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The Expedition of the Research Vessel "Polarstern" to the Antarctic in 2009 (ANT-XXV/5)

Edited by
Walter Zenk and Saad El Naggar
with contributions of the participants

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GEMEINSCHAFT

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ANT-XXV/5

11 April - 24 May 2009

Punta Arenas - Bremerhaven

Chief scientists
Walter Zenk (Punta Arenas – Las Palmas)
Saad El Naggar (Las Palmas – Bremerhaven)

Coordinator
Eberhard Fahrbach

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1. ZUSAMMENFASSUNG UND FAHRTVERLAUF

Walter Zenk, Leibniz-Institut für Meereswissenschaften, Kiel
Saad El Naggar, Alfred-Wegener-Institut, Bremerhaven

Polarstern verließ am 11.04.2009 gegen 18:00 Uhr den Hafen von Punta Arenas und trat nach fünfmonatigem Aufenthalt in der Antarktis die Heimreise an. Somit begann der letzte Reiseabschnitt ANT-XXV/5, der am 24.05.09 in Bremerhaven endete.

Die Überfahrt wurde zu einem umfassenden wissenschaftlichen Programm genutzt. Dazu waren täglich Stationsarbeiten und Schlauchbooteinsätze notwendig. Während des gesamten Fahrtabschnitts wurde ständig Seewasser an Bord gepumpt, um kontinuierlich chemische, biologische und ozeanografische Messungen durchführen zu können. Das Seewasser wurde mit dem fest installierten Bordwassersystem und einem zusätzlich installierten Pumpsystem im Brunnenschacht gefördert.

Am Anfang der Reise steuerte *Polarstern* in nordöstlicher Richtung den Vema-Kanal an, der auch Rio Grande Passage genannt wird. Die erste CTD-Station wurde am 13.04.09 ausgeführt (Station 276). Täglich gegen 13:00 Uhr wurde eine Flachwasser-CTD bis 200 m eingesetzt. Optische Profil-Messungen in der Wassersäule wurden parallel zu den CTD-Messungen durchgeführt. Diese wurden durch Messungen vom Schlauchboot aus begleitet. Das schlechte Wetter bis zum 29.04.09 störte einen Teil der Messungen. ADCP-Profile wurden kontinuierlich aufgenommen.

Am 22.04.09 erreichten wir den Eingang des Vema-Kanals, wo wir vier tiefe CTD-Stationen durchführten (Station 283 - 285, 288). Am Ende der Stationsarbeiten steuerten wir die Position 20°S, 23°W an, die wir am 29.04.09 erreichten. Danach nahm *Polarstern* nördlichen Kurs, überquerte am 01.05.09 den Äquator und erreichte am 04.05.09 den Wegpunkt 20°N, 23°W. Nach der letzten Station an dieser Position nahm *Polarstern* Kurs auf die Kanarischen Inseln, wo wir Las Palmas am 14.05.09 gegen 08:00 Uhr erreichten.

Nach kurzem Aufenthalt und Austausch von Personal verließ *Polarstern* den Hafen gegen Mittag und führte ca. 5 Seemeilen vom Hafen eine 12-stündige Teststation aus. Zwei Techniker der Firma IXSEA haben das akustische Array des Unterwasser-Navigations-System POSIDONIA elektrisch und akustisch getestet. Sie wurden am späten Abend von einem Boot nach Las Palmas zurückgebracht. Kurz danach setzte *Polarstern* ihre Reise fort. Das wissenschaftliche Programm wurde weitergeführt.

Zusätzlich fand ein Ausbildungsprogramm für Nachwuchswissenschaftler am Sediment-Echo-Lot-System PARASOUND statt. Das wissenschaftliche Programm wurde am 20.05.09 nachmittags mit der letzten Station (Station 311) abgeschlossen. *Polarstern* erreichte am 24.05.09 gegen 04:00 Uhr Bremerhaven, wo die Reise ANT-XXV/5 endete.

Auf dieser Reise wurde eine Reihe von automatisch messenden Plattformen erfolgreich getestet und eingesetzt. Diese Plattformen dienen zur Erfassung des Energie- und Materialaustausches zwischen Ozean und Atmosphäre und sind für den Einsatz auf Handels- und Forschungsschiffen (Voluntary Observing Ships VOS) geplant.

Die meteorologischen Messungen dienten in erster Linie, der Aerosol-Untersuchung mit Fernerkundungsmethoden. Ziel der Untersuchungen ist die Erfassung der meridionalen Verteilung des Aerosols in der Troposphäre, des Gradienten und von Aerosol-Wolken. Ein Acoustic Doppler Current Profiler (ADCP) wurde eingesetzt, um die saisonalen Strömungsverhältnisse im Ozean zu erfassen und zu analysieren. Zusätzlich sollen diese Messungen als Referenz für die verankerten Systeme am Äquator auf 23°W dienen.

Das in Richtung Äquator fließende Antarktische Bodenwasser ist ein wichtiger Bestandteil der globalen thermohalinen Zirkulation. Im westlichen Teil des Süd-atlantiks wird diese Strömung durch das nach Süden fließende Nordatlantische Tiefenwasser zum Teil kompensiert. Fluktuationen im Bodenwasser beeinflussen die globale Wassermassenverteilung. Die im Allgemeinen nach Norden gerichtete Strömung des Antarktischen Bodenwassers wird von der Topographie des Meeres-bodens beeinflusst. Ein Beispiel ist der Vema-Kanal, der ein Ziel dieser Reise war. Die mehr als dreißig-jährigen Messreihen im Vema-Kanal zeigen seit 1990 einen Anstieg der Temperatur. Das hier durchgeführte Programm setzte die langjährigen Messungen mit weiteren Daten fort.

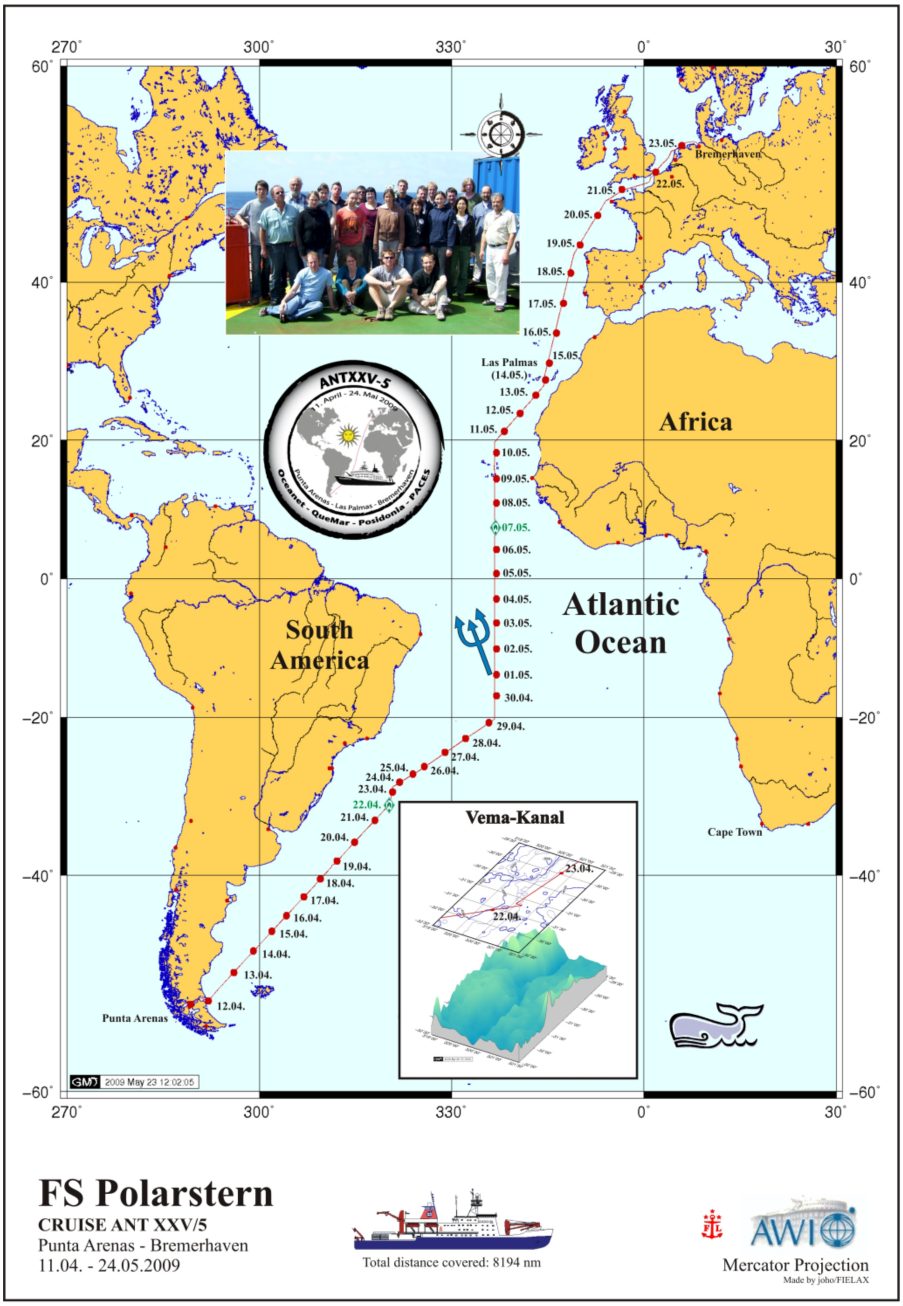


Abb. 1.1: Kurskarte der Polarstern Reise ANT-XXV/5
Fig. 1.1: Cruise track of Polarstern during the expedition ANT-XXV/5

ITINERARY AND SUMMARY

Polarstern left Punta Arenas via the Straits of Magellan on 11 April shortly after 18:00 LT. The fifth leg (ANT-XXV/5) concluded her five-months' long journey to Antarctica. The long passage across the Atlantic was used for a wide range of underway observations. It was supplemented by a limited number of intermediate stops for mostly shallow observations in the euphotic zone.

The ship headed in a northeasterly direction towards the Vema Channel (also called the Rio Grande Passage on international sea charts). A first CTD trial cast was taken on 13 April (Sta. 276) still on the far out reaching Patagonian shelf. In the following days a working scheme was developed that soon was repeated on a daily base: At 13:00 a shallow (< 200 m depth) CTD station was scheduled, followed by soundings with optical sensors simultaneously from the ship and the nearby zodiac. The latter mission was restricted to acceptable weather conditions which occurred not before 29 April. Continuous recordings with the acoustic Doppler current profiler (ADCP) in the upper water column supplemented earlier observations in lower latitudes of the Atlantic.

On 22 April we reached the entrance of the Vema Channel. Four deep CTD stations were occupied in the course of this abyssal canyon (Sta. 283-285, 288). After finishing this work at the northern extension of the Channel we proceeded to the way point 20° S, 23° W. From there on (29 April) we followed a meridional course crossing the equator two days later up to 20° N, 23° W. After reaching the end of the 23° W ADCP section at northern waypoint 20° N, 23° W the ship then took a direct course to the Canary Islands. After the last mid-day station (304) on 13 May the northbound return to Bremerhaven was then intentionally interrupted. On 14 May some personnel (including the chief scientists) were exchanged in the port of Las Palmas.

On 14 May *Polarstern* left the harbour of Las Palmas to continue the cruise to Bremerhaven. After acoustical and electrical tests of POSIDONIA transducers nearby Las Palmas for about 12 hours the IXSEA technicians left the ship via barge and we started the planned route to Bremerhaven.

The scientific programmes started in Punta Arenas were continued by daily stations and boat measurements nearby the ship. In addition to that a training programme on the sediment echo sounder PARASOUND was successfully carried out.

The scientific programme was completed on 20 May in the afternoon, when the last station (311) was carried out.

Polarstern arrived in Bremerhaven on 24 May in the morning, where the cruise ANT-XXV/5 was successfully completed.

A number of autonomous measurement platforms for energy and material exchange between ocean and atmosphere were tested. They are planned for future operations on commercial voluntary observing ships (VOS) and research vessels. The prime objective of the meteorological working group consisted of the remotely sensed composition of aerosol in the atmospheric column. The temporal evolution of aerosol properties will be studied in order to explore aerosol-cloud interactions and to establish meridional gradients of tropospheric aerosols.

Observations with the acoustic Doppler current profiler (ADCP) in the upper water column supplement earlier observation from lower latitudes of the Atlantic. The expected results will contribute to studies of intra-seasonal and seasonal fluctuation of the main current systems. In addition, these data serve as reference for registrations from moored instruments at the equator at 23°W.

The equatorward abyssal flow of Antarctic Bottom Water represents an important branch of the global thermohaline circulation. On the western side of the South Atlantic it compensates for the southward directed North Atlantic Deep Water. Fluctuations in the bottom water are therefore expected to interact with other limbs of the world-wide oceanic circulation. On its northbound flow Antarctic Bottom Water faces topographical constraints in form of submarine ridges. One of these is given by the Rio Grande Rise separating the Argentine Basin in the south from the Brazilian Basin in the north. Its zonal alignment is disrupted by a 600 meter deep gap called the Vema Channel. This south-north canyon provides a natural choke point for property fluctuations and transports of bottom waters entering the Brazilian Basin. Over thirty year-long bottom records from the Vema Channel depict a clear temperature increase beginning in the early 1990es. This trend has been repeatedly documented in observations from local CTD stations and moored thermometers.

2. WEATHER CONDITIONS

Heinz-Günther Hill and Hartmut Sonnabend
Deutscher Wetterdienst

Polarstern sailed from Punta Arenas on 11 April 2009 at 18:00 LT (22.00 UTC) bound for Bremerhaven. The weather situation was first characterized by a low which was passing the Drake Passage eastwards heading to Falkland Islands and was developing into a gale centre. Therefore, at the time of passing the Magellan Strait westerly winds were increasing up to Bft 10 during the first day of voyage.

With the further eastward proceeding of this gale centre a breakout of Antarctic cold air far reaching to the North was initiated. This process was intensified by another low which followed during the next days of which the frontal system passed the route of *Polarstern* on 17 April 2009, causing heavy thunderstorms.

Subsequently the subtropical high was established with centre at about 35°S and had intensified. At the edge of this high pressure region the Antarctic cold air affected the weather over the South American coastal waters and caused a number of atmospheric disturbances in this area during the next days. One of them formed up into a low over the coastal waters of Brasil. During the time from 22 April 2009 to 29 April 2009 it moved eastward slowly with a weak upper air flow while developing to a gale centre. On its way north *Polarstern* remained in the more or less close vicinity of this depression and experienced winds Bft 6 in average with Bft 8 to 9 at times.

Leaving the influence of this low pressure area, cruising weather was affected by the south easterly trade winds which appeared weak with winds Bft 3 to 4.

Corresponding to the annual climatologic course, the ITC was expected to be found on a very southerly position. Accordingly, *Polarstern* came across with active deep convection on 4 May 2009 at the latitude of 2°S. At this time the very active easterly part of the ITC was located between 3°N and 5°N at the coast of Africa, crossing the equator between 15°W and 20°W extending to the coast of Brazil near 3°S. Leaving the ITC on 7 May 2009 the journey proceeded with mainly weak northwesterly winds approaching the region of the north easterly trade winds on 8 May 2009. While passing this zone winds from north to northeast with Bft 4 to 6 occurred as was to be expected. On approach to Canary Islands winds were increasing to Bft 6 to 7 with gusts Bft 8 due to turbulences leeward of the islands.

Proceeding north from Las Palmas towards the temperate latitudes the general synoptic situation was predominated by the subtropical high and a low pressure system over the British Isles which caused a south spreading flow of cold air.

Northwesterly winds Bft 6 to 7 occurred on 15 and 16 May while during the following days *Polarstern* remained under the influence of the high pressure building towards the east with weakening pressure gradient and winds.

The final period of the voyage passing the Gulf of Biscay, the Channel and North Sea was characterized by calm weather conditions with westerly winds Bft 3 to 5.

The statistics of the weather conditions are displayed in Fig. 2.1 to 2.3.

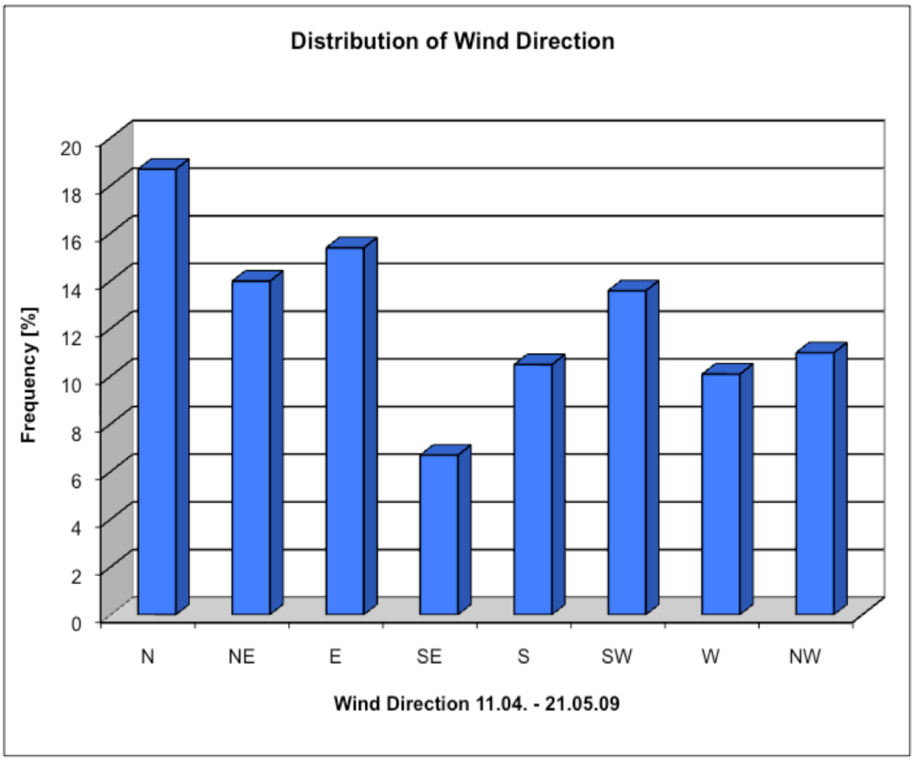


Fig. 2.1: Wind Direction 11.04. - 21.05.09

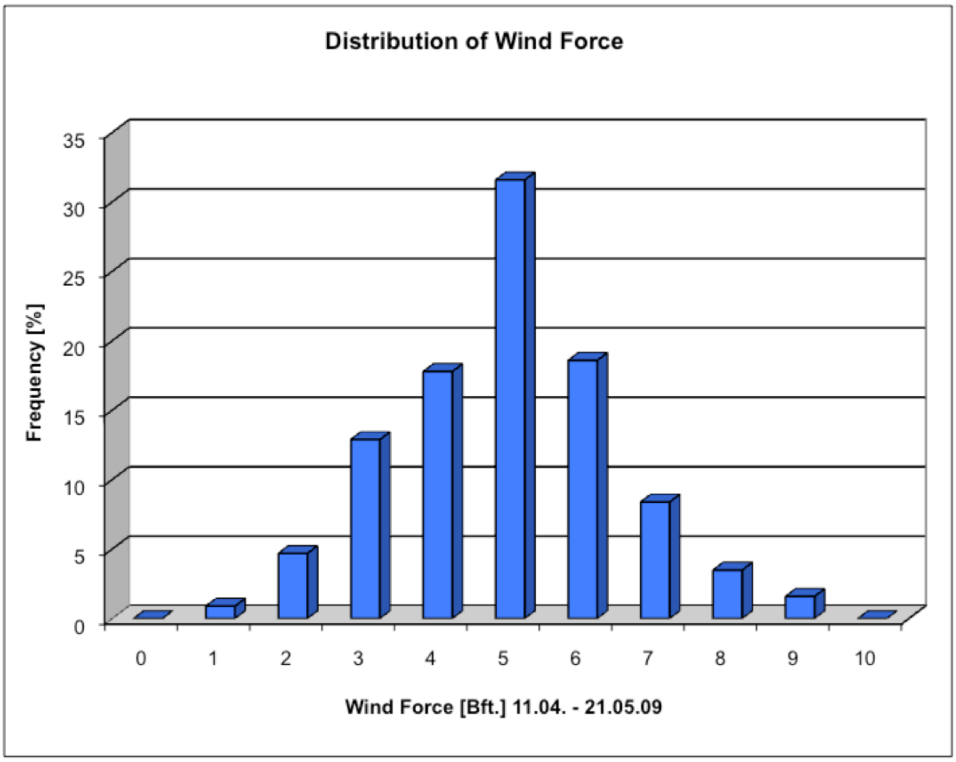


Fig. 2.2: Wind Force [Bft.] 11.04. -21.05.09

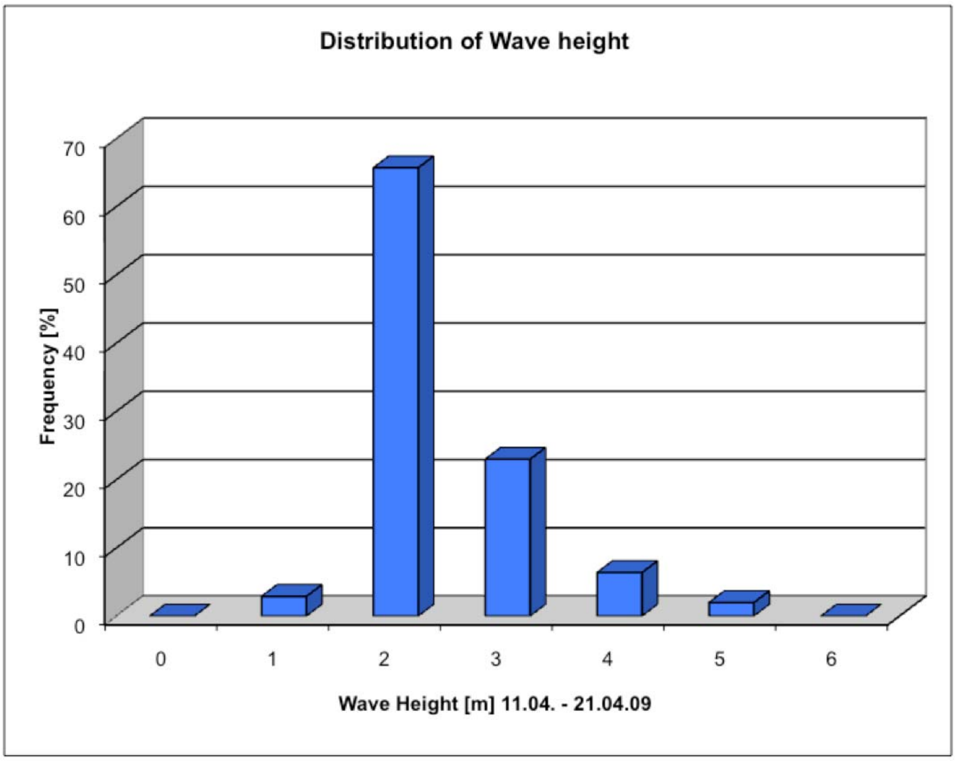


Fig. 2.3: Wave Height [m] 11.04. - 21.04.09

3. COMPARISON OF SATELLITE-BORNE WAVE MEASUREMENTS WITH A SHIPBORNE WAVE RADAR

Thomas Bruns[1], Katrin Hessner[2], Stephan Holsten[3] (not on board), Susanne Lehner[4], Thomas König[4], Wolfgang Rosenthal[5] (not on board), Xiaoming Li[4]

[1]Deutscher Wetterdienst
[2]OCEANWAVES GmbH, Lüneburg
[3]OHB-System AG, Bremen
[4]Deutsches Zentrum für Luft- und Raumfahrt, München
[5]GAUSS mbH, Bremen

Objectives

Many research activities onboard *Polarstern* critically depend on the weather and the sea state, in particular. Therefore, forecasting the height and direction of ocean waves has become an important component of the meteorological advisories provided by the German Weather Service (DWD). The global wave forecast system being run operationally by DWD is using altimeter measurements from four satellites, ERS-2, ENVISAT und JASON1+2 in the data assimilation scheme. In order to explore future utilization of remote sensing products, such as SAR (Synthetic Aperture Radar), DWD is participating in the German research project *DeMarine-Security* within the frame of the ESA/EU-Initiative Global Monitoring for Environment and Security *(GMES)*. Partners in the project are DLR, OHB Technology AG, Bremen and GAUSS mbH, Bremen. The project is aimed at improving the security of navigation by forecasting dangerous events.

A primary goal of the *Polarstern* wave experiment was therefore the measurement of ocean waves in areas with exceptional sea states using jointly remote sensing from altimeter and imaging radar (ENVISAT ASAR and TerraSAR-X) as well as visual observations, shipborne marine radar and altimeter measurements. Of particular interest were spectral and integrated ocean wave parameters of long and high waves. It is expected that the experiment will result in improved algorithms to retrieve wave spectra and significant wave height from SAR-data. Furthermore, the *Polarstern* experiment was used to investigate the capability to communicate such measurements, e.g. to weather centres or shipping companies by using new satellite techniques.

Work at sea

Wave Radar

In October 2008, the wave radar system WaMoS® II was installed in the Meteorological Office on A-Deck of Polarstern for the duration of ANT-XXV. The system had been developed at the GKSS-Research Centre, Geesthacht and rented for the project from OCEANWAVES GmbH. It consisted of a standard PC with an integrated PCI-card and evaluation software, being connected to the ship's marine X-Band radar. The system software is designed to extract wave information from the radar images (up to 3 miles from the antenna) by analyzing the spatial and temporal changes of the radar backscatter from the sea surface (sea clutter), and to determine directional wave and surface current information. Products are the complete two-dimensional wave spectrum, from which the statistical sea state parameters are derived in real time, including significant wave height (H_S), peak wave period (T_P), peak wave length (λ_P) and peak wave direction (θ_P) (Fig. 3.1).

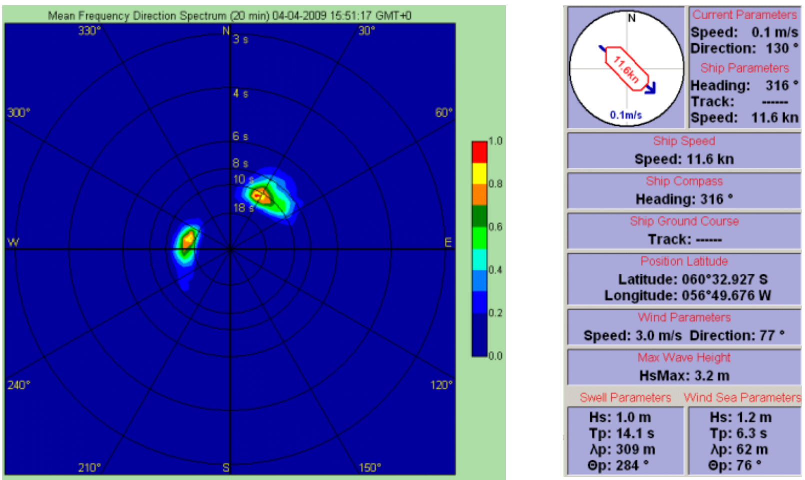


Fig. 3.1: Cutout of a WaMoS® screen display: Two-dimensional wave spectrum and display of integral parameters and ship specific data, taken on 4 April 2009.

In agreement with the ship's command the radar range had to be set to 1.5 nm (short pulse mode) for providing useable images. This was possible only in a distance to coasts, ship routes and icebergs. During the first two legs of ANT-XXV work concentrated on finding the optimal radar settings and calibrating the system using onboard visual observations and available buoy data.

Satellite Communication

In order to test and demonstrate the transfer of environmental and ship data via ORBCOMM-satellites, an additional PC with ORBCOMM-Communication Software was connected to the WaMoS® system and a small ORBCOMM-Antenna was installed on deck. Compressed data sets were then regularly sent whenever one of the satellites was near. ORBCOMM satellite AIS has then searched for reports of the *Polarstern* position. AIS is in a testing phase and did not yet yield satisfactory results in areas of dense ship traffic. The observations shown over the South Atlantic belong to the first successful confirmations of an AIS ship position in open waters (Fig. 3.2).

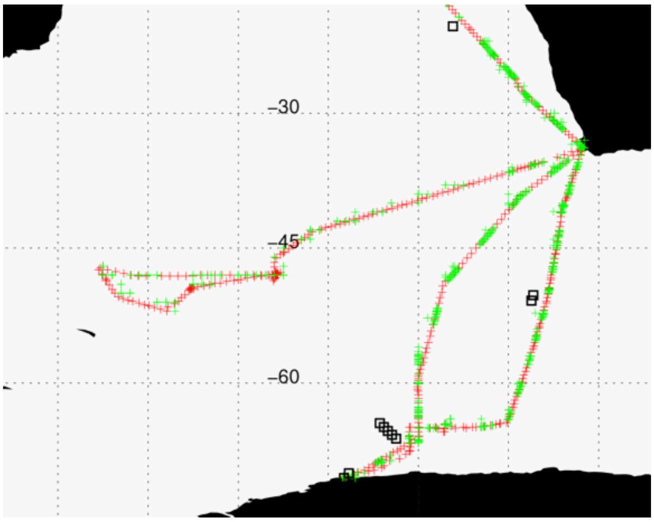


Fig. 3.2: ORBCOMM SatAIS reports (green) of Polarstern superimposed on the vessel's track(red).

The transmitted data sets also included onboard measurements of significant wave height and other integrated parameters as reported by the WaMoS® system. These data were thus accessible during the cruise at the German receiving station in real time (Fig. 3.3).

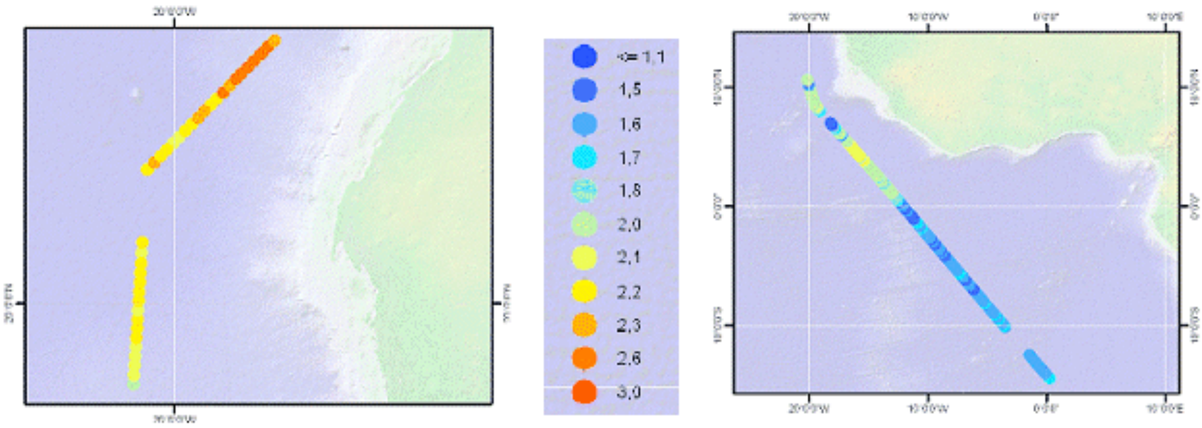


Fig. 3.3: Significant wave heights along the Polarstern track during leg ANT-XXV/1 from Bremerhaven to Cape Town.

Wave Height Comparisons

The actual measurement campaign began with leg ANT-XXV/3 „LOHAFEX" in January 2009. With the exception of a few days when ice demanded radar operation in the far range, wave spectra have continuously been recorded until the end of ANT-XXV/5. Fig. 3.4 shows measured significant wave heights in comparison with wave analyses and up to 9 hourly forecasts by DWD and the European Centre For Medium Range Weather Forecast (ECMWF) as well as onboard visual observations.

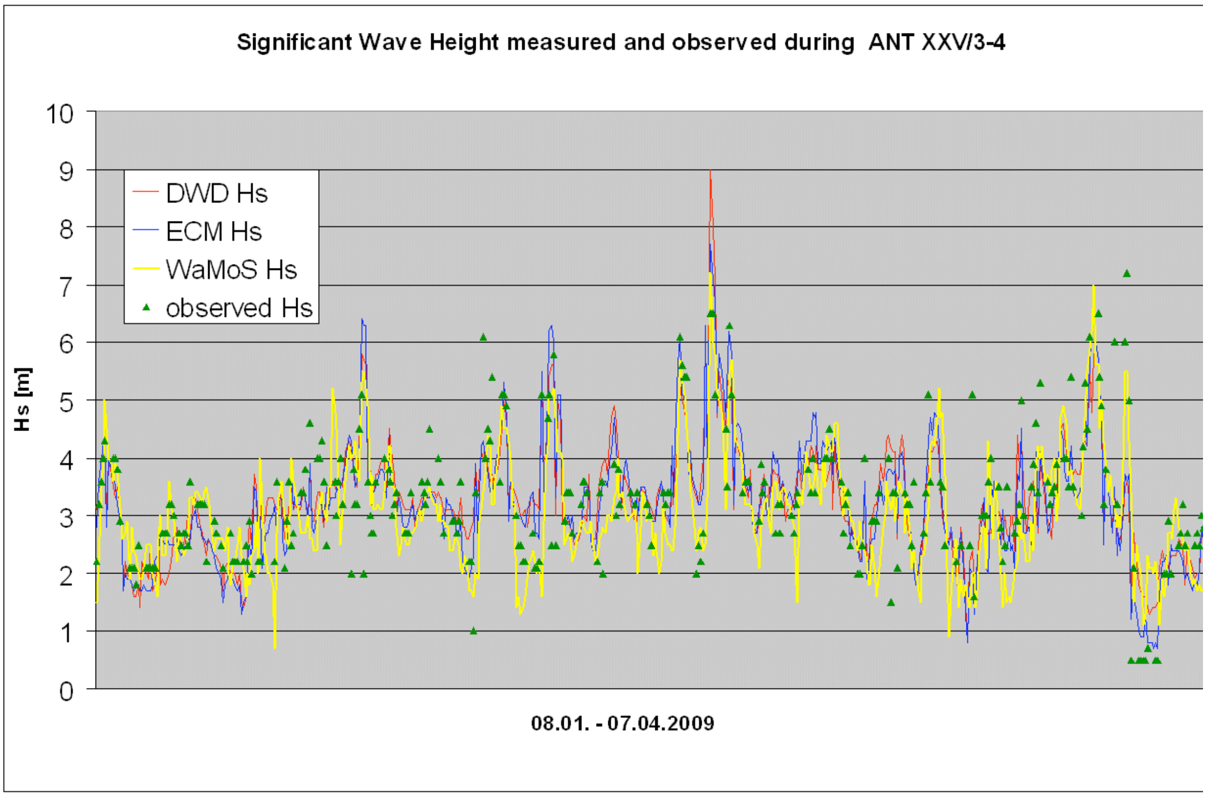


Fig. 3.4: Time series of significant wave heights measured by WaMoS® (yellow), observed visually (green triangles) and analysed and forecast by DWD (red) and ECMWF (blue)

During leg ANT-XXV/4 (Drake Passage) an Optiwave radar altimeter was operated by the Centre National d'Etudes Spatiales (CNES, the French government space agency) within the frame of a geodetic experiment. This offered the unique opportunity to compare WaMoS® measurements with independent measurements. For significant wave height there is good agreement between the two measurement systems and with satellite-borne altimeters as well (Fig. 3.5).

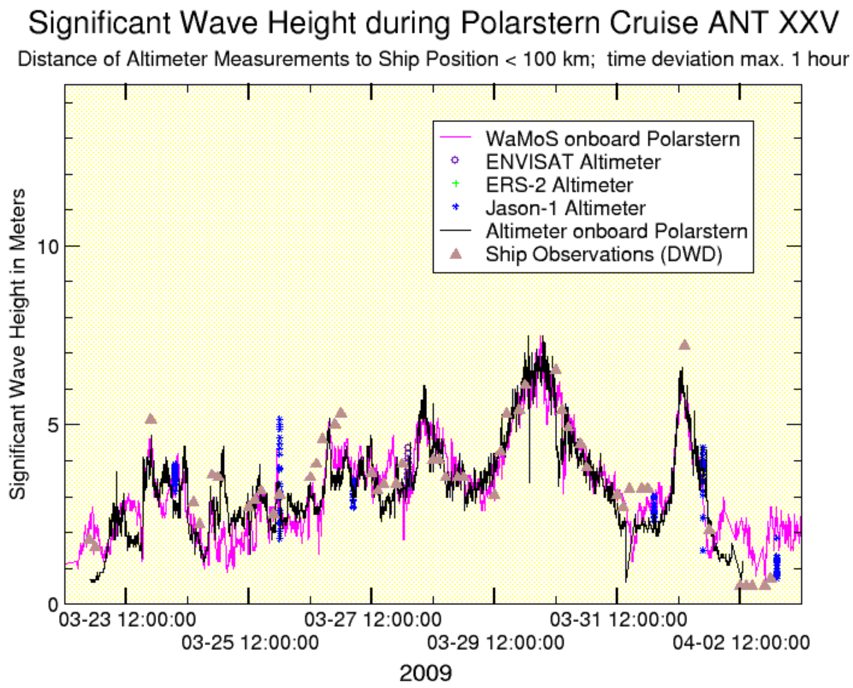


Fig. 3.5: Time series of significant wave height observed visually and measured by WaMoS®, satellite-borne altimeters, shipborne Optiwave-Altimeter during ANT-XXV/4 in the Drake Passage

Satellite Imaging

During the cruise the weather situation around the ship was monitored using different imaging satellite systems, namely METEOSAT, ENVISAT ASAR and the new German high resolution TerraSAR, a radar satellite with up to one meter resolution. While the NOAA and METEOSAT data were used to judge and predict the weather situation on board, the radar satellites will be used later to validate wind field and sea state predictions of the DWD model. Examples are shown in the following figs. 3.6, 3.7, 3.8, 3.9.

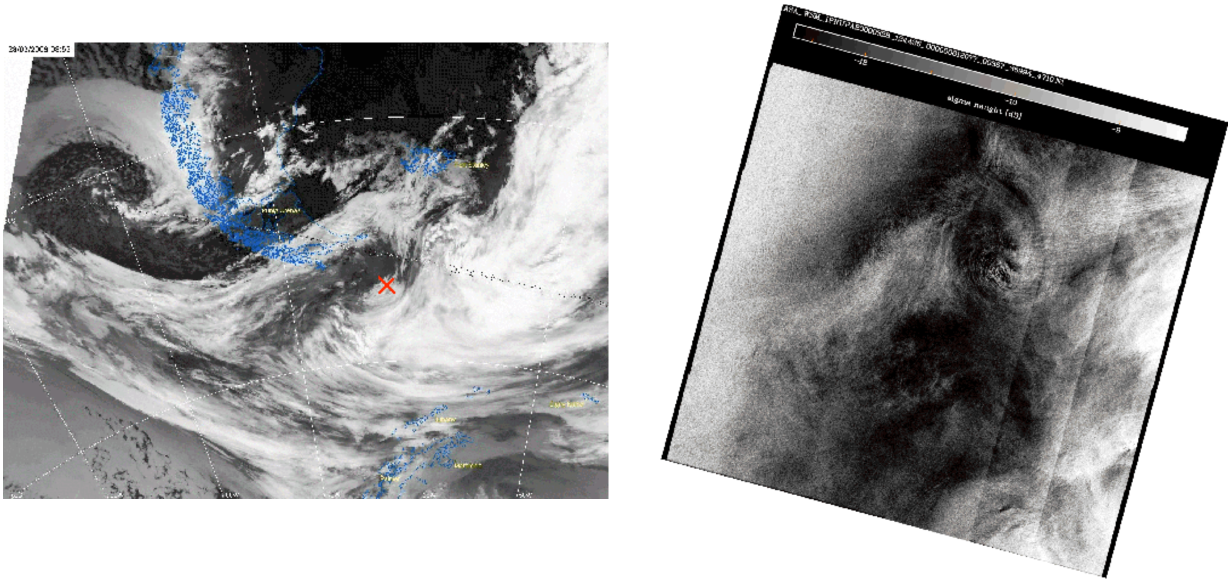


Fig. 3.6: Set of satellite images during the Polarstern passage across the Drake Passage on 28 March 2 from NOAA (left) and ENVISAT ASAR (right)

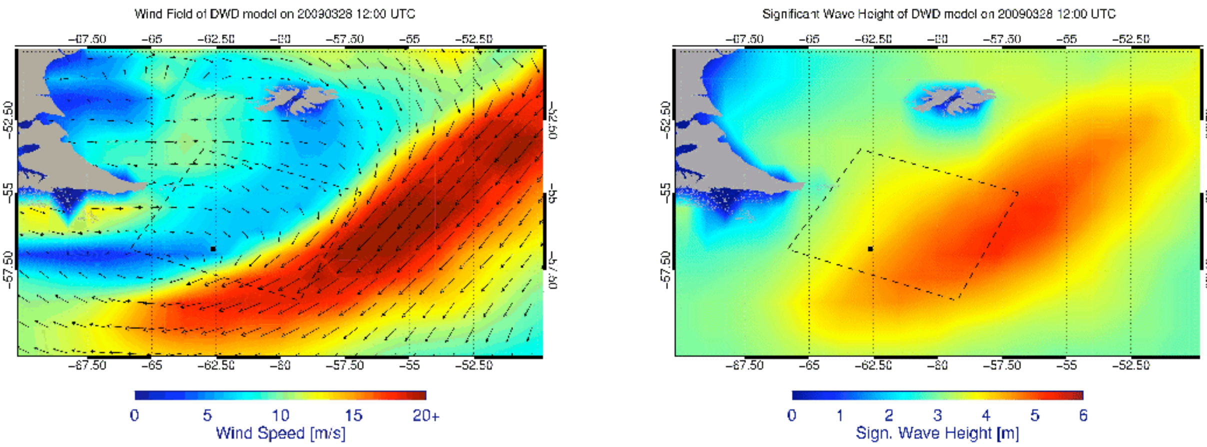


Fig. 3.7: DWD wave model wind and wave height on 28 March while Polarstern was inside the SAR image of Fig. 3.6. frames indicating the position and orientation of the above shown ASAR image.

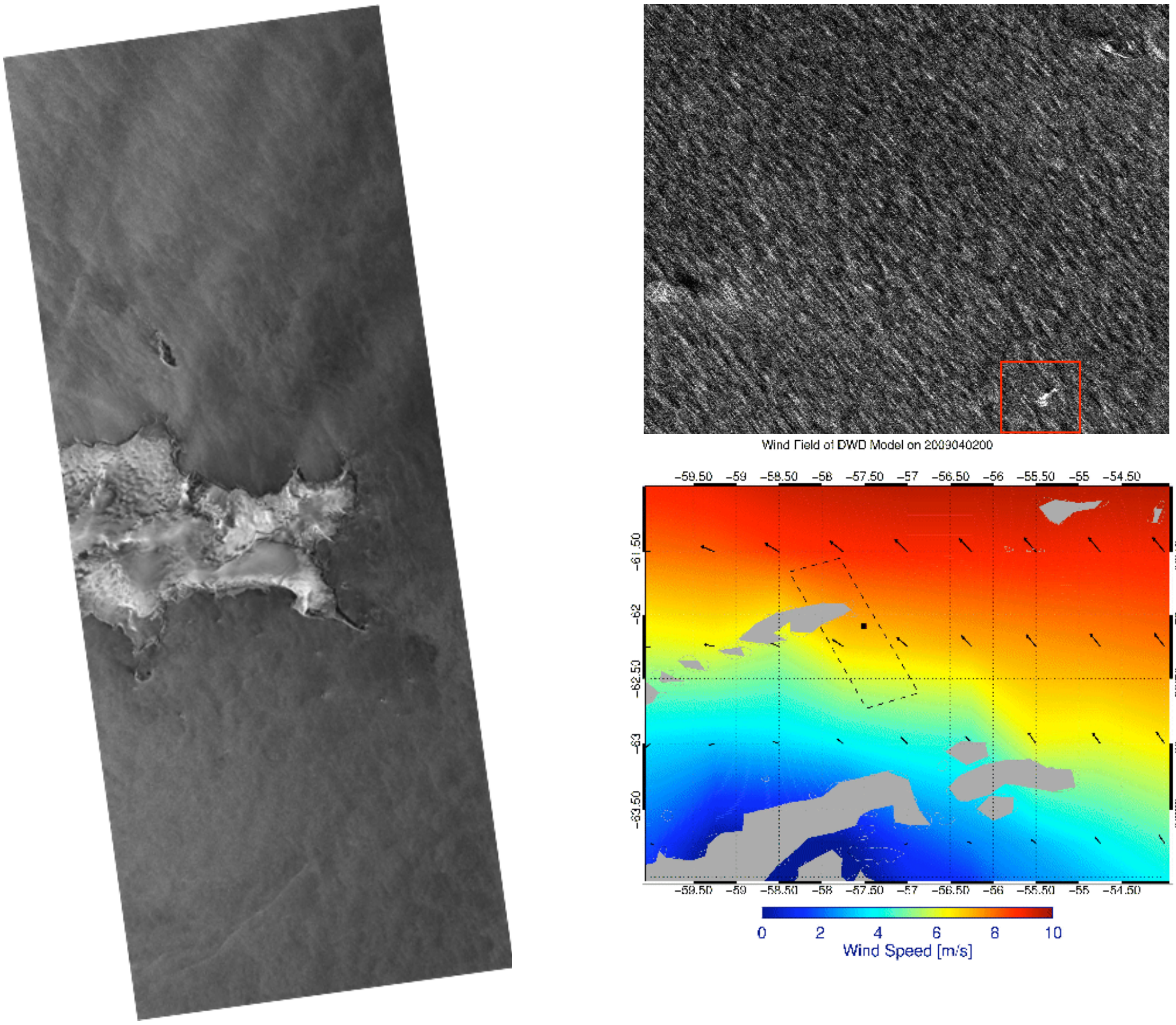
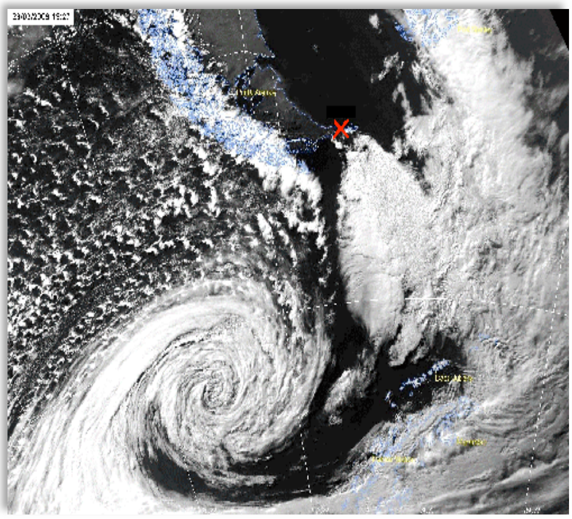


Fig. 3.8: On 1 April 23 UTC a TerraSAR X stripmap image (left) was acquired near King George Island directly over the actual position of Polarstern. Thus joint measurements of marine radar and high resolution WaMoS® are available in this case. In the high resolution sub-scene (upper right) the vessel is difficult to recognize (red square) due to the radar distortion in moving ocean waves. The lower right panel shows DWD model wind speed on 2 April 00 UTC with TSX scene and Polarstern position superimposed.



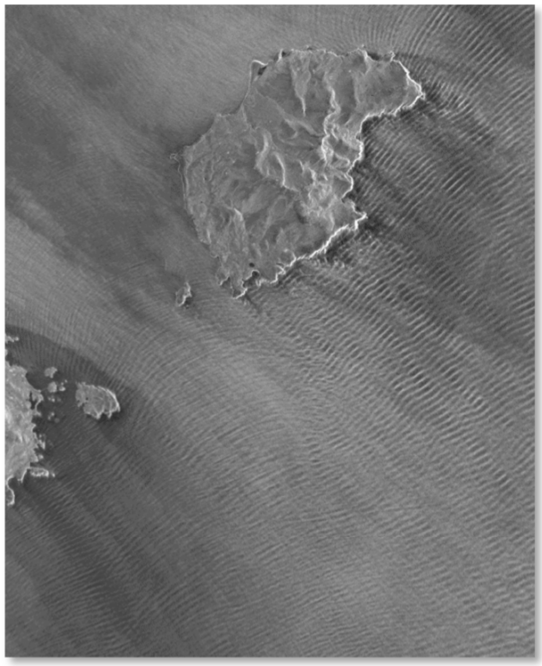


Fig. 3.9: To catch an image of Polarstern was not always successful, since the ship was frequently changing course according to the scientific programme. Shown is an 30 km x 100 km TerraSAR X image of the longest waves observed of more than 500 meters acquired on March 23 at Lennox Island, northeast of Cape Hoorn. The severe weather situation forced Polarstern to take shelter behind the southern tip of South America.

An event of "Parametric Rolling"

Leaving the LOHAFEX area (northeast of South Georgia) on 7 March at 23:28 UTC *Polarstern* suddenly started heavy rolling with angles up to 20° when heading against a cross sea with significant wave heights of approximately 4.5 meters (figs. 3.10, 3.11). A detailed analysis of the WaMoS® records identified this event as a typical case of "Parametric Rolling". One hour before two wave systems existed with slightly different directions and periods between 10 and 11s: Wind waves coming from WNW and swell waves coming from WSW, followed by a slow change of the swell direction, and finally merged with the wind sea. Resonance occurred when for minutes the period of wave encounter was close to half of the ship's "Eigen-period" of 17.3 seconds.

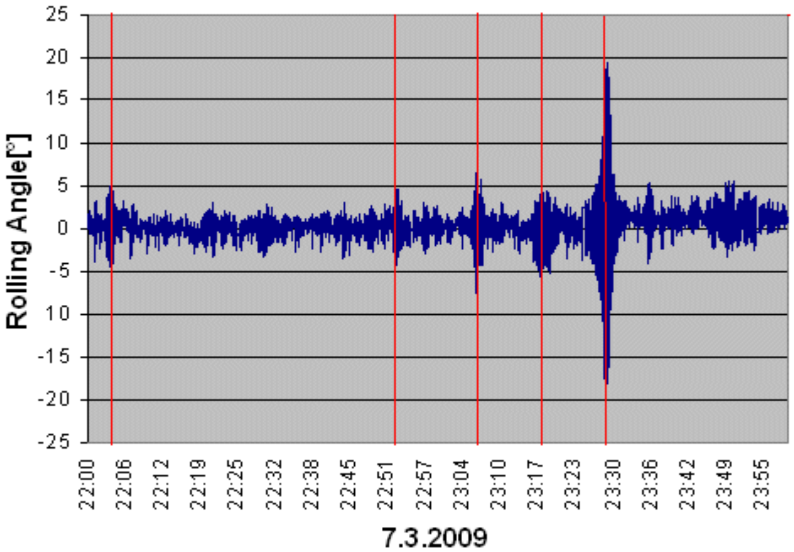


Fig. 3.10: Rolling angle of Polarstern on March 7 between 22:00 and 24:00 UTC. Previously to the extreme event at about 23:28UTC, there were other near resonance events, here marked with red lines.

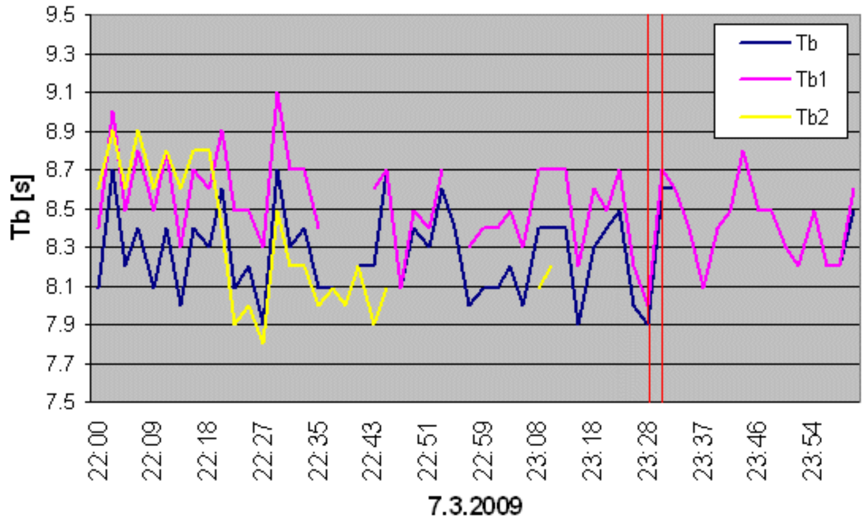


Fig. 3.11: Periods of encounter as calculated from ship course and speed, period and direction of the peak of the total wave spectrum (Tb) and sub-peaks (Tb1 and Tb2). There is a shift between the rolling event (red lines) and the time when Tb reached the critical value of 8.6s since values represent 20-min running means.

Outlook

WaMoS® remained onboard until *Polarstern* returned to Bremerhaven on 24 May 2009. It will take the following months to collocate and compare the measurements with the data obtained from the satellite-borne systems. Besides the successful onboard test it could also be shown, that environmental ship data can easily be sent ashore via satellite in near real time. This may be a first step to a future observation system, providing worldwide wave observations for the assimilation in numerical forecast models. Moreover, shipping companies would benefit from a system monitoring present and forecast sea states for all ships of their fleet.

Acknowledgements

Many thanks to Richard Biancale and Stavros Melachroinos (both CNES, Observatoire Midi Pyrennées, Toulouse) for providing their altimeter measurements during ANT-XXV/4.

4. HYDROGRAPHIC OBSERVATIONS IN THE VEMA CHANNEL

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Objectives

The equator bound flow of Antarctic Bottom Water (AABW) represents a significant limb of the global thermal circulation. In the South Atlantic the deep western boundary along the continental rise carries AABW northward. The advected water masses originate from the Weddell Sea, where they are formed by deep winter-time convection. At the latitude 32°S the abyssal flow encounters a topographical constrain in form of the zonally aligned Rio Grande Rise. This submarine mountain chain separates the Argentine Basin in the south from the Brazil Basin farther to the north. AABW finds its equatorward pathway through this natural impedance via a 790 km long canyon called Vema Channel (Fig 4.1). This meridionally directed channel provides a choke point for observations of water mass property and transport fluctuations. Such parameters are vital components in monitoring the global climate system.

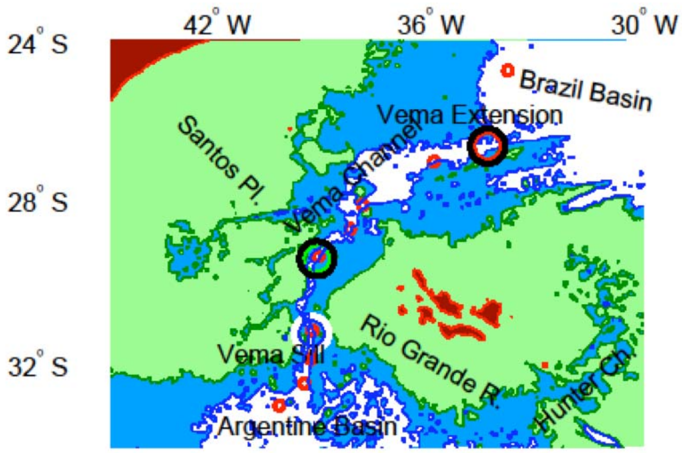

Fig. 4.1: Vema Channel of the South Atlantic. This canyon enables Antarctic Bottom Water to leave the Argentine Basin on its equator bound drift towards the Brazil Basin. Depths below 4600 m are shown in white. In the vicinity of the circled locations CTD casts were taken during Polarstern cruise ANT-XXV/5. Figure adopted from Zenk and Morozov (2007).

A decadal-scale record from the channel entrance (31°S, 39°W) indicates a clear increase of the lowest temperatures of the bottom water. Comparable observations from the exit region of the Vema Channel (26° S, 35° W) confirm the general near-bottom temperature rise since 1991 (northern circle in Fig. 4.1). Our prime objective was to revisit both sites for additional high precision CTD observations of the coldest AABW in the channel. The Vema Sill station (southern circle in Fig. 4.1) at the entrance is officially acknowledged as an ocean site observatory. *OceanSITES* is a worldwide system of long-term, deep water reference stations measuring regularly dozens of physical, geochemical, and biological variables (http://www.oceansites.org).

Work at sea

In view of the Vema Channel project on board four CTD stations were successfully occupied during ANT-XXV/5. They are summarized in Tab. 4.1. The CTD probe manufactured by SeaBird, Inc., was kindly provided by AWI Bremerhaven. It was equipped with two independent pairs of temperature and conductivity sensors. Four near-bottom samples were taken from the CTD rosette. Two bottles from each sample were already analyzed on board. The salinity values of five additional samples were determined about two months later in the laboratory in Kiel. A compilation is given in Tab 4.2a and b.

Tab. 4.1: CTD stations along the Vema Channel

Sta Nr. PS73-	Date 2009	Time at depth UTC	Latitude S	Longitude W	Depth m	Location
283	22 April	19:30	31° 11.86’	39° 19.18’	4469	Eastside Vema Sill
284	22 April	23:48	31° 11.90’	39° 26.17’	4581	Westside Vema Sill
285	23 April	22:23	29° 11.30’	39° 03.96’	4689	Vema Channel Mid
288	26 April	11:35	26° 40.84’	34° 14.48’	4716	Vema Extension

Tab 4.2a: Inventory of salt probes from Sta. PS73-283 (Vema Sill, east side)

Rosette Sampler				Status: 22-APR-2009
Rosette Bottle Nr.	Probe Nr.	Salinom. on Bord Op.W Dimmler, FILAX, Inc.	Transp. to Kiel Op. T Csernok, IFM-GEOMAR	Remarks
2 [1 failed to close]	1 - 4	Probe 2	Probe 3 Probe 4 Rest von 2	Probe 1 - Special probe, sealed (WZ)
3	5 - 8	Probe 5	Rest of 5 Probe 6	Probe 7 - Special probe, sealed (EF)

Tab 4.2b: Results from discrete near-bottom probes and CTD observations (last two columns) from Sta. PS73-283.

Salinometer Results						Status: 7-JUN-2009
Rosette Bottle Nr	Probe Nr for Kiel	Salt on Bord 2-MAY-2009 10:36 Autosal8400B	Salt in Kiel 28-JUN-2009 : Autosal8400B (Lab)	On Bord minus Lab in Kiel	POLAR-STERN CTD 1^{st} sensor pair	POLAR-STERN CTD 2^{nd} sensor pair
2	Rest of 2	34.671	34.673	- 0.002	34.666 at 4522 dbar	34.670 at 4522 dbar
2	3		34.672			
2	4		34.672			
3	Rest of 5	34.672	34.675	- 0.003		
3	6		34.673			

Preliminary results

In general the salinity values in Tab 4.2b appear astonishingly similar. Differences between data that were already determined on board, and those obtained in the lab in Kiel lie in the range of the instruments' accuracies (± 0.002). Obviously the second sensor pair of the used CTD probe agrees better with the bottle salinometer values than the first pair. For future analyses we will therefore prefer the data set obtained from the second sensor pair.

The new CTD measurements enable us to add another data triple to our long-term parameter (time, potential temperature, two locations) curves from the Vema Channel.

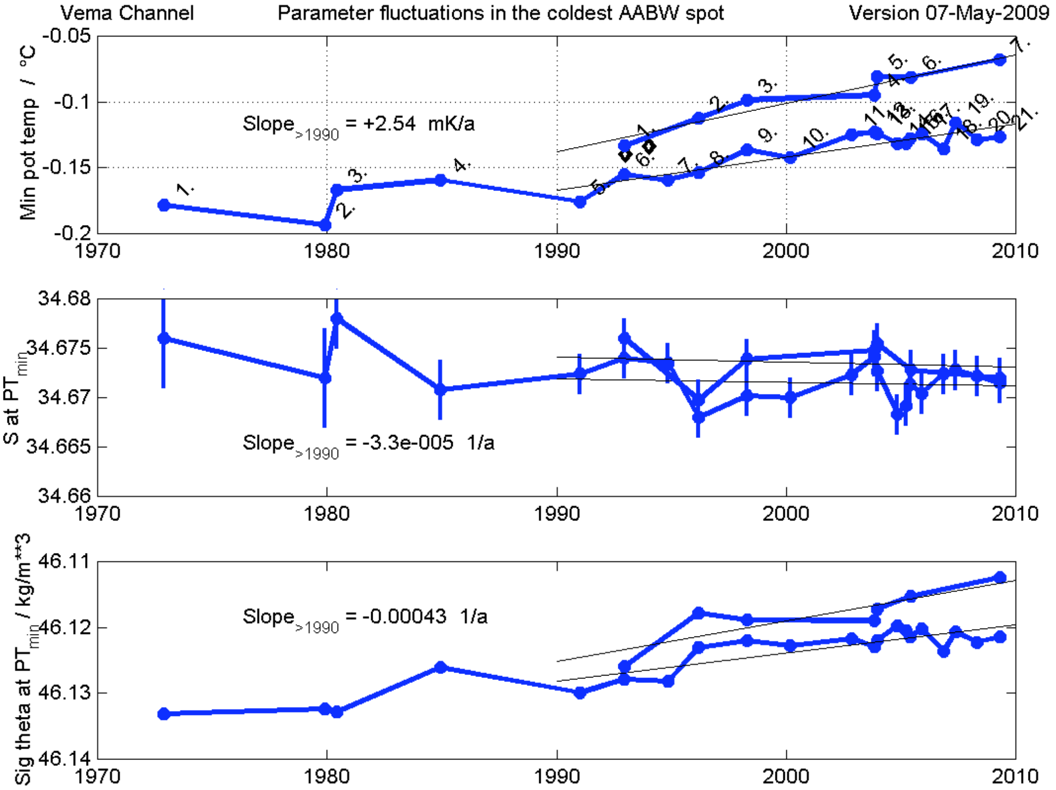

Fig. 4.2: Time series of the coldest bottom water (AABW) at the Vema Sill and the Vema Extension (short curves). Station locations are given in Fig. 4.1 by the lower and upper circles. Top: Potential temperature; middle: associated salinity with vertical accuracy bars; bottom: sigma4 (note the reversed y-axis). The shown digits with dots indicate the numbers of visits to both locations. The last data points on the right site were obtained during ANT-XXV/5. The indicated slopes were calculated from observations after 1990.

We are quite pleased to see indications of a comparable increase over the years in both shown temperature curves, i.e. from the entrance and from the exit of the pathway for AABW advection. The shift between both temperature series is, at least in parts, caused by vertical mixing with slightly warmer circumpolar water masses that lie above the bottom water (Zenk, 2008). Although measured with highest precision differences in salinity data are still close to the detection level to confirm the abyssal mixing along the channel as suggested by the temperature series. Obviously the sigma series is mainly controlled by the temperature. It also shows a clear trend towards lower values.

In how far the slight temperature rise between visits No. 20 and 21 at the Sill is significant remains presently unclear. In the future a stabilization or even falling of the lowest temperature in the Vema Channel might be expected. Observations in the source region of the youngest AABW in the Weddell Sea indicate a reversal of the local abyssal temperature. The slight cooling trend seems to be related to variations of atmospheric conditions. It affects both the intrusion of the Circumpolar Deep Water into the Weddell gyre and the circulation of the Weddell gyre itself. The scenario on the exported bottom water was diligently described by Fahrbach et al. (2004). In future observations at the Vema region we might expect a delayed impact of the sign change of the temperature drift at the formation site of AABW. Apparently more visits are necessary to recognize the potential arrival of the advected temperature signal at our *OceanSITE*.

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5. AUTONOMOUS MEASUREMENT PLATFORMS FOR ENERGY AND MATERIAL EXCHANGE BETWEEN OCEAN AND ATMOSPHERE (OCEANET) - OCEAN COMPONENT

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Objectives

The OCEANET project aims to further develop and test autonomous instrumentation for measurement of energy and matter exchange between the atmosphere and the surface ocean. At first, the instruments are tested and installed aboard *Polarstern*. Since the processes under investigation require both a rather comprehensive observational approach as well as high spatial and temporal coverage, unattended operation of the multi-parameter instrumentation aboard "Voluntary Observing Ships" is the long term goal of this initiative.

The oceanic component of this study places a strong focus on the marine carbon cycle in the surface ocean which is of high climatic relevance but at the same time susceptible to climate change. The surface ocean's CO_2 source/sink function is maintained by a complex interaction of physical, chemical and biological processes. Therefore its understanding requires measurement of various different parameters.

During the third OCEANET cruise the feasibility of autonomous underway measurements was assessed for a wide range of instruments for measurement of physical (temperature, salinity, turbidity), chemical (CO_2 partial pressure, pH, oxygen, total gas tension, nutrients), and biological parameters (chlorophyll a, colored dissolved organic matter CDOM).

Work at sea

During ANT-XXV/5 we operated several underway instruments in the wet laboratory of *Polarstern*. One centerpiece of this suite of underway systems was the FerryBox system by which autonomous underway measurements of temperature and salinity, turbidity, chlorophyll *a* fluorescence, dissolved oxygen, and pH were carried out. The data determined with the named sensors provide important information about the biological processes proceeding in the ocean. The measurement of the so-called variable chlorophyll fluorescence for instance, allows not only for determining the quantity of algae but, in addition, for evaluation of the measured algae activity. The passage of *Polarstern* crossing almost the entire Atlantic Ocean offers the possibility to generate a profile of the sea water quality of several thousand kilometres. The data was stored along with time and geographical position at 1-min intervals.

A second centerpiece of the ocean component of OCEANET was the comparison of different instruments for the measurement of the CO_2 partial pressure (pCO_2) in seawater.

The following two systems were more or less successfully operated throughout the cruise.

- **General Oceanics Underway pCO_2 System (GO)**
  The gas phase is equilibrated with seawater using a spray-head equilibrator that produces a fine spray. After the equilibration process the sample gas is dried and subsequently measured via NDIR using a LICOR 7000 gas analyzer. The LICOR is calibrated approximately every 3.5 h with 3 standard gases ranging from 184 to 745 ppmv.
- **PSI CO_2 Pro *Sensor***
  In this autonomous in-situ sensor, the CO_2 in a gas phase is equilibrated with the seawater via a tubular silicone membrane. The CO_2 in the gas phase is measured via a small NDIR cell that is calibrated every 6 h by a simple zero-point calibration.

Additionally, a novel optical and submersible nutrient sensor (ProPS, TriOS GmbH, Oldenburg, Germany) for dissolved nitrate and nitrite was operated during the entire cruise in an underway setup and was tested as a profiling device as well. In order to evaluate precision and accuracy of the sensor, nitrate concentrations were determined by a classical wet chemical method every 24h (in oligotrophic waters) and 8h (in eutrophic areas), respectively.

Fig. 5.1 shows the setup of all instruments schematically. The two similar GO systems (one ship borne (AWI), one portable (IFM-GEOMAR)) were connected directly to ship's seawater supply line which drew seawater from around 11 m depth. Temperature and salinity were measured directly at the seawater intake by the ship borne thermosalinograph. The PSI sensor, in contrast, was submerged into a thermally insulated flow-through water bath that was also connected to the seawater supply line. The containers water volume was 40 L and the water flow was maintained at approximately 10 L/min. In addition we submerged two gas tension devices (GTD Pro & HGTD, Pro Oceanus, Halifax, Canada) in the flow-through container which measured the total pressure of all dissolved gases in seawater. In a parallel setup (second flow-through container) we have installed a sensor package, consisting of the optical (UV based) nutrient sensor and two fluorometers (chlorophyll a and CDOM). An additional oxygen Optode sensor (Aanderaa, Norway) has measured every minute oxygen saturation and temperature.

For reference, discrete water samples for dissolved inorganic carbon (DIC) and total alkalinity (TA) were taken every 12 hours for analysis at IFM-GEOMAR in Kiel. The samples were drawn into 500 mL bottles and poisoned with saturated mercuric chloride solution. Depending on ambient nitrate concentrations, samples for nitrate/nitrite were measured instantaneously by a wet-chemical method (Grasshoff et al., 1964) up to three times per day. Frozen nutrient samples for analysis at IFM-GEOMAR were taken once a day, in order to yield an accurate reference dataset.

Finally, the nutrient sensor and the PSI CO_2 Pro sensor have been investigated for potential future profiling applications, such as being mounted on ship borne CTDs. For this purpose vertical profiles down to 100 m (ProPS) and 300 m depth (PSI CO_2 Pro) have been carried out, respectively. Discrete water samples were collected simultaneously for later analysis in Kiel.

Preliminary results

The CO_2 mole fraction (xCO_2) data as recorded by the GO systems is calibrated against the standard gases and together with the atmospheric pressure and the sea surface temperature the sea surface pCO_2 is calculated following the procedures described in Dickson *et al.* ("Guide to best practices for Ocean CO_2 measurements.", PICES Special Publication 3, 2007). We used the GO system as our reference system as this is most intensively tested and internationally accepted instrument.

The distribution of pCO_2 (Fig. 5.2) in the surface ocean along the meridional cruise track is in good agreement with our measurements during ANT-XXIV/4 and with the pCO_2 climatology (Takahashi et al., 2002). This partial pressure pattern is mainly driven by physical impacts (temperature dependency) and therefore follows the sea surface temperature (SST, Fig. 5.3). Nonetheless, decreased (raw) values for pCO_2 also demonstrate seasonal impacts of net community production, in particular near the equator and at higher latitude further north. Evaluation of measurements for other parameters (e.g. oxygen, gas tension) is still in progress.

The PSI CO_2 sensor was working during the first two weeks of ANT-XXV/5 properly and showed a qualitative good agreement with the reference systems. A first hydrocast with this sensor mounted on the CTD could be carried out successfully, although damage has occurred during recovery. The membrane interface was destroyed and therefore continuing underway measurements for the intercomparison weren't possible any longer. New spare parts were delivered aboard in Las Palmas and further comparison of pCO_2 instruments has been carried on for the last 10 days of this cruise. In addition, a second CTD cast was carried out with the repaired PSI sensor and a first continuous profile from 300 m to 0 m has been achieved. Post-processing and data evaluation is still in progress.

Most promising results have been obtained with the ProPS nitrate sensor. Measurements in the underway mode during the cruise (Fig. 5.4) have shown good agreement with the reference method. Furthermore the meridional cruise track allows us to draw directly conclusion from Sea Surface Temperature (SST) to the performance of the sensor. Recent publications (e.g. Sakamoto et al., 2009) have shown strong temperature dependency for this kind of measurements and first raw data is following this behavior, due to highly varying SST during this cruise. Measurements of this sensor combined with wet chemical analysis were carried out until the North Sea, in order to cover a broad range of nitrate concentrations.

Operated in a profiling mode (2 stations during the cruise, Fig. 5.5) the sensor has produced high resolution profiles for nitrate in the upper 100 m of the water column. Reference data and sensor output is in good accordance and temperature effects could be identified with simultaneous CTD measurements. Further evaluation and temperature compensation of the raw data is necessary and still in progress.

The evaluation of the entire dataset is currently underway aboard of *Polarstern* and later at the IFM-GEOMAR and GKSS.

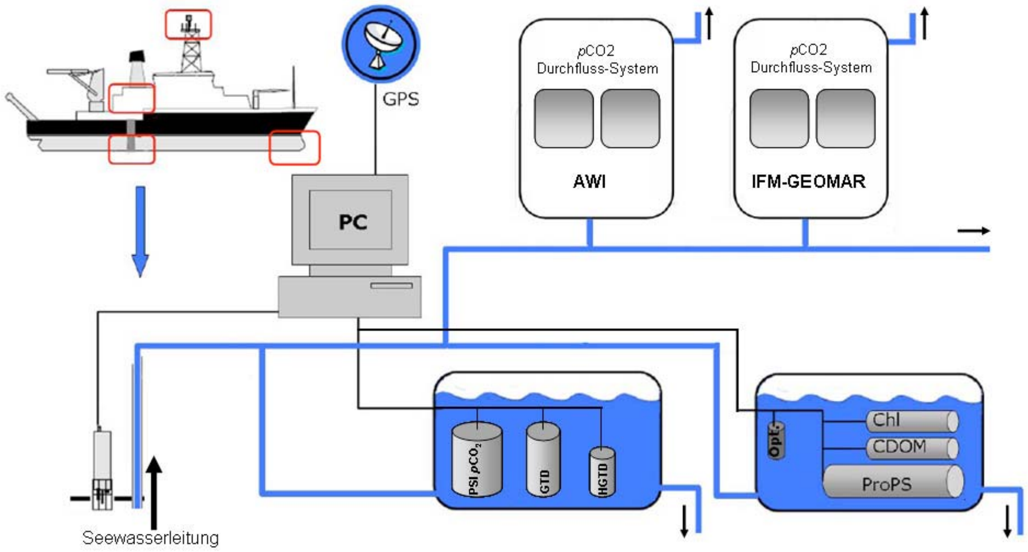

Fig. 5.1: Setup of underway measurements (not incl. FerryBox) during cruise ANT-XXV/5 of Polarstern

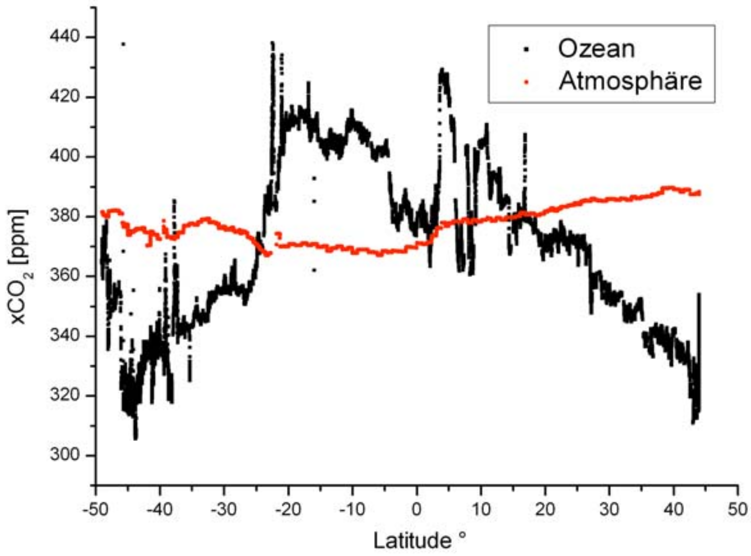

Fig. 5.2: pCO_2 measurements of the GO system aboard R/V Polarstern. Data is shown for atmospheric (red) and oceanic (black) partial pressure of CO_2.

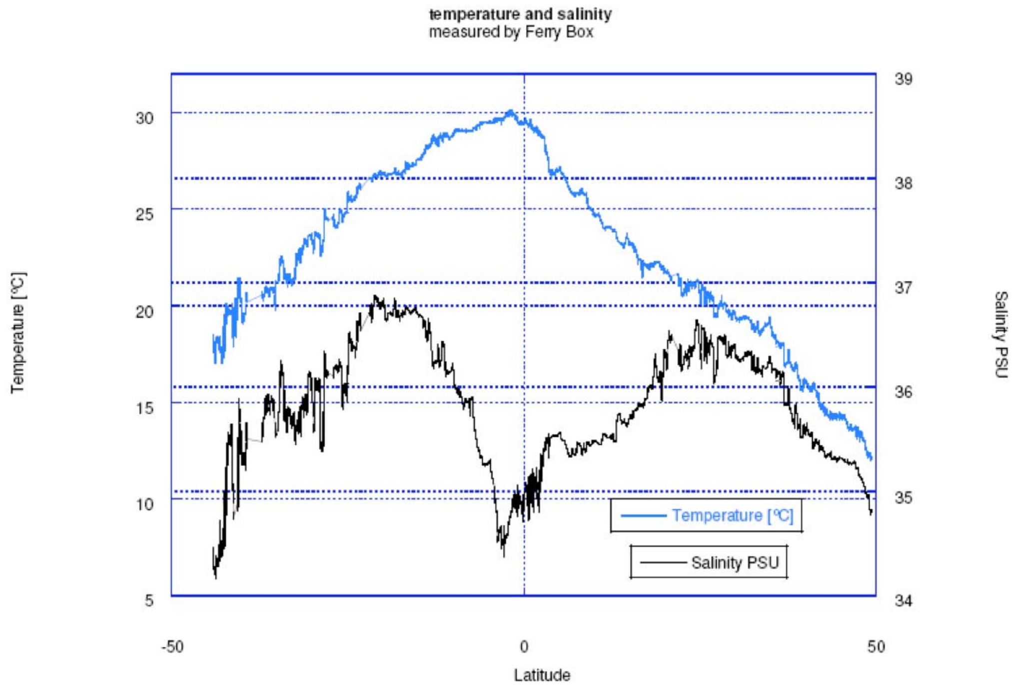

Fig. 5.3: Continuous data for salinity (black) and temperature (blue) recorded by the FerryBox during ANT-XXV/5

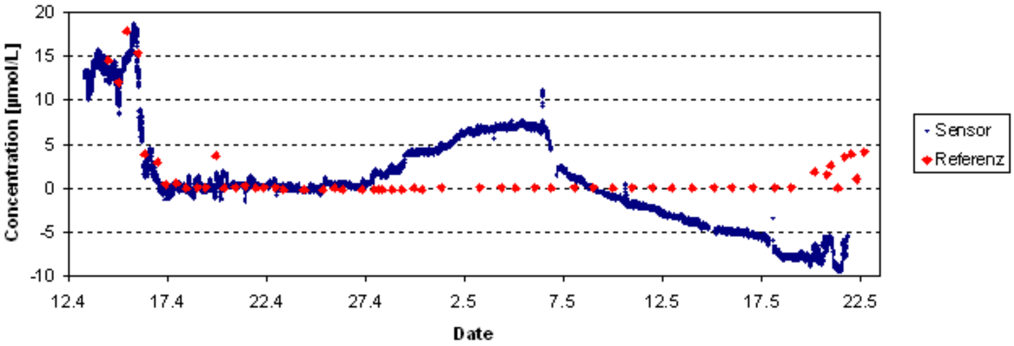

Fig. 5.4: Surface ocean sensor measurements of nitrate (raw values ProPS, blue dots) and wet chemical analysis as a reference (raw values, red dots) during the transit ANT-XXV/5 of Polarstern. Data show good agreement with conventional analysis until a temperature effect emerges, due to high SST in the tropics.

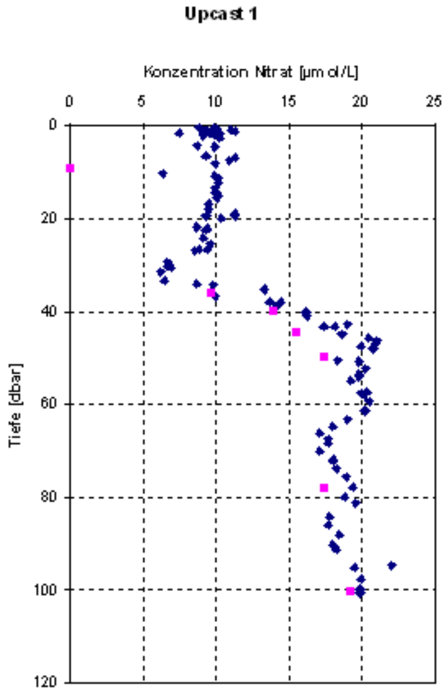

Fig. 5.5: ProPS measurements (raw values, blue dots) in the upper 100 m of the water column in the vicinity of the equator. Reference measurements (raw values, red dots) are following the same shape as the ProPS does. Temperature effects beneath the mixed layer (~25 dbar) could be identified.

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6. ROLE OF TEMPERATURE, CO_2 AND OXYGEN IN EVOLUTION: INTEGRATIVE ECOPHYSIOLOGICAL STUDIES ON FISH AND CEPHALOPODS (AWI)

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Objectives

Ecological physiologists have historically been interested in the effect of abiotic factors, such as temperature, hypoxia and salinity, on the physiology of animals, and how these factors influence physiological performance and species distribution patterns in nature. In general, these studies have had two approaches – to examine how the changes in the abiotic factors alter or disrupt physiological processes, and to study how animals adjust their physiological processes to adaptively respond to fluctuations in environmental conditions. Molecular approaches are more and more implemented for an understanding of the genetic basis.

Temperature has a large impact on all biological processes and is therefore especially important in marine ecosystems. Animal organisms, due to their inherently high levels of organisational complexity, specialize on environmental temperature much more than unicellular bacteria and algae (Pörtner, 2002). Accordingly, thermal tolerance windows differ between ectothermal animal species depending on latitude or seasonal temperature acclimatisation and are therefore related to geographical distribution. Tradeoffs and constraints in thermal adaptation become visible when ectotherms specialized on various temperature regimes and their tissues are compared. The hypothesis of oxygen limited thermal tolerance provides a conceptual framework for the investigation of how ectotherms compensate for changing ambient temperatures (Pörtner, 2001, 2002). Accordingly, thermal limitation becomes effective firstly at high hierarchical levels of organisation, the intact organism, and then at lower levels, cellular and molecular functions. Inadequate oxygen supply likely is the first indicator of cold intolerance in both water and air breathers, however, compensatory mechanisms likely set in before such limits are reached. (Pörtner, 2001, 2002). These limits exert their effects on the growth rate of individual specimens and the abundance of a population thereby shaping the biogeography of a species (Pörtner and Knust, 2007). Nevertheless, thermal limitations are based on molecular functions and the integration of single molecules into functional and regulatory networks. Similarly, studying the temperature adaptation of organisms in a changing environment therefore needs to consider the functional integration of single molecules into higher organisational levels.

Evolutionary adaptation to various climates is addressed in our department "Integrative Eco-Physiology" in comparative studies carried out with populations of the same species in climatic gradients or with congeneric species living in different climatic zones. For example, member species of the fish family Zoarcidae (eelpouts) inhabit temperate, subpolar and polar waters and represent a model system for the study of evolutionary adaptation versus seasonal acclimatisation to temperature. Therefore, a reasonable number of publications of our department have been emerged from studies on Antarctic eelpout (*Pachycara brachycephalum*) and common eelpout (*Zoarces viviparus*). Furthermore, our previous studies have demonstrated the high conservation level of functional genes in different eelpouts from boreal and Antarctic waters, corroborating that these species are excellent models in comparative functional genomics studies (cf. Lucassen et al. 2003; Mark et al. 2006). On the other hand Notothenioidei represent the most important and most specialized fish group in the Southern Ocean, occupying all available habitats, but seem to be more sensitive to climate change. These species have been used in a number of studies for elucidation of general principles (e.g. Langenbuch and Pörtner, 2003; Mark et al., 2005; Deigweiher et al. 2008).

Work at sea

During the cruise ANT-XXV/4 four fish traps were set up, an aquarium container system (AWI024) and a backup system in a cool container were installed. On 2 April the baited traps were deployed in the Admiralty Bay, at a water depth between 400 and 500 meters. Due to bad weather conditions and loss of station time before, the time at sea bottom had to be reduced to 24 hours approximately. The traps were recovered on 3 April (geographic position and station times are listed in the station book at the end of the last cruise report, Stat. No.: PS73/255-1 to PS73/255-4). Before trap recovering a CTD measurement was carried out close to the trap position to get information of water temperature and salinity (Stat. No.: PS73/258-1). In total more than 1,000 specimens of the Antarctic eelpout (*Pachycara brachycephalum*) were caught and were brought into the aquarium system. Together with the fish and cephalopods, which were caught during the Jubany campaign (project Mark, project Lucassen), the animals will be kept in the aquarium systems at 0°C water temperature and will be transferred alive to the AWI in Bremerhaven. During the cruise (ANT-XXV/5) the mean goal is to take care of the health of the fish.

Preliminary results

The catch quantity is comparable to the results from earlier expeditions in the years 1998 to 2006. It indicates that the abundance of *Pachycara brachycephalum* is significantly higher at King George Island than in the area of Scotia Arc and in the high Antarctic waters of the Eastern Weddell Sea. After several days of keeping the fish in the aquarium systems the mortality rate is very low and they recovered very quickly from catch stress and pressure difference of about 50 bar. The CTD measurement in the vicinity of the sampling stations showed a water temperature of +0.6°C at the bottom and a salinity of 34.4.

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7. AUTONOMOUS MEASUREMENT PLATFORMS FOR ENERGY AND MATERIAL EXCHANGE BETWEEN OCEAN AND ATMOSPHERE (OCEANET) - ATMOSPHERE COMPONENT

Timo Hanschmann[1], Michael Schlundt[1], Yann Zoll[1]
Not on board: A. Macke[1], K. Bumke[1], J. Kalisch[1], M. Hieronymi[1], H. Sandmann[2], C. Stick[2]

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Objectives

Clouds remain one of the biggest obstacles in our understanding of the coupled ocean-atmosphere climate system. Even under realistic forcing from observed wind, humidity and pressure fields climate models have difficulties to reproduce the correct spatial and temporal climatology of cloud cover. Because of the strong inhomogeneity of cloud pattern on those scales that are relevant for the radiative transfer processes it is obvious that subgrid-scale processes must be accounted for in radiative transfer parametrizations. Combined observations of cloud physical and radiative properties are a key to adjust or to validate such parametrizations. To this end, surface radiation flux measurements are performed together with observations of the state of the cloudy sky.

Furthermore the turbulent fluxes of heat, momentum, humidity and CO_2 are measured to close the energy and mass budget at the sea surface. Most measurements are part of the Leibniz network-project OCEANET (see also the cruise report ANT-XXIV/4 for more detailed information on OCEANET). A related goal is to quantify the role of clouds and sea surface waves on the small scale temporal and spatial variability of the solar radiation below the sea surface.

A further objective is to provide validation data for temperature and humidity profiles from the new infra-red sounding radiometer IASI on-board the first European polar orbiting operational weather satellite MetOp.

Work at sea

The upward looking pyranometer Kipp&Zonen CM21 and the pyrgeometer CG4 operated by IFM-GEOMAR have been used on this cruise. Every 15 seconds full sky images were obtained from a weather proofed digital camera system manufactured at IFM-GEOMAR. This enables a detailed analysis of the role of cloud cover and cloud type on the radiation budget at the sea surface.

As for the *Polarstern* transects ANT-XXIII/10, ANT-XXIV/1 and ANT-XXIV/4 a multi-channel microwave radiometer (HATPRO, Radiometer Physics) was utilized for continuous observations of atmospheric temperature and humidity profiles as well as liquid water and precipitable water path.

In addition to the radiation measurements mentioned above in cooperation with the Institute for Medical Climatology (Uni Kiel) a UV spectrometer system for continuous recording of solar UV irradiance has been used. The system consists of a Bentham DM 150 double monochromator with a photomultipier tube detector operated in a temperature stabilised box. The calibration of the system is traceable to the Physikalisch Technische Bundesanstalt (PTB).

Together with infrared radiometer measurements of cloud bottom temperature, sun photometer measurements of aerosol optical thickness the data from the microwave radiometer provide a unique set of information to interpret the amount of downwelling solar and thermal radiation at the sea surface.

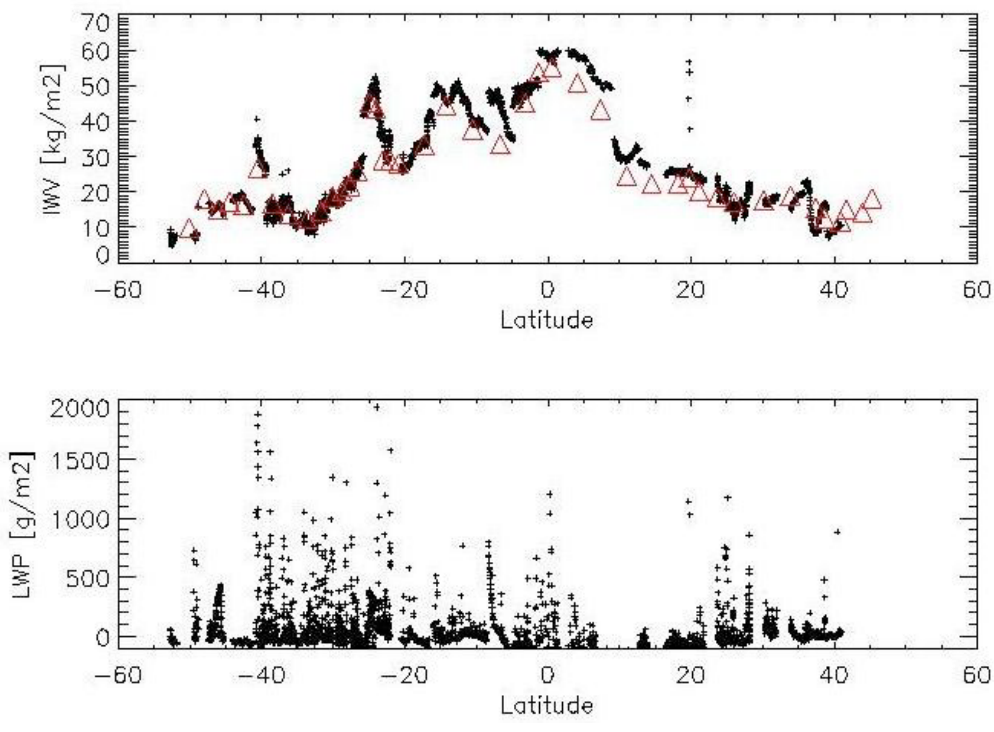

Fig. 7.1: Time series of water vapor path (upper diagram) and liquid water path (lower diagram) from the HATPRO microwave radiometer. The water vapor path from the radio sonde measurements is also shown.

In addition to the continuous profiling by means of the HATPRO microwave radiometer, radiosondes have been launched whenever *Polarstern* was in the field of view of the IASI instrument on board MetOp.

As for the spring transect in 2008 a new instrument (Licor combined with a METEK sonic anemometer) to derive turbulent fluxes of momentum, water vapor and CO_2

was tested for measurements under marine conditions. Although the principle performance was satisfactory it turned out that electronic noise in the data transmission often produced spurious results. A second turbulence measurement system (M100 absorption hygrometer and USA-1 sonic anemometer) was running simultaneously for quality check. It functioned properly for the entire cruise.

In cooperation with the Phyto-Optics Group of AWI and IUP Bremen (Dr. Astrid Bracher) spectral solar radiation at various depths was obtained by means of a RAMSES spectroradiometer. The focus of interest is on light fluctuations in the upper layer due to wave motion of the surface. In order to quantify spatiotemporal characteristics of light fluctuations at various depths light pattern projected on a white diffuse reflecting plate were filmed. At the end of the day the upper layers light regime in the ocean shall be connected to diverse sea state conditions.

Preliminary results

Fig. 7.1 shows the time series of water vapor path and liquid water path (LWP) along the cruise. The *in-situ* observed water vapor path or integrated water vapor (IWV) from the radiosonde measurements is also shown, and provides a generally good agreement with the indirectly obtained microwave products. Largest water vapor paths of more than 50 gm^{-2} are observed at the thermal equator, where the warm conditions and strong cloud induced upwind pumps most humidity from the ocean into the troposphere. The cloud LWP is given by the occasional data points above a background noise, which needs to be corrected in the later analysis. The corrections make use of the sky camera images which indicate clear sky situations above the ship during day time.

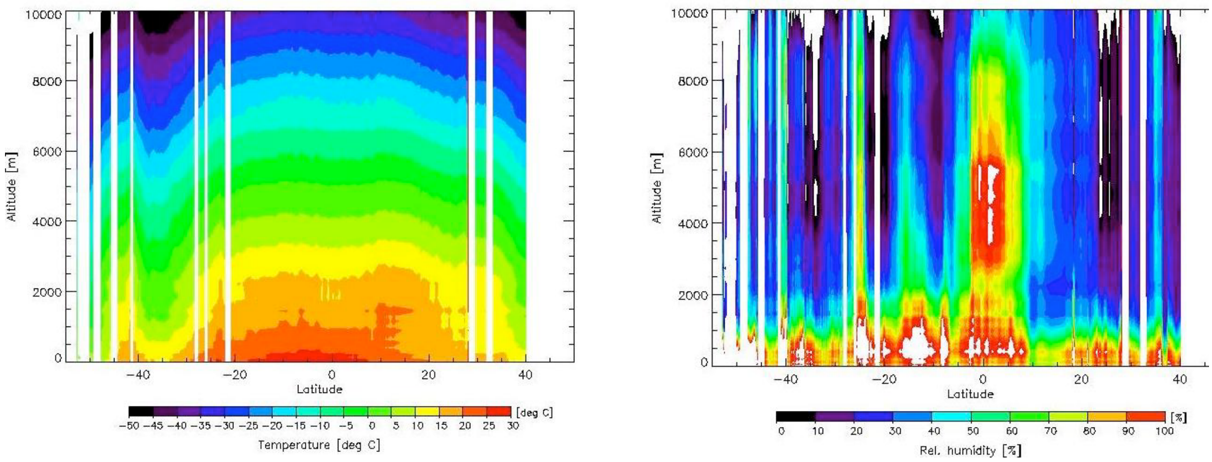

Fig. 7.2 / 7.3: Vertical profiles of temperature / humidity retrieved from the microwave radiometer along the cruise track, shown as a function of latitude.

Fig. 7.2 shows the meridional temperature profile along the *Polarstern* cruise. The corresponding humidity profiles are shown in Fig. 7.3. Besides the typical variations caused by the different climate regimes, a Saharan dry air layer advection can be identified around 20 degree north with warmer temperatures and lower humidity values. First comparisons with radiosonde ascents show that the temperature profiles are accurate within 1 – 2 Kelvin, and that large deviations exist for the humidity profiles. The latter is most likely caused by the usage of retrieval algorithms that are not optimized for marine and for tropical/subtropical conditions.

The daily time series of the downwelling shortwave and longwave radiation along the entire *Polarstern* cruise are summarized in Fig. 7.4. As a reference, the theoretical curve for clear sky radiation is also shown.

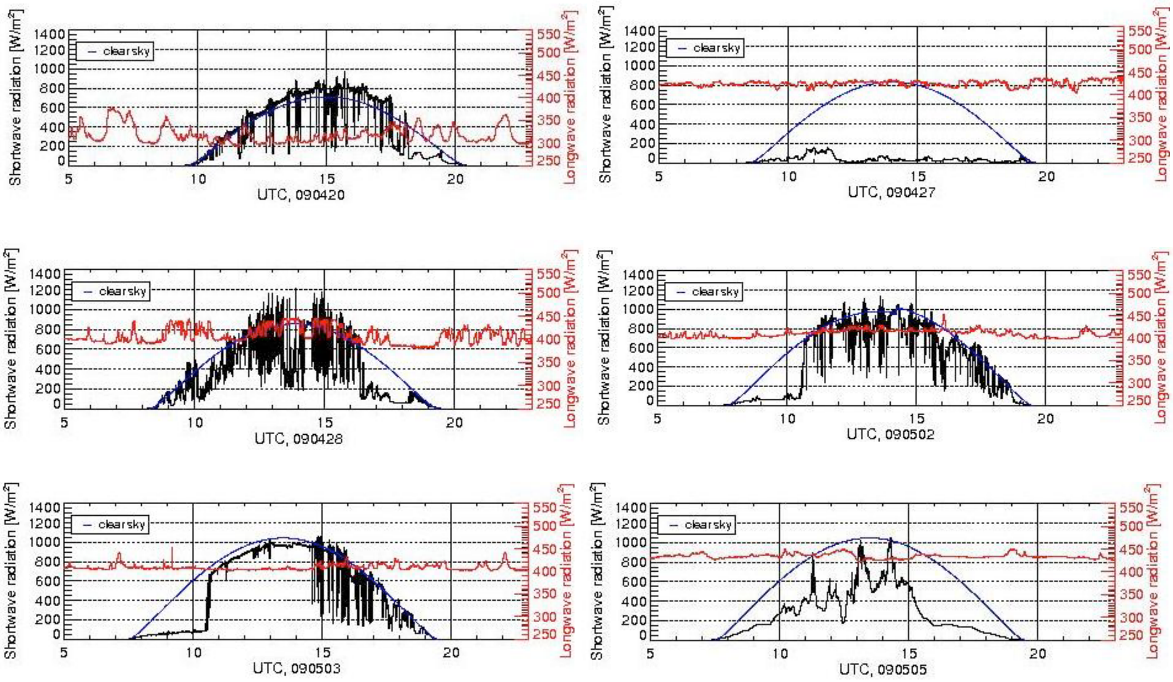

Fig. 7.4: Daily time series of downwelling broadband solar (black) and thermal (red) radiation for selected days. The reference clear sky radiation (blue) is shown for comparison

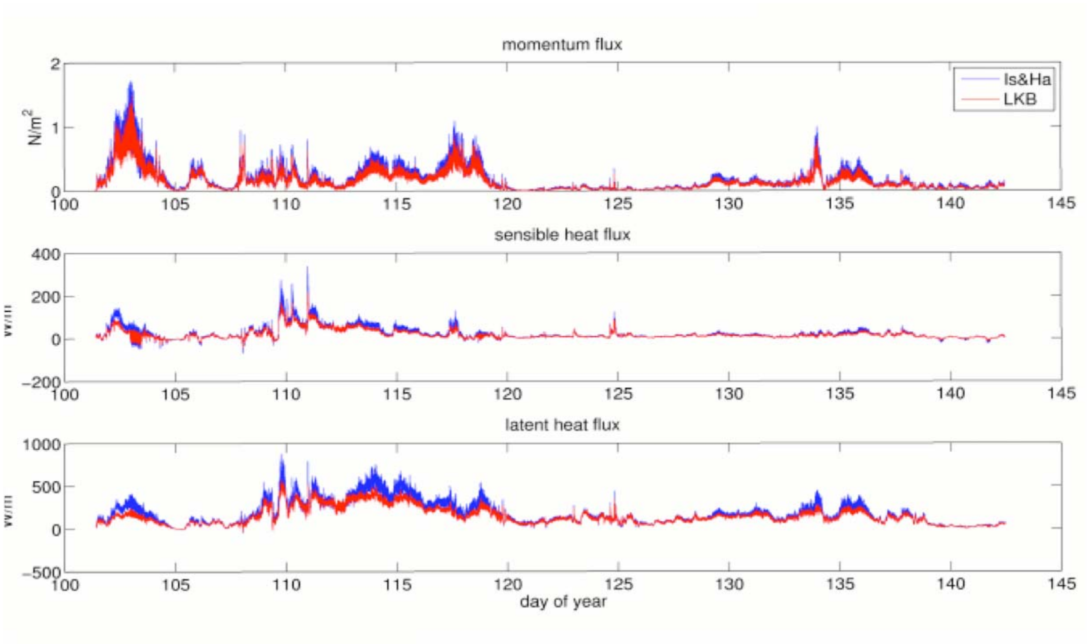

Fig. 7.5: Time series of two bulk parameterizations of momentum flux, sensible heat flux, and latent heat flux

Although clouds usually block the sun and reduce the downwelling solar radiation, many occasions of a radiation excess can be found, which is attributed to the increased diffuse downwelling solar radiation during broken cloud conditions (because of this termed as “broken cloud effect”). Further analysis will test the correlation between the observed cloud properties like cloud cover and liquid water path, and the surface radiation budget.

Fig. 7.5 shows a time series of momentum flux, sensible heat and latent heat flux derived from the ships meteorological data applied to the parameterizations from Isemer and Hasse (1987). For comparison the data is also applied to a parameterization by Liu et al. (1980).

Obviously, the choice of parameterization leads to a differences in both heat fluxes, which may reach a factor of 2 for latent heat flux according to a difference of 200 to 300 W/m^2 (around day 103 and 115).

Fig. 7.6 shows on the left hand side spectrally integrated shortwave irradiation measurements in the first 25 m of the water column (with mean and standard deviation at the various depths) gathered during ANT-XXV/1 (current data is still under examination). Due to light focusing and defocusing at the rough surface extreme variations of light availability occur. Longer measurement periods at defined depths are necessary to obtain properly averaged radiation profiles. On the right hand side the averaged irradiation is plotted along the spectrum (range of 320 - 950 nm, the visible range is marked above) - bluish light penetrates water the deepest and almost every red light is absorbed at 10 m.

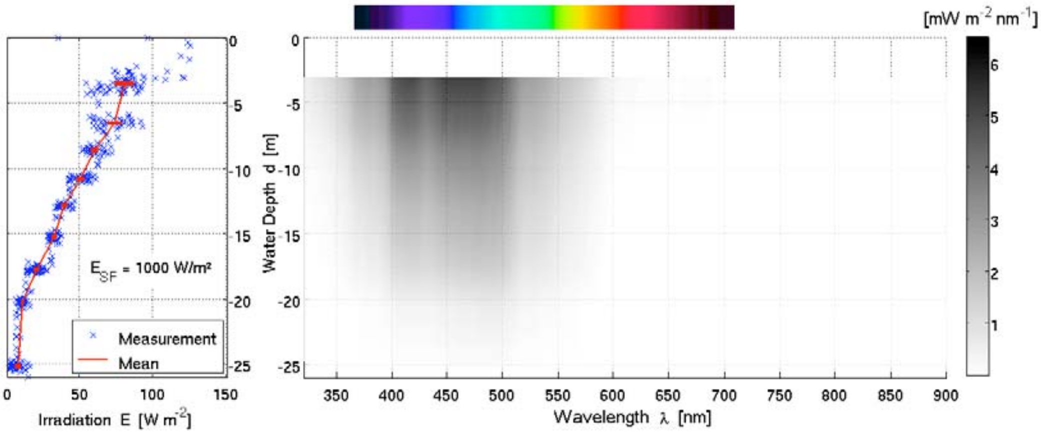

Fig. 7.6: Underwater irradiation measurements with the spectroradiometer RAMSES, left: spectrally integrated and right spectra over depth (ANT-XXV/1, 26.11.2008).

Fig. 7.7 displays results of the underwater camera device (IFM-GEOMAR self-construction) gathered during ANT-XXIV/4 (current data is still under examination). Light fluctuations are projected on a white board (0.3 x 0.45 m) and filmed by a digital camera in an underwater housing. Image cuts provides spatial information of the brightness distribution (ordinate). With 30 frames per second we gain temporal records of light variability (abscissa). With water depth the impact of the water surface structure on light fluctuations changes - in the first meters light variability is effected by waves in the small gravity - capillary wave transition range (upper figure at 1 m), with depth gravity waves and "the sea state" playing a mayor role.

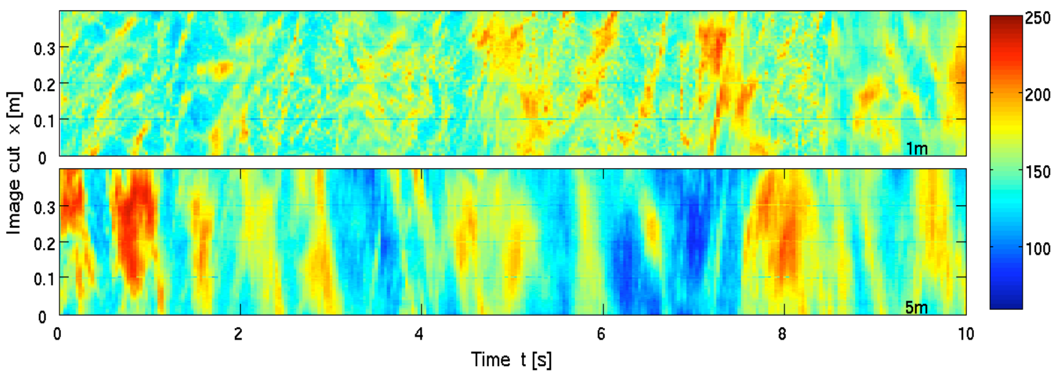

Fig. 7.7: Spatiotemporal distribution of filmed underwater light pattern in 1 m and 5 m water depth. (ANT-XXIV/4, 10.05.2008).

In order to study the influence of the solar zenith angle, the total ozone column, the cloud cover, and the aerosol optical depth of a marine environment spectral UV measurements were performed every 3 minutes from sunrise to sunset. Fig. 7.8

shows the diurnal cycle of the erythemal irradiance on 9 May 2009. The erythemal irradiance is derived from the measurements of spectral UV irradiance weighted by the erythemal action spectrum. Different values of erythemal irradiance for solar altitudes below 35° are caused by shadowing effects of *Polarstern's* superstructure.

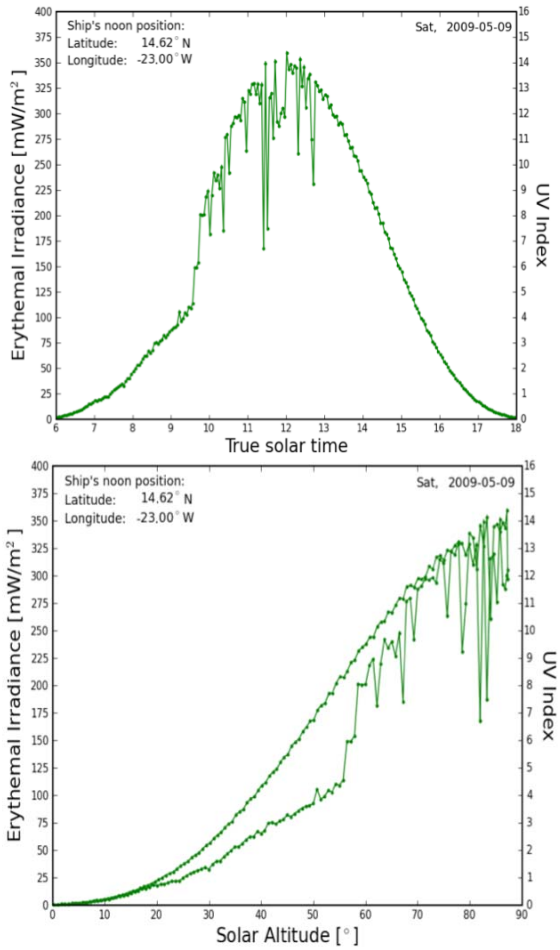

Fig. 7.8: Erythemal irradiance in dependence on true solar time and solar altitude on 9 May 2009 measured with the spectroradiometer Bentham DM150, Graphics by Henner Sandmann

The time series of daily noon time UVB and UVA irradiance in dependence on latitude is shown in Fig. 7.9. The UVB (UVA) integral has boundaries from 290 to 320 nm (320 to 400 nm respectively). Both UVB irradiance and UVA irradiance show the expected dependence on different midday solar zenith angles at different latitudes. The varying values of UVA and UVB irradiance are due to the presence of clouds. UVA irradiance is more than one order of magnitude higher than UVB irradiance.

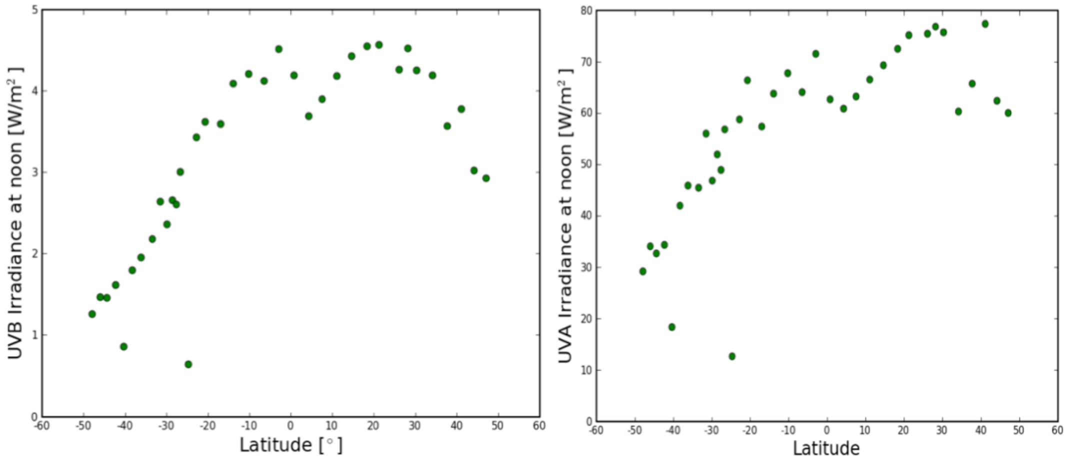

Fig. 7.9: Midday UVB irradiance (left) and UVA irradiance (right) in dependence on latitude.

As the daily UV dose is more important on biological systems than maximum noon time UV values the time series of daily dose of erythemal irradiance in dependence on latitude is shown in Fig. 7.10. Maximum values of 6352 J/m^2 have been observed on 11 May 2009 (latitude at noon time: 21.2°N, solar altitude: 86.7°)

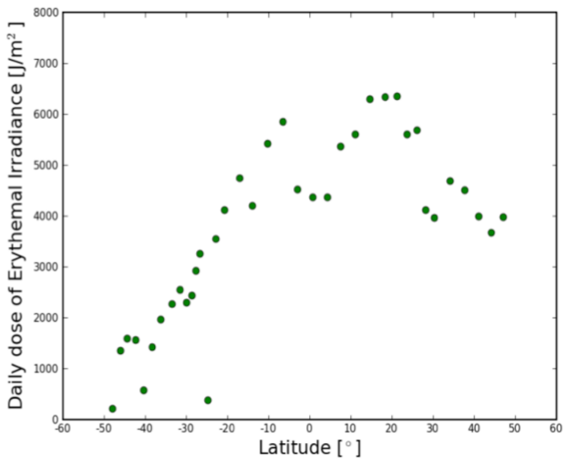

Fig. 7.10: Daily dose of erythemal irradiance in dependence on latitude.

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8. ELEMENTAL MERCURY SEA-AIR FLUX

Joachim Kuss, Martin Kunze,
not on board: Bernd Schneider, Klaus-Peter Wlost, Detlef E. Schulz-Bull

Leibniz-Institut für Ostseeforschung Warnemünde, Warnemünde

Objectives

The objective of the study is to determine the elemental mercury (Hg^0) sea-air flux in various geochemical provinces of the Atlantic Ocean, in the frame of a project funded by the German Science Foundation (DFG). The spatial variability of the Hg^0 flux is investigated in relation to prevailing biological conditions and physical forcing factors like wind and solar radiation. The results obtained during this cruise from Punta Arenas (Chile) – Bremerhaven (April/May 2009, ANT-XXV/5) is additionally used as a seasonal intercomparison to the transect ANT-XXV/1 Bremerhaven - Cape Town in November 2008.

Mercury is mobilized by anthropogenic activity and is subsequently introduced into the sea by wet and dry deposition and by river drainage. But the sea could also become a significant source because of Hg^0 sea-air gas exchange. Transformation of ionic mercury to volatile Hg^0 is possibly caused by photon-induced reactions mediated by organic carbon and/or by algae and bacteria in surface waters. The spatial and seasonal variability of the Hg^0 emission has been shown for the Baltic Sea in 2006 (Kuss and Schneider, 2007) and is investigated in the Atlantic Ocean during the two cruises of *Polarstern*. The following questions are attempted to be answered during the study:

- How do the atmospheric and oceanic circulations and thus the biogeochemical regimes determine the Hg^0 concentration in surface waters?
- Is the Hg^0 concentration in surface water related to biological processes?
- Do enhanced Hg^0 concentrations occur mainly in regions with predominance of primary production or of heterotrophic respiration?
- Is the elemental mercury (Hg^0) emission of the Atlantic Ocean variable in space and time?
- Is the release of Hg^0 controlled by latitudinal-dependent solar radiation?

Work at sea

The measurements were done from about 50°S to 50°N, that was from the South American shelf to the English Channel. During the transect seawater from the clean-seawater supply system of *Polarstern* was sampled. It was continuously analyzed for elemental mercury and carbon dioxide. Three times a day samples were filtrated for chlorophyll a, phaeopigments, dissolved and particulate organic carbon measurements. Additionally, 48 samples were taken for reactive and total mercury

(Hg^{reac}, Hg^{tot}) determination in the IOW trace metal lab (Christa Pohl, Ursula Hennings). Also samples were taken for volatile organic halocarbon analysis and large volume filtration was performed for the determination of particle bound persistent organic pollutants. Moreover, the mixed layer depth was determined almost daily by CTD casts.

Elemental mercury

The Hg^0 concentration in Atlantic surface water was determined at high resolution. This was achieved by a new method that relies on measurements of air that is equilibrated with surface seawater with respect to Hg^0 (Hg^0_{equ}). Therefore clean-seawater that was pumped from below the ship's hull was continuously dispersed into the headspace of a 20 L gas bottle by a shower head and is drained close to the bottom of the bottle. After 1 hour the Hg^0 in the headspace air (Hg^0_{equ}) was measured by cold-vapour atomic fluorescence spectroscopy following pre-concentration by gold amalgamation. About 750 duplicate measurements of Hg^0_{equ} have been done. In addition, a total of about 7500 samples of Hg^0_{atm} of the marine atmosphere were measured. The air samples were drawn via Teflon tubing from the front of the top deck.

A new software called "QueckIOW" has been improved for the retrieval, synthesis and storage of the mercury data and hydrographic and meteorological data from DAVIS-Ship of *Polarstern.* Moreover, the software enabled preliminary data processing steps (K.-P. Wlost). Also a membrane equilibrator (Jostra Quadrox) was tested for the continuous (5 minute intervals) Hg^0 water measurements. The results seem promising.

Carbon dioxide

The partial pressure of CO_2 in surface water was recorded each minute (48 000 data points). We used a non-dispersive infrared spectrometer coupled to a small bubble-type equilibrator (0.5 L) with a temperature probe. About twice a day the CO_2 concentration in the atmosphere was measured (1,500 data points) for comparison, if the relative wind direction was from outside the ship's sector.

Organic carbon

For the determination of dissolved and particulate organic carbon (DOC/POC), chlorophyll a, and phaeopigments, 111 water samples were taken for each parameter and subjected to filtration. Filters and filtrates were immediately cooled to -20°C and were then stored deep-frozen until analyses in the laboratories of the IOW.

Total and reactive mercury

For the determination of reactive and total mercury (Hg^{reac}/Hg^{tot}) 48 samples were taken in collaboration with the trace metal group of the IOW (Dr. Christa Pohl and Ursula Hennings). The samples were acidified for later analysis in the trace metal lab of the IOW.

Chlorophyll measurements by a fluorescence spectrometer

In collaboration with the AWI-Biooptics group the FAST-TRACKA fluorescence spectrometer was run continuously. The water was taken from about 12.5 m depth by a schnorkel installed in the moon-pool of *Polarstern.*

Volatile halogenated hydrocarbons and persistent organic pollutants

For the analysis of volatile halogenated hydrocarbons 10 samples were taken from surface water by the CTD/rosette system. Samples are stored cool (~4°C) and in the dark. The water samples will be subjected to analysis by purge & trap with gaschromatography mass spectrometry (GC-MS) in the IOW lab.

During the transect water from the ship's clean seawater supply system was subjected to filtration. On 32 sections of between 5 and 24 hours seawater was continuously filtrated for later analyses of particle bound persistent organic pollutants in the IOW. The filtrated volume was between 0.5 and 2.5 m^3. The filters were stored deep frozen (Martin Kunze and Detlef E. Schulz-Bull).

Preliminary results

Elemental mercury in water and air

The data (Fig. 8.1a) show a clear regional variability of elemental mercury in surface water (Hg^0_{equ}). Low levels of Hg^0_{equ} were measured on the South American shelf at latitude of 50°S. At the shelf slope the Hg^0_{equ} value drop temporarily below the low Hg^0 air concentration, probably caused by a different water mass (upwelling, Falkland Current). The concentration of Hg^0 in the marine atmosphere of the southern hemisphere ranged between 0.5 to 1 ng/m³. At greater distance from the shelf the Hg^0_{equ} concentration increased to 2 - 3 ng/m³ and was mainly recorded in that range until 10°S. Also, at about 40° and 22°S two smooth maxima were measured of about 3 ng/m³ and 4 ng/m³, respectively (Fig. 8.1a). From about 5°S going northward, the Hg^0_{equ} steeply increased within a few tens of miles to more than 9 ng/m³. Then Hg^0_{equ} slightly declined close to the equator and subsequently showed a second peak of 8 ng/m³ at 1°N. The strong equatorial maximum of the Hg^0_{equ} coincides with a salinity minimum (Fig. 8.1b). Perhaps, it could be linked to the ITCZ of the former winter month and the rain events prevailing at that time. Further north the Hg^0_{equ} slowly decreased to about 1.5 ng/m³ until 12°N and then stayed close to the equilibrium with the atmospheric background concentration of the northern hemisphere of mainly between 0.8-1.6 ng/m³. North of 30°N the Hg^0_{equ} concentration was frequently below the atmospheric Hg^0 value, making the sea a temporary sink in that areas.

The data set requires further validation before it can be used for the sea-air flux (F_{Hg0}) calculation: $F_{Hg0}=k^*(Hg^0_{equ}-Hg^0_{atm})/H$. A prerequisite for gas exchange is a sea-air concentration difference ($Hg^0_{equ}-Hg^0_{atm}$) deviating from zero, but the flux is also controlled by the dynamics at the sea surface. The gas exchange transfer velocity (k) that is dependent on wind speed accounts for the turbulence at the water surface. H is the Henrys' Law constant of Hg^0.

Carbon dioxide

The concentration of CO_2 in the marine atmosphere (CO_2^{atm}) was relatively constant in comparison to surface water values. It was in the range of 380 to 390 ppm (in dry air) in the southern hemisphere. North of the equator CO_2 concentration increased to between 390 to 400 ppm (in dry air). In the following, the actual partial pressure of CO_2 in wet air (pCO_2^{atm}) is compared to the pCO_2^{wat}.

The development of the partial pressure of CO_2 in the water (pCO_2^{wat}) during the transect from about 50°S to 20°N showed a strong variability (Fig. 8.1c). In the beginning of the cruise the pCO_2^{wat} (black dots) was clearly below the atmospheric partial pressure (pCO_2^{atm}, light blue dots), indicating an episodic imprint of net primary production in that area. Only at the shelf slope of the South American continent a higher pCO_2 was measured, probably indicating upwelling at that time or an indication of the Falkland Current. From 35° to 25°S the pCO_2^{wat} in water was close to the atmospheric value. Then the pCO_2^{wat} increased to about 420 μatm and remained at roughly that level until 5°S, making that area a source region for atmospheric CO_2. Between 5°S and 10°N the pCO_2^{wat} was again below 400 μatm, but still above the pCO_2^{atm}. North of the equator the pCO_2^{wat} varied between 450 and 370 μatm indicating a variability of the surface water between a slight CO_2 sink and a moderate source until about 15°N. Then pCO_2^{wat} was close to the atmospheric value until 25°N, where pCO_2^{wat} began to decline along the following transect. It decreased almost continuously from about 380 μatm to 300 μatm until the European shelf parallel to falling temperature (Figs. 8.1a and b). Also the CO_2 data is preliminary and has to be validated and interpreted in relation to other data sets. A comparison is planned with other CO_2 recordings during the ANT-XXV/5.

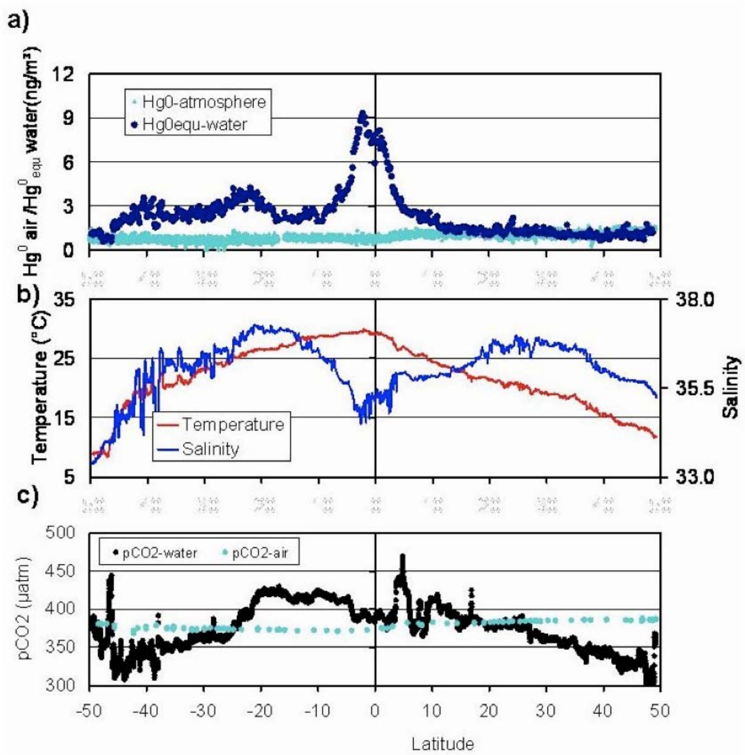

Fig. 8.1: Recordings from 50°S (-50) to 50°N (50) of a) elemental mercury in the atmosphere and in equilibrium with water, b) of temperature and salinity, and c) pCO_2 in air and in surface water during ANT-XXV/5

Forthcoming analyses

An improved interpretation of the elemental mercury recordings is especially expected from the forthcoming data of the trace metal group of IOW (Dr. Christa Pohl) about reactive and total mercury concentrations. Also indications about a more biological origin or a pure physical cause of the elevated Hg^0 concentrations in some regions is expected to be obtained from the analyses of dissolved and particulate organic matter by the lab for "Natural organic trace substances" (Dr. Klaus Nagel, IOW), the phytoplankton pigment analyses (Dr. Falk Pollehne and Dr. Norbert Wasmund, IOW), and the fluorescence recordings of the FRRF of the bio-optics group of the AWI (Dr. Astrid Bracher).

We like to thank the chief scientists Dr. Walter Zenk and Dr. Saad El Naggar for organisation and for some insight into the deep water processes of the South Atlantic and the realization of the Neumayer III station in Antarctica, respectively. We also thank the captain and the crew of *Polarstern* for excellent support during the campaign, especially, that the chemistry lab of *Polarstern* was made available for continuous water and air analyses. We are grateful for funding by the DFG and AWI.

Reference

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9. PARASOUND ON ANT-XXV/5

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Background

Sea floor and sub-bottom reflection patterns obtained by the deep sea sediment echo sounder PARASOUND (ATLAS HYDROGRAPHIC, Bremen, Germany) characterize the uppermost sediments of the Ocean in terms of their acoustic behavior down to about 200 m below the sea floor. This can be used to study depositional environments on larger scales in terms of space and time and to identify suitable coring locations. On ANT-XXV/5 the area at sea along the routine course track from Las Palmas to the eastern English Channel is particularly suitable for PARASOUND system testing and training because the range of sea-floor topography, sediment penetration and water depth (shallow water to more than 5,000 m) allows to use all possible modes of operation.

The parametric system PARASOUND was upgraded from DS II to DS III-P70 in May 2007, which included a complete installation of new hardware and software and replacement of the original system installed on *Polarstern* in 1989. Between June 2007 and May 2008, three sea-trial phases including software updating and testing at sea (ARK-XXII/1a, ANT-XXIV/1, ANT-XXIV/4), as well as two expeditions using the new system in preliminary modes were carried out (ARK-XXII/2, ARK-XXIII/3). The technical specifications of the upgraded system, the new functions as well as technical problems are described in the cruise reports of the legs above.

Objectives

There are the following objectives for using PARASOUND on ANT-XXV/5:

- to update the system with new software versions
- to test the system for full motion compensation and different transmission modes
- to train seven students for self-efficient operation of the new PARASOUND system P-70
- to develop a PARASOUND data-storage and data-management structure.

The update and test became necessary after a lack of full motion compensation was observed on previous cruise legs ARK-XXIII/3 and ANT-XXV/1, and problems occurred for transmission modes „Pulse Train“ and „Quasi-Equidistant“.

The training course will ensure sufficient PARASOUND surveys for geological projects carried out on forthcoming expeditions of the *Polarstern*, *Maria S. Merian* and *Sonne* in 2009-2011, where the students will participate and PARASOUND has to be used.

For the new system P70 a data storage and management structure is needed to be worked out for sufficient acquisition, storage and transfer of data from the vessel into the AWI Mass Storage and availability of data via the data base PANGAEA.

Work at Sea

On 14 May a group of 11 persons came on board in Las Palmas to work with the PARASOUND system. A software update was carried out by Jörn Ewert from Atlas Hydrographic. The new installation included CM V 1.38.30, AHS V 2.0.10 and Parastore V 3.2.8. A previous installation of TRF V 1.0.7 and AHC V 3.1.3 was checked. After a brief system check Jörn Ewert left the ship in the evening of the same day at Las Palmas roadstead.

The remaining group used the system during 24-hour operations per day under expedition conditions. PARASOUND was switched off on 22 May at 18:15 UTC in the western North Sea. Data acquisition and temporary storage was for testing and training purposes only. No survey or research was carried out.

Testing of motion compensation revealed significant improvements compared to the previous version. With measured heave amplitudes of about up to 4 m a minimal component of motion is visible in the Parastore Echogram Windows at very high resolution (10 m-window). However, the motion compensation as observed under the given conditions was considered as fully sufficient for scientific surveys and research using PARASOUND P-70 on *Polarstern*. Problems were observed with system stability (both Hydromap Control and Parastore), autonomous depth detection, pulse rates and printing of data. A detailed list of documentation was compiled.

The training course included knowledge about the system, switching the system off and on, watch keeping, depth control, working with different modes of pulse transmission, data acquisition, storage, printing, data visualization, processing, replay and data management. The participants were trained to operate the system self efficiently and were prepared for trouble shooting.

A seven-page documentation on data management was compiled (PARASOUND – AWI – PANGAEA, Data Storage and Management, Version 1.0 by Peter Gerchow, Gerhard Kuhn, Jens Matthiessen and Frank Niessen) which includes chapters on “Storage, Backup, Quality Control, Transfer”, “Data and Directory Structure” “Storage and Data Paths using Atlas Parastore” and “Navigation Data”. The purpose of the documentation is to provide clear guidelines how the data have to be handled from acquisition into the final AWI Mass Storage in order to allow full availability via the data base PANGAEA. This also includes the prerequisite to extract meta data. The document is not only a guideline for PARASOUND data management on *Polarstern* but is also applicable for RVs *Maria S. Merian*, *Meteor* and *Sonne*.

Conclusions

Although the new software versions revealed improvement, the PARASOUND system on *Polarstern* is not free of faults yet. The participants of the PARASOUND course consider the training a success and very useful for preparing PARASOUND operators prior to expeditions. A PARASOUND data management structure is now in place. Some of the older cruise data have to be re-arranged in order to fulfill the new requirements.

10. REPLACEMENT OF THE DOAS-SYSTEM ON BOARD *POLARSTERN*

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Objectives

The aim of our stay onboard was to change the set-up of the already installed DOAS System and to test its functionality aboard the ship.

The older system installed in 2007 had been out of order a few times and additionally there had been complaints about its noise. Therefore, it was decided in the beginning of the year 2009 to rebuild the setup. For this purpose a new measurement system had been developed, which was installed on the ship on 14 May 2009. It consists of a telescope unit, a 10 m fiber optics cable and a temperature regulated spectrometer unit.

In comparison with the former spectrometer the new OMT spectrometer is expected to have better detection limits and shorter possible integration times, since the CCD used is of a new, so called 'back-thinned'-type which has an up to five times higher quantum efficiency.

Work at sea

Measurements

Since 14 May 2009 7:00 pm scattered light measurements with both spectrometers (UV and VIS) had been made. The telescope's elevation angle sequence is 1°, 2°, 3°, 5°, 10°, 20°, 40°, 90° and each spectrum has an exposure time of 2 minutes which results in a total exposure time for one series of measurements of 16 minutes. Different exposure times have been tested as well.

The UV-spectrometer's range is from 310 to 440 nm with a resolution of 0.4 nm when using a 50μm slit and a BG3 filter. The obtained spectra were analysed with regard to the following gases: NO_2, O_3, O_4, BrO and IO.

The VIS-spectrometer's range is from 420 nm to ca. 570 nm with a resolution of 0.5 nm when using a 50 μm slit and no filter. For those spectra only a preliminary analysis for IO concentrations had been done so far to get an idea of the comparability of both spectrometers since the IO absorption bands are within a range covered by both spectrometers.

First results between Las Palmas and the European continent are between 0.5 and 1.0 pptv for low elevation angles. IO results seem to stay below the current detection limit of 0.5 pptv.

New possibilities

Aerosol retrieval: The MAX-DOAS method allows obtaining aerosol profiles. For this the wavelength dependence of scattering processes is used for interpreting the O_4 slant column density values obtained at different wave lengths. Suitable O_4 absorption bands can be found at 360 nm, 477 nm and 577 nm. The known distribution of O_4 can then be used to calculate the actual changes in the path of light caused by aerosol particles.

The new components

- The Telescope

The telescope's task is to focus scattered light from the sky from a defined field to view and elevation angle onto the fiber optics cable. To accomplish this an inclination sensor is included and connected directly to the motor unit also used for positioning the telescope to a given elevation angle. This system replaces the old and bulky cardanic setup and improves its reliability as well as it saves room and weight onboard. Furthermore the usual lens optics has been replaced by a parabolic mirror and is thus not prone to chromatic aberrations any more enabling us to measure a wider spectral range. Calibration lamps are also included.

- The fiber optics cable

The 10 m long cable consists of 19 quartz fibers with a diameter of 200 μm each. Its task is to guide the light collected by the telescope to the different spectrometers. On their side the cable is split up into 4 bunches, three of them containing 6 fibers and the last one containing only one. Thus we are able to connect 4 different spectrometers at most at the same time.

- The spectrometer unit

The spectrometer unit obtains the scattered light spectra. In addition to the two spectrometers itself it also contains the power supply units for the different components, temperature regulation circuits for the spectrometers and a relais-card for different telescope functions. While the detectors CCD chips are cooled to about -6°C the remaining optical system is stabilized at 22°C to avoid condensing water as well as to guarantee optical stability.

11. SEA TRIAL AND TESTS OF THE NEW UPGRADED UNDER WATER NAVIGATION SYSTEM POSIDONIA

Saad El Naggar[1], Dominique Roger[2], Gildas Touin[2] (not on board),
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[2]IXSEA, Brest

Objectives

The underwater navigation system POSIDONIA was upgraded during the shipyard stay of *Polarstern* in Bremerhaven. Newly designed hard and software were installed and tested in the harbour of Bremerhaven. New acoustic array and window were fix-installed nearby the moon pool in addition to the mobile acoustic array. A complete new electronic cabinet was installed, modified and tested.

The final sea trial and calibration had been carried out during the cruise on the way to Las Palmas during ANT-XXV/1 and showed serious deficiencies. To plan the work in Bremerhaven additional tests were required during ANT-XXV/5.

Work at sea

Two technicians from IXSEA came on board in Las Palmas and carried out acoustical and electrical tests. They confirmed that the antenna did not meet the specifications or was damaged and would have to be replaced in Bremerhaven. The IXSEA technicians disembarked at about 21:00 local time via barge.

APPENDIX

A.1 BETEILIGTE INSTITUTE / PARTICIPATING INSTITUTIONS

A.2 FAHRTTEILNEHMER /CRUISE PARTICIPANTS

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

A.4 STATIONSLISTE / STATION LIST PS 73

A.1 TEILNEHMENDE INSTITUTE / PARTICIPATING INSTITUTIONS

	Address
AWI	Stiftung Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft Postfach 120161 27515 Bremerhaven/Germany
DWD	Deutscher Wetterdienst Geschäftsbereich Wettervorhersage Seeschifffahrtsberatung Bernhard Nocht Str. 76 20359 Hamburg/Germany
DLR	Deutsches Zentrum für Luft- und Raumfahrt (DLR) Münchner Straße 20 82234 Weßling/Germany
GAUSS	GAUSS mbH Werderstrasse 73 28199 Bremen/ Germany
GKSS	GKSS-Forschungszentrum Geesthacht Max-Planck-Str. 1 21502 Geesthacht/Germany
IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften Düsternbrooker Weg 20 24105 Kiel/Germany
IOW	Leibniz-Institut für Ostseeforschung Warnemünde Seestrasse 15 18119 Warnemünde/Germany
IUP	Institut für Umweltphysik Universität Heidelberg Im Neuenheimer Feld 229 69120 Heidelberg/Germany

	Address
IXSEA	IXSEA Rue Rivoalon, Sainte Anne du Portzic F-29200 Brest/France
R. F. Laeisz	Reederei F. Laeisz (Bremerhaven) GmbH Brückenstr. 25 D-27568 Bremerhaven/Germany
MedKlim	Institut für Medizinische Klimatologie an der Universität Kiel Hermann-Rodewald-Strasse 5 24118 Kiel/Germany
OCEANWAVES	OCEANWAVES GmbH Munstermannskamp 1 21335 Lüneburg/Germany
OHB	OHB-System AG Universitätsallee 27-29 28359 Bremen/Germany
ZMAW	Zentrum für Meeres- und Klimaforschung (ZMK) Bundesstrasse 53, 20146 Hamburg /Germany

A.2 FAHRTTEILNEHMER / CRUISE PARTICIPANTS

Name/ Last name	Vorname/ First name	Institut/ Institute	Beruf/ Profession
El Naggar	Saad	AWI	Physicist
Boche	Martin	F. Laeisz	Captain
Denecke	Mirko	F. Laeisz	Engineer
Dufek	Tanja	AWI	Student, Physics
Fiedler	Björn	IFM-GEOMAR	PhD student, Chemistry
Gerchow	Peter	AWI	Engineer
Gottschalk	Julia	AWI	Student, Physics
Hanschmann	Timo	IFM-GEOMAR	Student, Meteorology
Hill	Heinz-Günther	DWD	Meteorologist
Ho	Sze Ling	AWI	Phd student, Geology
Koschnick	Nils	AWI	Technician, Chemistry
Kuhn	Gerhard	AWI	Geologist
Kunze	Martin	IOW	PhD student, Chemistry
Kuß	Joachim	IOW	Chemist
Lampel	Johannes	Uni Heidelberg	Student, Physics
Matthiessen	Jens	AWI	Geologist
Max	Lars	AWI	Student, Geology
Niessen	Frank	AWI	Geologist
Piller	Inga	IFM-GEOMAR	Student, Chemistry
Radtke	Sabrina	GKSS	Student, Biology
Riethdorf	Jan-Rainer	GKSS	Geologist
Rohardt	Ann-Kathrin	AWI	Student, Biology
Schlundt	Michael	IFM-GEOMAR	Student, Meteorology
Slaby	Beate	AWI	Student, Physics
Sonnabend	Hartmut	DWD	Technician
Tschritter	Jens	Uni-Heidelberg	Physicist
Windisch	Heidrun	AWI	Biologist
Zenk	Walter	IFM-GEOMAR	Oceanographer
Zoll	Yann	IFM-GEOMAR	Meteorologist

A.3 SCHIFFSBESATZUNG / SHIP'S CREW

No.	Name	Rank
1.	Pahl, Uwe	Master
2.	Fallei, Holger	1. Offc.
3.	Farysch, Bernd	Ch. Eng.
4.	Hering, Igor	2. Offc.
5.	Reinstädtler, Marco	2. Offc.
6.	Kohlberg, Eberhard	Doctor
7.	Koch, Georg	R. Offc.
8.	Kotnik, Herbert	2. Eng.
9.	Schnürch, Helmut	2. Eng.
10.	Westphal, Henning	2. Eng.
11.	Holtz, Hartmut	Elec. Eng.
12.	Dimmler, Werner	ELO
13.	Feiertag, Thomas	ELO
14.	Hebold, Catharina	ELO
15.	Hofmann, Jörg	ELO
16.	Clasen, Burkhard	Boatsw.
17.	Neisner, Winfried	Carpenter
18.	Burzan, Gerd-Ekkeh.	A.B.
19.	Hartwig-Lab., Andreas	A.B.
20.	Kreis, Reinhard	A.B.
21.	Kretzschmar, Uwe	A.B.
22.	Moser, Siegfried	A.B.
23.	Posada Martinez, S.	A.B.
24.	Schröder, Norbert	A.B.
25.	Schultz, Ottomar	A.B.
26.	Beth, Detlef	Storek.
27.	Dinse, Horst	Mot-man
28.	Fritz, Günter	Mot-man
29.	Kliem, Peter	Mot-man
30.	Krösche, Eckard	Mot-man
31.	Watzel, Bernhard	Mot-man
32.	Fischer, Matthias	Cook
33.	Tupy, Mario	Cooksmate
34.	Völske, Thomas	Cooksmate
35.	Dinse, Petra	1. Stwdess
36.	Hennig, Christina	Stwdess/N.
37.	Hischke, Peggy	2. Stwdess
38.	Hu, Guo Yong	2. Steward
39.	Streit, Christina	2. Stwdess
40.	Sun, Yong Sheng	2. Steward
41.	Wartenberg, Irina	2. Stwdess
42.	Ruan, Hui Guang	Laundrym.
43.	Winter, Andreas	Trainee
44.	Langhinrichs, Jacob	Apprent.
45.	Waterstradt, Felix	Apprent.

A.4 STATIONSLISTE / STATION LIST PS 73

Station PS 73	Date	Time (start)	Time (end)	Position (Lat.)	Position (Lon.)	Depth (m)	Gear
PS73/276-1	13 April 2009	13:28	13:56	50° 2.18' S	63° 59.00' W	133,0	CTD/rosette water sampler
PS73/277-1	15 April 2009	17:16	17:36	45° 39.62' S	57° 32.84' W	3750,5	CTD/rosette water sampler
PS73/278-1	17 April 2009	16:00	16:30	42° 5.69' S	52° 39.60' W	5615,5	CTD/rosette water sampler
PS73/279-1	18 April 2009	16:00	16:28	40° 7.74' S	50° 6.51' W	5414,0	CTD/rosette water sampler
PS73/280-1	19 April 2009	16:01	16:16	38° 4.32' S	47° 30.50' W	5163,2	CTD/rosette water sampler
PS73/281-1	20 April 2009	16:00	16:15	35° 53.04' S	44° 48.86' W	4878,7	CTD/rosette water sampler
PS73/282-1	21 April 2009	16:00	16:15	33° 14.80' S	41° 40.83' W	4574,7	CTD/rosette water sampler
PS73/283-1	22 April 2009	17:49	20:56	31° 11.80' S	39° 18.97' W	4446,5	CTD/rosette water sampler
PS73/284-1	22 April 2009	22:15	01:00	31° 11.84' S	39° 26.44' W	4571,2	CTD/rosette water sampler
PS73/285-1	23 April 2009	20:49	22:23	29° 11.09' S	39° 3.94' W	4674,5	CTD/rosette water sampler
PS73/286-1	24 April 2009	15:04	15:19	28° 35.37' S	37° 53.41' W	4400,2	CTD/rosette water sampler
PS73/287-1	25 April 2009	15:03	15:17	27° 32.63' S	35° 51.63' W	3695,0	CTD/rosette water sampler
PS73/288-1	26 April 2009	09:56	12:51	26° 41.79' S	34° 14.07' W	4777,7	CTD/rosette water sampler
PS73/289-1	27 April 2009	15:00	15:15	24° 38.67' S	30° 45.71' W	5260,7	CTD/rosette water sampler
PS73/290-1	28 April 2009	15:03	15:15	22° 42.98' S	27° 30.68' W	5362,5	CTD/rosette water sampler
PS73/291-1	29 April 2009	14:58	15:17	20° 31.56' S	23° 52.52' W	5390,5	CTD/rosette water sampler
PS73/291-2	29 April 2009	15:02	15:27	20° 31.56' S	23° 52.52' W	5257,7	Rubber boat, Zodiak
PS73/292-1	30 April 2009	14:00	14:45	16° 49.72' S	23° 0.10' W	4821,2	Rubber boat, Zodiak
PS73/292-2	30 April 2009	14:05	19:33	16° 49.71' S	23° 0.11' W	4885,2	CTD/rosette water sampler
PS73/293-1	02 May 2009	14:00	14:15	10° 8.60' S	22° 59.90' W	4780,5	CTD/rosette water sampler
PS73/294-1	03 May 2009	14:01	14:47	6° 19.64' S	22° 59.90' W	4501,7	Rubber boat, Zodiak
PS73/294-2	03 May 2009	14:08	14:27	6° 19.55' S	22° 59.92' W	4501,5	CTD/rosette water sampler
PS73/295-1	04 May 2009	14:00	14:45	2° 49.14' S	23° 0.05' W	5249,2	Rubber boat, Zodiak
PS73/295-2	04 May 2009	14:05	14:19	2° 48.93' S	23° 0.05' W	5251,0	CTD/rosette water sampler
PS73/296-1	05 May 2009	14:00	14:18	0° 55.53' N	23° 0.00' W	4524,2	CTD/rosette water sampler
PS73/297-1	06 May 2009	15:32	15:57	4° 27.32' N	22° 59.68' W	4184,7	CTD/rosette

Station PS 73	Date	Time (start)	Time (end)	Position (Lat.)	Position (Lon.)	Depth (m)	Gear
PS73/276-1	13 April 2009	13:28	13:56	50° 2.18' S	63° 59.00' W	133,0	CTD/rosette water sampler
							water sampler
PS73/298-1	07 May 2009	14:00	14:12	7° 41.17' N	22° 59.97' W	4456,2	CTD/rosette water sampler
PS73/299-1	08 May 2009	13:59	14:47	11° 15.41' N	23° 0.00' W	5108,5	Rubber boat, Zodiak
PS73/299-2	08 May 2009	14:01	14:14	11° 15.43' N	23° 0.02' W	5103,7	CTD/rosette water sampler
PS73/300-1	09 May 2009	13:01	13:15	14° 37.31' N	22° 59.85' W	3979,7	CTD/rosette water sampler
PS73/301-1	10 May 2009	13:01	13:16	18° 15.92' N	22° 59.93' W	3524,0	CTD/rosette water sampler
PS73/302-1	11 May 2009	12:58	13:38	21° 14.20' N	21° 46.48' W	4361,5	Rubber boat, Zodiak
PS73/302-2	11 May 2009	13:03	13:16	21° 14.19' N	21° 46.48' W	4361,0	CTD/rosette water sampler
PS73/303-1	12 May 2009	12:59	13:40	23° 41.67' N	19° 18.70' W	3442,0	Rubber boat, Zodiak
PS73/303-2	12 May 2009	13:04	13:20	23° 41.69' N	19° 18.68' W	3442,2	CTD/rosette water sampler
PS73/304-1	13 May 2009	12:59	13:12	26° 5.86' N	16° 51.54' W	3521,1	CTD/rosette water sampler
PS73/305-1	15 May 2009	13:00	13:13	30° 17.34' N	14° 45.04' W	2928,0	CTD/rosette water sampler
PS73/306-1	16 May 2009	13:00	13:42	34° 2.05' N	13° 37.67' W	0,0	Rosette water sampler
PS73/306-2	16 May 2009	13:03	13:35	34° 2.07' N	13° 37.67' W	4419,7	CTD/rosette water sampler
PS73/307-1	17 May 2009	13:00	13:45	37° 35.29' N	12° 31.04' W	5039,7	Rubber boat, Zodiak
PS73/307-2	17 May 2009	15:16	15:40	37° 35.22' N	12° 30.59' W	5041,5	CTD/rosette water sampler
PS73/308-1	18 May 2009	13:02	18:06	41° 1.83' N	11° 23.07' W	2728,0	CTD/rosette water sampler
PS73/308-2	18 May 2009	13:10	13:48	41° 1.86' N	11° 23.01' W	2728,0	Rubber boat, Zodiak
PS73/309-1	19 May 2009	11:59	12:30	44° 0.24' N	10° 0.89' W	4909,5	Rubber boat, Zodiak
PS73/309-2	19 May 2009	12:03	12:20	44° 0.24' N	10° 0.91' W	4909,2	CTD/rosette water sampler
PS73/310-1	20 May 2009	11:00	11:30	46° 56.86' N	7° 19.33' W	0,0	Rubber boat, Zodiak
PS73/310-2	20 May 2009	11:05	11:18	46° 56.89' N	7° 19.29' W	4394,2	CTD/rosette water sampler
PS73/311-1	20 May 2009	16:24	16:36	47° 31.50' N	6° 46.17' W	248,2	CTD/rosette water sampler

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