, propagation often improves because the surging solar wind compresses the plasma in the ionosphere, leading to higher electron density. Then the picture changes dramatically: free electrons, which are essential for refracting radio waves, vanish into the magnetotail and the electron density drops sharply. This causes loss of refraction on higher frequencies and increased signal attenuation on lower frequencies.

Further results shown in the following diagrams in Figure 4.10.4 show four consecutive days starting on 2 November 2021 at 00:00 UTC. Every data point is a reception of our signals as reported by one of the receiving stations. The Y axis is the signal-to-noise ratio of the received signal in dB based on a bandwidth of 2,500 Hz (the detection threshold is about –31 dB). The lower part displays the horizontal components X and Y of the geomagnetic field in the same time scale.

The diagram in Figure 4.10.4 shows all reception reports on all frequency bands and receiving stations over those four days (a total of 13,264 reports). The frequency band is denoted by colour, with darker spots meaning higher frequency. While the chart shows the usual day/night variations, the number of reports decreases abruptly with the onset of the magnetic storm. Around midnight from the 3 to 4 November, the count starts to pick up for about three hours, then diminishes and falls to zero around 07:00 UTC on 4 November. This is followed by a 10-hours period with no reception reports at all, meaning that shortwave communications between *Neumayer Station III* and the rest of the world was impossible during this time frame.

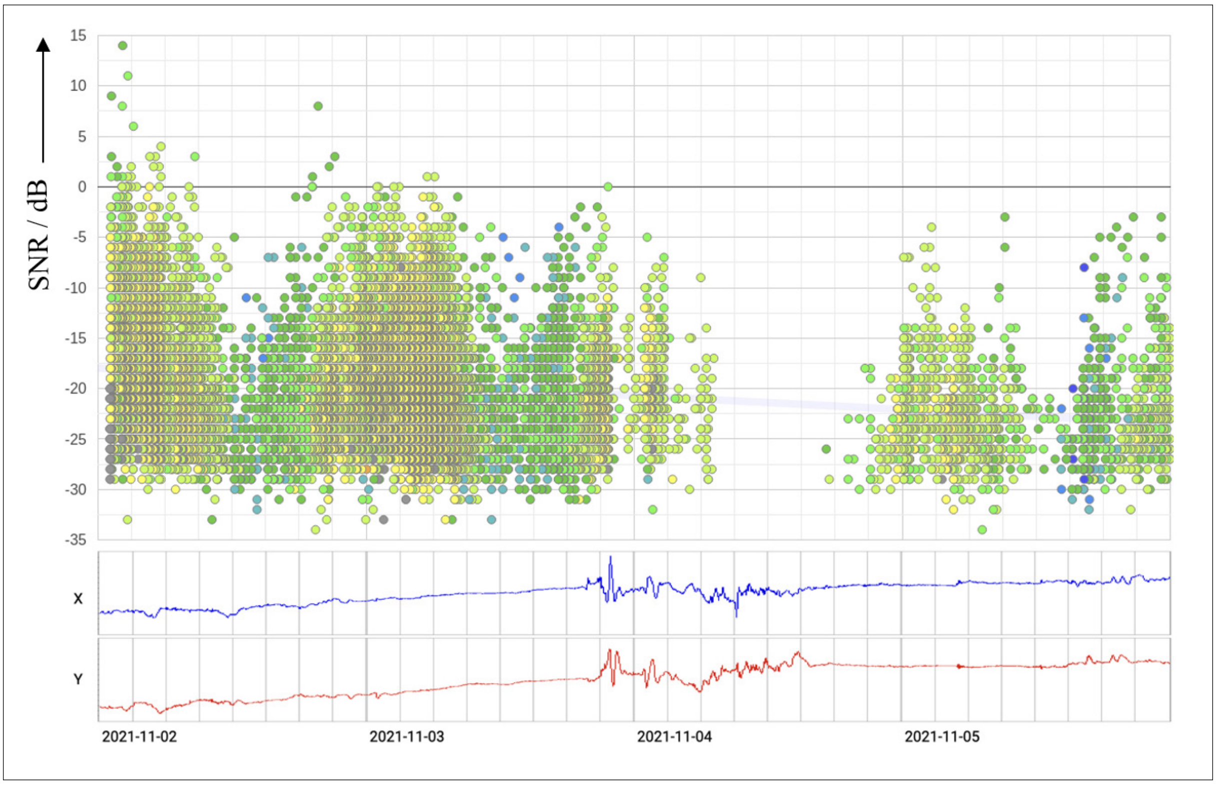


Fig. 4.10.4: The figure shows reported signal-to-noise-ratio of the transmitter spots during the event on 2 November and the magnetic components x an y.

Geomagnetic disturbances already decayed considerably during those hours, but as free electrons had been depleted from the ionosphere, solar radiation needed some time to create sufficient new ionisation. Eventually the first signals were received starting 18:00 UTC onwards on 4 November. However, they were significantly weaker than in the preceding days.

The development becomes more pronounced when examining a specific target area. The diagram in Figure 4.10.5 shows only reception reports from stations located in North America. At this time of the year and solar cycle, communication paths from *Neumayer Station III* to this world region were open mainly during night-time hours.

The magnetic storm severely impacted communications during the night from the 3 to 4 November. Reception reports were much rarer and signals considerably weaker. The situation improved during the night from the 4 to 5 November but was still far below normal (compared with the night from 2 to 3 November). A “positive phase“, i.e. an improvement in propagation during the first storm hours, is not detectable.

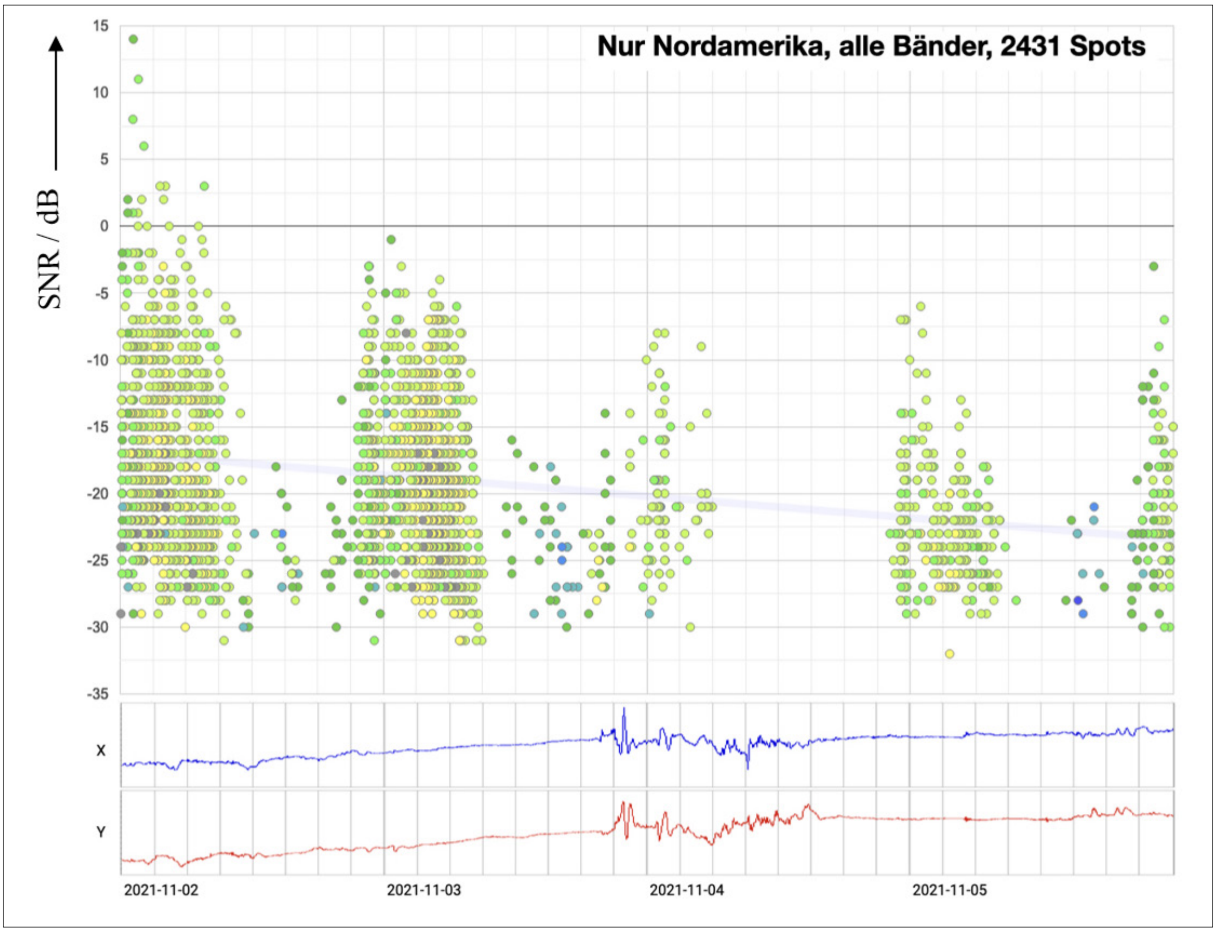


Fig. 4.10.5: Reported signal-to-noise-ratio of the transmitter spots from North America

This is just an example how space weather impacts radio propagation and how this can be derived from the gathered data. As the course of the solar cycle proceeds, we hope to collect enough geomagnetic storm events so that it may be possible to determine patterns.

Receivers at SPUSO were working continuously and produced spots as shown in Table 4.10.2. It is obvious that the maximum number of spots are received on the 7 MHz band. The received spots decrease with increasing frequency. This proves that the ionospheric propagation conditions for these higher frequencies were very “poor”.

During the next years, we expect a significant increase in the number of spots on the higher frequency bands.

A closer look into details of the monthly distribution not depicted here shows on the 160 m band a maximum for May and June, while the minimum of spot numbers for the 20 m band appears in the months of June and July. For the 80 m band there appears to be a decrease in spot numbers over the year from 11,449 in January down to 6,400 in December.

Tab. 4.10.2: Obtained spots from the receivers at *SPUSO.*

Frequency [MHz]	Band [m]	Number of reports
1.83	160 m	37,334
3.57	80 m	79,993
5.36	60 m	35,361
7.04	40 m	1,006,951
10.14	30 m	485,403
14.07	20 m	385,234
18.11	17 m	17,783
21.07	15 m	2,692
24.93	12 m	1,058
28.07	10 m	843
50.03	6 m	5

Data management

The data generated from the beacon receiver is saved locally on network storage at *Neumayer Station III*, as well as on a worldwide database called "wsprnet.org". This offers worldwide access via a web interface. Both offer archive functions as well as basic analysis functionality.

The wsprnet.org archive collects all received spot reports worldwide since 2008. In Oct 2021 about 3.3 million and in April 2022 about 4 million spot reports were stored per day. All spots can be downloaded with free access, compiled monthly, to a compressed CSV file. In addition, noise measurement results and locally stored results are available on the server at *Neumayer Station III*.

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 a great many voluntary supporters in this project. Our warm thanks go to the radio amateurs Dipl. Ing. Rainer Englert and IT Specialist Christian Reiber from DARC for setting up and tuning the receiver hardware, as well as preparing the TX antenna in Germany. Christian Reiber played a major role in the drafting the report on the work and propagation interpretation results from the transmitter and the transmitters spot evaluation. Dipl.-Ing. Jörg Logemann developed and improved the active antenna and the new receiver power preamplifier with great enthusiasm. Special thanks go also to Felix Riess, Roman Ackle, Theresa Thoma, Karsten Boedecker and several researchers unknown to us at *Neumayer Station III*, who installed and repaired the antennas and set-up the transmitter and receiver systems on-site with untiring commitment

4.11 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) Linda Martina Orth[2], Hannes Keck[2]
Not in the field: Rolf Weller[2], Frank Stratmann[1]

[1]DE.TROPOS
[2]DE.AWI

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.

Work in field

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

Besides CCN also INP sampling was established, using the low volume filter sampling setup available in the AWI Air Chemistry Observatory. These activities aim at the number concentrations of INP in the air, active at temperatures above -25°C. Filter samples are collected on polycarbonate filters and immediately frozen for later analysis in the TROPOS laboratories (Wex et al. 2019). The weekly filter change and handling is done by the AWI-staff, as well. These samples are the first ever collected for INP analysis at Dronning Maud Land in Antarctica spanning the whole annual cycle. The here presented data cover the first 20 months of samples. 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 two full years of CCN data for *Neumayer Station III* have been gained (Fig. 4.11.1). 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}.

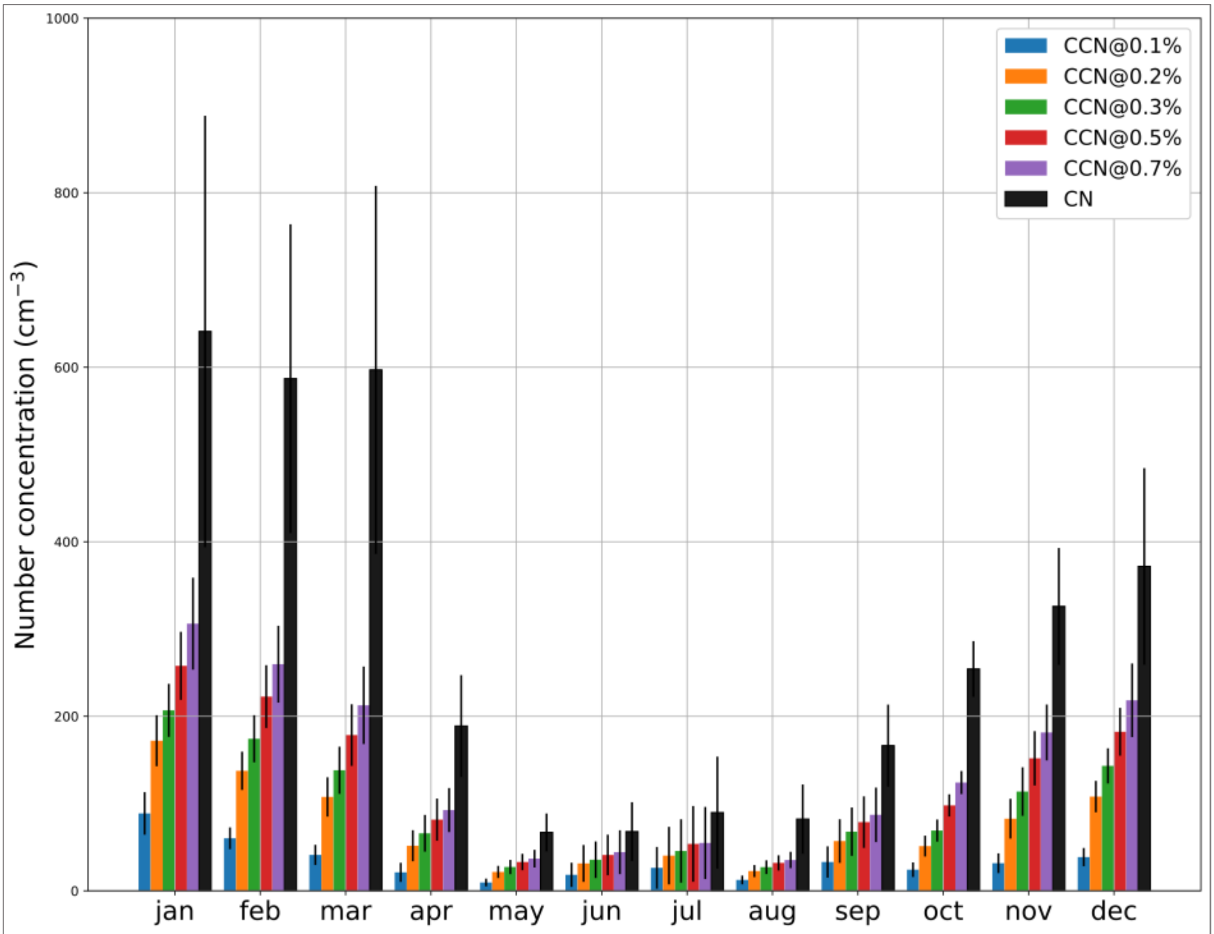


Fig.4.11.1: Two-years annual cycle of the number concentration of cloud condensation nuclei between 0.1 % and 0.7 % supersaturation and the total particle concentration CN. The current data set ranges from December 2019 until November 2021.

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.

INP results

INP freezing spectra from the off-line analysis of all so far available filter samples is shown in Figure 4.11.2. In general, the INP concentrations are very low even compared to other measurements in the southern hemisphere (blue area: Tatzelt et al. 2021, grey area: McCluskey et al. 2018). As a preliminary result only few samples are ice active at temperatures warmer than -15° C, which might point 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.

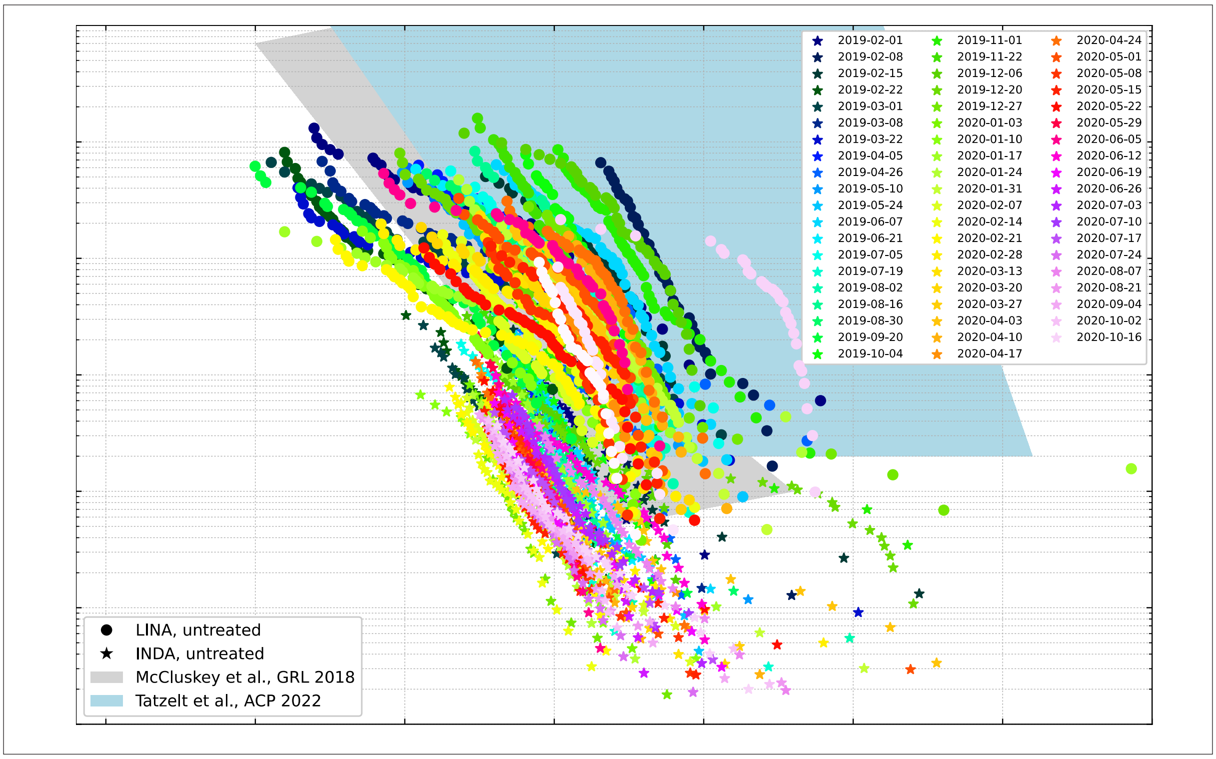


Fig.4.11.2: INP freezing spectra (blue area: Tatzelt et al. 2021, grey area: McCluskey et al. 2018). Sample period ranges from Feb 2019 until Oct 2020 with weekly to biweekly resolution. The date gives the start day of the sampling period.

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.

SH position is 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 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

Ashbaugh LL, Malm WC, Sadeh WZ (1985) A residence time probability analysis of sulfur concentrations at grand Canyon National Park. Atmospheric Environment (1967) 19: 1263-1270 https://doi.org/10.1016/0004-6981(85)90256-2

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

Herenz P, Wex H, Mangold A, Laffineur Q, Gorodetskaya IV, Fleming ZL, Panagi M, Stratmann F (2019) CCN measurements at the Princess Elisabeth Antarctica research station during three austral summers. Atmospheric Chemistry and Physics 19: 275-294 https://doi.org/10.5194/acp-19-275-2019

McCluskey CS, Hill TCJ, Humphries RS, Rauker AM, Moreau S, Strutton PG, Chambers SD, Williams AG, McRobert I, Ward J, Keywood MD, Harnwell J, Ponsonby W, Loh ZM, Krummel PB, Protat A, Kreidenweis SM, DeMott PJ (2018) Observations of Ice Nucleating Particles Over Southern Ocean Waters. Geophys Res Lett 45: 11989-11997 https://doi.org/10.1029/2018gl079981

Petters MD, Kreidenweis SM (2007) A single parameter representation of hygroscopic growth and cloud condensation nucleus activity. Atmospheric Chemistry and Physics 7: 1961-1971

Roberts GC, Nenes A (2005) A continuous-flow streamwise thermal-gradient CCN chamber for atmospheric measurements. Aerosol Sci Technol 39: 206-221

Tatzelt C, Henning S, Welti A, Baccarini A, Hartmann M, Gysel-Beer M, van Pinxteren M, Modini RL, Schmale J, Stratmann F (2021) Circum-Antarctic abundance and properties of CCN and INP. Atmos Chem Phys Discuss [preprint] https://doi.org/10.5194/acp-2021-700

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

4.12 EDEN ISS

Vincent Vrakking[1] (not in the field), Jess Bunchek[2];	[1]DE.DLR
Not in the field: Daniel Schubert[1], Paul Zabel[1], Conrad	[2]GOV.NASA
Zeidler[1], Markus Dorn[1], Robert Ferl[3], Anna-Lisa Paul[3]	[3]EDU.UFI

Objectives

Sustained human presence in space requires the development of new technologies to maintain environmental control, to manage wastes, 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* (*NM-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, dubbed the Mobile Test Facility (MTF), has been designed to provide fresh produce for overwintering crews at *NM-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 *NM-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; 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, and will be, 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.

Work in field

ANT-Land 2020/21 Neumayer Station III summer field season

A detailed overview of EDEN ISS related activities carried out by members of the German Aerospace Center and NASA during the ANT-Land 2020/21 summer season has been documented in the previous year's ANT-Land report (Vrakking et al. 2021).

Nominal Operations Phase – 2020/21 Neumayer Station III winter season

For the ANT-Land 2020/21 winter field season, operational activities were carried out by the dedicated on-site operator from NASA who stayed at *NM-III* as part of the regular overwintering crew. Remote support was provided by the consortium partners to assist the overwinterers in operating the greenhouse.

The EDEN ISS greenhouse was in operation since the 2 March 2021, when the overwinterer, together with the summer season expedition crew member of the German Aerospace Center, carried out the initial sowing operations in the greenhouse.

Once the summer season ended, the on-site operator, with occasional support from the rest of the overwintering crew, took over all activities within the greenhouse.

Most of the time needed for operations of the EDEN ISS greenhouse was dedicated to nominal operational, scientific, and maintenance activities, such as:

- Seeding various crops
- Transferring juvenile plants from germination area to cultivation trays
- Pruning/training fruiting crops, such as tomatoes and cucumbers
- Harvesting various crops
- Microbial sampling within the facility

- Sampling and storing harvested biomass
- Cleaning and disinfecting surfaces, filters and tanks
- Exchanging consumables (e.g. filters, oxygen tablets, ozone cells)
- Regular (weekly) tele-cons with remote operations team in Bremen
- Emptying waste water tanks and refilling fresh water tanks
- Preparing and exchanging nutrient stock solutions
- Preparing and exchanging acid and base supply
- Sensor calibration
- Cleaning and repairing thermal control system piping leaks
- Cleaning and exchanging misting nozzles in the aeroponic plant cultivation trays
- Repairing and exchanging pumps
- Time lapse imaging, videography and photography for data collection and outreach

In total 315 kg of fresh food was produced for the overwintering crew between March 2021 and January 2022, with the final harvest on 15 January 2022. Valuable additional knowledge was gained about the operation of the greenhouse and a large amount of scientific data, as well as samples, were collected throughout the year. This resulted in improved operation procedures, communication, and control software. Furthermore, technical issues were observed that need to be improved in order to optimize the operation of the greenhouse, so that more food can be produced with fewer resources.

In parallel with the operations on-site at *NM-III*, data evaluation, documentation, and publication from the previous winter seasons were continued by the EDEN ISS partners. Details are provided in a later section.

ANT-Land 2021/22 Neumayer Station III summer field season

During the 2021/22 summer season, no additional project members from the German Aerospace Center travelled to Antarctica, so all activities were instead carried out by the on-site operator, with invaluable support from the summer season crew. As the EDEN ISS greenhouse facility is not planned to be utilized during the 2022 winter season, and is scheduled for return to Germany at the beginning of 2023, the focus of the activities during the summer season was to conclude final plant harvests, clean the facility, and prepare the different subsystems for an extended hibernation phase for the remainder of 2022.

During this hibernation phase, most subsystems are shut down, with only critical systems enabled to maintain the internal climate at an acceptable level and with the remote monitoring and control capabilities fully operational to allow the project team to monitor conditions from Germany.

During the summer season at *NM-III*, the following work was carried out with respect to the EDEN ISS project:

- Facility inspection and status documentation
- Microbial sampling within the facility
- Cleaning the facility in preparation of maintenance and repair work

- Cleaning the Nutrient Delivery System (NDS) piping with hot water
- Exchanging consumables (e.g. CO2 canisters, filters)
- Testing the EDEN ISS safety system (gas concentration and smoke sensors)
- Preparing return freight and documentation for ship transport to Europe
- Draining cooling fluid from the TCS piping for the LED cooling loop
- Cleaning and storing aeroponic plant cultivation trays
- Inspecting and cleaning the Atmosphere Management System (AMS) cooling coil
- Inventorying consumables and equipment in the MTF, the multi-purpose laboratory, and the various storage areas
- Safety briefings for the 2022 winter field season crew

For the ANT-Land 2022/23 winter field season, as mentioned, no operational activities are scheduled. Periodic inspections of the facility will be carried out by the on-site overwintering crew to identify and address any potential issues; the facility will be monitored remotely from the Mission Control Center in Bremen to ensure the internal environment stays at the desired setpoints.

Preliminary (expected) results

Detailed data and sample analyses from the 2021/22 operations phase are still ongoing. However, some preliminary results from previous years have already been collected and are described below.

Aside from the data which have previously been published, such as the performance of the Plant Health Monitoring system (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 ISPR plant cultivation system performance (Boscheri et al. 2019), a number of new publications have been prepared based on results from the Antarctic operations phases.

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. Design of this greenhouse demonstrator is ongoing, and a publication on the current status is anticipated for later 2022.

Furthermore, additional information on crew time and work load has been presented (Poulet et al. 2021; 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). A publication on the detailed power and energy demand of the EDEN ISS Mobile Test Facility is currently being prepared.

NASA Hardware Testing

For the 2021 season, a novel plant cultivation system developed at NASA's Kennedy Space Center was brought to Antarctica for testing in the MTF. The goals of this hardware testing were to compare the performance of the system in the MTF and with an operator independent of the hardware development with performance of the system at NASA's facilities, as well as to compare biomass production in the NASA hardware with the same crops being cultivated in the aeroponic system of the EDEN ISS greenhouse. The NASA system is a passive porous tube nutrient delivery system, with a small water reservoir which is manually filled with nutrient solution. Once the system is primed (e.g. filled with nutrient solution and air having been vented from the system), the nutrient solution is taken up by the plant roots without requiring pumps.

Fig. 4.12.1: Lettuce grow-out in the NASA plant cultivation system

Throughout the year, three plant cultivation cycles were successfully completed: the first two grow-outs with 'Outredgeous' lettuce (see Fig. 4.12.1) and the third grow-out with 'Red Robin' tomato. Plant tissue samples for microbiological, molecular, and nutrition analyses were collected during both 'Outredgeous' lettuce grow-outs in both the NASA system and concurrent aeroponic tray system to enable direct comparison of the biomass produced in the two systems. The hands-on experience with the system and the comparative plant production data will help to improve both systems going forward.

Fig. 4.12.2: Germinating plants in the Future Exploration Greenhouse in March 2021

Biomass production

Table 4.12.1 shows the amount of biomass harvested each month during the 2021 operations phase. As mentioned previously, the facility was put into operational mode at the beginning of March, with first sowing occurring on the 2 March. Figure 4.12.2 shows the first germinating plants on the 15 March. First harvest occurred at the beginning of April and the last harvest of the aeroponic trays occurred on 15 January, 2022. In total, around 315 kg of fresh edible biomass was harvested.

Tab. 4.12.1: Monthly fresh biomass harvest during the 2021 winter season

Month	Fresh Weight Edible Biomass [kg]
April	22.47
May	37.21
June	32.32
July	16.35
August	23.17
September	28.79
October	22.95
November	54.56
December	50.86
January	26.25

Based on feedback from the previous operation phases, the variety of cultivars available for cultivation in the MTF had again been greatly increased for the 2021 winter season. Among the new crops were cauliflower, broccoli, beans, peas, ‘Amoroso’ tomatoes, and new pepper cultivars. The new crops and cultivars were grown to determine their performance in the closed-loop growth environment of the MTF, the crew time and effort required to grow them and, most importantly, to provide additional variety to the winter crew at *Neumayer Station III*.

Crew time and work load

For the 2021 mission, the on-site operator was asked to track the amount of time which was spent on activities related to operating the MTF. These activities included regular communication with the project team at DLR, nominal operations in the facility such as cleaning, seeding and harvesting, as well as off-nominal activities in case of, for example, component failures. Similar investigations were carried out in past years, but these previous investigations were limited in the accuracy of crew time tracking and the differentiation of crew time spent across multiple activities carried out within the greenhouse. To improve the data collection process in the 2021 season, the on-site operator recorded crew time with a Timeular Tracker device and software. The Timeular system allowed for straightforward monitoring of crew time for different activities by changing the orientation of an 8-sided tracking die. Depending on this orientation, and the activity assigned to each side of the die, time was automatically tracked and assigned to a specific task in the companion software application. Tracked categories were Daily Check, Sowing, Pruning/Trellising, Harvesting, Cleaning, Repair, Maintenance, and Miscellaneous.

Based on the experience of the on-site operator these categories did not fully cover all the different tasks which needed to be carried out. As such, a more detailed breakdown was established based on the monthly crew survey, with crew time assigned to 28 different tasks (ranging from environment monitoring to plant pollinating to produce cleaning) across 5 categories (Daily operations, Cultivation Operations, Routine Operations, Maintenance and Utilization).

Whenever multiple members of the winter crew were simultaneously active in the MTF, such as during larger harvests or off-nominal events, crew time was tracked manually for additional crew members.

An overview of the daily average crew time needed for the main categories of tasks is presented below in Table 4.12.2. Note that the time periods in the left column reflect the time period between two surveys.

The data presented in Table 4.12.2 reflects the crew time of the dedicated on-site operator and does not include the crew time of the other members of the winter crew.

Tab. 4.12.2: Crew Time Measurements from the 2021 experiment phase

Time Period	**Daily Average Crew Time [min]**				
	Daily	**Cultivation**	**Routine**	**Maintenance**	**Utilization**
24 March – 21 April	26.5	22.0	43.0	91.1	36.0
22 April – 15 May	18.6	106.8	11.6	55.2	97.0
16 May – 17 June	12.6	82.0	13.0	76.2	59.4
18 June – 16 July	18.6	79.8	19.8	37.4	58.8
17 July – 13 August	20.4	50.7	57.0	64.1	46.0

Time Period	Daily Average Crew Time [min]				
	Daily	Cultivation	Routine	Maintenance	Utilization
14 August – 13 September	22.1	59.5	51.5	55.8	80.0
14 September – 13 October	16.7	88.5	30.5	9.8	118.5
14 October – 16 November	19.6	81.9	28.1	9.4	111.2
17 November – 7 December	20.2	111.0	42.4	13.3	116.8
8 December – 20 January	9.0	90.5	42.5	9.0	86.5

Psychological investigations

As part of ongoing investigations into the effects of isolated, confined, extreme environments, as well as the influence of human-plant interactions on crew biobehavioural health, volunteering winter crew members completed a monthly survey from February 2021 through January 2022, plus a pre- and post-mission survey completed in November 2020 and March 2022, respectively. Separate questionnaires were previously completed by the 2018 winter crew, with results published in Schlacht et al. 2019. The questionnaire for the 2021 season was adapted from the Veggie questionnaire used by astronauts on the ISS. This updated survey was comprised of 11 areas that aimed to capture enjoyment and time spent conducting various plant-related activities, sensory stimulation, and the active and passive psychological effects of having live plants and available fresh food in an environment where no other source of either is available.

Additionally, the on-site operator completed NASA Task Load Index (TLX) surveys from October through December 2021. The TLX surveys, coupled with crew time reporting and pairwise comparison surveys, aimed to capture the relationship between crew time and workload and to identify which tasks should be conducted or prioritized with respect to workload, as well as identify where augmented reality could be integrated into future system designs to better support operators.

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 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

Boscheri G, et al. (2016) The EDEN ISS Rack-like Plant Growth Facility. 46th International Conference on Environmental Systems.

Boscheri G, et al. (2019) EDEN ISS Rack-like food production unit: results after mission in Antarctica. 49th International Conference on Environmental Systems, Boston, Massachusetts, United States.

Fahrion J, et al. (2019) Microbial Monitoring in the EDEN ISS greenhouse, a mobile test facility in Antarctica. Extreme Microbiology in Frontiers in Microbiology.

Maiwald V, et al. (2020) From ice to space: a greenhouse design for Moon or Mars based on a prototype deployed in Antarctica, CEAS Space Journal, Springer, https://doi.org/10.1007/s12567-020-00318-4, ISSN 1868-2502

Nesteruk S, et al. (2021) Image Compression and Plants Classification Using Machine Learning in Controlled-Environment Agriculture: Antarctic Station Use Case, IEEE Sensors Journal, 1–1, https://doi.org/10.1109/JSEN.2021.3050084

Poulet L, et al. (2021) Crew time in a space greenhouse using data from analog missions and VEGGIE, Life Sciences in Space Research, 31, pages 101-112, Elsevier, https://doi.org/10.1016/j.lssr.2021.08.002, ISSN 2214-5524

Schlacht I, et al. (2019) Impact of Plants in Isolation: The EDEN-ISS Human Factors Investigation in Antarctica. In: Stanton, N. (eds), Advances in Human Factors of Transportation. AHFE 2019. Advances in Intelligent Systems and Computing, vol. 964, Springer, Cham. https://doi.org/10.1007/978-3-030-20503-4_71

Tucker R, et al. (2020) NDVI imaging within space exploration plant growth modules – A case study from EDEN ISS Antarctica, Life Sciences in Space Research, 26, pages 1-9, Elsevier, https://doi.org/10.1016/j.lssr.2020.03.006, ISSN 2214-5524

Vrakking V, et al. (2017) Service Section Design of the EDEN ISS Project. 47th International Conference on Environmental Systems.

Vrakking V, et al. (2021) 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 758, pages 59-66, Bremerhaven, Germany, https://doi.org/10.48433/BzPM_0758_2021, ISSN: 1866-3192

Zabel P, et al. (2015) Introducing EDEN ISS: A European project on advancing plant cultivation technologies and operations. 45th International Conference on Environmental Systems.

Zabel P, et al. (2017) Future Exploration Greenhouse Design of the EDEN ISS Project. 47th International Conference on Environmental Systems.

Zabel P, et al. (2019) Crewtime in a Space Greenhouse based on the Operation of the EDEN ISS Greenhouse in Antarctica. 49th International Conference on Environmental Systems, Boston, Massachusets, USA, 2019

Zabel P, et al. (2020) Biomass Production of the EDEN ISS Space Greenhouse in Antarctica during the 2018 experiment phase. Frontiers in Plant Abiotic Stress – Higher Plants Algae and Cyanobacteria in Space Environments.

Zeidler C, et al. (2019) The Plant Health Monitoring System of the EDEN ISS Space Greenhouse in Antarctica during the 2018 Experiment Phase. Front. Plant Sci. 10:1457, https://doi.org/10.3389/fpls.2019.01457

Zeidler C, et al. (2021) Crew time and workload in the EDEN ISS greenhouse in Antarctica, Life Sciences in Space Research, Elsevier, https://doi.org/10.1016/j.lssr.2021.06.003, ISSN 2214-5524

Zeidler C, Woeckner G (2021) Using Augmented Reality in a Planetary Surface Greenhouse for Crew Time Optimization, ACM CHI 2021.SpaceCHI: Workshop on Human-Computer Interaction for Space Exploration, 14.05.2021, Virtual Conference

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

Not in the field: Saeid Bagheri Dastgerdi, Melanie Behrens, Maria Hoerhold, Martin Werner DE.AWI

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.

Work in field

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, are conducted. During the field season of ANT-Land 2021/22 necessary maintenance work on the instrument was done. Due to the Covid pandemic situation, no personnel could travel for this maintenance work to *Neumayer Station III*, but instead the work was done remotely with the support of the overwintering team. The maintenance included the exchange of spare parts and re-calibration of the instrument to ensure the automatic, continuous isotope analyses of the atmospheric water vapour for another 12 months, at least.

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.

The first fully continuous monitoring of water vapour isotopic composition at *Neumayer Station III*, Antarctica, during the 2-year period from February 2017 to January 2019 have now been published in the scientific journal The Cryosphere (Bagheri Dastgerdi et al. 2021). Seasonal and synoptic-scale variations in both stable water isotopes $H_2{}^{18}O$ and HDO are reported, and their links to variations in key meteorological variables are analysed. In addition, the diurnal cycle of isotope variations during the summer months (December and January 2017/18 and 2018/19) has been examined.

It was found that changes in local temperature and specific humidity are the main drivers for the variability in $\delta^{18}O$ and δD in vapour at *Neumayer Station III*, on both seasonal and shorter timescales. In contrast to the measured $\delta^{18}O$ and δD variations, no seasonal cycle in the deuterium excess signal in vapour (d-excess) is detected. However, a rather high uncertainty in measured d-excess values especially in austral winter limits the confidence of this finding. Overall, the d-excess signal shows a stronger inverse correlation with specific humidity than with temperature, and this inverse correlation between d-excess and specific humidity is stronger for the cloudy-sky conditions than for clear-sky conditions during summer-time. Back-trajectory simulations performed with the FLEXPART model show that seasonal and synoptic variations in $\delta^{18}O$ and δD in vapour coincide with changes in the main sources of water vapour transported to *Neumayer Station III*. In general, moisture transport pathways from the east lead to higher temperatures and more enriched $\delta^{18}O$ values in vapour, while weather situations with southerly winds lead to lower temperatures and more depleted $\delta^{18}O$ values. However, on several occasions, $\delta^{18}O$ variations linked to wind direction changes were observed, which were not accompanied by a corresponding temperature change. Comparing isotopic compositions of water vapour at *Neumayer Station III* and snow samples taken in the vicinity of the station reveals almost identical slopes, both for the $\delta^{18}O$-δD relation and for the temperature-$\delta^{18}O$ relation.

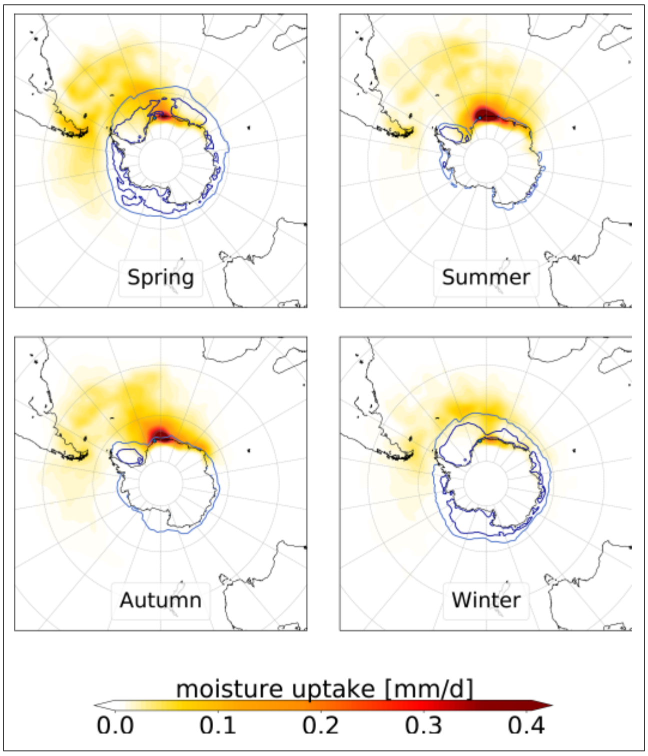


Fig. 4.13.1: Simulated mean moisture uptake occurring within the boundary layer in the pathway to Neumayer Station III during the last 10 days modelled by FLEXPART using ECMWF ERA5 data, for spring (SON), summer (DJF), autumn (MMA), and winter (JJA), considering the years of 2017 and 2018. The mean sea ice edge based on ERA5 reanalysis for ice coverage of more than 45 % and 90 % is shown as light blue and dark blue lines. (Figure taken from Bagheri Dastgerdi et al., TC, 2021)

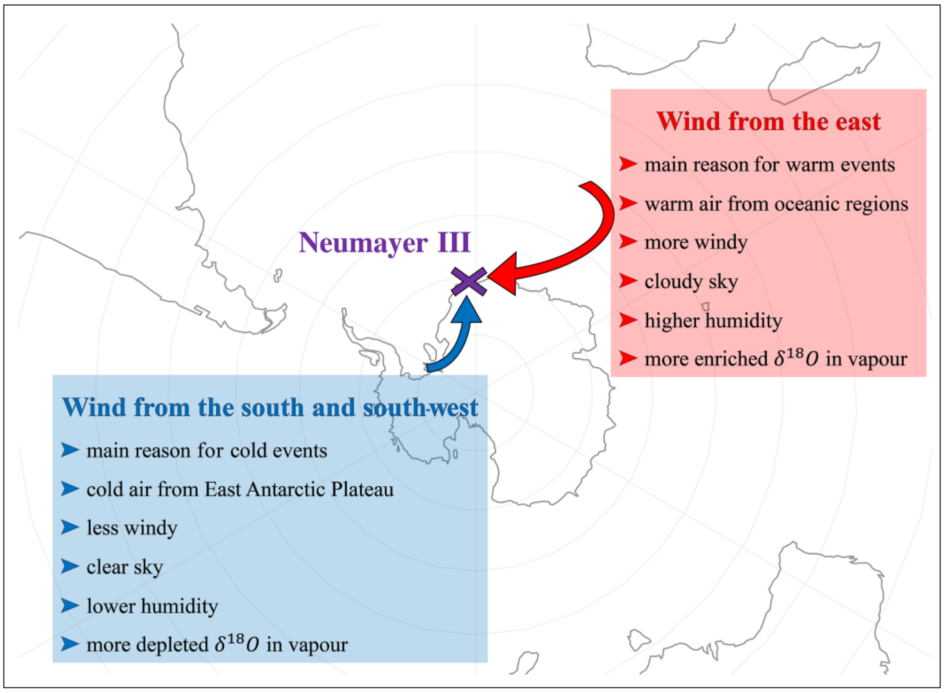


Fig. 4.13.2: Frequent wind patterns at Neumayer Station III and their meteorological and isotopic characteristics (Figure taken from Bagheri Dastgerdi et al., TC, 2021)

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 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.

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

Céline Le Bohec[1,2], Daniel Paranhos Zitterbart[3,4]
Aymeric Houstin[4], Alexander Winterl[4]

[1]FR.CNRS
[2]MC.CSM
[3]EDU.WHOI
[4]DE.FAU

Objectives

The goal of the project MARE is the operation of a long-term Emperor Penguin Life Observatory in Atka Bay (on land and at sea), to evaluate the dynamics and trends of this population, and, ultimately, to determine the amplitude of the adaptive capacities of the species.

Despite the pristine appearance of Antarctica, its species and ecosystems are under considerable threat. 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. Up to now, the general biology of the entire species (e.g. all the breeding, life-history, and demographic parameters) is based on the monitoring of a single colony: the one of Pointe Géologie in Terre Adélie, located at ca. 20 min walking distance to the *Dumont D'Urville Station*. 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 scebario. In that context, this second worldwide Life Observatory of emperor penguins (started in 2017 in Atka Bay) aims to measure the species' adaptive potential to climate change and associated fluctuations in prey abundance and distribution.

WP1: Life-long monitoring of the birds is performed using Radio-Frequency Identification (RFID). Since 2017, each year and over several decades, 300 five-month-old emperor penguin chicks from Akta Bay colony (out of the 7,000 chicks present at the end of the breeding cycle each year) are marked with small Passive Integrated Transponders (PIT) in order to monitor birds of known-age and -history throughout their life. Microtagged individuals are detected and identified, year after year, with Mobile Identification Systems (MIS), i.e. RFID-antenna-sledges temporarily deployed on access passageways to birds' breeding sites (Fig. 4.14.1) and RFID-antenna mounted on ECHO-Rover (Fig. 4.14.2).

WP2: As umbrella species, seabirds play an important role in determining the size of conservation areas. Thus, gathering knowledge about the species' distribution at sea is fundamental to help us to define and map marine biological 'hotspots' and/or Marine Protected Areas (MPA). Up to know, knowledge of the distribution at sea and of foraging activities and strategies of emperor penguins is scarce and anecdotic, a few individuals from a few (more accessible) populations have been equipped one or a couple times. To fill this gap, since 2017, emperor penguins from Atka Bay colony are equipped, over regular intervals and at different stages of their life cycle, with miniaturized multi-sensor biologgers (TDR, Accelerometer, Sound, VHF-GPS or ARGOS) to understand how this species uses the space at sea during the breeding/wintering season, their migration, and their wintering at-sea habitats.

In addition, through yearly collection of stomach contents (dead birds, mainly chicks), we aim to determine the geologic provenance of the gastroliths gathered on the sea floor, the diet and trophic level (and their yearly variability) on which they are foraging. Reciprocally, geological contents (pebbles) collected in these samples will improve the geologic characterization of the foraging grounds and thus the glacial-geologic history of the Ekströmisen region (in collaboration with Prof. O. Eisen AWI and Dr. N. Koglin BGR). Moreover, prevalence and yearly variability of microplastics and contaminants are from now under investigations through the analyses of the stomach contents of these dead birds (collaboration with Dr. G. Gerdts, AWI).

The proximity of *Neumayer Station III* research station to the Atka Bay emperor penguin colony represents a tremendous opportunity to fill these objectives. Moreover, the characteristics of both colonies – Pointe Géologie (the colony our team is also monitoring electronically through camera systems within the framework of the IPEV 137 project) – and Atka Bay colonies. They are very different regarding numerous aspects that make their comparison even more valuable in order to obtain a realistic picture concerning the health and potential threats of a species including their adaptive potentialities while facing environmental changes.

Fig. 4.14.1: RFID-antenna-sledge temporarily deployed on the emperor penguin colony

Fig. 4.14.2: ECHO-Rover and SPOT

Work in field

The ANT-Land 2021/22 summer season of the MARE programme ran between 6 November 2021 and 14 January 2022 on the Atka Bay emperor penguin colony.

Between 11 November 2021 and 6 January 2022, 300 five-month-old emperor penguin chicks from the colony of Atka Bay were microtagged. Each of these chicks was also measured (flippers and beak), blood sampled, weighted, and temporarily marked before release (for not recapturing them another time).

Between 11 November 2021 and 10 January 2022, 3 RFID-antenna-sledges have been tested and 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. We also successfully tested and used the ECHO rover to approach groups of penguins from the sea-ice sub-colony to assess the maneuverability of ECHO and the potential impact of its movement on the emperor penguins' reaction and behaviour.

Between 11 November 2021 and 7 December 2021, 22 breeding emperor penguin adults were equipped with GPS-TDR-Acc-VHF dataloggers, among which 3 were equipped with sound recording-biologgers. After identifying an adult feeding its chick at the peripheral of the colony, we isolated the duo outside of the colony in a corral. The chick was handled as previously described, and adults were measured (flippers and beak), blood and feather sampled, marked subcutaneously with a PIT-tag, externally equipped with data-loggers using Tesa-tapes and Colson-ties, weighted, and temporarily marked before release (in order to identify the bird for the recapture/retrieval of the equipment). Then, visual observations and checks with VHF-antennas were performed every approximately 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 19 of 22 (86 %) deployed devices. 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.

From the 31 December 2021 to 6 January 2022, 8 well-molted fledglings, leaving the colony in groups to reach the sea, were captured and equipped with ARGOS-dataloggers (Fig. 4.14.3).

Fig.4.14.3: Emperor penguin fledging chicks equipped with ARGOS dataloggers

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 94 dead emperor penguin chicks were collected (59 frozen 1-3 mo chicks, 35 freshly dead 5 mo chicks) for biometry. Stomach contents of 26 of them were collected.

Finally, during the stay of the BBC team, we spent several hours to half-days with the team to advise them, let them film our work in the field and discuss the contribution of MARE programme/results to the protection of the Emperor penguin.

Preliminary (expected) results

The first “on-land” objective of MARE programme, which aims to model the population dynamics/trends of Atka Bay colony thanks to the yearly microtagging of fledging chicks and identification through MIS (use of RFID-antenna-sledges and ECHO-Rover started this season 2021–2022), is based on a long-term data collection (capture-mark-recapture method): age-specific vital traits (survival and breeding success rates) necessary to feed the population models will be available after a minimum of 10 years of electronic monitoring (note that to our knowledge in *Pointe Géologie* colony, emperor penguins start to reproduce in average at 5-year old).

Regarding the phenology/census of the Atka Bay emperor penguin colony this season 2021/2022: interestingly and in contrast to most of the previous monitored years, the colony was and remained mainly on the ice shelf, divided in 2 main sub-colonies: the eastern one on the shelf (close by the "Winterlager" area) composed of 3 groups, and the western one (close by the Postbox), almost until the end of December. 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.

Chick mortality was very low this year: from 6 November 2021 to 10 January 2022, only 35 chicks were found dead on the colony (compared to the 1,251 dead chicks in 2019–2020), and one predation/scavenging event by Southern Giant Petrels (*Macronectes giganteus*) was observed.

The second at-sea objective of MARE Programme, which aims to identify crucial feeding grounds (precious tool for mapping MPAs) and foraging strategies of emperor penguin breeding in Atka Bay and its variability over time thanks to biologging technology, was highly fruitful in terms of publications over the last year (Houstin et al. in press, in revision), and additional analyses are still in progress – the publication (Houstin et al. in prep.) will be submitted soon. For instance, we discovered that juvenile emperor penguins commonly travel beyond the limits of the jurisdiction of the regulatory agency of the Southern Ocean, much further north than previously known. We showed that they spent the vast majority of their time outside of the extents of proposed or existing MPAs, and their distribution extends up to 1,500 km north of the species range used by International Union for Conservation of Nature (IUCN) to evaluate the global conservation status of the species. These results demonstrate that existing and planned conservation efforts in the Southern Ocean do not provide effective protection for emperor penguins. Such data are crucial to design MPAs and assess the status of the species in the IUCN Red List of Threatened Species. Moreover, data collected this season 2021–2022 and up to now (Figs. 4.14.4 and 4.14.5) allow us to identify and evaluate yearly changes in their foraging strategies respectively mirroring these changes occurring in their environment.

Finally, geological analyses of the gastroliths collected in the 2018/19 season are in progress at BGR, with first results obtained within the framework of a MSc thesis (Hoog 2020). The analysis of 41 stomachs collected in the 2018/19 season has been completed at the AWI

Heligoland, in collaboration with partners from Switzerland (University of Basel), and the publication (Leistenschneider et al. in prep.) will be submitted soon.

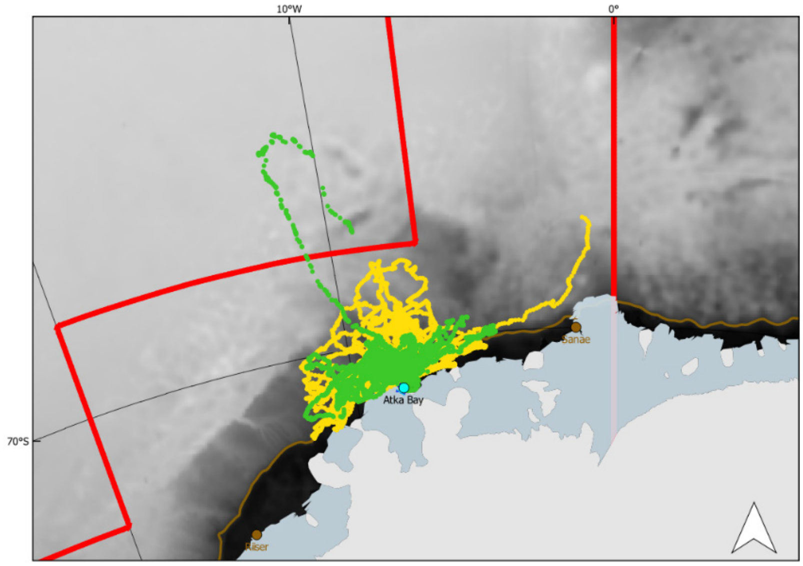


Fig. 4.14.4: Distribution at sea during the summer (GPS-tracks) of adult emperor penguins equipped at Atka Bay *in 2017–2018 and 2018–2019 (in yellow; Houstin et al. in prep.) and in 2021–2022 (in green; unpublished data).*

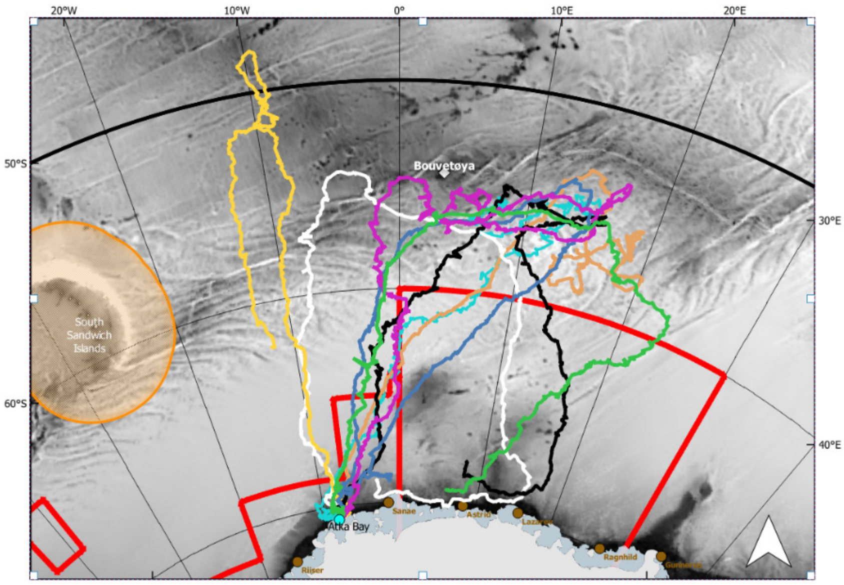


Fig. 4.14.5: Distribution at sea over their first months at sea of the 8 juvenile emperor penguins tagged with ARGOS at Atka Bay *in 2021–2022 (unpublished data)*

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.

in press, in revision) 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 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

Houstin A, Zitterbart DP, Winterl A, Richter S, Planas-Bielsa V, Chevallier D, Ancel A, Fournier J, Fabry B, Le Bohec C (2022) Biologging of emperor penguins – attachment techniques and associated deployment performance. In press in PLOS ONE (bioRxiv: https://doi.org/10.1101/2021.06.08.446548).

Houstin A, Zitterbart DP, Heerah K, Eisen O, Planas-Bielsa V, Fabry B, Le Bohec C (2022) Juvenile emperor penguin range calls for extended conservation measures in the Southern Ocean. Final revision in Royal Society Open Science (bioRxiv: https://doi.org/10.1101/2021.04.06.438390).

Hoog A, 2020. Petrologie und Geochemie von Pinguin-Gastrolithen aus der Atka-Bucht, Ekström Schelfeis, Dronning Maud Land, Antarktis. MSc Arbeit, BGR/Universität Hannover, 107p.

4.15 MICA-S – Magnetic Induction Coil Array – South

Tanja Fromm[1], Benita Wagner[1], Alicia Rohnacher[1], Timo Dornhöfer[1], Lorenz Marten[1]
Not in the field: Jölund Asseng[1], Hyomin Kim[2], Marc Lessard[3], Khan-Hyuk Kim[4], Hyuck-Jin Kwon[5], Jürgen Matzka[6], Michelle Salzano[3]

[1]DE.AWI
[2]EDU.NJIT
[3]EDU.UNH
[4]KR.KHU
[5]KR.KOPRI
[6]DE.GFZ

Objectives

The objective is to continuously observe 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 a heavy storm in August 2021 the data acquisition computer and the GPS antenna were damaged beyond repair. Both devices could be replaced shortly after.

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 2021/22 the magnetometer has been moved into the new pit and setup with the currently measured magnetic declination of -14° C and an inclination of -60° C.

Due to the ice shelf movement of approximately 154 m per year, the location of the pit also changes. At 1 February 2022 it was located at 70°40'34,5"S and 8°16'29,0"W.

Preliminary results

Figure 4.15.1 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 geomagnetic latitudes.

Since its installation in January 2018, results from MICA-S have been published by Salzano et al. 2019; Kim et al. 2019; Kim et al. 2020; Kim et al. 2021 and Salzano et al. (under review).

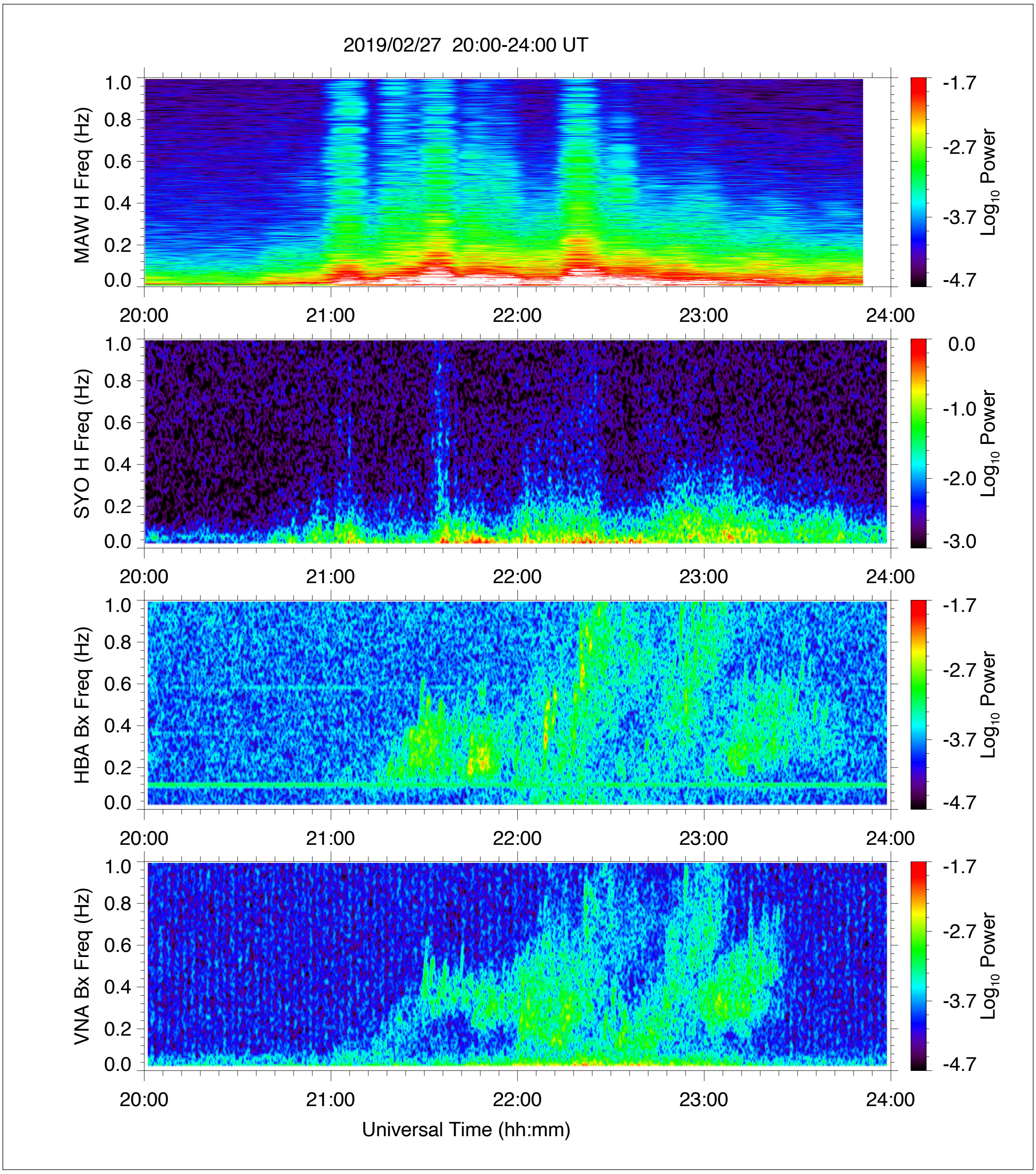


Fig. 4.15.1: Geomagnetic spectrograms for 27 February 2019 using data from Antarctic stations Mawson (MAW), Syowa (SYO), Halley Research Station (HBA), and Neumayer Station III (VNA). Intervals of Pulsations of Diminishing Periods (IPDPs), a subtype of EMIC waves, are observed at HBA and VNA (-62.2 and -60.6 CGM lat; Salzano et al, under review). Near-simultaneous Pi1Bs are observed at MAW and SYO (-70.4 and -66.5 CGM lat).

Data management

Data (plots and cdf-files) are 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.

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

Salzano M, Lessard M, Kim H, Engebretson MJ, Horne RB, Clilverd MA, Seemala GK, Sinha AK, Sinha S, Kim KH, Fromm T, Matzka J, Kadokura A, Tanaka Y, Waters CL (2019) Investigating the Relationship between IPDPs and Pi1B Waves. American Geophysical Union, Fall Meeting 2019, abstract #SM23F-3279.

Kim K-H, Kwon H-J, Kim HH, Jin, Shin J, Fromm T, Matzka J and Lessard M (2019) Local generation of EMIC waves near the plasmapause: Coordinated magnetosphere-ionosphere-ground observations. Asia Oceania Geosciences Society, Annual Meeting, ST23-D5-AM1-308-00.

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

Kim H, Shiokawa K, Park J, Miyoshi Y, Miyashita Y, Stolle C, Kim K-H, Matzka J, Buchert S, Fromm T, Hwang J (2020) Ionospheric Plasma Density Oscillation Related to EMIC Pc1 Waves, Geophysical Research Letters, 47(15). https://doi.org/10.1029/2020gl089000.

Kim H, Shiokawa K, Park J, Miyoshi Y, Miyashita Y, Stolle C, Kim K-H, Matzka J, Buchert S, Fromm T, Hwang J (2020) Ionospheric Plasma Density Oscillation Related to EMIC Pc1 Waves, Geophysical Research Letters, 47(15). https://doi.org/10.1029/2020gl089000.

Salzano M et al, Modeling the effects of drift shell splitting in two case studies of simultaneous observations of substorm-driven Pi1B and IPDP-type EMIC waves, manuscript in preparation (under review in JGR: Space Physics).

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

Olaf Eisen[1,2], Mohammadreza Ershadi[5], Timo Dornhöfer[1], Lorenz Marten[1], Reinhard Drews[5], Tanja Fromm[1]
Not in the field: Ole Zeising[1], Daniel Steinhage[1], Tore Hattermann[3], Frank Pattyn[4]

[1]DE.AWI
[2]DE.Uni-Bremen
[3]NO.NPolar
[4]BE.ULB
[5]DE.Uni-Tübingen

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.

Work in field

After preparation of the maintenance on 24 November the autonomous pRES (ApRES) system at the site MIMO-EIS-8 was dug out by a team of four people over two hours and dismounted on 25 November 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 26 November 2021 with an antenna separation of 8 m. The system records measurements every hour with data storage in joint files about every 4 h (5 MB limit for file size). Additional pRES re-measurements were performed on 25 and 26 November at seven locations (MIMO-EIS-4 to MIMO-EIS-8, MIMO-EIS-A (formerly also known as site6) and MIMO-EIS-B (formerly also known as site7). Measurements at a new position, MIMO-EIS-C, were initialized and should be re-measured in the 2022/23 season (Tab. 4.16.1).

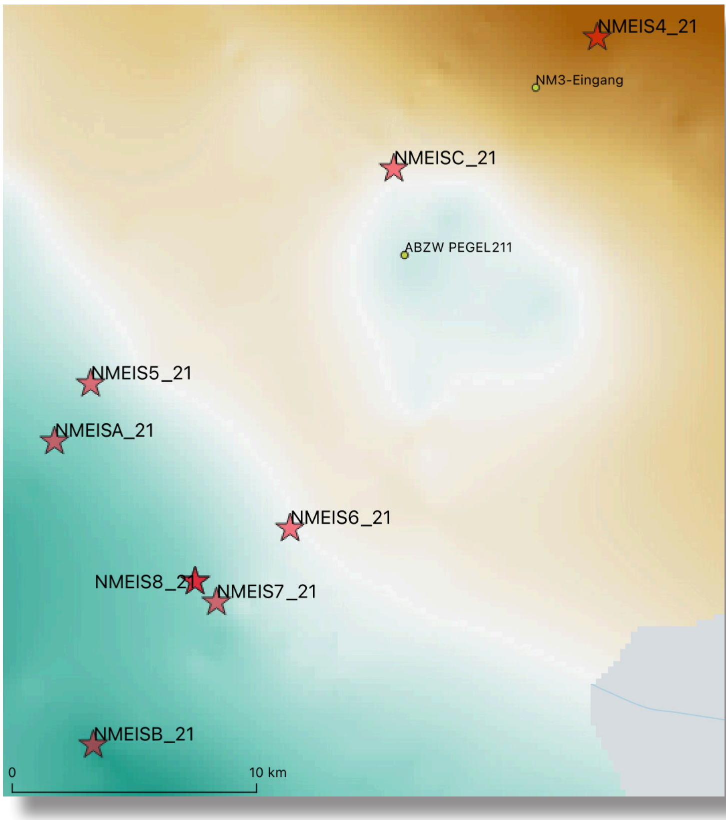


Fig. 4.16.1: Position of all MIMO-EIS measurement sites (red stars) on the Ekström ice shelf with key features indicated (positions as of season 2021/22). Coloured underlay is seafloor bathymetry (Smith et al. 2020) interpolated from seismic lines, with green showing the trough up to 900 m water column depth (dark green).

Fig. 4.16.2: Site MIMO-EIS-8: Retrieval of the ApRES system controller (photo left: yellow box in the center pit – indicated by red arrow) and two frame antennas (front and back pits) on 25 November and photo (right) of the site after completion of the new deployment on 26 November, with the system buried at about 20 cm depth below the current surface 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 without flag.

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.

As the objectives of MIMO-EIS are strongly overlapping with the those of the project ReMeltRadar, field operations and expertise were joined as much as possible. For instance, if the newly deployed polarimetric ApRES near the grounding line of Ekströmisen as part of ReMeltRadar (see Chapter 4.18) will successfully operate over the next year, it is considered to continue the operation of that system as a longer-term station as site MIMO-EIS-D. The added value of such joint operation was already evident during the season: first data analysis for the annual re-measurements indicated some issues with the coherence between the measurements from January 2021 and November 2021 at the site MIMO-EIS-6. Therefore, on 7 December 2021 the site was revisited and further measurements acquired during pRES measurements for the project ReMeltRadar. A second incidence was related to storage warning transferred via the Iridium health message. We therefore used the opportunity of the outgoing ReMeltRadar traverse on 2 January 2022, which passed near the site, to check and clean the SD cards in the instrument. The instrument was again set in a full operational state for unattended mode for the winter season and the 2021/22 season maintenance of the instrument was successfully terminated.

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 waiting after fresh snow accumulation), future measurements of the site MIMO-EIS-4 should only be conducted with a snow machine, as the usually very thick fresh snow cover near the Ekströmisen shelf edge makes operation of the Hilux cumbersome and less reliable off the main groomed routes north and east of NM (more details are available in the half-monthly report for November 2021).

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. 4.16.1). 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.

One difficulty is the slightly changing antenna distance from season to season at the discrete sampling sites because of different operators. Although this is not a particularly serious problem, it slightly increases the uncertainties in the derived properties.

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, apart during a short period where its operation was interrupted while an application of a new operation permit was pending. Analysis of the continuous ApRES data is ongoing. First results indicate that the temporal variability is very similar in both years 2020 and 2021. 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.

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. 4.16.1: Position of pRES measurements on Ekströmisen and preliminary values for the basal melt rate ab averaged over roughly three seasons. *1: only time period 2020/21–2021/22; *2: position 2019/20; *3 Initialization of measurements, no values for basal melt rate available yet.

Station	Latitude 2019/20 °	Longitude 2019/20 °	Latitude 2021/22 °	Longitude 2021/22 °	ab m/a
MIMO-EIS-4	-70.650367	-8.204067	-70.64796	-8.20669	2.05
MIMO-EIS-5	-70.749433	-8.813783	-70.74602	-8.81896	0.37
MIMO-EIS-6	-70.8127	-8.619417	-70.80945	-8.62387	0.33
MIMO-EIS-7	-70.83555	-8.712133	-70.83217	-8.71765	0.40
MIMO-EIS-8	-70.826067	-8.73145	-70.82333	-8.73736	0.55 *1
MIMO-EIS-A	-70.76807 *2	-8.862936 *2	-70.8769	-8.87788	0.34
MIMO-EIS-B	-70.880067	-8.872583	-70.6848	-8.4507	0.42
MIMO-EIS-C			-70.6848	-8.4507	n.a. *3

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.

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 cruise 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 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

Berger S, Helm V, Hattermann T, Neckel N, Glaude Q, Zeising O, Sun S, Pattyn F, Eisen O (2020). Basal melting of Dronning Maud Land ice shelves twice as high as previously estimated. EGUsphere, https://doi.org/10.5194/egusphere-egu2020-15477.

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

Eisermann H, Eagles G, Ruppel A, Smith EC & Jokat W (2020) Bathymetry beneath ice shelves of western Dronning Maud Land, East Antarctica, and implications on ice shelf stability. Geophysical Research Letters, 47, e2019GL086724. https://doi.org/10.1029/2019GL086724

Richter O, Gwyther D E, King MA, and 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

4.17 GrouZE – Grounding Zone of the Ekström Ice Shelf – Geophysical Characterization with GPS, Seismology and Magnetotelluric

Tanja Fromm[1], Timo Dornhöfer[1], Lorenz Marten[1], Louisa Kinzel[1];
Not in the field: Vera Fofonova[1], Oliver Ritter[2], Mirko Scheinert[3], Veit Helm[1], Angelika Humbert[1]

[1]DE.AWI
[2]DE.GFZ
[3]DE.TU-Dresden

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 are 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, in prep). 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 observerd 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 intend to 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 will allow us to locate icequake activity from 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 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.

Work in field

After a long delay in Capetown due to an extended quarantine of 40 days, the field work started at 27 December 2021 at *Neumayer Station III* preparing the traverse to the southern end of the Ekström Ice Shelf. The traverse departed at 2 January 2022 and reached the joint camp with the ReMelt-Radar group on the 3 January 2022. Within the next 10 days, we set up 15 three component broad band seismometer and 7 geodetic GNSS stations within 25 km distance of the grounding line (see Tab. 4.17.1). All stations were revisited to gather a first data set and ensure correct technical functionality. Additonally, we visited Forstefjell nunatak and serviced the seismometer station DS4, part of the geophysical observatory, and the GNSS station, part of the DML-GIA project, to accommodate for the reduced season due to Corona. The GrouZE traverse ended on the 12 January 2022, when the camp at the grounding line was dismantled and the traverse train relocated to the seismometer station VNA3 on Sorasen for the yearly maintanence work as part of the Geophysical observatory.

Tab. 4.17.1: Positions and setup dates of seismological and GNSS stations

Station	Date	Lat	Lon	Distance from Camp [km]
GR01	03.01.22	-71.664243	-8.446323	8.5
GR02	03.01.22	-71.603462	-8.407115	15.0
GR03	06.01.22	-71.667585	-8.625893	6.5
GR04	04.12.22	-71.672204	-8.778908	8.8
GR05	06.01.22	-71.713914	-8.688444	3.5
GR06	04.01.22	-71.720478	-8.367719	7.9
GR07	06.01.22	-71.699569	-8.656309	3.6
GR08	06.01.22	-71.712314	-8.627925	1.8
GR09	04.01.22	-71.726786	-8.528122	2.3
GR10	04.01.22	-71.734428	-8.715425	4.4
GR11	09.01.22	-71.791628	-8.707241	8.5
GR12	09.01.22	-71.885089	-8.786180	19.1
GR13	09.01.22	-71.888681	-8.915400	21.5
GR14	10.01.22	-71.924614	-8.718864	22.7
GR15	10.01.22	-71.921816	-8.848584	23.7
GPS01	06.01.22	-71.689138	-8.614407	4.0
GPS04	06.01.22	-71.720096	-8.681335	3.1
GPS05	05.01.22	-71.734536	-8.710578	4.2
GPS02	04.01.22	-71.705903	-8.649805	2.9
GPS03	06.01.22	-71.713184	-8.664934	2.8
GPS06	06.01.22	-71.770087	-8.795499	8.7
GPS07	09.01.22	-71.882095	-8.938741	21.3

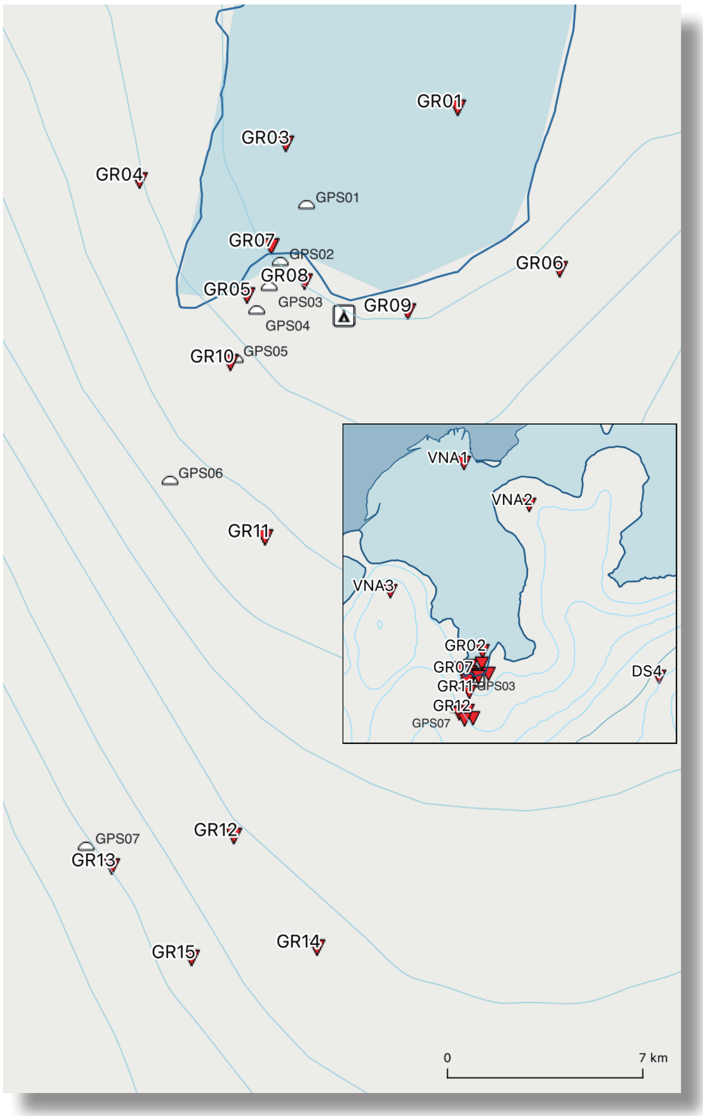


Fig. 4.17.1: Positions of seismological stations (GR01-GR15) and GNSS stations (GPS1-GPS7). The inset shows the larger area with the seismometer stations of the Geophysical Observatory for orientation. VNA1 is approximately at Neumayer Station III.

Preliminary (expected) results

A first look at the seismological data set of approximately 18 hours with the complete network reveals tide related icequakes on the stations within 8 km distance to the grounding line (GR01. To GR11, Figs. 4.17.1 and 4.17.2). Stations 12 to 15 do not reveal obvious tidal seismicity. Teleseismic earthquakes are visible on all 15 seismometer stations.

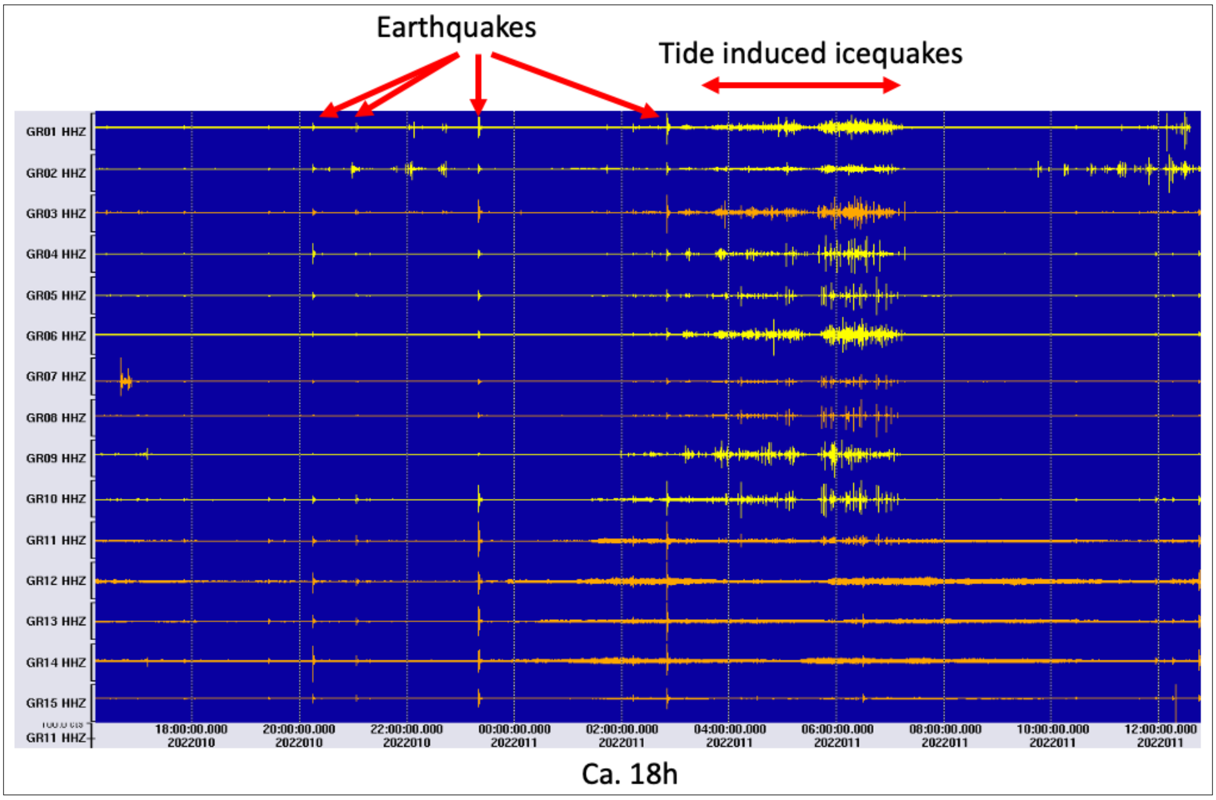


Fig. 4.17.2: The 18 hours long seismogram of the compete seismic network reveals tide induced icequakes at seismometer stations GR01–GR11 and teleseismic earthquakes registrations at all stations.

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.

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 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

Fromm T, Schlindwein V, Helm V, Fofonova V (in prep.) Observations of the quarter- and terdiurnal ocean tides affecting Ice Shelf dynamics of Ekström Ice Shelf, Antarctica.

4.18 Remelt Radar – Determining Ice Shelf Rheology and Ocean Induced Melting across Timescales

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

[1]DE.Uni-Tübingen
[2]DE.AWI
[3]COM.UCL
[4]UK.BAS

Objectives

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.

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.

Work in field

The area of interest is the Ekström Ice Shelf, East Antarctica, using the *Neumayer Station III* as a logistical hub for field surveys on the ice shelf and in the grounding zone. The first field season took place from 11/2021 – 01/2022. Repeat measurements are planned for the successive field season in 2022/23.

Field work was conducted in parts using snowmachines or the Hilux (canopy) operating directly from *Neumayer Station III*, in collaboration with the MIMO-EIS project (see Chapter 4.16 this issue). In a second phase, data were collected after a 120 km traverse with snow tractors from Neumayer to the southern grounding line of the Ekström Ice Shelf (Fig. 4.18.1). Logistics were efficiently shared with the GrouZE project operating in the same area (see Chapter 4.17)

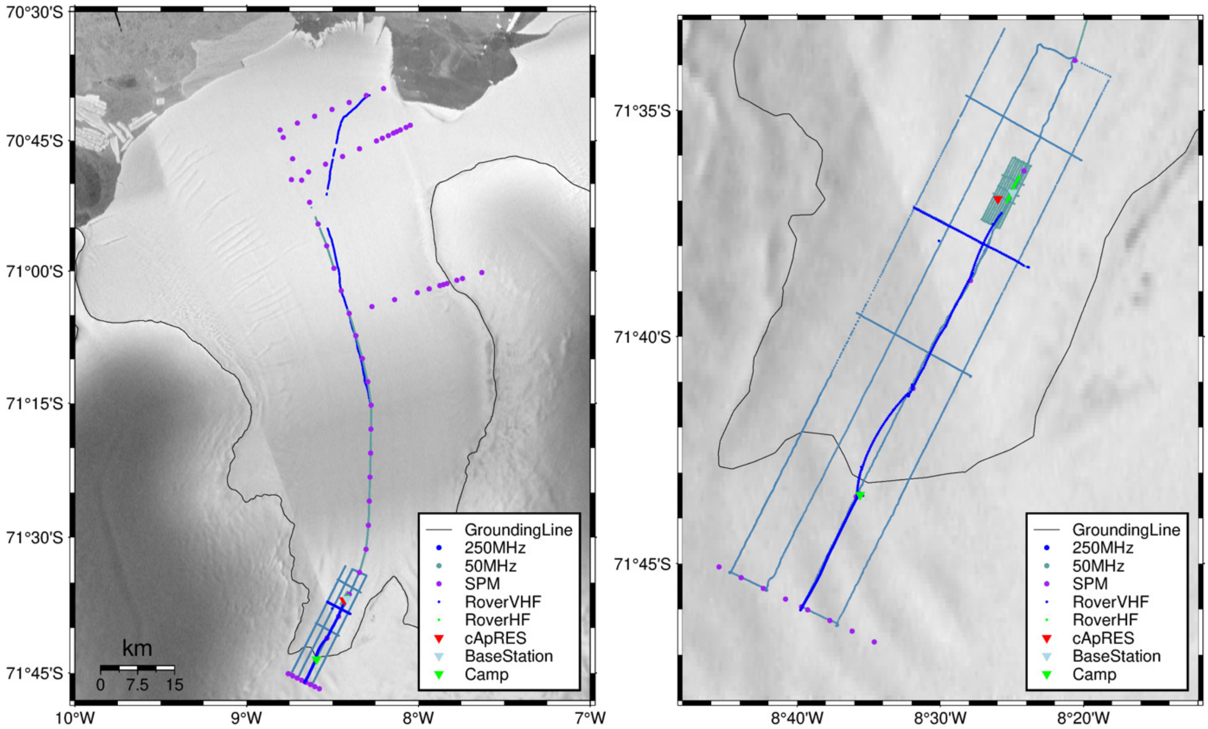


Fig. 4.18.1: (Left) Overview for locations of GPR profiles (250 & 50 MHz), static polarimetric measurements (SPM), kinematic polarimetric measurements (KPM), continuous melt rates (cApRES, referred to as MIMO-EIS-D in Chapter 4.16)), and the kinematic HF-SAR profile; (right) close up of the research area near the grounding zone

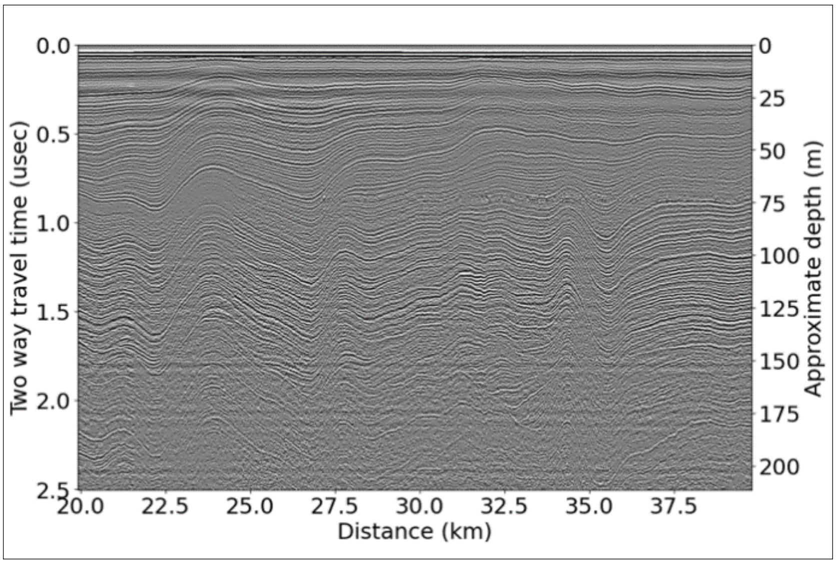
Preliminary (expected) results

Spatial variability of ocean-induced melting from seasonal to centennial timescales

For capturing yearly averaged melt rates, > 50 sites were visited on the ice shelf's central flowline and three cross-profiles with the phase-coherent VHF ApRES radar sounder STM (Static polarimetric measurements) locations marked in Figure 4.18.1. Repeat measurements envisaged in 2022/23 will allow to disentangle the observed thickness change into individual components of firn compaction, strain thinning and ice-loss from ocean-induced melting over that time interval.

In order to resolve the seasonal and sub-seasonal time scales a VHF ApRES sounder was setup to measure every 3 h near the grounding-zone (-8.342° E, -71.616° S). The VHF ApRES was configured alternating between mono-polarised (HH) and quad-polarised (HH, HV, VH, VV) measurements. These data will complement similar measurements conducted within the MIMO-EIS (see Chapter 4.16) project closer to the ice-shelf front (Eisen et al. 2020), providing a unique dataset to understand the temporal forcing of ocean-induced melting, e.g., with variable sea-ice cover and tides.

The spatiotemporal pattern of ocean-induced melting over decadal to centennial timescales is archived in the internal ice stratigraphy as imaged by ground-penetrating radars. Using a profiling radar at frequencies of 250 and 50 MHz, profiles with a cumulative length of > 100 km were collected along the center-flowline and with grid-shaped patterns near the grounding zone. Ice thickness down to a maximum of 1,000 m depth, and internal stratigraphy in the upper 200 m were successfully recorded (Fig. 4.18.2). Combining these data with ice flow models of varying complexity (Višjnević et al. 2022) opens the door to reconstruct patterns of the surface accumulation and basal melt rates over centennial timescales through inversion, including e.g., simulation-based inference.



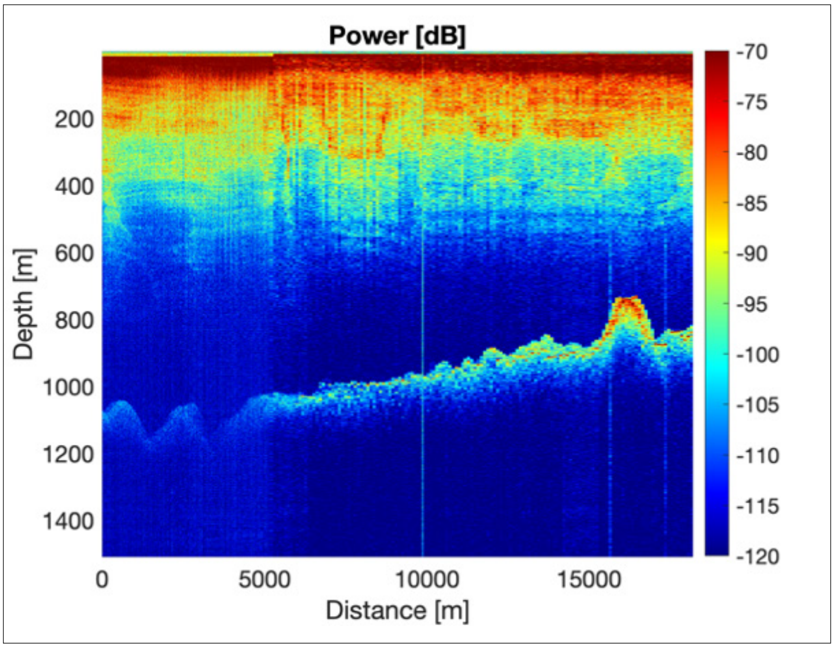


Fig. 4.18.2: (Top) Example with near continuous internal layering in the upper 200 m recorded with ground penetrating radar (250 MHz) in the along-flow direction; (bottom) example of VHF ApRES ice thickness measurements; corresponding power and phase anomalies between different polarizations are available for each trace.

Processes governing ocean-induced melting at sub-kilometers scales

A body of research suggests that ocean induce melting beneath ice shelves is not homogenous, but varies on sub-kilometer scales. Ice-shelf channels and basal terracing are suspected sites where such localized melting manifests itself in the ice-shelf geometry. Analysis of previous airborne radar data and seismic reflection surveys at the Ekström Ice Shelf show that basal terraces are prevalent in the grounding-zone, exhibiting characteristic near vertical walls at the ice-ocean interface. Within the ground-penetrating radar grids we localized a number of basal terraces and their 3D extent, however, other important parameters such as the wall angles cannot be determined from this dataset which is at the limit of its imaging capacity at this point. To overcome this, we collaborate with UCL and BAS who have developed an HF version of the ApRES sounder that is suitable for synthetic aperture processing (Hawkins et al. 2020). This system was towed in start-stop mode with 1 m increments using a newly developed rover system positioned with a real-time kinematic GPS. This successful proof-of-concept paves the way for ground-based, automized imaging with phase-coherent radars also in other areas of interest such as subglacial hydrological channels or grounding-zone landforms. Thanks to the previous radar and seismic surveys at Ekström Ice Shelf, we can now trace the evolution of individual terraces over time, potentially several decades, and discern where the vertical walls may initially form and how they are maintained during downstream ice advection.

Spatial variability of ice anisotropy

The SPM points used to map the yearly-averaged melt rates with the VHF pRES sounder were measured in polarimetric mode so that the radio-wave propagation can be evaluated in terms of birefringence and anisotropic scattering. This can be used to reconstruct the depth-variable ice fabric (Ershadi et al. 2022). Given the large coverage in along and across flow transects this has potential to detect mechanically weak or strong zones within the ice shelf. If those exist, this will have implications to understand the efficiency of ice-shelf buttressing and this inter-coupled with ice-shelf dynamics itself. Using the rover in combination with a polarimetric VHF pRES, we collected polarimetric data at 20 and 100 m spacings over > 25 km along and across the grounding-zone. This unique dataset will investigate how and if ice-fabric changes across this transition zone, with corresponding implications for the ice-shelf rigidity farther downstream.

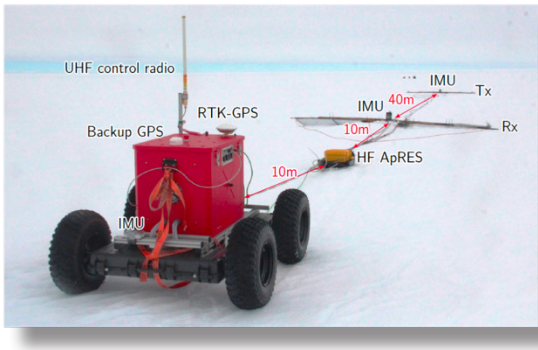


Fig. 4.18.3: Rover connected to the polarimetric VHF ApRES (left) and the HF ApRES (right).

Data management

The data will be made available in the PANGAEA data repository (World Data Center PANGAEA) Data Publisher for Earth & Environmental Science (www.pangaea.de), two years after data collection or immediately with a primary publication. 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 and and the DFG Emmy Noether Grant (DR 822/3-1). In all publications, based on this field work, the following publication will be cited:

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

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

Ershadi R, Drews R, Martín C, Eisen O, Ritz C, Corr H, Christmann J, Zeising O, Humbert A, Mulvane R, (2022) Polarimetric radar reveals the spatial distribution of ice fabric at domes in East Antarctica, The Cryosphere, in typesetting.

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. (in review 2022) Predicting the steady-state isochronal stratigraphy of ice shelves using observations and modeling, The Cryosphere Discussions, [preprint], https://doi.org/10.5194/tc-2022-23

4.19 GNSS-Reflecto-/Refractometry

Ladina Steiner[1], Olaf Eisen[1];
Not in the field: Holger Schmithüsen[1], Stefanie Arndt[1], Christian Haas[1], Jens Wickert[2]

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

Objectives

The project aims at developing a methodology for deriving automated and continuous specific surface mass balance 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.

Work in field

After arriving at the *Neumayer Station III* on 9 November 2021 after more than two weeks of quarantine, the freight was checked and all parts connected. The GNSS receiver settings were checked, and a script programmed for automatic data download to the *Neumayer Station III* data server.

The GNSS-RR system was successfully tested inside the station for multiple days. The two high-end and one low-cost antennas and mountings were then installed at the snow sensor mast (Fig. 4.19.1), operated by AWI meteorology, south of the Spuso on the 16 November 2021. The receiver box including a two high-end and one low-cost receiver, a raspberryPi and a switch, was deployed on the 17 November 2021 and everything connected to power, LAN, and the three GNSS antennas.

Several optimizations occurred after the installation. The high-end GNSS receivers lost periodically all satellites. Complete resetting and updating to the newest firmware did solve this problem. Due to the help of the IT at AWI, a virtual machine (VM) was set-up at the *Neumayer Station III* server for this project, providing a reliable raw data transfer to the data server of *Neumayer Station III*. A FTP server was set up for receiving data via FTP push directly sent by the receivers and a cronjob running at the VM to move the data from the FTP server on the VM to the data server at *Neumayer Station III*. The usage of the raspberryPi enabled the connection of the low-cost receiver to the network and thus automated data download to the data server at *Neumayer Station III*. All receivers and the data collection and transfer are working successfully since the installation. Thanks to AWI's O2A support, all the raw data will be additionally transferred to the AWI data server at Bremerhaven, allowing the analysis of the GNSS-RR data in the next months.

Fig. 4.19.1: GNSS snow monitoring system setup in the vicinity of the Neumayer Station III at the Ekström Ice Shelf *on 22 November 2021, with view towards West; the GNSS antenna on top of the mast serves as a reference station and additionally collects reflected GNSS signals visible on the ground from the surrounding snow surfaces. The two lower GNSS antennas (one high-end and one low-cost) will collect refracted GNSS signals when fully covered and buried by accumulated snow. Power and LAN supply is provided by the nearby AWI air chemistry observatory (Spuso) and connected to the receivers in the black box.*

Preliminary (expected) results

Nine days of high-quality data were taken manually back to AWI Bremerhaven and were analyzed to get very preliminary results. Refracted GNSS observations from the fast-moving Ekström Ice Shelf have been post-processed for SWE estimation in a first step. A continuous SWE time series could be estimated with a high temporal resolution of 15 minutes (Fig. 4.19.2). The results show a high level of agreement with the reference observations, calculated from snow accumulation data collected by a laser distance sensor at the same site, and the snow density of the upper layer of 402 kg/m^3, observed by our own manual snow liner observations.

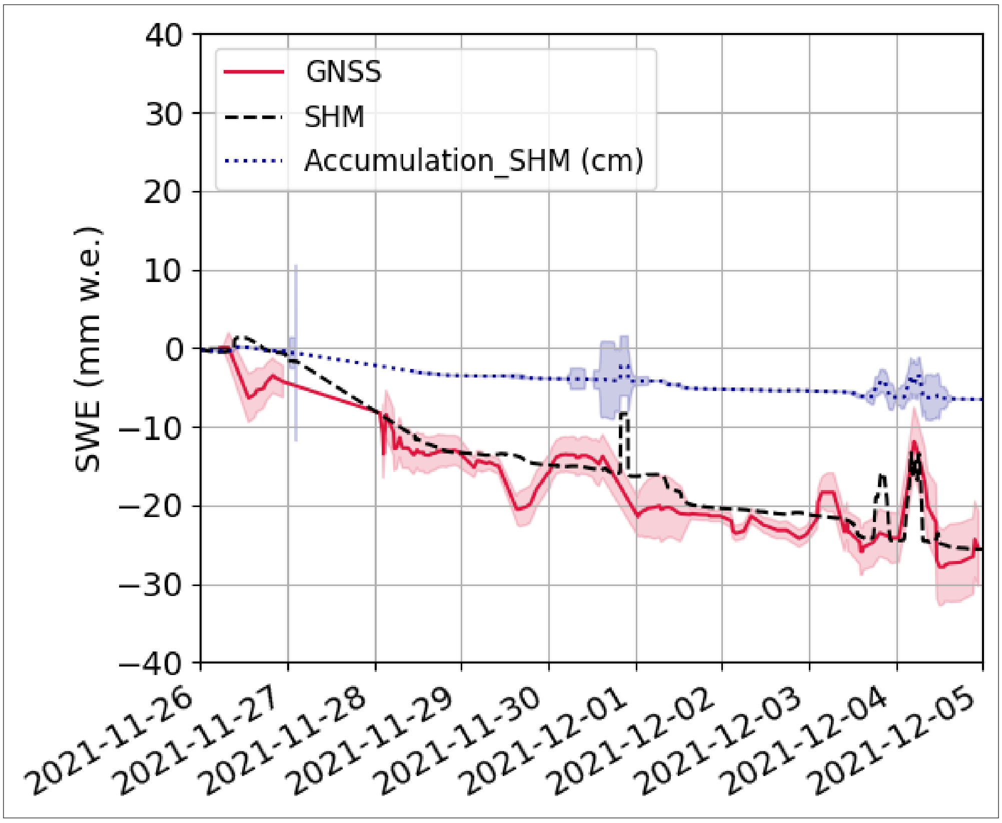


Fig. 4.19.2: Continuous SWE time series, estimated from refracted GNSS observations at the Ekström Ice Shelf *in 2021*

A previous study (Simeonov, 2021) illustrated the feasibility of using reflected GNSS observations for deriving snow accumulation time series at the same location. A high level of agreement with the snow accumulation observations by the nearby snow buoy was achieved. These preliminary results are very promising for the future combination of both methods and the retrieval of automated and continuous *in-situ* surface mass balance time series.

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 cruise 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 PoF-IV, Subtopic 2.3, 2.4, 2.1.

The following publication will be cited in all publications:

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

Simeonov T (2021) Derivation and analysis of hydrological parameters from ground-based GNSS stations. PhD thesis, TU Berlin, Germany

4.20 SLIFT: Microstructural and Mechanical Properties of Snow used to lift *Neumayer Station III*

Sepp Kipfstuhl DE.AWI
Not in the field: Johannes Freitag,
Peter Köhler (Logistics)

Objectives

Neumayer Station III is built on the surface of the *Ekström* ice shelf and has to be lifted once or twice a year by about 1.5 and 3 m, respectively. It is resting on 16 legs (ccele) standing on plates (size: ¾ m by 4 m). The main goal of the SLIFT project is to investigate the density distribution underneath and in the close vicinity of the station as well as the microstructural and mechanical properties of the snow used to lift *Neumayer Station III*. The technical questions to be answered are whether or not the settling of the station (50-100 cm per year) could actively be influenced and why the plates underneath the 86ccele sometimes tilt in an uncontrolled way. The scientific question is if the accelerated densification process of the snow under the station differs from that of natural firn in the same density range.

Work in field

Snow and firn cores were drilled into the processed snow in the garage, the basement of the station to depths of 3 m and 10 m, respectively. Cores were drilled into snow unloaded and in snow compacted by the bipode plates the 16 legs of the station were resting on before and after the station was lifted. For comparison cores were drilled in the direct vicinity of the station where snow is accumulating but moved away and where the main traffic takes place as well as in a distance of about 1 km against the main wind direction believed to be not influenced by the station. The density of the cores was determined in low and high resolution by weighing full core sections and in higher resolution by weighing core sections cut into pieces of 10 cm length.

Preliminary (expected) results

The density of naturally deposited snow on the EIS varies around 400 kg/m^3 at the surface. The density in the direct vicinity of the station where vehicle move is denser, about 450 to 500 kg/m^3. Snow used for lifting the station moved by a Pistenbulli down into the garage shows densities between 500 and 550 kg/m^3 and snow blown by a snow blower underneath the bipode plates has typical values between 550 to 600 kg/m^3. The compacted snow in the uppermost 3 m under the bipode plates increased its density by about 100 kg/m^3 to values between 650 and 700 kg/m^3 within about a year. Deeper down the density increases only to values slightly above 700 kg/m^3. The same is observed in unloaded snow between the bipodes and at the surface where the vehicles drive around. There, the density increases also by about 100 kg/m^3 during the first year and slows down afterwards.

In Bremerhaven the density of the two 10 m long cores drilled in the garage were analysed by computed tomography. A first section of that cores (density: 700 kg/m^3) has been scanned by a large area scanning macroscope. After one year to two years of settling the snow already shows the typical microstructural features observed in natural firn in depths much deeper (30-40 m) and older. Worth mentioning before conclusions are drawn is that the weight of the *Neumayer Station III*, about 2,300 metric tons, is only of the order of one third of the snow mass filling the volume of the 8 m deep garage.

It seems that settling appears independent of the initial density of the processed snow and the station is not controlling the settling of the 10 m high snow mountain caused by the station since 2009.

Data management

Data processing is in progress.

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 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.

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

Peter Jonczyk[1] [1]DE.AWI
Not in the field: Dr Anette Küster[2], Jan Koschorreck[2] [2]DE.UBA

Objectives

This project aims to protect the polar environment from contaminants by studying hazardous substances in Antarctic samples and making these data available to chemical regulation. The following research questions should be answered within the scope 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.

Work in field

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 and -25° C.

Preliminary (expected) results

It has been successfully demonstrated that samples from Antarctica can be sampled opportunistically and transported to the German ESB at Fraunhofer IME.

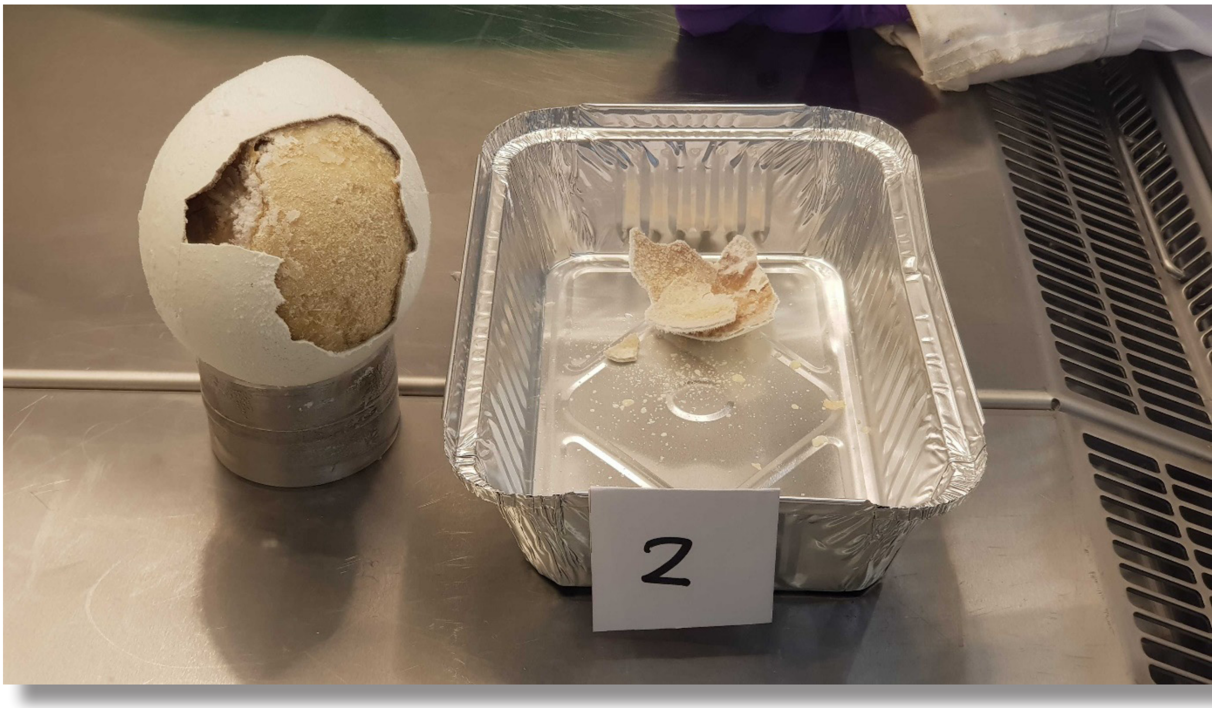


Fig. 4.21.1: Frozen egg from an emporer penguin

The penguin egg samples support the investigations of the German Environement Agency (UBA) on the feasibility of an ESB for samples from Antarctica. However, it also became apparent that more quality control is needed for sampling and interim storage, as only egg No.2 had the quality required for chemical analysis. For this egg, first results have been provided for elements, including metals and for per-und polyfluoralkyl substances (PFAS). Based on the individual egg, dry weight concentrations were 0,02 µg/g for Cobalt, 6,62 µg / kg for Copper, 0,085 µg/kg for Arsenic, 4,69 µg/g for Selenium, 1,82 ng/g for titanium and 154 ng/g for mercury. Furthermore, wet weight concentrations in the egg were 1,55 ng/g for PFOS (lin.) and 2,59 ng/g for PFDA.

Tab. 4.21.1: Comparison of contaminant levels in eggs from herring gulls (Heuwiese, Baltic Sea, 2019) and Emporer Penguin (Antarctica, 2020)

Parameter	Copper	Mercury	Arsenic	Selenium	PFOS	PFDA
Unit	µg/g dw	ng/g dw	µg/g dw	µg/g dw	ng/g ww	ng/g ww
Heuwiese (Baltic Sea)	2,525	605	0,2305	1,8925	37,474	0,25
Antarctica	6,62	154	0,085	4,69	1,55	2,59

After a promising start, 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 the 2020/21 have arrived in June 2022 at Fraunhofer IME. The eggs are now processed according the 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.

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 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

Umweltbundesamt (2020). Schwerpunkt 1-2020: PFAS. Gekommen, um zu bleiben.48S. https://www.umweltbundesamt.de/publikationen/schwerpunkt-1-2020-pfas-gekommen-um-zu-bleiben

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.

5. *KOHNEN STATION*

5.1 Kottaspegel 2021/22

Olaf Eisen[1], Peter Köhler[1](Glaciology), Klaus Guba[2]

[1]DE.AWI
[2]DE.LAEISZ

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 charaterise 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 for the traverse between *Neumayer Station III* and Kottas camp in yearly to bi-yearly temporal resolution and all the way to *Kohnen Station* every two to three years. Results will be put in context to former measurements of density in the same region.

Work in field

After arrival at *Neumayer Station III* on 6 November 2021 the traverse equipment was prepared. First density measurements were conducted in the vicinity of *Neumayer Station III*. After a delay caused by bad weather for about a week the measurements along the traverse commenced on 24 November, reaching *Kohnen Station* on 2 December. Measurements along the traverse were performed with the standard setup, i.e., a two-person team on a snowmachine with two Nansen sleds accompanying the traverse train. In total, 1,094 stakes readings were obtained and 430 new stakes newly deployed. In the vicinity of all overnight stays, density measurements were performed with the dual tube snow sampler (Dallmayr et al. 2020). Here, a sampling tube with 52 mm internal diameter is vertically pushed in the upper snow surface (up to 100 cm) (see Tab. 5.1.1) and snow density is calculated from sample volume and in-field weight measurement using a portable electronic scale.

Preliminary (expected) results

Collation of measurement values is ongoing. For the scientific interpretation of results, we plan to jointly analyse all snow height and density measurements in the regions of interest obtained over the last decades. As first results indicates that the accumulation since the last measurements in the 2019/20 season have been about 30 to 50 % higher in the near-coastal area than the long-term average. On the polar plateau, near *Kohnen Station*, the mean annual snow accumulation amounted to 23 +/- 3 cm since last measurements in 2019.

Tab. 5.1.1: Location of density measurements performed with the dual-tube sampling tool

Date	CoreID	Latitude °	Longitude °	mean density kg/cm³	mean depth cm
24.11.21	DML_KO21_SC01	-71.52609	-8.31569	394	22.6
25.11.21	DML_KO21_SC02	-72.36288	-9.01784	386	15.5
26.11.21	DML_KO21_SC03	-73.12646	-9.69013	365	33.25
27.11.21	DML_KO21_SC04	-73.91528	-9.7343	352	15.0
28.11.21	DML_KO21_SC05	-74.20651	-9.7459	378	19.8
29.11.21	DML_KO21_SC06	-74.86873	-8.33312	312	38.7
30.11.21	DML_KO21_SC07	-75.00194	-4.9741	327	48.5
01.12.21	DML_KO21_SC08	-75.01602	-1.29012	345	39.1
02.12.21	DML_KO21_SC09	-75.00367	0.05377	335	41.2

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 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

Dallmayr R, Freitag J, Hörhold M, Laepple T, Lemburg J, Della-Lunga, D, Wilhelms F (2020). A dual-tube sampling technique for snowpack studies. Journal of Glaciology 1–7. https://doi.org/10.1017/jog.2020.85.

5.2 FIDEMEKO2

Peter Köhler (Glaciology) DE.AWI
Not in the field: Angelika Humbert, Ole Zeising

Objectives

FIDEMEKO (firn densification measurements *Kohnen*) aims to collect continuously, year-round measurements using an advanced phase-sensitive radio-echo sounding system (ApRES) for deducing the firn densification rate in the second and third densification state. This will serve as dataset for validation of the newly developed firn densification model solidFIDEMO, a funded project by the DFG SPP1158 at the TU Kaiserslautern (now TU Darmstadt), lead by Prof. R. Müller and the applicant of FIDEMEKO. The first publication of simulations from this project was published recently, Schultz et al. 2022 and the data at *Kohnen Station* is chosen here as a location of cold firn with low accumulation rates and in particular because of the well known past surface mass balance and temperature.

Understanding firn densification is crucial for estimating mass balance of ice sheets from observing elevation change, as the density-depth profile and its changes over time are required to compute mass change from volume change. Additionally, firn densification determines the time of pore closure in firn and hence difference of age between the porous ice matrix and the air content. Both topics require a profound knowledge of the density-depth function and the densification as a function of time.

In the past decades only few densification experiments in laboratories have been carried out, which gave some basic understanding of the mechanism taking place during densification. More investigations were done on density profiles in firn, obtained from numerous firn cores at different locations. These firn cores retrieve a density-depth function at one point in time, which is an important information in itself, however, the quantity one would aim for deriving models for firn densification are indeed densification rates, thus changes in density over time, or vertical strain rates. As firn consists of a layering of denser layers sandwiched between less dense layers, tracking the movement of individual layers over time allows to estimate vertical strain rates. Radar backscattering is driven by contrasts in density or other factors changing dielectric properties. Thus layering can be observed with radar soundings. One way to perform that is FMCW radar measurements. As the vertical strain rates are supposed to be in the order of 10-9 s-1 to 10-11 s-1 changes in depth derived alone from travel time is not sufficient and hence observations of phase changes are the method to be applied. The phase sensitive radio echo sounding (pRES) systems (Brennan et al. 2013), which are widely used for basal melt rate estimation (Corr et al. 2002; Nicholls et al. 2015), are the ideal instruments for these observations, as the vertical strain rates are a by-product which is required for estimating basal melt rates. With the new dataset, and the climate reconstruction of the deep drill at EDML, the new firn densification model will be tested.

Work in field

The ApRES system installed on 15 January 2019 in the science trench at *Kohnen Station* was shut down on 06 December 2022. The last measurement was recorded on 05 December 2022. Thus, the data set for FIDEMEKO (1) consists of 1,070 automatically triggered measurements, see next section for data examples.

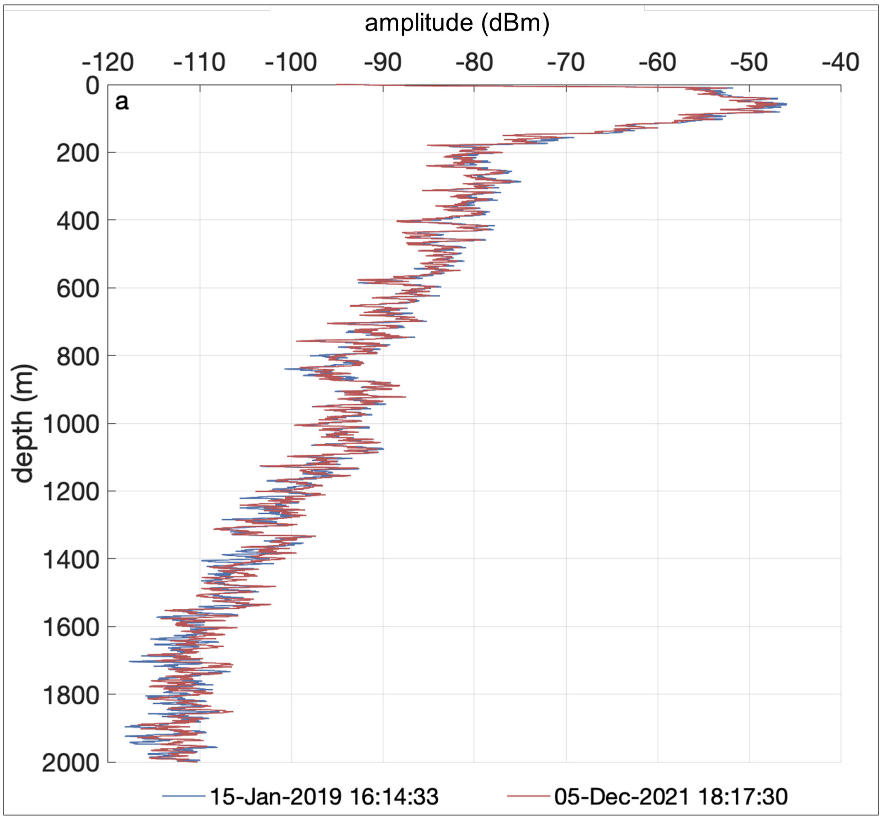


Fig. 5.2.1: Two measurements of the FIDEMEKO data set

After replacement of memory cards and the battery, the system was restarted for the follow-up project FIDEMEKO.

Preliminary (expected) results

The recorded measurements need to be processed back in office to extract the densification rates. The figure shows the first and last recording of the collected data. The shown data are of good quality, thus we expect to be able to extract the vertical motion of the detected internal layers for determing the densification at *Kohnen Station*. First simulations with the solidFIDEMO model showed that the transition between the first an second stage of firn densification is not well represented in the model. A simpler modelling approach, such as prefered by many altimetry-centred modelling, does however, show a surprisingly good fit.

Data processing will be done similarly to the one presented in Zeising and Humbert (2021).

Data management

After processing, the data will be archived, published and disseminated according to international standards by the World Data Center PANGAEA Data Publisher for Earth & Environmental Science (https://www.pangaea.de) within two years after the end of the 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 2.3 and 2.4.

In all publications, based on the field measurements, the PANGAEA entry will be cited, as well as 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

Brennan PV, Lok LB, Nicholls KW and Corr HFJ (2013) Phase- sensitive FMCW radar sys- tem for high- precision Antarctic ice shelf profile monitoring. IET Radar Sonar Navig., 8(7), 776–786 https://doi.org/10.1049/iet- rsn.2013.0053

Corr HFJ, Jenkins A, Nicholls KW and Doake CSM (2002) Precise measurement of changes in ice-shelf thickness by phase- sensitive radar to determine basal melt rates. Geophys. Res. Lett., 29(8) https://doi.org/10.1029/2001GL014618

Nicholls KW, Corr HFJ, Stewart CL, Lok LB, Brennan PV, Vaughan DG (2015) A ground- based radar for measuring vertical strain rates and time-varying basal melt rates in ice sheets and shelves. Journal of Glaciology, 61(230), pp. 1079-1087, http://dx.doi.org/10.3189/2015JoG15J073

Schultz T, Müller R, Gross D and Humbert A (2022) On the contribution of grain boundary sliding type creep to firn densification – an assessment using an optimization approach, The Cryosphere, 16, 143–158, https://doi.org/10.5194/tc-16-143-2022

Zeising O and Humbert A (2021) Indication of high basal melting at the EastGRIP drill site on the Northeast Greenland Ice Stream, The Cryosphere, 15, 3119–3128, https://doi.org/10.5194/tc-15-3119-2021

6. FLIGHT CAMPAIGNS

The previously planned flight campaigns were cancelled due to major delays in the journey and damage to the aircraft.

7. OTHER SCIENTIFIC PROJECTS WITH AWI PARTICIPATION

7.1 Beyond EPICA – Oldest Ice Core

Matthias Hüther[1], Olivier Alemany[2], Romain Duphil[2], Philippe Possenti[2], Gregory Teste[2], Carlo Barbante[3], Saverio Panichi[4], Michele Scalet[4], Calogero Monaco[4]
Not in the field: Frank Wilhelms[1], Frédéric Parrenin[2]

[1]DE.AWI
[2]FR.IGE
[3]IT.CNR-IST
[4]IT.ENEA

Objectives

The Beyond EPICA drilling project requires, before to start proper drilling, the installation of heavy surface equipment. All these elements, which are absolutely needed have been prepared by the drilling group since 2018 and have been set up at Little Dome C during the field seasons 2019/20 and 2021/22. This report summarises the field seasons 2019/20 and 2021/22 (no field activity in 2020/21 due to COVID constraints), describing all the surface elements that have been set up on the drilling site at Little Dome C.

Work in field

All drilling infrastructures have been set up between the seasons 2019/20 and 2021/22. Nothing was done on the field in 2020/21 due to COVID constraints.

<u>During the 2019/20 season</u> the wooden floor and the drilling tent were set up (by a team of 5 persons on site). All heavy equipment was moved by overland traverse to DC.

The very beginning of the season was dedicated to the refreshment of the Traverse caravans on the *Concordia* site (with the help of IPEV staff) in order to be able to host the team on site, properly.

The tent has been specifically designed between the BE-OI drilling group and a private company. It had been delivered to Hobart Tasmania in September 2020 and was transported by ship and traverse to Little Dome C (LDC).

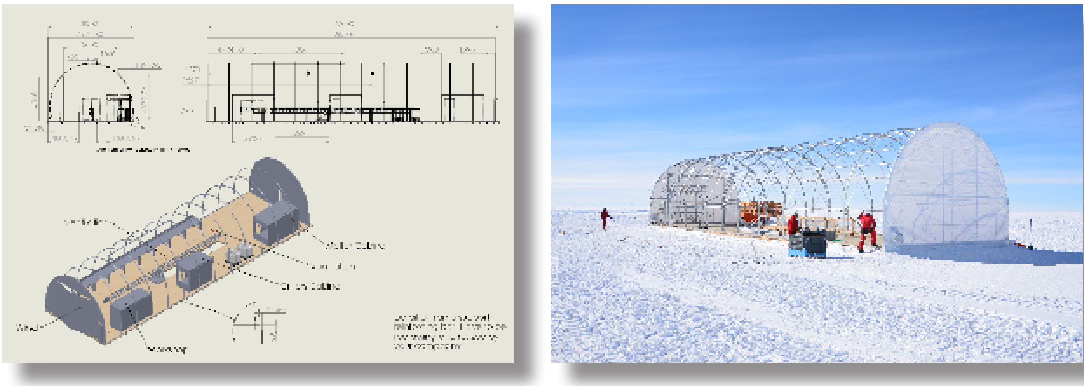


Fig. 7.1.1: Drawing of the tent and surface equipment (left); tent under construction in January 2020 (right)

All this heavy work was successfully performed between late December 2019 and mid-January 2020.

During the 2020/21 season the AWI drill workshop in a Mobile Expandable Container Configuration (MECC) and 2 containers with drill liquid and drill pieces were shipped to Hobart and moved together with all other heavy equipment by overland traverse to DC.

Season 2021/22

IPEV logistics (and PNRA) provided strong support to the project both for transporting several tons of material from the coast to the coring site (via the two traverses) but also for the installation of the drilling area and the ice core storage containers on site, the preparation of ice core logging and cutting tables, the installation and preparation of the generator set and the electric installation of the camp at little Dome C. From AWI 2 containers with 310 ice core boxes were shipped to LDC.

Fig. 7.1.2: The drilling tent at the start of the season (left); installation of the "trapanelle" corer in the tent (right)

The general logistical and technical support of *Concordia* staff and the *Concordia* system has been very helpful.

The main objective of this season was the installation of all the surface elements necessary for the Beyond EPICA deep drilling, drilling and reaming of the pilot hole (to a depth of 120 meters), setting up of the casing in the pilot hole and finally the first tests of the deep drill provided by AWI.

The first part of the season was (again) dedicated to preparing the caravans on the *Concordia* site (before leaving for LDC), then after arriving on site, clearing the snow of the camp at Little Dome C (really a lot of snow gathered, because nothing had been done on site season 2020/21). These operations were carried out by our Italian colleagues from the PNRA (M. Scalette, Callogero and S. Pannichi), between 25 November 2021 and 5 December 2021.

They were then joined by colleagues from the IPEV staff who were responsible for the electrical installation of the camp (putting the generator into service, cabling to the main distribution cabinet and setting up the power lines between the main installations of the drilling camp (drilling tent, workshop, Vsat, recreation tents, Swiss Radix drilling tent, etc.)). These electrical operations began late November and were completed just before Christmas 2021.

The activities directly linked to drilling and setting up of the surface elements began a little later, with the arrival of P. Possenti, G. Teste and M. Hüther on site by 2 December 2021

This group first completed the excavation of the tilting trench to the depth of 8.5 meters, which allowed to tilt the drilling mast from the horizontal to the vertical position.

As soon as this was completed, they set up the French “trapanelle” shallow drill and began drilling the pilot hole to a depth of 120 meters. The hole was then reamed to a diameter of 260 mm (passing through diameters 180 mm and 220 mm). These pilot hole preparation operations were carried out between 2 December 2021 and 20 December 2021.

Fig. 7.1.3: First core extracted from Beyond EPICA drilling

In parallel with this phase of the pilot hole drilling, the rest of the personnel involved in the BE-OI project arrived on site on the 4 December 2021. They started to assemble and set up all the surface elements in the drilling tent: the three Viessmann cabins (which will be used to host the drill chips smelter, a small workshop and the drillers cabin). As soon as the cabins were set up, the chips smelter (designed and prepared by the Copenhagen team) was installed in the dedicated cabin.

On 9 December 2021 we took advantage of the arrival of Raid 1 at LDC (part of the vehicles bringing several containers of BE-OI equipment, including drilling fluid, a spare cable, wood, etc.) to get support from the vehicles and their cranes to set up the EPICA winch with its cable installed on it. Following this installation, we mounted the new motor on the winch reduction gearbox, then the control cabinet (with its drivers and shunt resistor) allowing to control the winch speed and torque.

Once the pilot hole was completed, the whole team was mobilised to set up the casing in place (to make the first 120 meters of the borehole in the firn watertight). The casing consists of a stack of fiberglass tubes with an outside diameter of 255 mm (thickness 9.5 mm) 5 meters long and held together via a steel cable with a diameter of 7 mm and a fluorosilicone rubber seal. This rather complex installation required the involvement of the entire Beyond EPICA team and the use of a tripod and an electric hoist. The casing was completely set in place on 23 December 2021. The verticality and orientation of the borehole's top most section and the casing was checked with the new small IGE logger (26 December 2021) specially made for the project.

Fig. 7.1.4: The Beyond EPICA team before the setting up of the casing

As soon as the casing was in place, the team again split in two. Two persons were dedicated to testing the new medium-depth corer (300-meter corer) of the F2G platform (French Ice Drilling Facility). The tests of this new system have been done between Christmas 2021 and 10 January 2022.

The rest of the team focused on the rest of the surface installations that remained to be installed: 14 meters long mast with its support and two new activators (allowing to tilt it) and its associated tilting driver, aluminum channel allowing to recover the drilling fluid in the tilting trench, all surface hydraulic equipment (including two cubic meter tanks, surface pumps and hoses…).

As soon as these operations were completed, we made an opening in the roof of the drilling tent on 29 December 2021 to allow the tilting of the drilling mast in the vertical position. Tilting tests were immediately carried out as well as the precise positioning of the tower. Following these tests, we installed the extraction table (which had previously been extended by the mechanics of the IPEV on the *Concordia Station*), the surface hydraulic assembly which makes it possible to inject the drilling fluid into the hole, and the core cutting and logging tables. All these surface operations ended on 10 January 2022.

The assembly of the deep drill, which has been done under the responsibility of the AWI staff started at the very beginning of January. The assembly began with the anchor between the core barrel and the cable, then with the assembly of the anti-torque section and the motor section of the core barrel. Communication between the surface electronics and the engine section on-board electronics was tested. The electrical power transfer between the surface and the corer was also tested and after some trouble shooting and damage to two on-board electronics, the correct setting was found and the data and power transfers between the surface and the on-board engine section has been successfully tested (engine is running and can be controlled from surface control).

Following these tests, we began assembling the mechanics of the corer (junction, hollow shaft, core barrel, outer tube, etc.). Soon, adjustment problems were recognised, two persons (P. Possenti and O. Alemany) went to re-machine one of the core barrels (spiral in HDPE- to try to mount it in the outer tube) on 7 and 8 January 2022. Finally, we ran out of time on site, decided to end the season and send all the elements (mainly mechanical) for possible overworking back to Europe before to be used again next season.

Winching tests were carried out at the end of the season, by lowering and then raising the engine section of the corer to a depth of 100 meters. These tests were carried out on 10 January 2022.

Fig. 7.1.5: View of the camp from the top of the mast in an upright position (left); the drilling tent at the end of the season (right)

Most of the equipment has been stored or prepared for shipment to Europe, the first part of the team returned to *Concordia* on 14 January 2022

The rest of the BE-OI personnel returned to *Concordia* on 20 January 2021 with the living caravans, and the +4° C container which will remain at *Concordia* and will store the BE-OI frost-free elements (winch, mast, electronic spare parts…).

Preliminary (expected) results

The drilling infrastructure is installed at the field camp at Little Dome C.

Data management

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

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

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

In all publications, based on this field work, 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.

APPENDIX

A.1 Teilnehmende Institute / Participating Institutes

A.2 Expeditionsteilnehmer:innen / Expedition Participants

A.3 Logistische Unterstützung, Überwinternde / Logistics Support, Wintering Team

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTES

Affiliation	Address
BE.ULB	Université Libre de Bruxelles CP 160/03 Avenue F.D. Roosevelt B-1050 Brussels Belgium
COM.BBC	British Broadcasting Corporation Broadcastig House Peel Wing Portland Place W1A 1AA London United Kingdom
COM.Kässbohrer	Fa. Kässbohrer Geländefahrzeuge AG Kässbohrerstraße 11 88471 Laupheim Germany
COM.UCL	University College London Gower Street WC1E 6BT London United Kingdom
DE.AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
DE.BGR	Bundesanstalt für Geowissenschaften und Rohstoffe Stilleweg 2 30655 Hannover Germany
DE.Charite	Charité Universitätsmedizin Berlin Charitéplatz 1 10117 Berlin Germany
DE.DLR	Deutsches Zentrum für Luft- und Raumfahrt Institut für Raumfahrtsysteme Robert-Hooke-Straße 7 28359 Bremen Germany
DE.DNVGL-HH	DNV-GL-HH Brooktorkai 18 20457 Hamburg Germany

Affiliation	**Address**
DE.DWD	Deutscher Wetterdienst Seewetteramt Bernhard Nocht Str. 76 20359 Hamburg Germany
DE.FAU	Friedrich-Alexander-Universität Erlangen-Nürnberg Schlossplatz 4 91054 Erlangen Germany
DE.GFZ	Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences Potsdam Germany
DE.HS-Bremen	Hochschule Bremen Neustadtswall 30 28199 Bremen Germany
DE.LAEISZ	Reederei F. Laeisz GmbH Bartelstraße 1 27570 Bremerhaven Germany
DE.Med.Uni-Muenchen	Klinikum der Universität München Ziemssenstraße 1 80336 München Germany
DE.MPIB-Berlin	Max-Planck-Institut für Bildungsforschung Lentzallee 94 14195 Berlin Germany
DE.TROPOS	Leibniz-Institut für Troposphärenforschung Permoserstraße 15 04318 Leipzig Germany
DE.TU-Dresden	TU Dresden Institut für Planetare Geodäsie 01062 Dresden Germany
DE.TUM	Technische Universität München Lehrstuhl für Raumfahrttechnik Boltzmannstr. 15(5506)/II 85748 Garching b. München Germany
DE.UBA	Umweltbundesamt Wörlitzer Pl. 1 06844 Dessau-Roßlau Germany

Affiliation	Address
DE.UNI-Bremen	Universität Bremen Bibliothekstraße 1 28359 Bremen Germany
DE.UNI-Tübingen	Eberhard Karls Universität Tübingen Geschwister-Scholl-Platz 72074 Tübingen Germany
DE-KSF-ING	KSF Steimke, Dr. Hemmy & Partner mbB Alfred-Balzer-Str. 5 27570 Bremerhaven Germany
EDU.NJIT	New Jersey Institute of Technology Center for Solar-Terrestrial Research New Jersey USA
EDU.Pitt	University of Pittsburg School of Health and Rehabilitation Sciences 3860 South Water Street Pittsburgh PA 15203 USA
EDU.UFl	University of Florida Fifield Hall 2550 Hull Road Gainesville FL 32611 USA
EDU.UNH	University of New Hampshire Space Science Center Durham, New Hampshire USA
EDU.UPENN	University of Pennsylvania Perelman School of Medicine 3400 Civic Center Blvd Philadelphia PA 19104 USA
EDU.WHOI	Wood Hole Oceanographic Institution 266 Wood Hole Road MA 02543 Woods Hole USA
FR.CNRS	Centre National de la recherche scientifique 23 rue Becquerel Bâtiment 60 67087 Strasbourg France

Affiliation	Address
FR.IGE	Institut des Géosciences de l'Environnement CS 40700 38 058 Grenoble Cedex 9 France
GOV.NASA	NASA Johson Space Center Behavioral Health & Performance Laboratory 2101 NASA Parkway Houston, TX 77058 USA
IT.CNR-IST	National Research Council Institute of Polar Sciences Scientific Campus Ca' Foscari University Venice Via Torino, 155 30172 Venezia Mestre Italia
IT.ENEA	ENEA Lungotevere Thaon di Revel, 76 00196 Roma Italia
KR.KHU	School of Space Research Kyung-Hee University Gyeonggi Korea
KR.KOPRI	Division of Polar Climate Sciences Korea Polar Research Institute Incheon Korea
MC.CSM	Centre Scientifique de Monaco 8 Quai Antoine 1er MC 98000 Monaco
NO.NPOLAR	Norwegian Polar Institute Framsenteret Hjalmar Johansens gate 14 9296 Tromsø Norway
UK.BAS	British Antarctic Survey High Cross Madingley Road CAMBRIDGE CB3 0ET United Kingdom

A.2 EXPEDITIONSTEILNEHMER:INNEN / EXPEDITION PARTICIPANTS

Name/ Last name	**Vorname / First name**	**Institut/ Institute**	**Beruf/ Profession**	**Fachrichtung/ Discipline**
Bosiger	Yoland	COM.BBC	Journalist	Media
Drews	Reinhard	DE.Uni-Tübingen	Scientist	Glaciology
Eisen	Olaf	DE.AWI DE.Uni-Bremen	Scientist	Glaciology
Ershadi	Mohammadreza	DE.Uni-Tübingen	PhD student	Glaciology
Fromm	Tanja	DE.AWI	Scientist	Geophysics
Hawkins	Jonathan	COM.UCL	PhD student	Geophysics
Houstin	Aymeric	DE.FAU	Scientist	Biology
Kinzel	Louisa	DE.AWI	PhD student	Geophysics
Kipfstuhl	Josef	DE.AWI	Scientist	Glaciology
Koch	Inka	DE.Uni-Tübingen	Scientist	Glaciology
Köhler	Peter	DE.AWI	Scientist	Glaciology
Le Bohec	Céline	MC.CSM FR.CNRS	Scientist	Biology
Lewis	Justin	COM.BBC	Photographer	Media
McKeever	Casper	COM.BBC	Journalist	Media
Paranhos Zitterbart	Daniel	EDU.WHOI	Scientist	Physics
Steiner	Ladina	DE.AWI	Scientist	Geodesy
Vail	Alexander	COM.BBC	Journalist	Media
Winterl	Alexander	DE.FAU	PhD student	Physics

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

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession	Fachrichtung / Discipline
Baden	Markus	DE.AWI	Technician	Wintering Team 2021
Bähler	Stefanie	DE.LAEISZ	Inspection	Logistics
Beyer	Mario	DE.AWI	Technician	Logistics
Birk	Tobias	COM.Kässbohrer	Technician	Logistics
Böddeker	Karsten	DE.LAEISZ	Technician	Wintering Team 2022
Bunchek	Jess	DE.AWI	Scientist	Wintering Team 2021
Dornhöfer	Timo	DE.AWI	Scientist	Wintering Team 2021
Doron	Tanguy	DE.AWI	Cook	Wintering Team 2021
Eigendorf	Thomas	DE.DNVGL-HH	Inspection	Logistics
Guba	Klaus	DE.AWI	Physician	Logistics
Heuck	Hinnerk	DE.LAEISZ	Technician	Logistics
Hofmann	Werner	DE.LAEISZ	Cook	Wintering Team 2022
Hölzer	Aurelia	DE.AWI	Physician	Wintering Team 2022
Hornik	Jonas	DE.LAEISZ	Technician	Logistics
Jonczyk	Peter	DE.AWI	Physician	Wintering Team 2021
Keck	Hannes	DE.AWI	Scientist	Wintering Team 2022
KIDE.AWItter	Hendrik	DE.AWI	Technician	Logistics
Koch	Florian	DE.AWI	Technician	Wintering Team 2021
Marten	Lorenz	DE.AWI	Scientist	Wintering Team 2021
Mitteregger	Chistian	DE.LAEISZ	Technician	Logistics
Neuner	Benedikt	DE.LAEISZ	Technician	Logistics
Oblender	Andreas	DE.AWI	Technician	Logistics
Ockenfuß	Paul	DE.AWI	Scientist	Wintering Team 2021
Ort	Linda	DE.AWI	Scientist	Wintering Team 2021
Peter	Dirk	DE.LAEISZ	Cook	Logistics
Petri	Martin	DE.AWI	IT	Logistics
Reich	Stefan	DE.LAEISZ	Technician	Logistics
Riess	Felix	DE.LAEISZ	Technician	Logistics
Rohnacher	Alicia	DE.AWI	Scientist	Wintering Team 2022
Schubert	Holger	DE.LAEISZ	Technician	Logistics
Schulze	Markus	DE.AWI	Scientist	Wintering Team 2022
Schütt	Philipp	DE.LAEISZ	Technician	Logistics
Steimke	Olaf	DE-KSF-ING	Inspection	Logistics
Thoma	Theresa	DE.AWI	Technician	Wintering Team 2021
Trautmann	Michael	DE.LAEISZ	Technician	Wintering Team 2022
Wagner	Benita	DE.AWI	Scientist	Wintering Team 2022
Wesche	Christine	DE.AWI	Scientist	Expeditions leader

Name/ Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**	**Fachrichtung / Discipline**
Widdecke	Iris	DE.LAEISZ	Housekeeping	Logistics
Wiggins	Katrin	DE.LAEISZ	Technician	Wintering Team 2022

Die **Berichte zur Polar- und Meeresforschung** (ISSN 1866-3192) werden beginnend mit dem Band 569 (2008) als Open-Access-Publikation herausgegeben. Ein Verzeichnis aller Bände einschließlich der Druckausgaben (ISSN 1618-3193, Band 377-568, von 2000 bis 2008) sowie der früheren **Berichte zur Polarforschung** (ISSN 0176-5027, Band 1–376, von 1981 bis 2000) befindet sich im electronic Publication Information Center **(ePIC)** des Alfred-Wegener-Instituts, Helmholtz-Zentrum für Polar- und Meeresforschung (AWI); see https://epic.awi.de. Durch Auswahl "Reports on Polar- and Marine Research" (via "browse"/"type") wird eine Liste der Publikationen, sortiert nach Bandnummer, innerhalb der absteigenden chronologischen Reihenfolge der Jahrgänge mit Verweis auf das jeweilige pdf-Symbol zum Herunterladen angezeigt.

The **Reports on Polar and Marine Research** (ISSN 1866-3192) are available as open access publications since 2008. A table of all volumes including the printed issues (ISSN 1618-3193, Vol. 377-568, from 2000 until 2008), as well as the earlier **Reports on Polar Research** (ISSN 0176-5027, Vol. 1–376, from 1981 until 2000) is provided by the electronic Publication Information Center **(ePIC)** of the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI); see URL https://epic.awi.de. To generate a list of all Reports, use the URL http://epic.awi.de and select "browse"/"type" to browse "Reports on Polar and Marine Research". A chronological list in declining order will be presented, and pdf-icons displayed for downloading.

Zuletzt erschienene Ausgaben:

Recently published issues:

767 (2022) Expeditions to Antarctica: ANT-Land 2021/22 Neumayer Station III, Kohnen Station, Flight Operations and Field Campaigns, edited by Christine Wesche and Julia Regnery with contributions of the participants

766 (2022) The Expedition West-Alaska 2016 of the ERC group PETA-CARB to permafrost regions in western Alaska in 2016, edited by Josefine Lenz, Matthias Fuchs, Ingmar Nitze, Jens Strauss, Guido Grosse

765 (2022) The Expeditions PS130/1 and PS130/2 of the Research Vessel POLARSTERN to the Atlantic Ocean in 2022, edited by Simon Dreutter and Claudia Hanfland with contributions of the participants

764 (2022) The Expedition PS128 of the Research Vessel POLARSTERN to the Weddell Sea, Lazarew Sea, Riiser-Larsen Sea, Cosmonaut Sea, and Cooperation Sea in 2022, edited by Ralf Tiedemann and Juliane Müller with contributions of the participants

763 (2022) The MOSES Sternfahrt Expeditions of the Research Vessels ALBIS, LITTORINA, LUDWIG PRANDTL, MYA II and UTHÖRN to the Elbe River, Elbe Estuary and German Bight in 2021, edited by Ingeborg Bussmann, Norbert Anselm, Holger Brix, Philipp Fischer, Götz Flöser, Elisabeth von der Esch, Norbert Kamjunke

762 (2022) 28th International Polar Conference Polar Regions, Climate Change and Society, Potsdam, 01 – 05 May 2022 German Society for Polar Research, edited by H. Kassens, D. Damaske, B. Diekmann, F. Flisker, G. Heinemann, J. Herrle, U. Karsten, N. Koglin, F. Kruse, R. Lehmann, C. Lüdecke, C. Mayer, B. Sattler, M. Scheinert, C. Spiegel-Behnke, and R.Tiedemann

761 (2022) The Expedition PS127 of the Research Vessel POLARSTERN to the Atlantic Ocean in 2021/22, edited by Laura Hehemann with contributions of the participants

760 (2022) Messungen des oberflächennahen Ozons an Bord von Forschungsschiffen im Atlantik und an der Georg-von-Neumayer-Station in der Antarktis von 1977 bis 1996, by Peter Winkler

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

BREMERHAVEN

Am Handelshafen 12
27570 Bremerhaven
Telefon 0471 4831-0
Telefax 0471 4831-1149
www.awi.de

HELMHOLTZ