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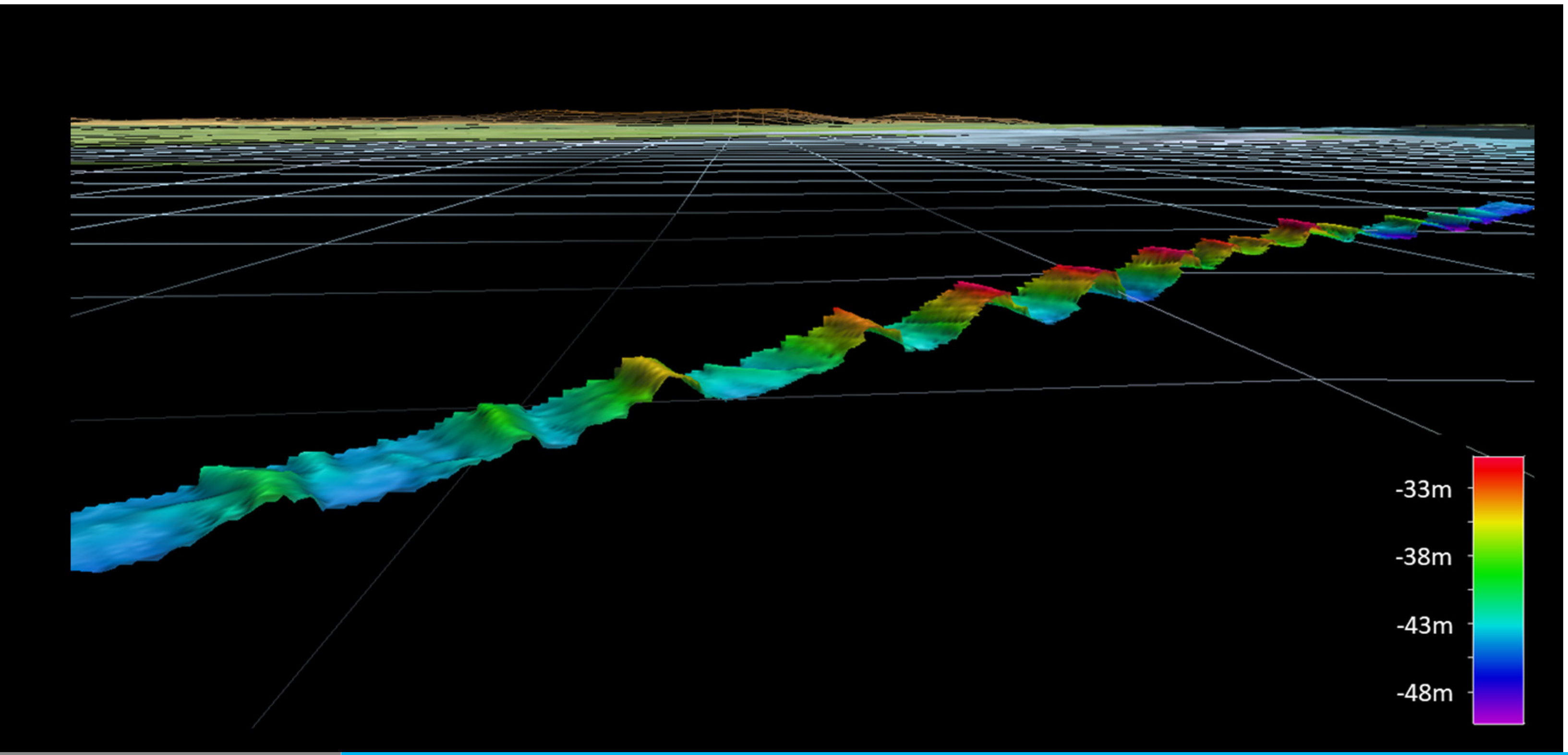

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Berichte
zur Polar- und Meeresforschung

Reports on Polar and Marine Research

The Expedition PS116 of the Research Vessel POLARSTERN to the Atlantic Ocean in 2018

Edited by

Claudia Hanfland and Bjela König
with contributions of the participants

HELMHOLTZ
GEMEINSCHAFT

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

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Titel: Fächerecholotdaten mariner Dünen in der Straße von Dover (Blick von der englischen Küste Richtung Frankreich). Die asymmetrische Form, welche die Dünen entlang der Strömung entwickeln, ist deutlich sichtbar. Das Hintergrundraster basiert auf GEBCO-Daten. Abbildung zusammengestellt von Niels Fuchs, AWI.

Cover: Multibeam echosounding data of marine dunes in the Strait of Dover (view from the English coast towards France). The asymmetric shape that dunes develop along the current is clearly visible. Background grid based on GEBCO data. Figure compiled by Niels Fuchs, AWI.

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PS116

11 November 2018 - 11 December 2018

Bremerhaven - Cape Town

Chief Scientists
Claudia Hanfland
Bjela König

Coordinator
Rainer Knust

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APPENDIX

1. ÜBERBLICK UND FAHRTVERLAUF

Claudia Hanfland, Bjela König AWI

Polarstern verließ den Heimathafen Bremerhaven für die Expedition PS116 am 11.11.2018 mit dem Mittagshochwasser. Aufgrund umfangreicher vorangegangener Werftarbeiten, hatte sich die Abfahrt um einen Tag verzögert. An Bord gingen 43 Besatzungsmitglieder, 45 Teilnehmende aus Wissenschaft und Logistik sowie zwei Meteorologen des Deutschen Wetterdienstes.

Die wissenschaftlichen Aktivitäten während PS116 umfassten folgende Tätigkeiten: Ausbildung von Nachwuchswissenschaftlern in Hydro-Akustik (auf dem Abschnitt Bremerhaven – Las Palmas), atmosphärische *en-route* Messungen und Wasserbeprobungen sowie Arbeiten der Logistik und des Rechenzentrums.

Die wissenschaftlichen Vorhaben im Einzelnen:

- POLMAR-TRAIN: Ausbildung von Masterstudenten der Universität Bremen, Fachbereich Geowissenschaften, und Doktoranden des AWI in geophysikalischen Methoden an den Echoloten; organisiert durch die Graduiertenschule POLMAR am AWI
- Plankton-Genomik: Bestimmung von Planktonvergesellschaftungen entlang eines meridionalen Schnittes durch den Atlantik mittels Taxonomie und DNA-Barcoding
- OCEANET: atmosphärische Messungen (physikalische Parameter, Aerosole) mittels Fernerkundung und LIDAR-Technik, Validierung des ESA Satelliten Aeolus wenn mit Fahrtroute kompatibel, durchgeführt von TROPOS (Leipzig)
- COSMIC-RAYS: Messung kosmischer Strahlung entlang eines meridionalen Schnittes durch den Atlantik (durchgeführt vom DESY Zeuthen)
- NISAAA: Ermittlung der Stickstoffisotopenzusammensetzung über dem Atlantik in Ammonium und Ammoniak
- Test eines Schleppsystem-Depressors
- Ermittlung von Prozessabläufen unter dem Blickwinkel der Arbeitssicherheit an Bord
- Installation von Software und Hardware-Komponenten in Vorbereitung auf das Driftexperiment MOSAiC
-

Bis zum Zwischenstopp in Las Palmas wurden auf insgesamt vier kleinen Stationen Planktonproben mit dem Handnetz gezogen sowie Temperatur- und Salzprofile der Wassersäule aufgezeichnet – letzteres als Voraussetzung für eine ordnungsgemäße Kalibration der Lotsysteme. Das Hauptaugenmerk dieses Abschnitts lag auf dem studentischen Training.

In Las Palmas gingen alle Teilnehmer und Dozenten des POLMAR-TRAIN Kurses sowie sechs weitere Wissenschaftler von Bord. Es stiegen sieben neue Kolleginnen und Kollegen auf, außerdem wechselte die Fahrtleitung.

Zur Weiterfahrt von Las Palmas nach Kapstadt, die am 22.11.2018 begann, waren fünf verschiedene wissenschaftliche Teams an Bord. Die Aufnahme bathymetrischer Daten wurde durch eine Studentin der Universität Bremen weitergeführt, die auf dem Abschnitt von Bremerhaven bis Las Palmas im Rahmen des POLMAR-TRAIN Trainingsprogramms mit einer Gruppe zum Echosounding-Training an Bord gekommen war. Zur Erfassung neuer bathymetrischer Daten wurde die Route von *Polarstern* während der Fahrt mehrfach leicht angepasst, um nicht auf alten, bereits vermessenen Tracks zu fahren. Parallel dazu wurden mehrere Profile mit der „underway"-CTD gefahren. Die Route wurde ebenfalls durch die erforderlichen Schnittpunkte mit Satellitenumlaufbahnen bestimmt, an denen das TROPOS-Institut Radiosonden steigen ließ, um die von einem neuen Satelliten gelieferten Daten abgleichen und bewerten zu können. Zusätzlich erfolgten durch das TROPOS-Institut Messungen mit einem LIDAR und weiteren Photosensoren. Durch das DESY wurden während der gesamten Fahrt Myonenmessungen zur Ermittlung der kosmischen Strahlen durchgeführt. Laufende Planktonbeprobungen erfolgten mit Hilfe des Seewassersystems und über regelmäßigen Einsatz des Handnetzes. Ständige Aerosol- und Luftkomponentenmessungen der Atmosphäre vor allem zur Ermittlung der Ammoniumwerte wurden ebenfalls betrieben. Zudem fanden während der gesamten Reise Routinearbeiten des DWD in der Bordwetterwarte statt.

Neben den genannten *en-route* Messungen führte die AWI-Logistik den Test eines Depressors durch, der zukünftig für das sichere Schleppen von Messgeräten unter dem Eis sorgen soll. Ziel ist es, den Schleppdraht direkt im Heckwasser dicht hinter dem Schiff zu stabilisieren und auch während der Fahrt halten zu können, damit dieser nicht mit den sich hinter dem Schiff wieder zusammenschiebenden Eisschollen in Kontakt kommen kann. Ein Schlepptest wurde bei verschiedenen Drahtlängen und Geschwindigkeiten mit dem Depressor und angehängtem Dummy mit Treibanker durchgeführt. Ein weiterer Schlepptest erfolgte unter Überwachung durch das GAPS, wieder bei verschiedenen Geschwindigkeiten und diversen Kursänderungen. Auf Grund der stabilen Lage des Depressors und guter Ergebnisse waren keine weiteren Tests erforderlich. Dank temporär abflauender Winde und geringerem Schwell war es möglich, einen ROV-Test vom Zodiac sowie direkt vom Arbeitsdeck aus durchzuführen. Für das Bundesamt für Seeschifffahrt und Hydrographie wurden fünf ARGO-Floats an vorgegebenen Positionen ausgesetzt.

Zur logistischen Vorbereitung des MOSAiC-Projekts waren drei AWI-Mitarbeiter an Bord, die im Dialog mit Schiffsführung und einzelnen Besatzungsmitgliedern Konzepte für Beladung, Datenmanagement und Sicherheit erarbeitet haben.

Die Fahrt endete am 11.12.2018 in Kapstadt, Südafrika.

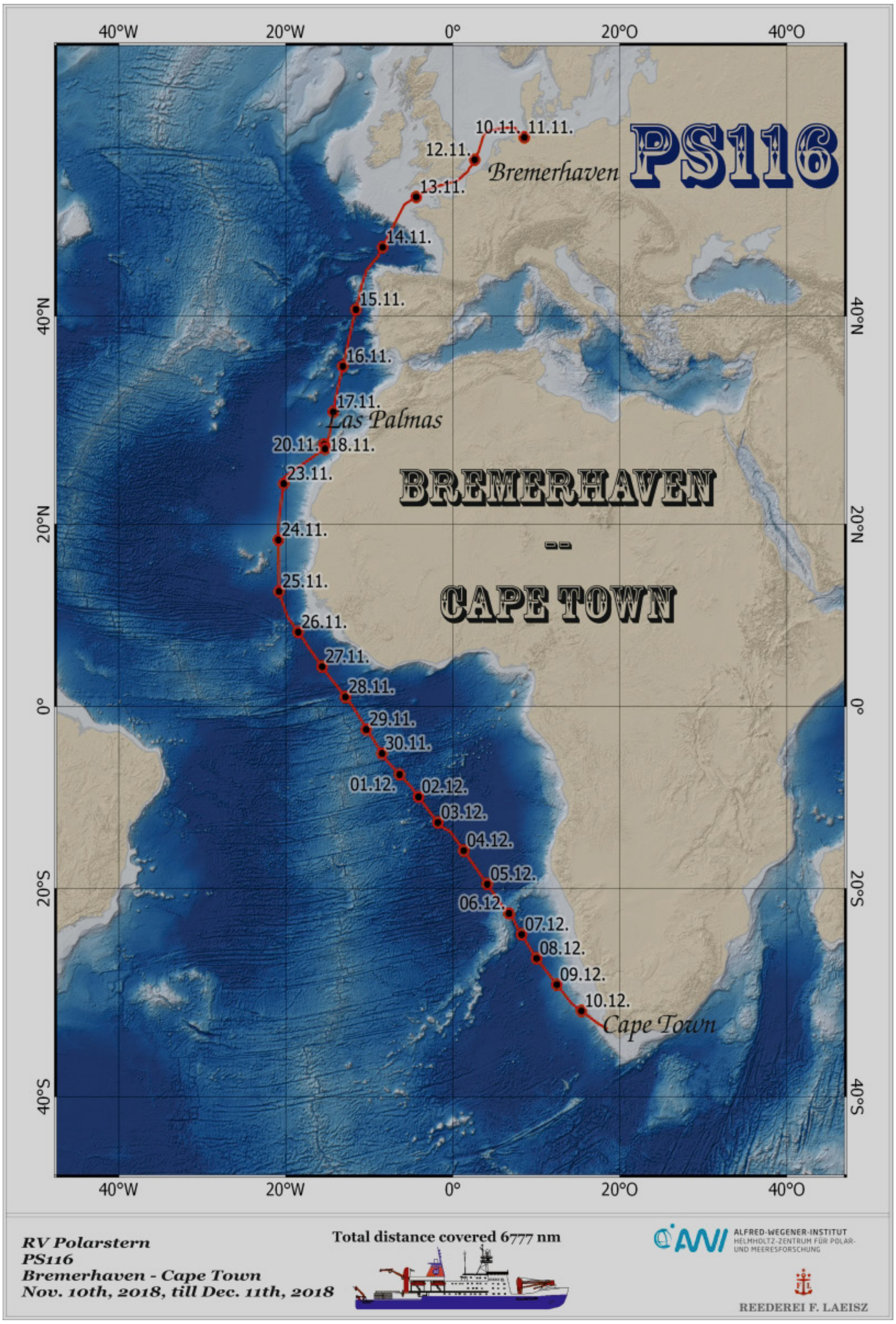

Abb. 1: Fahrtroute der Polarstern-Expedition PS116.
Siehe https://doi.pangaea.de/10.1594/PANGAEA.897872 für eine Darstellung des master tracks in Verbindung mit der Stationsliste für PS116.

Fig. 1: Cruise track of Polarstern expedition PS116.
See https://doi.pangaea.de/10.1594/PANGAEA.897872 to display the master track in conjunction with the list of stations for PS116.

SUMMARY AND ITINERARY

Polarstern left its port of registry, Bremerhaven, for expedition PS116 on 11 November 2019 at high tide. Due to extensive renovation works at the dockyard, the departure was delayed by one day. In total, 43 crew members, 45 members from science and logistics and two employees from Germany's National Meteorological Service went on board.

Scientific activities during PS116 comprised three different field of activities: training of early career scientists in the operation of the echosounding system of *Polarstern* (Leg Bremerhaven – Las Palmas only), scientific *en-route* measurements and sampling, and activities and maintenance of logistics and IT department.

In detail, the scientific activities during PS116 comprised the following work packages:

- POLMAR-TRAIN: Education and training of Master students of the University of Bremen, Department of Geosciences, and doctoral candidates from AWI, in geophysical methods in the echosounding systems (multibeam echosounder Atlas Hydrosweep DS3 and sediment echosounder Parasound P70)
- Plankton genomics: Determination of plankton communities along a longitudinal gradient across the Atlantic Ocean by means of taxonomy and DNA-metabarcoding
- OCEANET: Atmospheric measurements (physical parametres, aerosols) by means of remote sensing and LIDAR technique. Validation of ESA satellite Aeolus by ground-comparison profiles, ship-track permitting.
- COSMIC-RAYS: Determination of cosmic rays along a longitudinal gradient across the Atlantic Ocean
- NISAAA: Determination of the isotopic composition of nitrogen in ammonium and ammonia over the Atlantic Ocean
- Testing of a depressor system
- Identification of working processes in view of the development of a comprehensive safety concept for scientific work on board
- Installation of software and hardware components in preparation for the drift experiment MOSAiC

Four stations were carried out until the intermediate port call at Las Palmas, consisting of handnet deployment for plankton collection and registration of vertical temperature and salinity profiles if the water column. The latter was necessary for calibration of the echosounding systems. The main focus between Bremerhaven and Las Palmas was the student training on the Hydrosweep DS3 and the sediment echosounder Parasound P70.

After arrival in Las Palmas, all but one participant form the student training, all lecturers and six more scientists left *Polarstern*. Seven new scientists joined the leg, which also included a change in the cruise chief scientist.

There were five different scientific teams on board of *Polarstern* for the cruise from Las Palmas to Cape Town. The collection of bathymetric data was carried out by one student from the University of Bremen, who embarked in Bremerhaven together with a group of students from the POLMAR training programme who carried out echo sounding training until Las Palmas. To collect new bathymetric data, the track from Las Palmas to Cape Town was constantly adjusted to avoid sailing on previous tracks. Measurements with the underway-CTD were carried out additionally. Another aspect for route and speed changes during the cruise was the required meeting with a track from a new satellite. By releasing a radio sonde at the intersection the TROPOS team intended to gain information regarding the accuracy of the satellites measured data. There was a total of four meetings with this satellite. TROPOS also carried out measurements with a LIDAR and photo sensors. Muon measurements were carried out by a scientist from DESY to determine cosmic rays. Under way sampling of plankton by means of the sea water system and regular use of the hand net was carried out. Aerosol and air components of the atmosphere were constantly measured to determine ammonium data. Routine works of the DWD regarding weather were done all the way from Las Palmas to Cape Town.

Besides these under-way measurements the AWI logistics team carried out a test of a „Depressor“, which is intended for towing measuring instruments below the ice without putting the wire in jeopardy of being damaged by the ice that is closing behind the vessel while moving through the ice. Towing trials with different wire lengths and at different speeds were done with a dummy attached to the „Depressor”. Another test was done while observing the movements of the „Depressor“ with the GAPS. Due to stable performance of the „Depressor“ during course and speed changes no further tests were necessary. Because of reduced wind speed and decreasing wave heights, a ROV could be tested in the ocean. It was operated from the zodiac and directly from working deck. Another task was the deployment of five ARGO-Floats from BSH on given positions.

For planning and coordination reasons regarding the upcoming MOSAiC project three AWI employees worked on concepts for cargo storage, safety and data management together with the ship’s crew.

End of the cruise was in Cape Town on 11 of December.

2. WEATHER CONDITIONS DURING PS116

Manno Peters DWD

An intensive low northwest of Ireland was the dominant feature at the departure from Bremerhaven on 11 November 2018, 13 UTC. It was accompanied by southerly winds with Bft 5, broken clouds, some showers and temperatures at about 12 degrees. On 12 November *Polarstern* experienced more showers and Bft 6 at times at the sea area Thames in combination with a trough. The sea was building from 1.5 to 3 m. At night there were some thunderstorms with gusts of storm force. On 13 November the weather calmed down and the southwesterly winds decreased to Bft 5. Nevertheless the swell did not subside noticeable at the western exit of the English Channel. On 14 November southerly winds Bft 5 with sea 2 m were dominating while crossing the Bay of Biscay. The southeasterly winds decreased to Bft 4 in the vicinity of a secondary low west of Portugal. At the same time, storm lows over the northern Atlantic produced swell of 3.5 m. The cold front of such a low was crossing us north of the Canary Islands on 17 November leading to southwesterly winds Bft 7 and rain. Behind the cold front there were showers and the wind was veering to northwest decreasing to Bft 5. The swell was building about 5 m in the night to the 18 November. The longwave swell did not scare *Polarstern* much, but on the Canary Islands several near coastal damages were reported caused by the high waves. While arriving at Las Palmas on 18 November at 09 UTC, wind speed and swell decreased only a little. (Fig. 2.1).

Polarstern departed in direction to Cape Town on 22 November at 09:30 UTC. The cold front of a small scale low northeast of the Canary Island caused rain. The northerly winds only blew weakly. Further on there were northwesterly winds with Bft 5 to 6 at the edge of on extensive high south of the Azores. From 23 November we experienced the classical northeasterly trade winds accompanied by a low amount of cumulus clouds and temperatures slowly rising up to 25 degrees. In these days an intensive dust outbreak was observed originating from the Sahara and the Sahel. The force of the trade winds decreased off the coast of Guinea during the night to 26 November and the Intertropical Convergence Zone (ITCZ) was reached with light and variable winds. Several showers were observed at the southern edge of the surface position of the ITCZ on 27 and 28 of November. In this area temperatures about 28 degrees and a relative humidity of 80 % were measured. At the same time the southwesterly winds strengthened up to Bft 4 to 5. From 29 November onwards *Polarstern* was crossing the zone of the trade winds at the edge of the extensive high over the southern Atlantic. There, steady wind forces, low cumulus and stratocumulus clouds underneath a marked inversion were prevailing while the temperatures were decreasing a little. At first locally showers occurred, later on there was drizzle at some times. While approaching the African continent the cloud layer became thinner by 5 December. A low south of South Africa was moving eastwards on 6 and 7 December, causing southwesterly winds with a wind minimum of Bft 2 to 3. The southeasterly trades continued with Bft 5 by 8 December. The southerly winds decreased a little until the arrival at Cape Town in the morning of 11 December.

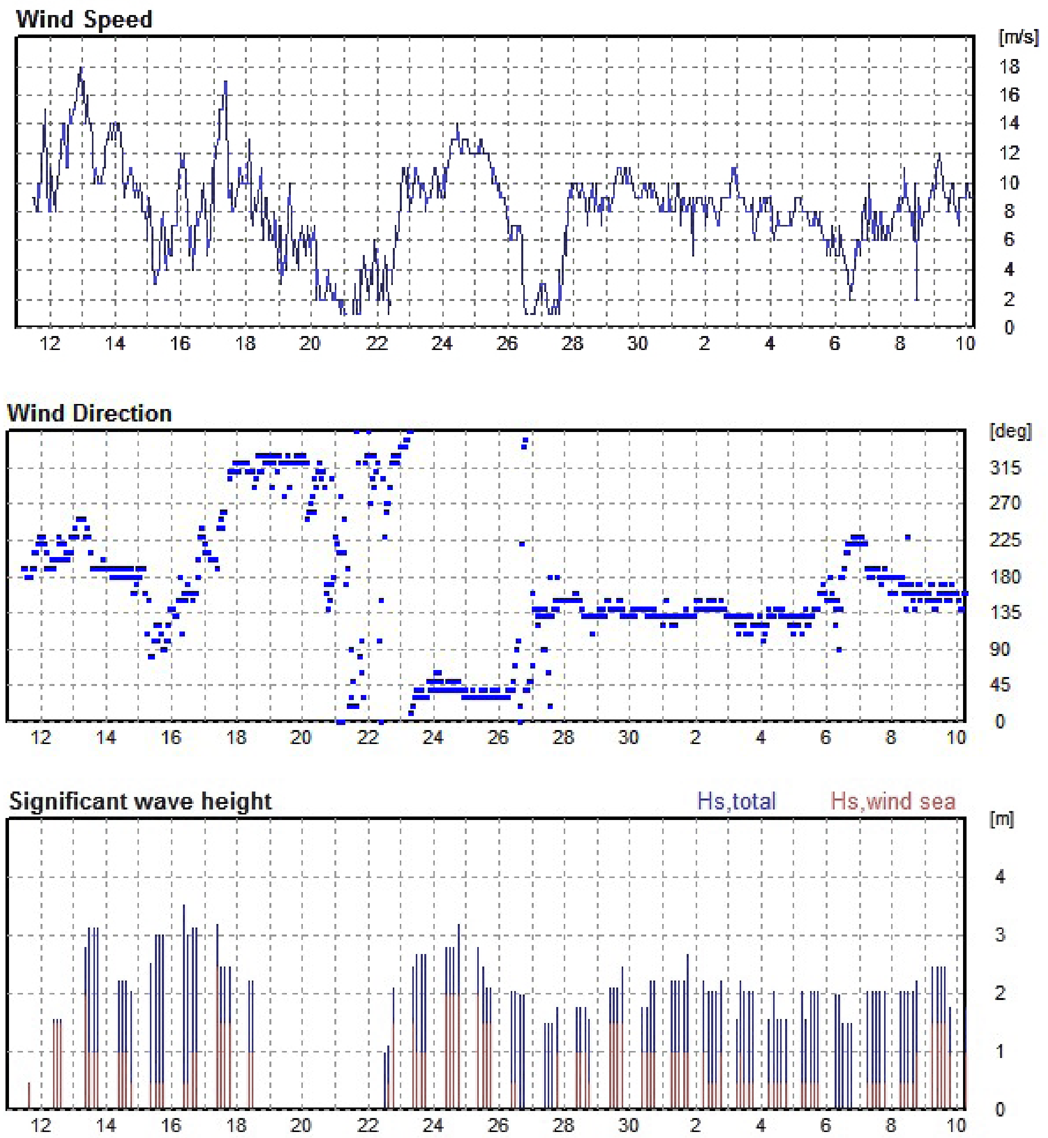

Fig. 2.1: Meteorological parameters during PS116 from 11 November 00 UTC to 11 December 2018 06 UTC (x-axis): (a) Wind speed in [m/s], (b) wind direction in [°C], (c) significant wave height in [m] (windsea fraction in red).

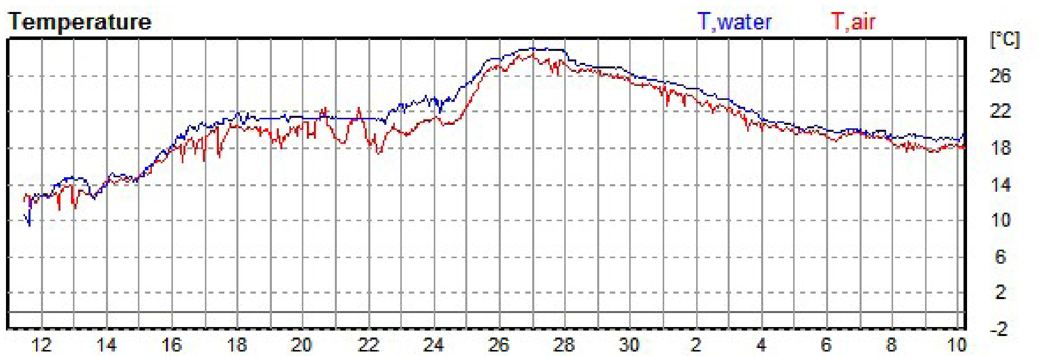

Fig. 2.2: Meteorological parameters during PS116 from 11 November 00 UTC to 11 December 2018 06 UTC (x-axis). Temperatures in [°C]: water (blue), air (red).

3. ECHOSOUNDING TRAINING COURSE (POLMAR-TRAIN)

Frank Niessen, Jan Erik Arndt, Simon Dreutter, Catalina Gebhardt, Johann Philipp Klages, Gerhard Kuhn (not on board), Claudia Hanfland — AWI

Grant-No. AWI_PS116_00

Objectives

POLMAR-TRAIN 2018 is a student-training course that was jointly run by the AWI-based Helmholtz Graduate School for Polar and Marine Research (POLMAR) and the University of Bremen. The purpose is to provide master students and doctoral candidates from the field of geosciences with a hands-on training in operating the hull-mounted echosounding systems of *Polarstern* (Teledyne multibeam echosounder HYDROSWEEP DS3 and sediment echosounder PARASOUND P70). Parallel to the practical training, the aim is to promote peer-learning by combining master students (beginners and advanced stage) and doctoral candidates / scientists in this course. In addition, we provide knowledge and literature about the near-surface marine geology along the south western and north western continental margin of Europe and Africa, respectively. Thus, the objectives of the work at sea are threefold:

(i) learn to operate the systems during shifts,

(ii) store, process and interpret the sub-bottom and bathymetric data and,

(iii) put the hydro-acoustic results into a broader regional perspective in order to understand the geology along the cruise track.

POLMAR-TRAIN is part of the programme "Master of Sciences Marine Geosciences" at the University of Bremen as well as of the scientific programme of POLMAR. Both programmes involve ship-based field-work for students and doctoral candidates. In addition, we take the opportunity to train participants of forthcoming marine expeditions in hydro-acoustic operation. The training is carried out by five lecturers affiliated with both the University of Bremen and AWI.

Work at sea

Educational Aspects

Twelve students from the University of Bremen, eight doctoral candidates, one scientist and one technician from AWI (Potsdam and Bremerhaven, respectively), participated in the training. Study topics of the participants include geology, geophysics, biological aqua culture, functional ecology, periglacial soil science, satellite remote sensing, environmental physics, sea-ice physics and chemical technology.

The course started with a theoretical introduction into the physics and techniques of echosounding and how to operate sounding systems, followed by a general introduction into the geology along the continental margins from the English Channel to the Canary Islands. Afterwards, students were introduced to hard and software and started going on watches (generally 4 hours each) in pairs of two each for both systems HYDROSWEEP and PARASOUND.

In groups of two to four, participants took over responsibilities for, in total, six regional areas of specific geological/geophysical characteristics along the cruise track to Las Palmas. These include:

- The English Channel from east of Dover to the Armorican Shelf edge
- The western Armorican Shelf and the slope/basin of the northern Bay of Biscay
- The area of and around the Galicia Bank
- The area west of major submarine canyons off northern Portugal
- The area of the boundary between the African and Eurasian plates
- The Agadir submarine canyon complex

The participants learned to interpret submarine geomorphological structures from bathymetric images, sediment echographs combined with information from the literature including seismic-profiles. With regard to multibeam-bathymetric data, participants were introduced to data acquisition, data processing, and visualization with different kind of profiling and GIS mapping software. For processing of PARASOUND data, the use of different software packages was applied including data conversion to SEG-Y. IHS™ Kingdom® software was introduced in order to let the participants combine information from bathymetric maps (GEBCO and/or HYDROSWEEP), *Polarstern* track lines and PARASOUND sub-bottom profiles (Fig. 3.1). In addition to data acquired during PS116, participants had access to both HYDROSWEEP and PARASOUND data from the following previous cruises: PS88, PS97 and PS105. Where ever possible, the track lines of cruise PS116 and previous cruises were placed with a small displacement to each other so that a slightly larger coverage of the sea floor is achieved for mapping. Exact repetition of sub-bottom results is avoided whenever possible.

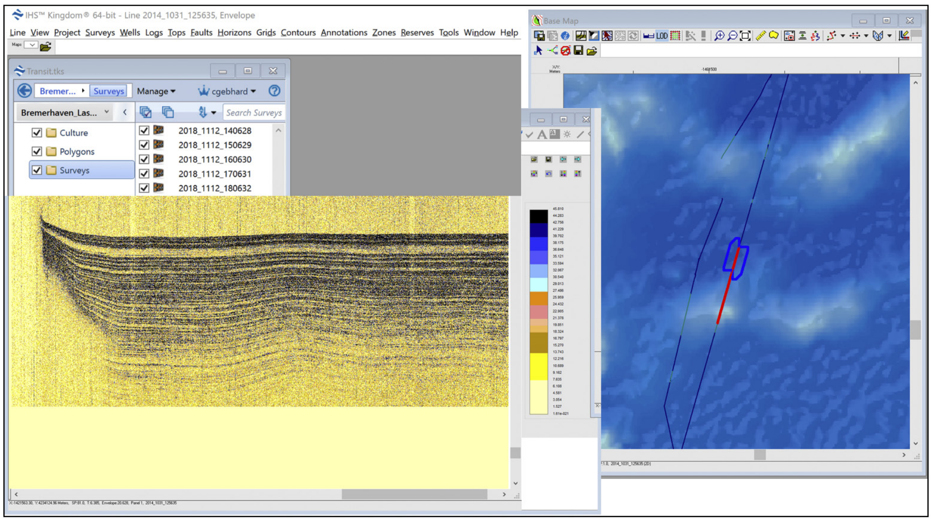

Fig. 3.1: Example of using IHS™ Kingdom® software to interactively combine PARASOUND track data visualized on bathymetric maps with sub-bottom profiles.

Technical Aspects

On the way from Bremerhaven to Las Palmas HYDROSWEEP recording started in the North Sea on 11.11.2018 at 18:51 UTC and ended on 18.11.2018 at 08:35 close to the island of Gran Canaria. PARASOUND recording was started on 12.11.2018 at 09:02 UTC east of the Strait of Dover and ended on 18.11.2018 at 09:02 UTC close to the Island of Gran Canaria. No system crashes occurred. The operational settings of PARASOUND transmissions are summarized in Table 3.1. During the entire cruise, we had avoided external depth control of PARASOUND by HYDROSWEEP because problems using this control were reported from PS98 (Kuhn et al. 2018). The problems are caused by PARASOUND noise interfering with HYDROSWEEP center beam sounding. This noise leads to irregular false depth determination by HYDROSWEEP. When imported as external depth into PARASOUND this can result in incorrect pulse-rate settings leading to data gaps at the sea floor. During PS116, along the continental slope from the Armorican Shelf into the abyssal plain of the Bay of Biscay, the operational mode of pulsing was changed from Single Pulse (SP) to Quasi-Equidistant (QED) operation. With this change the PHF frequency was increased from 18 to 19.25 kHz and the SLF frequency was decreased from 4 to 3.5 kHz. While this had no or only subtle effects on sub-bottom results, the noise interference by PARASOUND in the central beam of HYDROSWEEP was reduced significantly at higher than 18 kHz PHF PARASOUND pulsing frequencies.

Using Software PARASTORE PHF and SLF profiles were visualized online. PHF and SLF data were stored in ASD and PS3 (frequency carrier/lat.long.) formats. In addition, auxiliary data (navigation and PARASOUND settings) were stored in one-minute intervals. “Printing” of SLF data was performed using a PDF-creator of the operator PC via PNG output formats stored on disc.

Preliminary results

Educational Results

The concept of combining undergraduates and postgraduates in this training proved to be a successful approach. Next to guidance and discussion with the team of lecturers, peer-learning was an important factor for the success of this training concept.

The combination of theoretical background, practical work on the hydroacoustic systems (including troubleshooting), discussion of published data and student presentations was the right combination for a thorough and comprehensive training in echosounding techniques. However, the time available during PS116 was extremely short, because *Polarstern* left Bremerhaven one day later than scheduled (due to delayed ship-yard work). Also, the ship speed during the transect was relatively high, so that Las Palmas was already reached after seven days, whereas earlier training cruises had eight to ten days available for education for this part of the leg. Moreover, it is harder to run the echosounding systems at ship speeds well above 10 kn (average about 13 kn during PS116) compared to normal transit speeds of 10.5 kn.

All participants gave a 15 min presentation on their Bachelor, Master or PhD projects, which, in parts, included their previous experiences with hydro-acoustic data. In addition, at the end of the cruise, the groups responsible for the six regions along the cruise track (English Channel to Agadir Canyon as listed above) gave a 15-to-20-minute presentation each, in which they presented PARASOUND and HYDROSWEEP results obtained during PS116, PS105 (and/or during PS97/PS88 along parallel course tracks) in the context of the regional geology published elsewhere (provided to the students on board). In this way a very good overview was compiled about the characteristics of the geology of the continental margins. This includes understanding how the results documented by *Polarstern* hydroacoustic data support or extend the state-of-the-art knowledge. This combination turned out to be very effective for both motivating the students to acquire hydroacoustic data and developing interpretation skills. By using data from previous cruises, the different groups were able to work simultaneously without waiting for their area to be surveyed. It was straight forward to fit in interesting results, which were recorded during PS116. Reports were written by students who needed marking for their contributions.

Tab. 3.1. Settings of ATLAS HYDROMAP CONTROL for operating PARASOUND during cruise PS116

Used Settings	Selected Options	Selected Ranges
Mode of Operation	P-SBP/SBES, shallow and deep-sea settings	PHF, SLF
Frequency	PHF	19.25 kHz (QED), 18 kHz (SP)
	SLF	3.5 kHz (QED), 4 kHz (SP)
Pulse Length	No. of Periods	2 (Continuous Wave) 4 (Chirp)
	Length	0.5 ms (Continuous Wave) 1.14 ms (Chirp)
Transmission Source	Transmission Power	100%
	Transmission Voltage	159 V
	Beam Width	Automatic (4.5°)
Beam Steering	none	
Mode of Transmisson	Single Pulse (SP)	Auto according to water depth
	Quasi-Equidistant (QED)	Interval 1200-2250 ms
Pulse Types	Continuous Wave Frequency modulated (chirp)	Above 800 m of water depth Below 800 m of water depth
Pulse Shape	Rectangular	
Receiver	Output Sample Rate (OSR)	12.2 kHz
	Band Width (Chirp)	PHF: 2 kHz, SLF: 4 kHz
	Pulse Resolution (Chirp)	PHF: 0.369 m, SLF: 0.184 m
	Amplification	TVG Automatic, Shift: 40 dB
Reception Shading	none	
System Depth Source	Fix Min/Max Depth Limit	ATLAS PARASOUND PHF
		ATLAS HYDROSWEEP SLF (for very short periods only)
Water Velocity	C-Mean	Manual 1500 m/s
	C-Keel	System C-keel
Data Recording	PHF	100 m above Sediment
	SLF	200 m Penetration

Technical Problems

During the PARASOUND online operation, two problems occurred:

(1) While passing along the English Channel the ship's motion (heave, roll and pitch) increased steadily due to increasing influence of the sea state in the eastern Atlantic Ocean. Thus, the motion reached levels visible in PARASOUND data displays (PHF and SLF) in echogram windows for no, or incomplete, motion compensation. After contacting Teledyne in Bremen this problem was fixed via remote access to the PARASOUND system via satellite connection and full motion compensation was accomplished thereafter. Nonetheless, PARASOUND PHF and SLF data suffered from a strong overprint by ship's motion starting about at 12.11.2018 at 21:45 UTC until 13.11.2018 at 07:55 UTC. These uncorrected data sets were also stored on the ship's data base and transferred to the AWI data base on land eventually accessible through PANGAEA

(2) After entering deep water areas first along the slope of the northern continental slope of the Bay of Biscay, the transmission mode was switched to Quasi-Equal-Distant operation (QED, Tab. 1). Below a water depth of approximately 4,800 m (and similar over other abyssal plains thereafter) there was a strong increase in noise recorded in PHF data in the water column about 100 m above the sea floor. A somehow similar problem was noted during PS110 and described in the cruise report (Niessen 2019). During PS116 we observed two different types of noise above or below the echoes from the sedimentary record: (i) "clouds" of noise over some time along the track with single amplitudes almost as high as the sea floor reflections, and (ii), distinct "bands" of strong noise restricted to parts of single traces (or seismograms) re-occurring in regular lateral time intervals (Fig. 3.2). According to Niessen (2019) the first type of noise is from the uppermost water column (reflection from boundaries of water layers with different temperature, salinity and biota down to 500 m below sea level) and being picked up from near sea-floor echoes of a previous pulse reflected back to the transducer plate at the same time. The origin of the second type of noise is unknown. These noise problems were noted as critical for the sounding operation as they may cause faulty depth determination as long as the PHF signal is used as depth control of PARASOUND. Wrong depths result in incorrect calculation of sounding rates of QED pulses leading to gaps in recorded data from the uppermost sediments. During operation the problem can be overcome by decreasing the desired number of pulses in the water column and/or by increasing the minimum time interval between pulses in HYDROMAP Control. During PS116 and at water depth between 4,000 and 5,500 m, practical values turned out to be 3 pulses or time intervals as long as 2,300 ms. This is by far beyond the

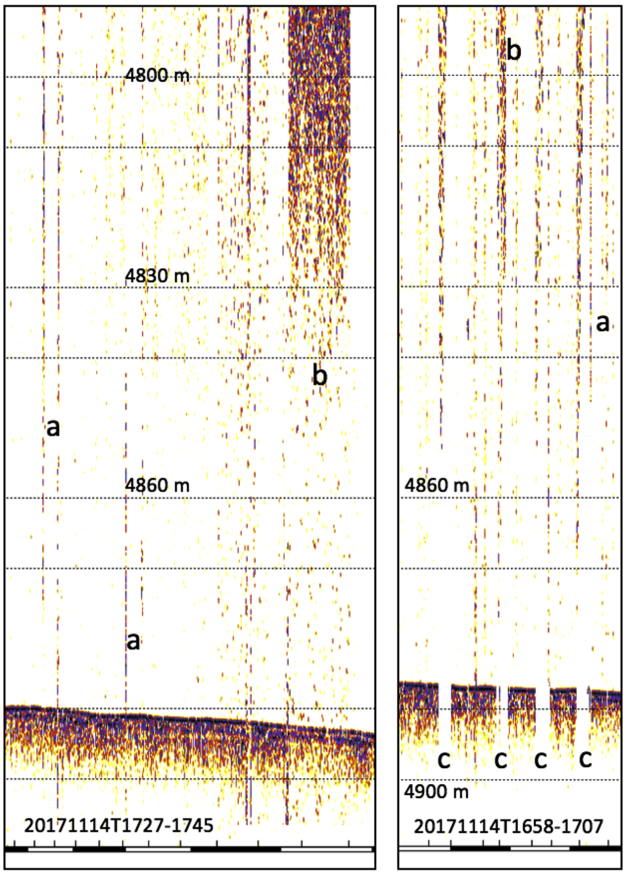

Fig. 3.2: PHF echogram window examples with noise described in text (a: distinct "bands" of noise, b: "clouds" of noise, c: resulting gaps due to faulty depth determination while using PHF for depth control).
Time-window code: yyyymmddT(ime)hhmm-hhmm (UTC), black or white bars at bottom mark lateral distance of 1 km each.

lateral resolution capabilities, which the system allows in general for operating at these depths. Whether or not a technical solution can be provided to improve the system is left to negotiations with the manufacturer after the cruise.

Data management

Hydroacoustic data (multibeam and sediment echosounder) collected during the expedition were copied to the *Polarstern* data base. From there the data will be transferred to the data mass storage at AWI Bremerhaven. Finally, the data will be stored and linked to the PANGAEA data repository at AWI. Furthermore, the data will be provided to international mapping projects and included in regional data compilations such as the Nippon Foundation-GEBCO (General Bathymetric Chart of the Oceans) Seabed 2030 Project.

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4. PLANKTON-E DNA

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Grant-No. AWI_PS116_00

Objectives

The scientific aims of the project are:

- To identify and quantify the taxonomic and functional changes of plankton communities in a large latitudinal transect along the Atlantic Ocean from Bremerhaven to Cape Town using water samples and a combined approach of visual taxonomy and DNA metabarcoding.
- To develop and validate a simplified method for inventory of relevant species from environmental DNA and Next Generation Sequencing (NGS) using water samples of small volume.
- To assess the association between environmental parameters and plankton species important for fisheries, principally preys of commercial fish.

Work at sea

Water samples were taken at 22 geographical positions evenly distributed along the cruise track: before, after and one crossing the equator. *Polarstern* has an underway system for pumping water from outside the vessel into the laboratories through a pipe. The tap connecting with the membrane pump, with the water take at 6 m depth, was running constantly along the travel. Each day, different volumes of water were concentrated through filters of different mesh, following the scheme presented next:

1: Filter 0.2 µm pore. Between 4 and 10 L. Coded and stored in absolute ethanol for further DNA metabarcoding in University of Oviedo laboratory.

2: Filter 46 µm mesh. Between 200 and 500 L, concentrated in circa 200 ml volume. It was split in two aliquots. One was filtered through 0.2 µm membrane and stored in ethanol for metabarcoding; the other was photographed under the microscope (several drops), and stored in formaldehyde for morphological identification.

3: Filter 250 µm mesh. Between 500 and 1,000 L, concentrated in circa 100 ml volume. Split in two aliquots that followed the same processing as in the previous case.

4: Samples were taken overboard with a manual plankton net of 20 µm mesh, approximately 200 L of volume concentrated in three replicates of 50 ml. They were aliquoted for filtering through 0.2 µm membrane and storing in ethanol for metabarcoding, and for morphological analysis, photographs under the microscope fixed in formaldehyde.

Onboard, samples 2 to 4 were visually analyzed with the microscope, and individuals were sorted for visual identification of the species using taxonomic guides, then stored in absolute ethanol for further DNA barcoding in University of Oviedo.

Water samples (two samples of 5 ml) were taken each day and stored at -20°C for further analysis of nutrients and other chemical parameters in AWI.

Metabarcoding (University of Oviedo), Barcoding (University of Oviedo) and complete visual identification (AWI) will be carried out at the home laboratories within one year after the cruise.

Preliminary and expected results

Pictures of individuals of some species found in this study are presented in Fig. 4.1, with examples of phytoplankton from the North Sea and the Bay of Biscay (Fig. 4.2). As expected, the species composition was not the same at different latitudes.

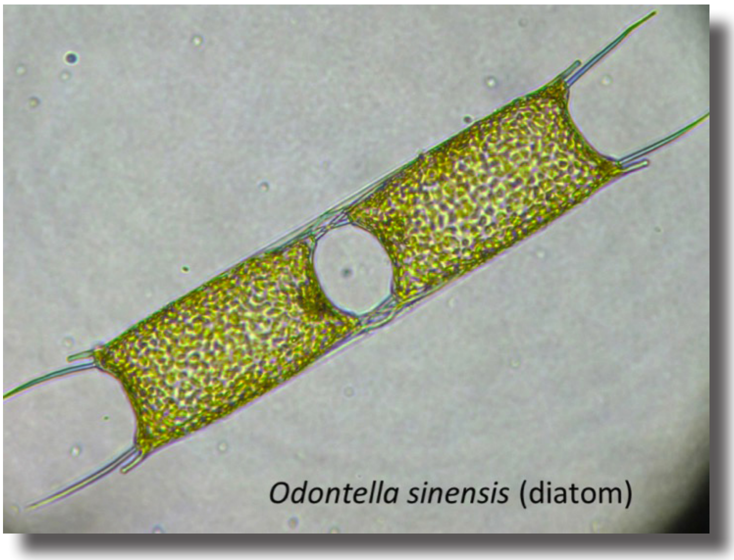

Fig. 4.1: Photograph taken onboard Polarstern *of an individual of the diatom species* Odontella sinensis *sampled from the North Sea*

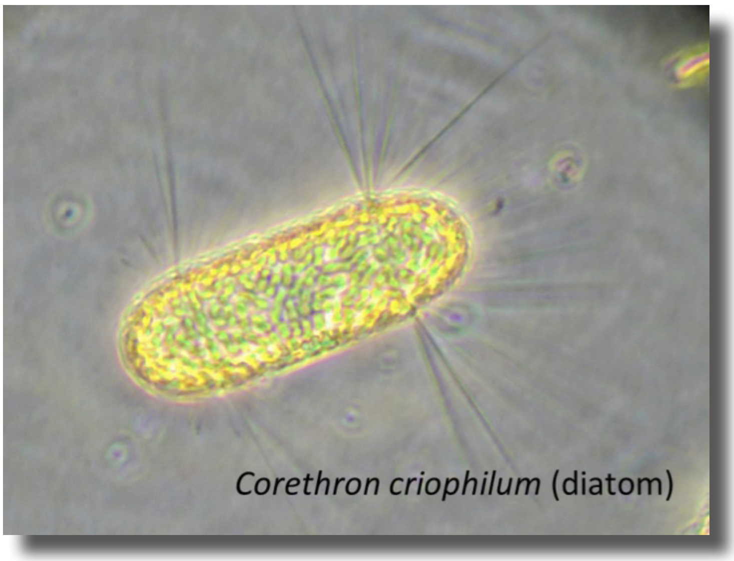

Fig. 4.2: Photograph taken onboard Polarstern *of an individual of the diatom species* Corethron criophilum *sampled from the Bay of Biscay*

DNA Barcoding (COI, 18S, RBCL and/or 16S rRNA genes as Barcodes) will be used for species ascertainment from individual samples. This way sequences associated to individual vouchers will be available. NGS Metabarcoding as in Borrell et al. (2017a,b) will serve for describing the plankton community. The Illumina platform (or Ion Torrent) will be employed.

The association between environmental parameters and plankton diversity, function and key species will be modelled and the model tested and validated using state of the art bioinformatics procedures.

The present study will contribute to understanding the crucial functional features of plankton communities across a long latitudinal trans-equatorial transect, and how they are influenced by environmental conditions. The use of NGS methodology for inventorying higher eukaryotes of interest for fisheries sustainability from plankton communities, at the large geographical and latitudinal scale proposed in this study, has never been published to date, and will compare to other large expeditions such as Tara Oceans.

Knowing the composition of planktonic communities is essential for both fundamental and applied purposes. On one hand, the community composition serves to understand how an ecosystem functions, based on the trophic levels and life history of the species assemblages (e.g. Thompson et al. 2015). The equilibrium of plankton communities is delicate. Zooplankton grazes on phytoplankton, and the community equilibrium is affected by their respective abundance and other factors such as pollution and nutrients (Jang et al. 2008). At the same time, the nutrients balance (for example N/P) is governed by the composition of plankton communities (Weber & Deutsch 2010). The balance phytoplankton-zooplankton and their particular species composition, as well as harmful algal blooms, are related with environmental factors including extreme climatic events such as hurricanes (Fuentes et al. 2010), and are expected to change across latitudes (Richardson 2008). Expectations are that diversity is greater near the Equator and decreases as latitude increases (e.g. Roy et al. 1998, Hillebrand 2004; Fuhrman et al. 2008). Some insights about transequatorial community variation, in particular of pelagic ichthyoplankton, have been achieved from the *Polarstern* (Ardura et al. 2016). In that study, the latitudinal pattern of diversity did not exhibit the expected temperate-tropical cline, reflecting instead a decline in low-oxygen zones (Ardura et al. 2016) and showing again the importance of environmental conditions for shaping plankton communities.

On the other hand, plankton analysis is crucial in fisheries sciences. Many commercial fish species have planktonic larvae, but they are so largely unknown that they have been called the “missing biomass” (e.g. Johnson et al. 2011). They feed on other (sometimes the same) plankton species, and are an important part of the trophic chain (e.g., Bulman et al. 2002; Walker et al. 2002). They are especially sensitive to climate change and other environmental alterations (e.g. Boeing & Duffy- Anderson 2008), likely related to alterations in the trophic chain and in particular in their preys, like copepods (e.g. Beaugrand et al. 2003). Larvae of important commercial species such as hakes feed on copepods (e.g. Morote et al. 2011). Copepod diversity exhibits a latitudinal cline associated with temperature (Rombouts et al. 2009), but there are evidences of zooplankton decline in tropical Atlantic waters (e.g. Piontkovski & Castellani 2009), and this can put at risk fisheries sustainability. More large-scale studies are necessary on ichthyoplankton communities and especially on their main preys at tropical latitudes.

Studying plankton communities from conventional methodology is laborious. It requires sampling large volumes of water, concentrating the plankton through filtration, sorting the individuals visually under the microscope, and classifying them taxonomically, sometimes with the help of DNA for species identification and quantification. For example, Ardura et al. (2016) have shown that DNA Barcoding is a promising methodology for ichthyoplankton inventory, and Fuentes et al. (2008) have applied RT-PCR for quantifying toxic algae, but new developments are still needed for application in large-scale routine surveys. The new methods of high throughput sequencing i.e. Next Generation Sequencing (NGS) on environmental DNA can help in species detection and inventory as has been proven for *Polarstern* ballast water (Zaiko et al. 2015a, b; Ardura et al. 2015), open waters (Zaiko et al. 2015b), estuaries (Borrell et al. 2017a) and others. These methods are very sensitive, and even relatively scarce species can be successfully detected from small water volumes – as small as 3 L, see for example inventories of port species from water in Borrell et al. (2017b). They are employed, for prokaryotes and some specific taxonomic groups like ciliates, in large oceanic expeditions like *Tara Oceans* (e.g. Sunagawa et al. 2015; Gimmler et al. 2016), but have been less applied for whole eukaryotic communities and almost nothing for targeting fish preys, to our knowledge. If these methods are adequately developed and independently validated for specific applications, they could be used for example for locating species of interest for fisheries like preys of commercial fish species, determining the functional equilibrium of planktonic communities (from the trophic level of the different species inventoried), and other applications.

Preliminary work conducted in *Polarstern* PS102 (2016) consisted of sampling water overboard using a 15-L bucket every day, filtered 1.5 L through 0.2 µm mesh filters and stored the filter in ethanol. We have performed DNA extraction from the filters when returning in Oviedo home laboratory. Despite very small water volume, sufficient DNA quantity was extracted from the filters for conducting further NGS employing universal primers for COI (zooplankton) and RBCL (phytoplankton). Sequences obtained in different days allowed a robust identification of several species of phytoplankton using strict thresholds in bioinformatics pipelines that were different in samples taken at different latitudes, as expected. The baseline obtained was very modest because the DNA concentration was low in the samples of such small volume. That previous experiment served to set up the minimum volume to be filtrated in 4 L. As seen above, in the present study in PS116 the volumes employed were much larger.

Predicted results are:

1. Sufficient DNA for a good coverage of the biodiversity with saturation curves reaching the plateau, will be obtained for all the samples.
2. According to 1) and other results of the research team, the results obtained from visual identification and metabarcoding will be largely coherent; individual barcodes will help to improve the genetic assignation and to enrich the reference databases.
3. As in Ardura et al. (2016), latitudinal variation in plankton diversity will exhibit lows in the low-oxygen zones.
4. Nursery zones for commercially important fish will be identified from the plankton communities obtained along the transect.

Data management

At least two peer-reviewed and SCI-indexed scientific publications are expected from this study. The samples will be stored at the University of Oviedo and AWI, available for the scientific community. DNA sequences will be released in public databases within one year after the end of the cruise.

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5. ATMOSPHERIC GASEOUS AMMONIA AND PARTICULATE AMMONIUM AND THEIR STABLE N - ISOTOPES AND THE DIVERSITY OF AIR-BORNE MICROORGANISMS ALONG A TRANSECT ACROSS THE ATLANTIC OCEAN

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Grant-No. AWI_PS116_00

Objectives

The overall aim of our project is to sample atmospheric air across a large-scale transect from Germany to Cape Town, South Africa, on the Atlantic Ocean. We want to characterize the concentrations of Ammonia (NH_3)- and Ammonium (NH_4^+) -containing aerosols and gas components in their regional distribution as well as their sources and sinks in the Atlantic and the background pattern of the ratios of their stable isotopes $\delta^{15}N$ / ^{14}N in size separated particles. The isotope ratios of ^{34}S / ^{32}S in airborne non – sea salt particulate sulphate will be determined, too, since SO_4^{2-} is often the counter ion of NH_4^+ in atmospheric samples. Additionally, we also sample bioaerosols like bacteria, fungi and algae to learn about the composition of their communities and their origin.

Gaseous Ammonia & Ammonium

Ammonia gas (NH_3) is - besides mineral dust and amines - the main alkaline compound in the atmosphere and takes part in acid – base reactions. It is the source of ammonium (NH_4^+) in atmospheric particles, droplets and ice cores. Ammonia is emitted into the atmosphere on a global scale mainly by volatilisation from liquid cattle waste, when urea is decomposed (e.g. Boettger et al. 1980; Lenhard and Gravenhorst 1980; Dentener and Crutzen 1994). In the marine atmosphere NH_3 could have its source in the surface water with high values of temperature and pH (Bell 2006). In special situations at marine sites bird colonies can accumulate huge amounts of wastes emitting NH_3. Gaseous NH_3- concentrations in maritime background areas are in the range of 5 - 50 ng N / m^3. The concentrations of gaseous NH_3 and particulate NH_4^+ drop by about one order of magnitude from the open ocean to the sea ice covered ocean (Ibrom et al. 1991).

Maritime airborne ammonium is mainly found in the nucleation and accumulation mode, whereas nitrate is found in the coarse mode (e.g. Junge 1963; Gravenhorst 1975; Gravenhorst 1978; Gravenhorst et al. 1998; Schaefer et al. 1993; Sievering et al. 1999; Hillamo et al. 1998). Therefore, ammonium and nitrate over the ocean are not found in the same particle size range and cannot be present as ammonium-nitrate. Airborne NH_4^+ and N *Non Sea Salt Sulfate* (NSSS) in remote areas are often closely associated in particle size and concentration. They frequently show molar ratios between 1 and 2, indicating NH_4HSO_4 and $(NH_4)_2SO_4$ mixtures (Gravenhorst 1978). However, NH_3 and DMS fluxes over the Atlantic did not show any correlation (Bell 2006). Gaseous ammonia probably reacts with newly formed acidic sulphur aggregates. A sea- salt contribution as a primary $(NH_4)_2SO_4$ aerosol is not realistic, since the weight ratio of Na/NH_4 is on the order of > 10^{+6} in sea water, but only of the order of 1-10 in airborne particles. A pure reaction of existing acidic sulphate and alkaline ammonia seems to be more likely for a correlation of sulphate and ammonium in aerosols (Gravenhorst 1975; Beilke and Gravenhorst 1978; Johnson et al. 2008). It is still a question of where NH_4^+ in atmospheric samples comes from.

∂ ¹⁵N ratios of ammonia and ammonium in the atmosphere

Determination of $\partial\,^{15}N\text{-}NH_4^+$ and $\partial\,^{15}N\text{-}NH_3$ isotope ratios in atmospheric samples is very rare. A generalized interpretation of the $\partial\,^{15}N$ values is proposed here: NH_3-source material (manure, urine, faces) have a high $\partial\,^{15}N$ value in a range of about + 0‰, compared to gaseous NH_3 in the atmosphere of about -20 ‰). The fractionation during volatilisation of NH_3 is very large, about up to 30 ‰. The particulate ammonium in the atmosphere has a high $\partial\,^{15}N$ value similar to the $\partial\,^{15}N$ value of the source material. The rain $\partial\,^{15}N\text{-}NH_4^+$ value seems to fall between $\partial\,^{15}N$ values for gaseous airborne NH_3 and for particulate airborne NH_4^+. Rain $\partial\,^{15}N$ values seem to be the result, that airborne particulate NH_4^+ has heavy $\partial\,^{15}N$ values and gaseous NH_3 light values. When entering the cloud base they will be incorporated into cloud droplets and subsequent into rain drops (Gravenhorst 1983). $\partial\,^{15}N$ values in rain could develop as weighted means of $\partial\,^{15}N$ values of NH_3 gas and of NH_4^+ particles in the updraft at cloud base.

Relatively high $\partial\,^{15}N\text{-}NH_4^+$ -ratios associated with heavy $\partial^{15}N$ values in Atlantic aerosol samples were attributed to continental NH_3-sources. They suggested that low aerosol NH_4^+ concentrations with light isotope $\partial\,^{15}N\text{-}NH_4^+$ values should indicate a marine NH_3 source.

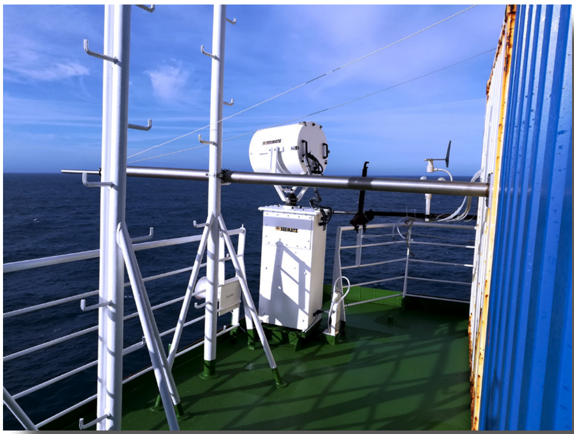
Work at sea

Gaseous NH_3 and particulate NH_4^+ in the lower atmosphere was sampled on the latitudinal transects of *Polarstern* PS116 from Bremerhaven to Cape Town. Generally, all sampling was carried out only when the horizontal relative wind came from about ± 80 degrees against the ship's course to avoid sampling of ship´s emissions. The backward trajectories of the air masses reaching *Polarstern* will be taken from DWD analysis and synoptic charts on board (Fig. 5.2).

For NH_3^- and NH_4^+ concentration and $\partial\,^{15}N\text{-}NH_3$ and $\partial\,^{15}N\text{-}NH_4^+$ isotope measurements the NH_4^+ and NH_3-gas molecules were accumulated on filter pack systems (90 mm diameter). The filter pack system consists of 4 stages with one teflon-membrane filter on the first stage to collect particles followed by three membrane filters acidified with citric acid to absorb ammonia in its gas phase (Fig. 5.1). Six individual stand-alone systems (filter pack, gas pump, gas meter, wind direction controller and an impactor) were installed on the deck above the bridge. If the relative wind was blowing from about ± 100 degrees against the ship's course a further filter pack system could be installed at the aft. The filters will be stored in 50 ml PE bottles at temperatures slightly above freezing point, to avoid cell brake up. The third NH_3 absorption filters in the filter packs will serve as blank values. Depending on the NH_4^+ mass found on each NH_4^+ -particle filter and on each NH_3 ammonia filter the solutions of filters will be bulked or kept individually and used for NH_4-N - and NH_3-N isotope analyses on land.

A high – volume impactor sampler (approx. 70 $m^3\,h^{-1}$) with 5 stages will collect *size* – fractionated airborne particles (Marple and Willeke 1976) which we use also for isotope analyses for the different particle size ranges. Each stage of the impactor (10 µm to > 0.1 µm radius) is covered with a teflon foil and a teflon membrane filter (filter Ø = 20 cm, particle r < 0.1 µm radius) that serves as back-up. The impactor is installed in the container on the monkey deck above the bridge and controlled by a wind vane. The direction of the intake opening is fixed with respect to the ship's axis. The aerosol filters will be stored in 50 ml PE bottles at temperature slightly above freezing point to prevent lysis of microbiological cells.

5.1.a)



5.1.b)

5.1.c)

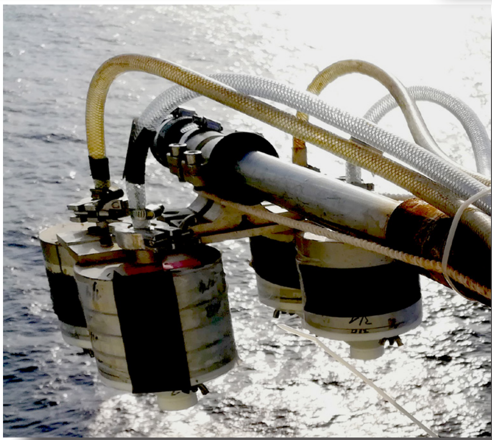


Fig. 5.1: (a) tubes gathering and leading the airflow into the impaktor; (b) impaktor inside the container; (c) four filter pack systems.

Some of the filter pack systems will be equipped in the first stage with glass-fiber membranes to collect air-borne microbes. The filters have been pre-sterilized at home prior to the sampling at 400°C overnight in an oven to burn all contaminating organic material. We want to detect biodiversity and community structures of air-borne microbes above the Atlantic Ocean and how these structures change from North to South along the transect. Additionally, we investigate whether these microbes are of marine or terrestrial origin by using Hysplit backward trajectory models of the National Oceanic and Atmospheric Administration (NOAA 2018). Possible correlations concerning microbial biodiversity and the distance to the continents as well as the origin of air masses might reveal whether the air represents just a means of transportation or a real microbial habitat. The determination of the species level occurs on extracted 16S DNA, thus, in order to avoid contamination the extraction will be carried out at home in sterile environment and the samples onboard will be stored at -80 C and on dry ice upon return

Preliminary results

Measurements were constantly taken during PS116, except during stops when relative wind direction or speed did not meet requirements and samples could have been contaminated by ship´s emissions. The weather respectively the relative wind direction was optimal throughout great parts of the cruise, i.e. the wind met almost constantly the front of the vessel. Only for the first three days after docking in Las Palmas the wind blew from the aft and sampling had to be stopped on the monkey deck. Therefore two filter pack systems with pumps and gas meters were installed in the aft of the working deck for sampling. After 2 days the wind direction changed again, but the filter packs remained on the working deck for further sampling. The collected samples might serve as positive control of our sampling systems since, presumably, particles of the ship´s emissions were collected on these filters. A thick brown layer of particles was observed which is not present on the sampled filters on the monkey deck.

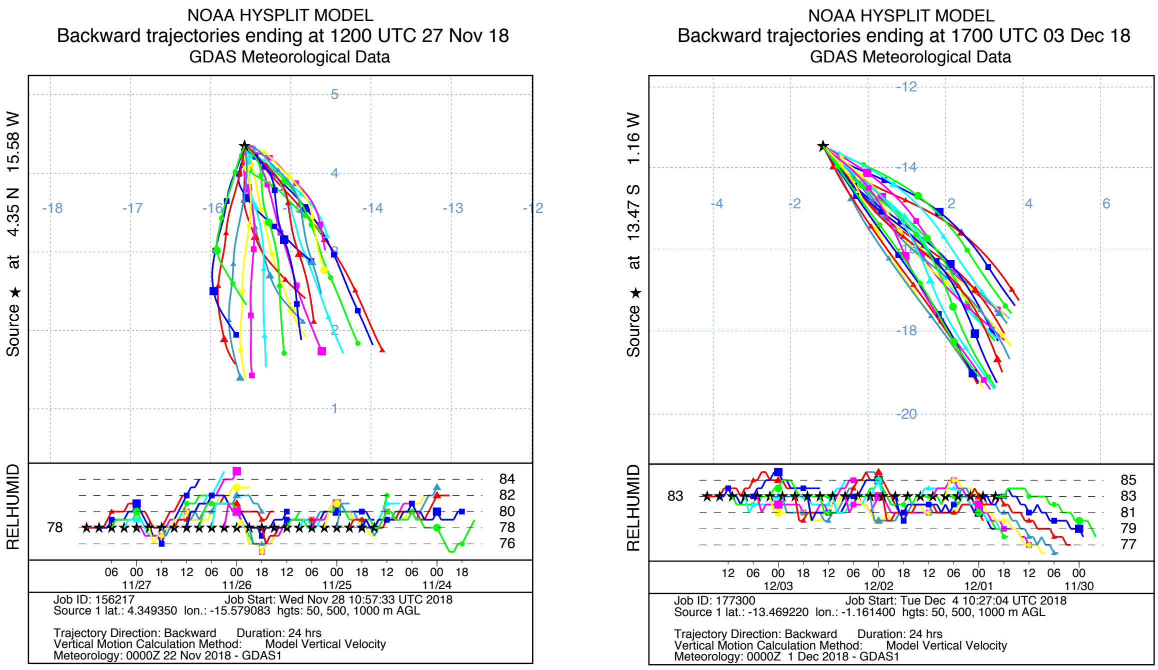


Fig. 5.2 a and b: Examples of daily ordered backward trajectories from the National Oceanic and Atmospheric Administration (NOAA) of air masses for 72 hours in three different altitudes (50 m, 500m, and 1000 m asl) from November 27 (a; left) and December 1 (b; right).

In total, ten measurements of the size-fractionizing impactor have been carried out with a total volume of 11336.5 m^3 of pumped air, resulting in the collection of 50 samples (40 sliced teflon foil filters and 10 cellulose back-up filters).

The collection of gaseous Ammonia and particulate Ammonium have been carried out nine times with a total volume of roughly 11.9 x 10^6 m^3 of pumped air. 300 cellulose filters, 20 glass-fibre filters and 60 teflon filters for aerosols were collected throughout the cruise.

Atmospheric air samples were collected on a daily basis on the monkey deck as well as in the pCO_2 device where the air is in equilibrium with the collected sea water. These samples will be investigated toward the isotope ratio of $\delta^{13}C$ and $\delta^{15}N$.

Tab. 5.1: Overview of the sampling success

Sampling system	date start	date end	air volume m³	type of sampling
Filter pack	13.11.2018	13.11.2018		negative controls
	13.11.2018	13.11.2018		negative controls
	14.11.2018	17.11.2018	1.2×10^6	sampling with 8 filter pack systems
	15.11.2018	15.11.2018		negative control on working deck
	15.11.2018	15.11.2018		negative controls
	15.11.2018	17.11.2018	220.269	sampling with 8 filter pack systems
	24.11.2018	29.11.2018	402.786	sampling with 4 filter pack systems on working deck
	26.11.2018	30.11.2018	0.4×10^6	sampling with 4 filter pack systems
	30.11.2018	05.12.2018	10.4×10^6	sampling with 8 filter pack systems
	05.12.2018	09.12.2018	$\sim 10 \times 10^6$	sampling with 8 filter pack systems
Impactor	13.11.2018	13.11.2018	39.4	impactor leaked
	14.11.2018	17.11.2018	-5176.2	connection between pump and gas meter leaked
	26.11.2018	30.11.2018	-2268.7	realized that gas meter counts backwards, although it is connected correctly
	30.11.2018	03.12.2018	-1962.7	Pump is misspoled, hence corrected
	03.12.2018	04.12.2018	2113.7	
	04.12.2018	05.12.2018	2085.4	
	05.12.2018	07.12.2018	2783.8	several stops, therefore longer sampling
	07.12.2018	08.12.2018	1797.5	
	08.12.2018	09.12.2018	~2000	

Data management

Data processing will be carried out after the wet-chemical measurements of the samples. However, this will take several months, since the samples remain onboard in storage upon return of the vessel to Bremerhaven in July 2019. As soon as the data is available it can be requested and used by other cruise participants.

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6. ATMOSPHERIC MEASUREMENTS OF AEROSOLS AND CLOUDS WITH A MOBILE SEA FACILITY OCEANET

Andreas Macke (not on board)[1], Ronny Engelmann (not on board)[1], Hartwig Deneke [1](not on board), Karsten Hanbuch[1], Alina Herzog[1], Nils Küchler[2], Kevin Ohneiser[1]

[1]TROPOS
[2]Uni Köln

Grant-No. AWI_PS116_00

Objectives

The OCEANET-ATMOSPHERE project gathers and delivers valuable atmospheric measurement datasets over the oceans – in regions of the world that are not easily accessible. For the last 8 years, a container-based platform has been operated regularly on board of *Polarstern* to obtain measurements and contrast atmospheric processes between the anthropogenic polluted northern hemisphere and the rather pristine southern hemisphere.

The OCEANET container contains several remote-sensing instruments. The primary instrument is a semi-autonomous multiwavelength polarization Raman-LIDAR developed at TROPOS. It is capable to measure backscattering coefficient profiles at three wavelengths (1,064 nm, 532 nn and 355 nm), the extinction coefficient, depolarization ratio at two wavelengths as well as the water-vapor mixing ratio.

Aerosol particle optical properties can be determined directly and serve as input for height-resolved inversion methods to estimate the main microphysical properties (e.g. size distribution) at any measured height. Thus, lofted free-tropospheric aerosol layers can be characterized separately from the marine boundary layer. Typical known free-tropospheric aerosols are anthropogenic emissions from North America, dust from the Saharan region or smoke from biomass burning in Central Africa. These aerosols are lifted up above land and are transported over the Atlantic Ocean for several days. During this transport aerosols influence the radiation budget of the Earth. Thus, the height-resolved information as derived from LIDAR is a crucial input for radiative transfer calculations to determine the direct aerosol radiative effect more precisely. In addition, the height-resolved measurements offer the opportunity to determine the extent of simultaneously occurring clouds, as well as the cloud's thermodynamic state of phase (liquid or solid) to investigate aerosol-cloud interactions and to determine the aerosol indirect radiative effect.

The second major instrument is a microwave radiometer (MWR, type: HATPRO) measuring brightness temperatures in the microwave region and using absorption bands of water vapor and oxygen, as well as the liquid water continuum to retrieve the integrated water vapor (IWV), temperature profiles up to 10 km altitude, and the liquid water path (LWP). In combination with the variability of the downward radiative quantities these time series make it possible to observe small scale atmospheric structures and cloud inhomogeneity.

A prototype of an automated motion stabilized sun photometer (type: CIMEL CE318-T) was tested during PS113. For PS116 this prototype was upgraded with new hardware as well as improved software. Here the functionality and stability of this platform was tested. Due to its nine channels it will offer the opportunity to apply more sophisticated retrievals, motion-corrected scanning capabilities and an anti-sea spray system.

Additionally, a scalable automatic weather station (SCAWS) from the DWD measures standard parameters such as temperature, pressure, humidity, and radiation (solar and infrared) on a 1-s time basis.

Four hand-held sun photometers (3x Type Microtops, 1x Type Calitoo) delivered additional data regarding the Aerosol Optical Thickness (AOD) of the atmosphere. The objective was to compare the performance of the two TROPOS instruments and the one instrument of University of university of Lille with one calibrated instrument from NASA as well as measurement of the AOD. In addition, the data of the CIMEL mounted on the container is used as reference.

Polarstern was also used to validate the recently launched European Space Agency (ESA) LIDAR-satellite Aeolus. Therefore, the ship was navigated into the overpass flight path of the satellite so that measurements taken by the remote sensing equipment on board can be compared to the satellite derived data.

Work at sea

The instrument set-up and initial calibration started call to port at Bremerhaven on 9 November and was finished on 10 November. The container was located on the helicopter deck (Fig. 6.1). All the observations were taken *en-route* and did not depend on any station time, though the ships speed was adjusted to match the Aeolus flight path. Regular maintenance procedures included daily cleaning of the radiation sensors and the All-Sky-Camera dome. The LIDAR windows were also cleaned on a regular basis depending on sea-spray or dust contamination. At high sun elevations the LIDAR system had to be turned off manually to protect the optical photomultipliers. All sensory data was monitored constantly to ensure high quality data.

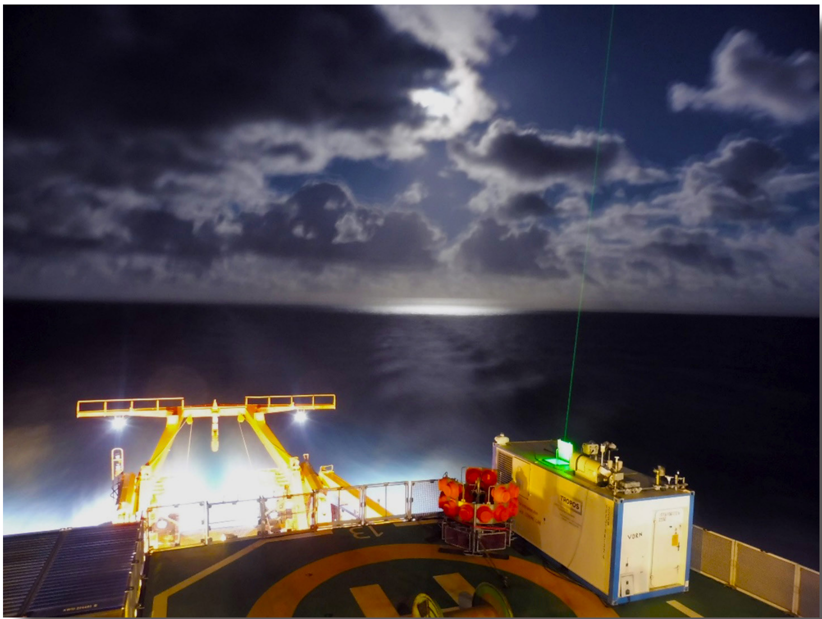

Fig. 6.1: Location of the OCEANET container on the helideck

Additionally, atmospheric data were taken manually and regularly using the Microtops and Calitoo instruments when sky condition were clear.

Expected and preliminary results

Measurements were constantly taken during PS116, except the stay in Las Palmas harbour and within the 200 miles area around South Africa due to governmental restrictions of Spain and South Africa.

Please refer to the cruise weather report for information on the weather and therefore measurement conditions throughout the transfer,

A first measurement example is shown in Fig 6.2. It is a very important and interesting time period as there is a large amount of Saharan dust as well as different types of clouds. On 23 November many low clouds (Cumulus and Stratus) between 1 and 3 km height appeared. From the low depolarization ratio but high backscatter signal it can be concluded that it is pure liquid water clouds. On 25 November the ground distance of the clouds increased, cirrus and altostratus clouds were observed. As an indicator, the higher depolarization ratio shows that those clouds were ice containing (mixed phase) clouds. Later, between the 25 and 27 November, a Saharan dust layer occurred reaching heights from close to the surface and up to 4 km. In the same time, photometer measurements were conducted during cloud free situations measuring a large amount of Saharan dust aerosols too.

The cruise from Bremerhaven to Cape Town is a suitable route in order to study the influence of different types of aerosols in different climate zones on ice forming in cloud. Future studies concerning all the data will focus on clouds and aerosols, as an example the amount of clouds containing ice in dependence on the temperature and the aerosol type.

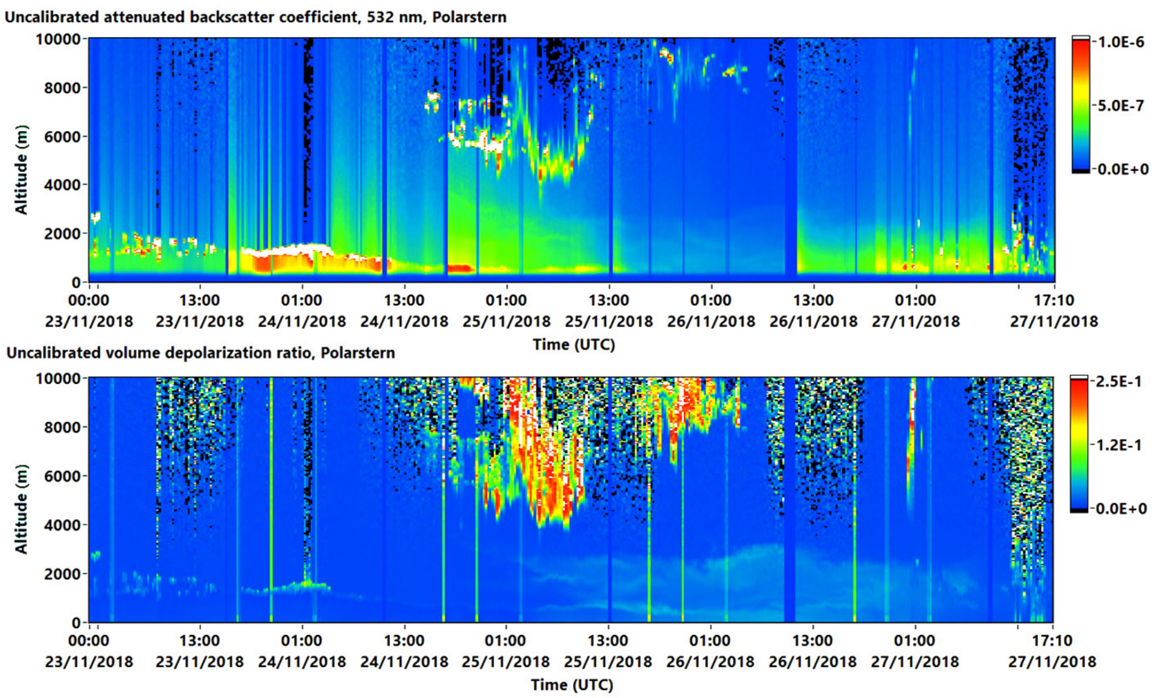

Fig. 6.2: Measurement example of lidar measurement from 23 to 27 November on Polarstern *(top: backscatter signal, bottom: depolarization ratio).*

Additional radiosondes were launched when necessary in order to obtain wind information for the validation of the recently launched ESA satellite Aeolus. For the German initiative EVAA (Experimental Validation and Assimilation of Aeolus observations), responsible for the validation of wind and aerosol products of Aeolus, the cruise was a unique opportunity to obtain ground-based remote sensing data across the Atlantic Ocean. During the cruise four fitting overpasses of Aeolus within 60 km to the satellites ground track and two additional overpasses with distances over 100 km were reached.

The microwave radiometer was calibrated with a high-precision blackbody target providing measurement accuracies of 0.5 K and better, and a very low noise level enabling the observation of small scale variations of IWV and LWP of +- 0.5 g m^{-2} and +- 0.1 g m^{-2}. A preliminary check of the calibration was performed by observing the calibration scenes. All channels showed the expected scene temperatures for a period of several minutes.

Fig. 6.3 shows time series of IWV, LWP, and 0 °C and -11 °C isoline altitudes obtained by the MWR for 23 to 27 November. The increase of the isolines' heights in the beginning of the measurement period indicates the crossing of the Ferell-Hadley cell boundary, which is also reflected by an increasing IWV.

The results obtained from LIDAR data correspond well with the data of the MWR. The LWP shows the presence of clouds with LWP up to 0.5 kg m^{-2} between 23 and 25 November. The presence of ice on the 25th is supported by the height of the -11°C isoline that is located around 6 km altitude. The Saharan dust period was associated low LWP values due to the absence of low clouds. However, the LWP was above zero coinciding with the presence of high clouds indicating the presence of liquid in these clouds.

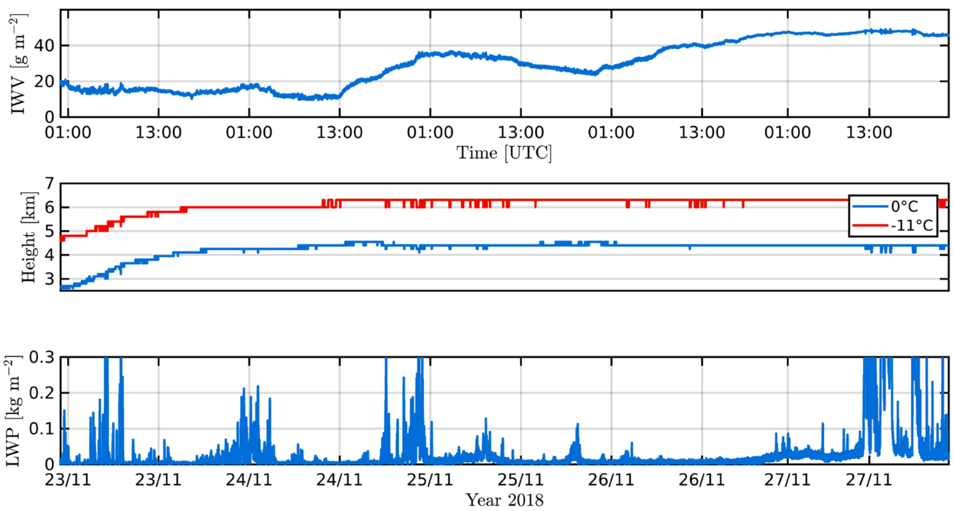

Fig. 6.3: Integrated water vapour (top), heights of 0°C and -11°C isolines (middle) and liquid water path (bottom) retrieved by the MWR.

Data management

All data processing will be carried out at TROPOS in Leipzig. The primary address for the data access should therefore be TROPOS but as soon as the data are available they can be used by other cruise participants after request. Additionally, it is foreseen to upload the quality checked data to the PANGAEA repository. However, this data processing and upload procedure might take a few months.

7. DATA ACQUISITION OF A COMBINED NEUTRON MONITOR AND MUON TELESCOPE ON BOARD POLARSTERN

Bernd Heber[1] (not on board), Michael Walter[2] (not on board), Juliana Stachurska[2]

[1]Uni Kiel
[2]DESY

Grant-No. AWI_PS116_00

Objectives

To study the variation of the cosmic neutron and muon spectra in dependence on a large latitude range (Winkler 2010), to study the dependence of the cosmic ray flux on solar activity (Heber 2013) and the Earth magnetosphere (Matthiä et al. 2013). The latitudinal modulation of the count rate is a measure of the detector sensitivity (Caballero-Lopez and Moraal 2012, see also Mishev et al. 2013). Previous trips have shown that the sensitivity of the mini-neutron monitor is good, but needed to be improved on in case of the muon telescope. Therefore, the new muon telescope (Haungs et al. 2014) was installed in 2017, the software of which needed to be updated to enable a for-pressure and for-temperature correction of the count rate in a timely manner.

Work at sea

There is a mini-neutron monitor as well as a muon telescope installed on board of the *Polarstern*, that measure the fluxes of these secondary particles produced in cosmic ray interactions in the atmosphere.

The intensity of galactic cosmic rays entering the atmosphere is modulated by solar activity and the Cut-Off rigidity (Galsdorf 2014). As the cut-off rigidity rises from 3 GV at Bremerhaven up to 15 GV in equatorial regions before decreasing again to 5 GV at Cape Town, data taken onboard the *Polarstern* during the Atlantic passage can help us to better understand the rigidity spectrum of Ground Level Enhancements. Both detectors monitor the particle fluxes over a long time period, and can measure the modulation of the count rates as a function of the solar cycle.

The muon and neutron count rate also depends on meteorological parameters, such as air pressure and temperature. Therefore, the data taken needs to be corrected (see Röntgen 2013), making a precise knowledge of the conditions at the time of data taking important. Transfer of the weather data from the meteorological station on board and transfer of the ship position data to the notebook running the muon telescope had been established and the incoming weather and ship position data reduced and combined with the data taken by the muon telescope. Further, a new device was installed which measures the pressure and temperature close to the muon telescope and mini-neutron monitor. Also here, the data is reduced *on-site* and combined with the previously mentioned measurements. The pressure and temperature readout and reduction has been automatized in a similar manner to the muon data taking and reduction and the data transfer from the *Polarstern* to DESY updated accordingly. Now, both detectors are expected to work fully autonomously. Pre-analysis of the data taken confirms data quality and stability.

Preliminary (expected) results

The muon and neutron monitoring is a long term process, taking several years. From this passage alone, we expect to further improve the data quality taken by the new muon detector. We will use data taken when the *Polarstern* is stationary (e.g. at the pier in Cape Town, SA) to analyze the influence of pressure and temperature variations on the muon and neutron count rate to correct the data. Data taken while at the pier is therefore indispensable. Preliminary analysis of the muon telescope data is shown in Fig. 7.1. The data quality is good, and the count rate is stable except for daily variations due to meteorological variations. As expected, the count rate decreases with decreasing latitude towards the equator, and increases again for increasing Southern latitudes. The latitudinal modulation of the count rate can be seen very clearly, showing the high sensitivity of the new muon detector. The figure is the result of combining muon detector data with weather and ship position data.

Data obtained will be combined with data from previous and future passages. The earliest predictions for the next solar minimum are in 2019. By continuously monitoring the cosmic ray induced secondary muons and neutrons, we expect to have a better understanding of atmospheric and the geo- magnetic filter over the solar cycle and of the rigidity spectrum of Ground Level Enhancements.

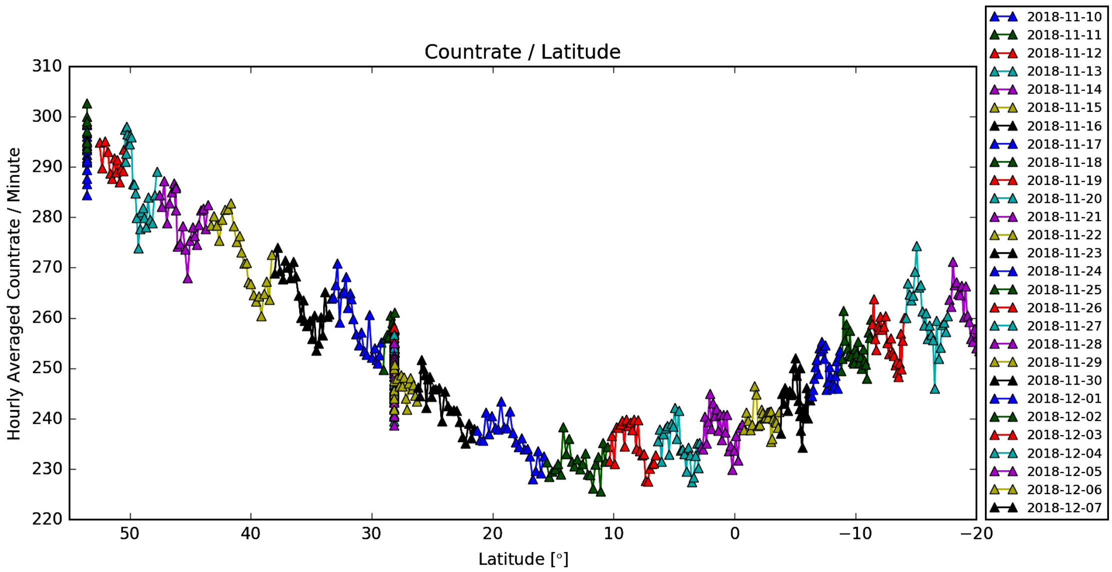

Fig. 7.1: Hourly averaged muon telescope count rate as a function of latitude. As expected, the count rate decreases towards the equator. The daily fluctuations due to temperature and pressure variations are visible.

Data management

The data collected with the neutron and muon monitors are stored at DESY and available on the website cosmicatweb.desy.de. Via this website, the data as well as analyzing tools are provided to high school students for scientific projects.

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8. SYSTEM-TESTING OF A COMBINED LAUNCH AND RECOVERY SYSTEM (LARS) AND DEPRESSOR WITH UNDERWATER PULLEY FOR TOWED VEHICLES AND OTHER MEASURING SYSTEMS

Sören Krägefsky[1], Johannes Lemburg[1] (not on board), Christoph Otto[2] (not on board), Vincent Abel[1], Levy Hoffmann[1]

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Grant-No. AWI_PS116_00

Objectives

Polar life depends on the production of micro algae, which is closely coupled to sea ice dynamics. Accordingly, this coupling is also shown by the behaviour and distribution of polar animals.

Quasi synoptic measurements of physical, chemical and biological parameters underneath the sea ice are vital to gain fundamental insight and understanding of processes in the polar regions.

These measurements need a synergistic integration of different sensors. Due to the high carrier capacity, permanent power supply (long operating time) and data communication abilities (high resolution measurements) via the towing cable, towed vehicles are particularly suited for the measuring task. In ice-covered areas, however, towed devices are in danger to be damaged and ruptured by the sea ice. Deployment of towed systems in these areas needs special deployments methods and deployment apparatus.

A combined launch and recovery system (LARS) and depressor with underwater pulley is under development, allowing secure deployment of towed undulating vehicles and other towed measuring systems. During the cruise, sea trials were performed to test the behaviour of the LARS/depressor and its impact on the flight performance of a towed system, giving information needed for further improvement of the LARS/Depressor.

Work at sea

The LARS/Depressor system was deployed with help of the A-Frame of *Polarstern*. During the tests a dummy simulating a towed sensor platform was used. Forces and flight behaviour were measured and recorded. Tests of the flight behaviour were performed at different towing speeds (1,5 - 4 kn) at two stations for about 3.5 hours in total.

Preliminary (expected) results

Tests show a stable flight behaviour of the LARS/Depressor without negative impact on the flight behaviour of the towed vehicle. The system allows secure routing of the towing cable from the A-Frame down the ice free close vicinity of the ship, redirected by the pulley of the depressor to the towed vehicle underneath the ice.

Data management

Data recorded during the test only serves improvement of the system under development.

9. ARGO-FLOAT DEPLOYMENT

Sören Krägefsky[1], Anja Schneehorst[2] (not on board), Simon Tewes[2] (not on board), Vincent Abel[1], Levy Hoffmann[1]

[1]AWI
[2]BSH

Grant-No. AWI_PS116_00

Objectives

The main objective of the Argo programme is to provide a quantitative description of the evolving state of the upper 2,000 m of the ocean by collecting profiles of temperature and salinity from the surface to 2,000 m. Argo data is used for initialization of ocean and coupled (ocean atmosphere) forecast models, data assimilation and dynamical model testing. It has been demonstrated that the assimilation of Argo data in the models improved weather and climate forecast. Profiling float data have an enormous range of applications. The more distinctive categories for Argo data use are: educational uses, operational uses and research uses.

Work at sea

Argo floats were deployed at five different positions along the cruise track of the ship from Bremerhaven to Cape Town at positions (3°N; 14.5°W), (0°; 12°W), (3°S;-10°W),(6°S;-8°W) and (9°S;5°W), respectively. Pre-deployment tests were performed. All floats were deployed successfully.

Preliminary (expected) results

Argo floats will deliver profiles of temperature and salinity measurements in the upper 2,000 m of the water column while drifting. Data will be used among others for assimilation in weather and climate forecast models.

Data management

Data will be made available by Argo for educational, operational and research use.

10. LOGISTICS AND SAFETY

Verena Mohaupt, Bjela König AWI

Grant-No. AWI_PS116_00

Objectives

Two members of the AWI Logistics department joined *Polarstern* on the way from Las Palmas to Cape Town to get to know the existing processes on board regarding research work. Main goal is the development of a standardized safety concept for the MOSAiC project and expeditions in general.

Work at sea

The main work was the observation of all research related processes on board and development of a wording for the expedition handbook. Further logistic resources, constraints and possibilities on board have been explored in order to give best advice to the MOSAiC teams and to coordinate the storage, lab and workspace distribution.

Preliminary (expected) results

Expedition handbook, containing all requirements and necessary information for cruise leaders, co-leaders and participants.

Data management

There was no data acquisition for scientific outcomes.

11. DATA CENTRE ACTIVITIES DURING PS116

Stephan Frickenhaus, Roland Koppe, Jörg Matthes, Tilman Dinter, Peter Gerchow, Antonia Immerz — AWI

Grant-No. AWI_PS116_00

Objectives

Setup and test of IT-infrastructure components (hardware and software) handling the dataflow during the MOSAiC expedition 09/2019 – 09/2010. Components realize registration, storage, display and linkage of (meta) data obtained from sampling and measurement events.

Work at sea

The team of computer specialists installed and integrated software and hardware components of the O2A (Observation to Archive) framework into the *Polarstern* IT-infrastructure in preparation for the MOSAiC drift experiment. Preliminary tests with incoming data during ship movements were performed. The MCS (MOSAiC Central Storage) was configured and tested during this cruise. Preparations were made to connect the DShip-System to the Sensor-Metadata-Information System. A marketplace to configure on the fly virtual machines is part of the new IT-system to support analysis of scientific data during MOSAiC. An offline repository was initialised containing software packages and operating system distributions available during the MOSAiC expedition. Data were analysed with scripts using provided software packages to test the accessibility of measurement data and compatibility and coverage of repository. Transfer rates for satellite data products from AWI to *Polarstern* were evaluated. Representation of these products and test cases for different file formats were implemented on the Mapviewer-System for navigation and scientific purposes. Devices available in DSHIP were registered in the Sensor-Metadata-Information System. The compatibility of both systems was evaluated. The IT-infrastructure was discussed and analysed with IT-personel and nautical staff on board *Polarstern*.

Preliminary results

Detailed tests of the installed infrastructure need to be performed prior to MOSAiC. Training of crew members in the concepts and usage of the newly installed infrastructure is crucial to enable smooth workflows on board.

Data management

Data recorded during installation of IT-infrastructure only serves for setup and test of the system under real conditions.

APPENDIX

A.1 PARTICIPATING INSTITUTIONS

A.2 CRUISE PARTICIPANTS

A.3 SHIP'S CREW

A.4 STATION LIST

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

	Address
AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung Postfach 120161 27515 Bremerhaven Germany
BSH	Bundesamt für Seeschifffahrt und Hydrographie Bernhard-Nocht-Straße 78 20359 Hamburg Germany
DESY	Deutsches Elektronen-Synchrotron Platanenallee 6 15738 Zeuthen Germany
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschifffahrtsberatung Bernhard-Nocht-Str. 76 20359 Hamburg Germany
HU Berlin	Humboldt Universität Berlin Unter den Linden 6 10099 Berlin Germany
TROPOS	Leibniz-Institut für Troposphärenforschung Permoserstr. 15 04318 Leipzig Germany
Uni Bremen	Universität Bremen Fachbereich Geowissenschaften Klagenfurter Str. 2-4 28359 Bremen Germany

	Address
Uni Göttingen	Georg-August Universität Göttingen Abteilung Bioklimatologie Büsgenweg 2 37077 Göttingen Germany
Uni Hannover	Leibniz Universität Hannover Institut für Bodenkunde Herrenhäuser Str. 2 30167 Hannover Germany
Uni Kiel	Christian-Albrechts-Universität zu Kiel Institut für Experimentelle und Angewandte Physik Leibnizstr. 19 24118 Kiel Germany
Uni Köln	Universität Köln Institut für Geophysik und Meteorologie Pohligstraße 3 50969 Köln Germany
Uni Oviedo	Unidersidad de Oviedo Facultad de Medicina C/ Julian Claveria s/n 33006 Oviedo Spain
Uni Rostock	Universität Rostock Oskar-Kellner-Institut Justus-von-Liebig-Weg 2 18059 Rostock Spain

A.2 FAHRTTEILNEHMER / CRUISE PARTICIPANTS

No.	Name / Last name	Vorname / First name	Institut / Institution	Beruf / Profession	Fachrichtung / Scientific Field
1§	Abel	Vincent	AWI	Technician	Engineering Sc.
2*	Aladesanmi	Taiwo	Uni Bremen	Student	Geophysics
3*	Anhaus	Philipp	AWI	PhD Student	Physics
4*	Arndt	Jan-Erik	AWI	Scientist	Geophysics
5*	Beamish	Alison	AWI	Scientist	Biology
6	Boy	Diana	Uni Hannover	Student	Geosciences
7*	Brand	Marc	Uni Bremen	Student	Geosciences
8*	Diekstall	Denise	AWI	Technician	Geology
9*	Dinter	Tilman	AWI	Scientist	Physics
10*	Dreutter	Simon	AWI	Technician	Geophysics
11*	Fahmy	Ahmed	Uni Bremen	Student	Geology
12*	Farag	Mohamed	Uni Bremen	Student	Geophysics
13*	Frickenhaus	Stephan	AWI	Scientist	Mathematics
14*	Fuchs	Niels	AWI	PhD Student	Meteorology
15	Garcia-Vazquez	Eva	Uni Oviedo, ES	Scientist	Biology
16*	Gebhardt	Catalina	AWI	Scientist	Geophysics
17*	Geils	Jonah	Uni Bremen	Student	Geophysics
18*	Gerchow	Peter	AWI	Engineer	Logistics
19*	Hamelberg	Tim	Freelancer	Photographer	Public Outreach
20§	Hanbuch	Karsten	TROPOS	Engineer	Engineering Sc.
21*	Hanfland	Claudia	AWI	Scientist	Geology
22	Heimsch	Florian	Uni Göttingen	PhD student	Geosciences
23	Hempelt	Juliane	DWD	Technician	Meteorology
24	Herzog	Alina	TROPOS	Student	Meteorology
25§	Hoffmann	Levy	AWI	Student	Engineering Sc.
26*	Hossain	Akil	AWI	PhD Student	Physics
27§	Immerz	Antonia	AWI	Scientist	Logistics
28*	Klages	Johann	AWI	Scientist	Geology
29§	König	Bjela	AWI	Engineer	Logistics
30*	Koppe	Roland	AWI	Scientist	Engineering Sc.
31§	Krägefsky	Sören	AWI	Scientist	Logistics

No.	Name / Last name	Vorname / First name	Institut / Institution	Beruf / Profession	Fachrichtung / Scientific Field
32	Küchler	Nils	Uni Köln	PhD Student	Meteorology
33*	Lamping	Nele	AWI	PhD Student	Geology
34*	Leng	Yue	Uni Bremen	Student	Geophysics
35*	Martinez	Mariano	AWI	PhD Student	Biology
36*	Mattes	Jörg	AWI	Engineer	Engineering Sc.
37§	Mohaupt	Verena	AWI	Scientist	Logistics
38*	Niessen	Frank	AWI	Scientist	Geophysics
39	Ohneiser	Kevin	TROPOS	Student	Meteorology
40	Pavlak	Johanna	Uni Bremen	Student	Geophysics
41	Peters	Manno	DWD	Scientist	Meteorology
42*	Reuter	Runa	Uni Bremen	Student	Geology
43*	Rick	Johannes	AWI	Scientist	Biology
44*	Schwamborn	Georg	AWI	Scientist	Geology
45*	Sierra	Lombera	Uni Bremen	Student	Geophysics
46*	Soliman	Abdelrahman	Uni Bremen	Student	Geophysics
47*	Spotowitz	Lisa	AWI	PhD Student	Biology
48	Stachurska	Juliana	DESY	PhD Student	Physics
49*	Stein	Christian	HU Berlin	Photographer	Public Outreach
50	Teufel	Hannelore		Observer	Logistics
51*	Unger-Moreno	Katharina	Uni Bremen	Student	Geosciences
52*	Vorrath	Elena	AWI	PhD Student	Geology
53*	Zubkova	Aleksandra	Uni Bremen	Student	Geology

(*) disembarkation in Las Palmas
(§) boarding in Las Palmas

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

Bremerhaven - Las Palmas (and the same crew as below)

	Name	Rank
1	Wunderlich, Thomas	Master
2	Langhinrichs, Moritz	Chiefmate

Las Palmas - Cape Town

	Name	Rank
1	Langhinrichs, Moritz	Master
2	Spielke, Steffen	Chiefmate
3	Kentges, Felix	1st Mate
4	Fischer, Tibor	2nd Mate
5	Neumann, Ralph Peter	2nd Mate
6	Ziemann, Olaf Hermann Aug.	Chief
7	Grafe, Jens	2nd Eng.
8	Haack, Michael Detlev	2nd Eng.
9	Krinfeld, Oleksandr	2nd Eng.
10	Redmer, Jens	E-Eng.
11	Hofmann, Walter Jörg	Chief ELO
12	Ganter, Armin	ELO
13	Himmel, Frank	ELO
14	Hüttebräucker, Olaf	ELO
15	Nasis, Ilias	ELO
16	Rudde-Teufel, Claus Friedrich	Ships doc
17	Loidl, Reiner	Bosun
18	Reise, Lutz	Carpen
19	Brück, Sebastian	MP Rat.
20	Klee, Philipp	MP Rat.
21	Möller, Falko	MP Rat.
22	Neubauer, Werner	MP Rat.
23	Bäcker, Andreas	AB
24	Hans, Stefan	AB
25	Wende, Uwe	AB
26	Preußner, Jörg	Storek
27	Gebhardt, Norman	MP Rat
28	Luckhardt, Arne	MP Rat
29	Plehn, Markus	MP Rat
30	Rhau, Lars-Peter	MP Rat
31	Schwarz, Uwe	MP Rat

	Name	Rank
32	Schnieder, Sven	Cook
33	Möller, Wolfgang Hans	Cooksm.
34	Silinski, Frank	Cooksm.
35	Czyborra, Bärbel	Chief Stew.
36	Wöckener, Martina	Nurse
37	Chen, Dansheng	2nd Stew.
38	Dibenau, Torsten	2nd Stew.
39	Nagel, Jens	2nd Stew.
40	Silinski, Carmen	2nd Stew.
41	Sun, Yong Sheng	2nd Stew.
42	Ruan, Hui Guang	Laundrym.
43	Kreutzmann, Lennart	Apprent.
44	Peper, Sven	Apprent.

A. 4 STATIONSLISTE / STATION LIST

Station	Date	Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS116_0_ Underway-1	2018-11-11	13:31	53,56852	8,55365	2,9	WST	profile start	Start after Bhv. WST is being operated permanently and hence does not require termination. WST station no will be issued and attributed automatically to ecvery new cruise by DShip, and hence does not require a „Profile End“
PS116_0_ Underway-1	2018-11-22	10:41	27,98520	-15,26823	933	WST	profile start	Start after Las Palmas
PS116_0_ Underway-2	2018-11-18	07:14	28,17156	-15,27161	1850	ADCP_150	profile end	profile start on 12.11., not clear why it is not recorded
PS116_0_ Underway-2	2018-11-22	10:47	27,96192	-15,26710	854	ADCP_150	profile start	Start after Las Palmas
PS116_0_ Underway-2	2018-12-10	06:24	-31,98267	14,67369	NA	ADCP_150	profile end	End before Cape Town
PS116_0_ Underway-3	2018-11-12	12:48	51,85359	2,53582	31,4	FBOX	profile start	Start after Bhv
PS116_0_ Underway-3	2018-11-18	07:14	28,17156	-15,27161	1850	FBOX	profile end	End before Las Palmas
PS116_0_ Underway-3	2018-11-22	10:55	27,92877	-15,26814	735	FBOX	profile start	Start after Las Palmas
PS116_0_ Underway-3	2018-12-10	06:25	-31,98372	14,67572	NA	FBOX	profile end	End before Cape Town
PS116_0_ Underway-4	2018-11-11	13:34	53,57011	8,55345	2	MAG	profile start	
PS116_0_ Underway-4	2018-11-12	08:11	52,91880	3,24378	22,3	MAG	profile end	
PS116_0_ Underway-5	2018-11-12	12:48	51,85359	2,53582	31,4	PCO2_GO	profile start	Start after Bhv
PS116_0_ Underway-5	2018-11-18	07:14	28,17156	-15,27161	1850	PCO2_GO	profile end	End before Las Palmas
PS116_0_ Underway-5	2018-11-22	10:55	27,92877	-15,26814	735	PCO2_GO	profile start	Start after Las Palmas
PS116_0_ Underway-5	2018-12-10	06:25	-31,98399	14,67625	NA	PCO2_GO	profile end	End before Cape Town
PS116_0_ Underway-6	2018-11-12	12:48	51,85359	2,53582	31,4	PCO2_ SUB	profile start	Start after Bhv
PS116_0_ Underway-6	2018-11-18	07:14	28,17156	-15,27161	1850	PCO2_ SUB	profile end	End before Las Palmas
PS116_0_ Underway-6	2018-11-22	10:55	27,92877	-15,26814	735	PCO2_ SUB	profile start	Start after Las Palmas
PS116_0_ Underway-6	2018-12-10	06:26	-31,98561	14,67947	NA	PCO2_ SUB	profile end	End before Cape Town

Station	Date	Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS116_0_ Underway-7	2018-11-12	15:38	51,37169	1,87807	31,2	TSG_KEEL	profile start	Start after Bhv
PS116_0_ Underway-7	2018-11-18	07:14	28,17156	-15,27161	1850	TSG_KEEL	profile end	End before Las Palmas
PS116_0_ Underway-7	2018-11-22	13:02	27,57724	-15,57443	544	TSG_KEEL	profile start	Start after Las Palmas
PS116_0_ Underway-7	2018-11-23	09:21	24,86636	-20,14804	3965	TSG_KEEL	profile end	terminated due to maintenance
PS116_0_ Underway-7	2018-11-23	14:23	23,62776	-20,35618	4010	TSG_KEEL	profile start	Start after maintenance
PS116_0_ Underway-7	2018-12-10	06:24	-31,98304	14,67440	NA	TSG_KEEL	profile end	End before Cape Town
PS116_0_ Underway-8	2018-11-12	15:38	51,37169	1,87807	31,2	TSG_ KEEL_2	profile start	Start after Bhv
PS116_0_ Underway-8	2018-11-18	07:14	28,17156	-15,27161	1850	TSG_ KEEL_2	profile end	End before Las Palmas
PS116_0_ Underway-8	2018-11-22	13:02	27,57724	-15,57443	544	TSG_ KEEL_2	profile start	Start after Las Palmas
PS116_0_ Underway-8	2018-11-23	09:21	24,86636	-20,14804	3965	TSG_ KEEL_2	profile end	terminated due to maintenance
PS116_0_ Underway-8	2018-11-23	14:23	23,62776	-20,35618	4010	TSG_ KEEL_2	profile start	Start after maintenance
PS116_0_ Underway-8	2018-12-10	06:25	-31,98347	14,67524	NA	TSG_ KEEL_2	profile end	End before Cape Town
PS116_0_ Underway-9	2018-11-12	08:34	52,83501	3,18496	19,4	GRAV	profile end	restart as Underway-11
PS116_0_ Underway-10	2018-11-11	13:33	53,56977	8,55350	2,1	HVAIR	profile start	
PS116_0_ Underway-10	2018-11-12	08:11	52,91815	3,24334	22,4	HVAIR	profile end	
PS116_0_ Underway-11	2018-11-12	09:07	52,71072	3,11772	20,2	GRAV	profile start	Start after Bhv
PS116_0_ Underway-11	2018-11-18	07:14	28,17156	-15,27161	1850	GRAV	profile end	End before Las Palmas
PS116_0_ Underway-11	2018-11-22	10:41	27,98520	-15,26823	933	GRAV	profile start	Start after Las Palmas
PS116_0_ Underway-11	2018-12-10	06:27	-31,98611	14,68050	NA	GRAV	profile end	End before Cape Town
PS116_0_ Underway-12	2018-11-12	09:07	52,71072	3,11772	20,2	MAG	profile start	Start after Bhv
PS116_0_ Underway-12	2018-11-18	07:14	28,17156	-15,27161	1850	MAG	profile end	End before Las Palmas
PS116_0_ Underway-12	2018-11-22	10:41	27,98520	-15,26823	933	MAG	profile start	Start after Las Palmas
PS116_0_ Underway-12	2018-12-10	06:27	-31,98648	14,68125	NA	MAG	profile end	End before Cape Town

Station	Date	Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS116_0_ Underway-13	2018-11-12	09:07	52,71072	3,11772	20,2	HVAIR	profile start	Start after Bhv
PS116_0_ Underway-13	2018-11-18	07:14	28,17156	-15,27161	1850	HVAIR	profile end	End before Las Palmas
PS116_0_ Underway-13	2018-11-22	10:41	27,98520	-15,26823	933	HVAIR	profile start	Start after Las Palmas
PS116_0_ Underway-13	2018-12-10	06:26	-31,98582	14,67992	NA	HVAIR	profile end	End before Cape Town
PS116_0_ Underway-14	2018-11-11	15:15	53,64566	8,41744	11,6	OCEANET	station start	
PS116_0_ Underway-14	2018-11-11	15:15	53,64566	8,41744	11,6	OCEANET	profile start	Start after Bhv
PS116_0_ Underway-14	2018-11-12	08:30	52,85208	3,19619	18,1	OCEANET	profile end	End before Las Palmas
PS116_0_ Underway-14	2018-11-12	09:30	52,62284	3,08746	23,5	OCEANET	profile start	Start after Las Palmas
PS116_0_ Underway-14	2018-11-18	07:14	28,17156	-15,27161	1850	OCEANET	profile end	terminated due to maintenance
PS116_0_ Underway-14	2018-11-22	10:41	27,98520	-15,26823	933	OCEANET	profile start	Start after maintenance
PS116_0_ Underway-14	2018-12-10	06:26	-31,98502	14,67827	NA	OCEANET	profile end	End before Cape Town
PS116_0_ Underway-14	2018-12-10	06:27	-31,98673	14,68179	NA	OCEANET	station end	
PS116_0_ Underway-15	2018-11-12	09:30	52,62284	3,08746	23,5	HS	station start	Start after Bhv
PS116_0_ Underway-15	2018-11-12	09:30	52,62284	3,08746	23,5	HS	profile start	
PS116_0_ Underway-15	2018-11-18	07:14	28,17156	-15,27161	1850	HS	profile end	End before Las Palmas
PS116_0_ Underway-15	2018-11-22	14:52	27,34770	-16,00213	504	HS	profile start	Start after Las Palmas
PS116_0_ Underway-15	2018-12-09	19:14	-31,18179	12,99930	3370	HS	profile end	End before Cape Town
PS116_0_ Underway-15	2018-12-09	19:14	-31,18199	12,99933	3370	HS	station end	
PS116_0_ Underway-16	2018-11-12	09:30	52,62284	3,08746	23,5	PS	station start	
PS116_0_ Underway-16	2018-11-12	09:30	52,62284	3,08746	23,5	PS	profile start	Start after Bhv
PS116_0_ Underway-16	2018-11-18	07:14	28,17156	-15,27161	1850	PS	profile end	End before Las Palmas
PS116_0_ Underway-16	2018-11-22	14:51	27,34888	-16,00013	506	PS	profile start	Start after Las Palmas
PS116_0_ Underway-16	2018-12-09	19:14	-31,18113	12,99916	3381	PS	profile end	End before Cape Town

Station	Date	Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS116_0_ Underway-16	2018-12-09	19:14	-31,18121	12,99917	3385	PS	station end	
PS116_0_ Underway-17	2018-11-22	10:43	27,97949	-15,26776	1002	SVP	profile start	
PS116_0_ Underway-17	2018-12-10	06:24	-31,98212	14,67265	NA	SVP	profile end	
PS116_1-1	2018-11-14	06:42	46,21892	-7,96379	4776	HN	station start	
PS116_1-1	2018-11-14	06:48	46,21961	-7,96395	4778	HN	station end	
PS116_1-2	2018-11-14	06:49	46,21968	-7,96397	4778	SVP	station start	
PS116_1-2	2018-11-14	07:49	46,21935	-7,96416	4776	SVP	at depth	
PS116_1-2	2018-11-14	08:56	46,21941	-7,96426	4777	SVP	station end	
PS116_2-1	2018-11-15	14:00	40,19829	-11,74080	5161	UCTD	station start	
PS116_2-1	2018-11-15	14:20	40,13236	-11,76283	5161	UCTD	station end	
PS116_3-1	2018-11-16	11:04	35,67430	-13,14440	4876	UAV	station start	
PS116_3-1	2018-11-16	11:08	35,67581	-13,14411	4872	UAV	station end	
PS116_3-2	2018-11-16	11:09	35,67596	-13,14403	4875	HN	station start	
PS116_3-2	2018-11-16	11:11	35,67644	-13,14364	4878	HN	station end	
PS116_3-3	2018-11-16	11:13	35,67669	-13,14344	4874	UCTD	station start	
PS116_3-3	2018-11-16	11:23	35,67823	-13,14180	4870	UCTD	station end	
PS116_4-1	2018-11-17	09:07	31,80204	-14,22775	4291	HN	station start	
PS116_4-1	2018-11-17	09:09	31,80189	-14,22743	4292	HN	station end	
PS116_4-2	2018-11-17	09:10	31,80205	-14,22720	4294	UCTD	station start	
PS116_4-2	2018-11-17	09:26	31,79922	-14,22610	4287	UCTD	station end	
PS116_5-1	2018-11-18	09:26	28,12620	-15,35431	709	UAV	station start	
PS116_5-1	2018-11-18	09:41	28,12607	-15,35439	708	UAV	station end	
PS116_6-1	2018-11-27	21:51	2,99962	-14,49986	4715	FLOAT	station start	

Station	Date	Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS116_6-1	2018-11-27	21:51	2,99957	-14,49982	4715	FLOAT	station end	
PS116_6-2	2018-11-27	21:56	2,99679	-14,49967	4750	HN	station start	
PS116_6-2	2018-11-27	21:56	2,99661	-14,49967	4881	HN	station start	Start twice
PS116_6-2	2018-11-27	21:56	2,99633	-14,49966	4822	HN	station end	3x Handnet in a row
PS116_6-2	2018-11-27	21:57	2,99562	-14,49959	4750	HN	station start	
PS116_6-2	2018-11-27	21:58	2,99509	-14,49947	4743	HN	station end	
PS116_6-2	2018-11-27	21:59	2,99437	-14,49922	4750	HN	station start	
PS116_6-2	2018-11-27	22:00	2,99367	-14,49886	4750	HN	station end	
PS116_6-3	2018-11-27	22:04	2,99051	-14,49576	4718	UCTD	station start	
PS116_6-3	2018-11-27	22:20	2,97353	-14,48173	4748	UCTD	station end	
PS116_7-1	2018-11-28	19:15	-0,00057	-11,99893	3986	FLOAT	station start	
PS116_7-1	2018-11-28	19:16	-0,00117	-11,99879	3980	FLOAT	station end	
PS116_8-1	2018-11-29	13:14	-2,74555	-10,27572	3697	LARS-D	station start	
PS116_8-1	2018-11-29	14:20	-2,79327	-10,25143	3544	LARS-D	station end	
PS116_9-1	2018-11-29	16:48	-2,99889	-9,99995	3882	FLOAT	station start	
PS116_9-1	2018-11-29	16:49	-2,99959	-9,99955	3917	FLOAT	station end	
PS116_9-2	2018-11-29	16:50	-3,00025	-9,99941	3929	HN	station start	3x Handnet in a row
PS116_9-2	2018-11-29	16:51	-3,00060	-9,99941	3935	HN	station end	
PS116_9-2	2018-11-29	16:52	-3,00112	-9,99948	3931	HN	station start	
PS116_9-2	2018-11-29	16:53	-3,00148	-9,99958	3947	HN	station end	
PS116_9-2	2018-11-29	16:54	-3,00202	-9,99976	3939	HN	station start	
PS116_9-2	2018-11-29	16:55	-3,00258	-9,99986	3944	HN	station end	
PS116_9-3	2018-11-29	16:57	-3,00466	-9,99871	3996	UCTD	station start	

Station	Date	Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS116_9-3	2018-11-29	17:08	-3,01749	-9,99058	4113	UCTD	station end	
PS116_10-1	2018-11-30	11:46	-5,24116	-8,50680	3972	LARS-D	station start	
PS116_10-1	2018-11-30	15:36	-5,44718	-8,35187	3845	LARS-D	station end	
PS116_11-1	2018-11-30	20:23	-6,00052	-7,99949	4398	FLOAT	station start	
PS116_11-1	2018-11-30	20:23	-6,00056	-7,99947	4395	FLOAT	station end	
PS116_11-2	2018-11-30	20:25	-6,00268	-7,99894	4349	HN	station start	3x Handnet in a row
PS116_11-2	2018-11-30	20:26	-6,00325	-7,99888	4402	HN	station end	
PS116_11-2	2018-11-30	20:27	-6,00366	-7,99885	4411	HN	station start	
PS116_11-2	2018-11-30	20:27	-6,00389	-7,99885	4410	HN	station end	
PS116_11-2	2018-11-30	20:28	-6,00425	-7,99886	4402	HN	station start	
PS116_11-2	2018-11-30	20:28	-6,00452	-7,99888	4404	HN	station end	
PS116_11-3	2018-11-30	20:35	-6,00943	-7,99730	4409	UCTD	station start	
PS116_11-3	2018-11-30	20:47	-6,02091	-7,98354	4705	UCTD	station end	
PS116_12-1	2018-12-02	01:48	-8,99627	-5,00380	4487	FLOAT	station start	
PS116_12-1	2018-12-02	01:49	-8,99644	-5,00366	4472	FLOAT	station end	
PS116_13-1	2018-12-03	15:00	-13,31997	-1,45411	5616	HN	station start	4x Handnet in a row
PS116_13-1	2018-12-03	15:01	-13,32045	-1,45374	5623	HN	station end	
PS116_13-1	2018-12-03	15:01	-13,32073	-1,45355	5619	HN	station start	
PS116_13-1	2018-12-03	15:02	-13,32103	-1,45336	5626	HN	station end	
PS116_13-1	2018-12-03	15:02	-13,32140	-1,45315	5636	HN	station start	
PS116_13-1	2018-12-03	15:03	-13,32180	-1,45299	5629	HN	station end	
PS116_13-1	2018-12-03	15:06	-13,32470	-1,45204	5684	HN	station start	
PS116_13-1	2018-12-03	15:07	-13,32584	-1,45147	5710	HN	station end	

Station	Date	Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS116_13-2	2018-12-03	15:09	-13,32826	-1,45005	5721	UCTD	station start	
PS116_13-2	2018-12-03	15:20	-13,34177	-1,44211	5771	UCTD	station end	
PS116_14-1	2018-12-05	15:00	-19,96985	4,45101	5409	HN	station start	3x Handnet in a row
PS116_14-1	2018-12-05	15:02	-19,97133	4,45173	5412	HN	station end	
PS116_14-1	2018-12-05	15:02	-19,97165	4,45188	5413	HN	station start	
PS116_14-1	2018-12-05	15:03	-19,97221	4,45214	5412	HN	station end	
PS116_14-1	2018-12-05	15:03	-19,97252	4,45229	5411	HN	station start	
PS116_14-1	2018-12-05	15:04	-19,97283	4,45242	5410	HN	station end	
PS116_14-2	2018-12-05	15:06	-19,97436	4,45317	5413	UCTD	station start	
PS116_14-2	2018-12-05	15:16	-19,98550	4,46228	5410	UCTD	station end	
PS116_15-1	2018-12-06	08:14	-22,49226	6,47644	2551	ROV	station start	ROV 3x deployed under varying conditions
PS116_15-1	2018-12-06	10:02	-22,49031	6,46622	2542	ROV	station end	
PS116_16-1	2018-12-06	13:09	-22,63460	6,84821	1146	ROV	station start	
PS116_16-1	2018-12-06	13:47	-22,63373	6,84612	1115	ROV	station end	
PS116_16-1	2018-12-06	13:51	-22,63341	6,84592	1149	ROV	station start	
PS116_16-1	2018-12-06	14:16	-22,62987	6,84458	1166	ROV	station end	
PS116_17-1	2018-12-07	08:23	-24,37544	7,96409	4734	HN	station start	3x Handnet in a row
PS116_17-1	2018-12-07	08:24	-24,37589	7,96321	4733	HN	station end	
PS116_17-1	2018-12-07	08:25	-24,37616	7,96274	4737	HN	station start	
PS116_17-1	2018-12-07	08:26	-24,37644	7,96226	4734	HN	station end	
PS116_17-1	2018-12-07	08:26	-24,37673	7,96180	4735	HN	station start	
PS116_17-1	2018-12-07	08:27	-24,37700	7,96138	4739	HN	station end	
PS116_17-2	2018-12-07	08:33	-24,38118	7,96356	4735	UCTD	station start	

Station	Date	Time	Latitude	Longitude	Depth [m]	Gear	Action	Comment
PS116_17-2	2018-12-07	08:45	-24,39127	7,97675	4732	UCTD	station end	
PS116_18-1	2018-12-08	08:31	-26,90178	9,78274	4816	HN	station start	3x Handnet in a row
PS116_18-1	2018-12-08	08:32	-26,90216	9,78244	4812	HN	station end	
PS116_18-1	2018-12-08	08:32	-26,90230	9,78230	4813	HN	station start	
PS116_18-1	2018-12-08	08:33	-26,90249	9,78206	4814	HN	station end	
PS116_18-1	2018-12-08	08:33	-26,90270	9,78179	4926	HN	station start	
PS116_18-1	2018-12-08	08:34	-26,90320	9,78106	4814	HN	station end	
PS116_18-2	2018-12-08	08:39	-26,90710	9,78171	4814	UCTD	station start	
PS116_18-2	2018-12-08	08:50	-26,91537	9,79418	4814	UCTD	station end	
PS116_19-1	2018-12-09	08:30	-29,82008	11,93110	3960	HN	station start	Start twice
PS116_19-1	2018-12-09	08:30	-29,82031	11,93066	3961	HN	station start	3x Handnet in a row
PS116_19-1	2018-12-09	08:31	-29,82063	11,92999	3959	HN	station end	
PS116_19-1	2018-12-09	08:31	-29,82080	11,92965	3957	HN	station start	
PS116_19-1	2018-12-09	08:32	-29,82107	11,92905	3960	HN	station end	
PS116_19-1	2018-12-09	08:32	-29,82127	11,92861	3962	HN	station start	
PS116_19-1	2018-12-09	08:33	-29,82158	11,92792	3957	HN	station end	
PS116_19-2	2018-12-09	08:40	-29,82585	11,92922	3960	UCTD	station start	
PS116_19-2	2018-12-09	08:49	-29,83045	11,94096	3956	UCTD	station end	last station before Cape Town

Gear abbreviations	Gear
ADCP_150	ADCP 150kHz
FBOX	FerryBox
FLOAT	Float
GRAV	Sea Gravimeter
HN	Hand Net
HS	Hydrosweep
HVAIR	High Volume Air Sampler
LARS-D	LARS_Depressor
MAG	Magnetometer
OCEANET	Atmosphere Observatory
PCO2_GO	pCO2 GO
PCO2_SUB	pCO2 Subctech
PS	Parasound
ROV	Remotely Operated Vehicle
SVP	Sound Velocity Profiler
TSG_KEEL	Thermosalinograph Keel
TSG_KEEL_2	Thermosalinograph Keel 2
UAV	Unmanned Aereal Vehicle
UCTD	Underway CTD
WST	Weatherstation

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