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The Expedition of the Research Vessel "Polarstern" to the Antarctic in 2007 (ANT-XXIII/10)

Edited by
Andreas Macke
with contributions of the participants

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GEMEINSCHAFT

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ANT-XXIII/10

12 April 2007 - 4 May 2007

Cape Town - Bremerhaven

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Andreas Macke

Koordinator / Coordinator

Eberhard Fahrbach

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1. FAHRTVERLAUF UND ZUSAMMENFASSUNG

Andreas Macke
IFM-GEOMAR

Am 12. April 2007 verließ das Forschungsschiff *Polarstern* mit 42 Besatzungsmitgliedern, zwei DWD-Mitarbeitern und sechs Wissenschaftlern Kapstadt zur Forschungsreise ANT-XXIII/10 auf kürzester Strecke durch Süd- und Nordatlantik nach Bremerhaven (Abb. 1). Während der 23 Reisetage wurden insgesamt 6423 Seemeilen zurückgelegt. Unterbrochen wurde die Fahrt nur durch einen etwa achtstündigen Aufenthalt auf Las Palmas, um Treibstoff zu bunkern. Das wissenschaftliche Ziel der Fahrt war eine kontinuierliche Profilierung der Atmosphäre durch die drei Klimazonen Mittlere Breiten, Subtropen, und Tropen beider Hemisphären sowie die Bestimmung der Strahlungsbilanz an der Meeresoberfläche. Zusätzlich zu den meteorologischen Messinstrumenten der DWD-Wetterstation wurden folgende Instrumente zu Reisebeginn an Bord installiert:

1) HATPRO Multikanal-Mikrowellenradiometer zur Erfassung des Vertikalprofils von Temperatur und Feuchte sowie des Flüssigwasserpfades (IFM-GEOMAR)
2) Full-Sky-Imager zur Bestimmung des Wolkentyps- und Bedeckungsgrades (IFM-GEOMAR)
3) Kipp & Zonen Net Radiometer CNR-1 mit auf- und abwärts schauenden Pyranometer und Pyrgeometer (IORAS)
4) Handbetriebenes Sonnenphotometer zur Bestimmung der optischen Dicke des atmosphärischen Aerosols (NASA, IORAS)

Des weiteren wurde ein "High Volume Air Sampler" zur Bestimmung des bodennahen Aerosols (LGGE) sowie ein "Differential Optical Absorption Spectrometer DOAS (UNI-Heidelberg) zur Bestimmung der bodennahen Spurengase in Betrieb genommen. Auf Wunsch der Forschungseinheit "Physikalische Ozeanographie" des IFM-GEOMAR hat der bordeigene Acoustic Doppler Current Profiler (ADCP) von Fahrtbeginn bis 20 Grad Nord dreidimensional Strömungsgeschwindigkeiten des oberflächennahen Ozeans aufgezeichnet. Zur optimalen Kalibrierung des ADCP wurden täglich um 10:00 und 16:00 Uhr Bordzeit für jeweils 10 Minuten eine 45 Grad Auslenkung aus den Kurs heraus wieder hinein gefahren.

Die Digitalkamera des mitgebrachten Sky-Imagers fiel am zweiten Tag aus, konnte aber durch ein ebenfalls mitgebrachtes Ersatzgerät ersetzt werden. Aus softwaretechnischen Gründen war der erste Einsatz des HATPRO auf See mit

Schwierigkeiten verbunden. Erst nach einer Woche kurz vor dem Äquator verliefen die Messungen ordnungsgemäß.

Die Messung der atmosphärischen Parameter wurden kontinuierlich während der gesamten Fahrt durchgeführt.

Während der Überflüge des ersten Europäischen operationellen polarumlaufenden Wettersatelliten MetOp-A wurden zusätzliche Radiosondenaufstiege vorgenommen, um die Feuchte- und Temperaturprofile des Interferometers IASI an Bord von MetOp-1 zu validieren.

Bis auf ein Sturmtief über dem Golf von Biskaya war die Wetterlage zumeist durch Hochdruckeinfluss mit geringer Bewölkung bestimmt, was der Atmosphärenprofilierung sehr entgegenkam. Abbildung 2 zeigt eine Übersicht der Wetterbedingungen anhand der täglichen maximalen Lufttemperatur, der Tagessumme der solaren Einstrahlung sowie der Windrichtung- und stärke.

Die wissenschaftlichen Arbeiten wurden am 4. Mai morgens beendet. Am gleichen Tag lief *Polarstern* einen Tag vor der geplanten Ankunft in Bremerhaven ein.

ITINERARY AND SUMMARY

On 12 April, 2007 *Polarstern* left Cape Town for the cruise ANT-XXIII/10 along the shortest track through the South and North Atlantic to Bremerhaven (Fig. 1.1). On board there were 42 crew members, two DWD employees and six scientists. The cruise lasted 24 days with a total distance of 6,423 nm. It was interrupted only by an 8 hour stop at Las Palmas to bunker fuel. The scientific goal of this cruise was to achieve a continuous profile of the atmosphere in the three climate zones mid-latitudes, sub-tropics, and tropics in both hemispheres as well as to determine the radiation budget at the sea surface. In addition to the meteorological measurement devices of the DWD weather station the following instruments had been sent to Cape Town by AWI and were installed on board at the beginning of the cruise:

1) HATPRO multi-channel microwave radiometer to determine the vertical profiles of temperature and humidity as well as the liquid water path (IFM-GEOMAR)
2) Full-sky imager to determine cloud type and cloud cover (IM-GEOMAR)
3) Kipp & Zonen net radiometer CNR-1 with up- and down-looking pyranometer and pyrgeometer (IORAS)
4) Hand-held sun-photometer to determine aerosol optical thickness (NASA, IORAS)

In addition a high volume air sampler to determine the surface near aerosol (LGGE) as well as a Differential Optical Absorption Spectrometer DOAS (UNI-Heidelberg) to determine surface near trace gases were put into operation. Upon request by the research unit "Physical Oceanography" of IFM-GEOMAR the onboard Acoustic Doppler Current Profiler ADCP had been monitoring the surface near ocean current velocities from departure until 20 degrees north.

In order to optimize calibration of the ADCP two changes in the cruise track, each of which was 45 degrees out of the track and back into the original one, were performed twice a day at 10 a.m. and 4 p.m. ship time.

On the second day the digital camera of the sky imager failed and had to be replaced by a second replacement camera that has also been brought to *Polarstern*. Because of software reasons the first operation of a HATPRO on the open sea turned out to be difficult. It was only after one week in the vicinity of the equator that the measurements ran correctly.

The measurements of atmospheric parameters had been continuously performed along the entire cruise.

Additional radiosondes were launched during overpasses of the first European operational polar-orbiting weather satellite MetOp-1 in order to validate temperature and humidity profiling by the interferometer IASI onboard MetOp-1.

Except for a heavy storm system over the Bay of Biscay the weather situation was mostly determined by high pressure influence with clouds, which favoured the atmospheric profiling. Figure 1.2 shows an overview of the weather conditions exemplarily for daily sums of solar irradiation and wind direction as well as wind speed.

In the morning of 4 May the scientific work was terminated. On the same day *Polarstern* reached Bremerhaven one day ahead of schedule.

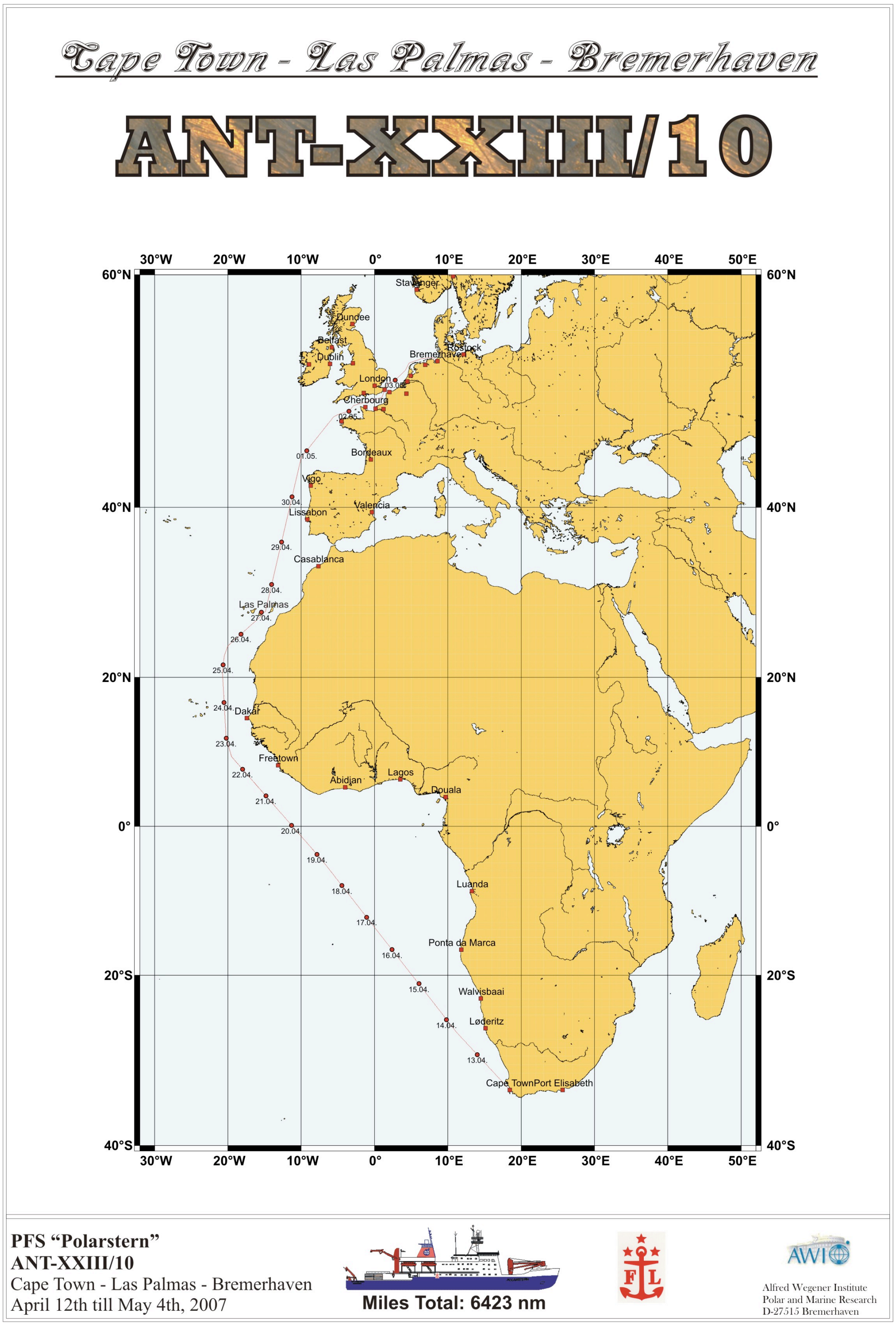

Fig. 1.1: Cruise track of POLARSTERN during research cruise ANT-XXIII/10

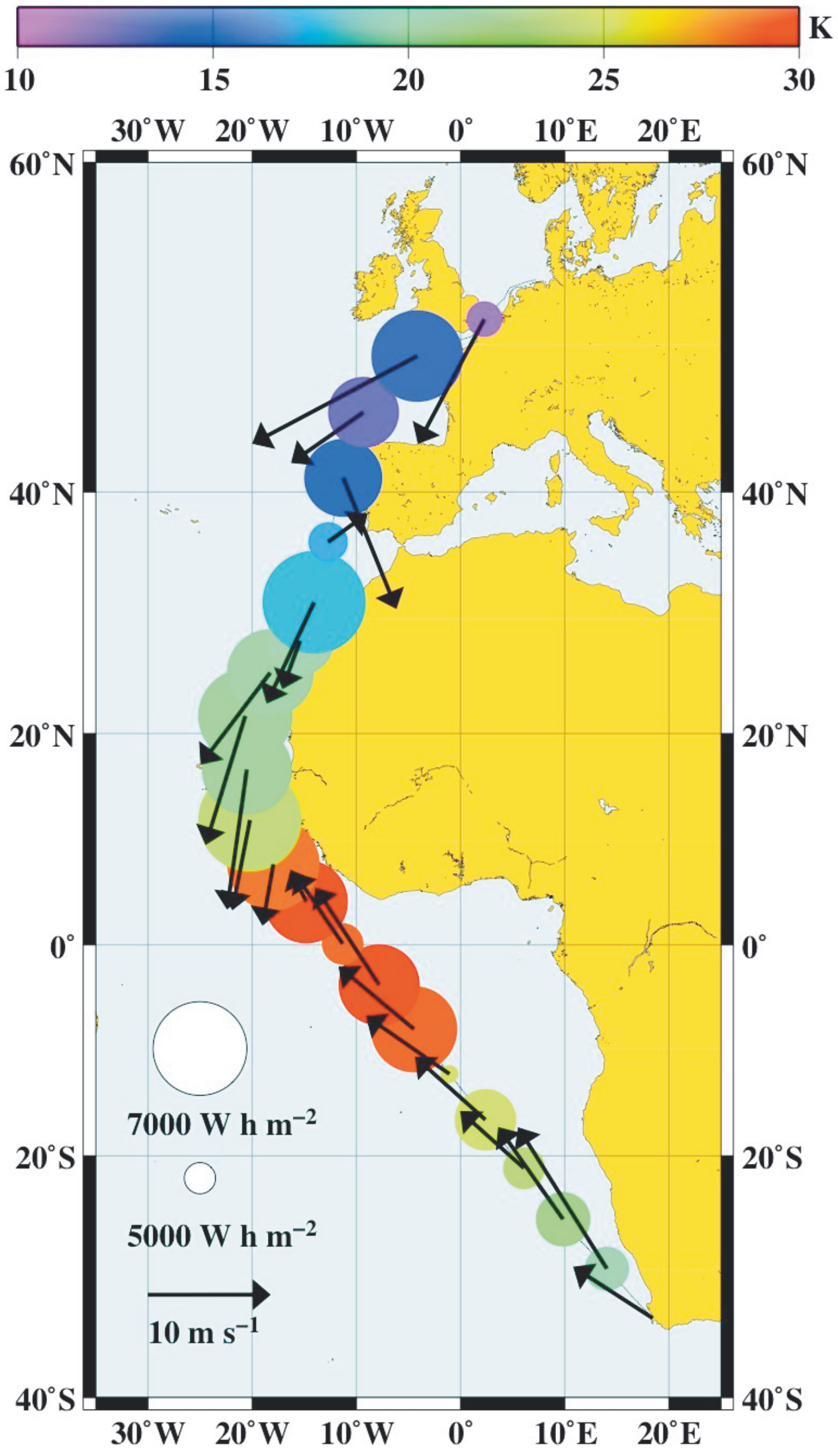

Fig. 1.2: Overview of meteorological conditions along cruise ANT-XXIII/10. Arrows indicate wind speed and direction, colours of the circles denote maximum temperature, and the size of the circles is proportional to the daily sum of solar irradiance at the sea surface. Graphics provided by S. Morin.

2. WEATHER CONDITIONS

Hartmut Sonnabend, Edmund Knuth
DWD Hamburg

Polarstern left the harbour of Cape Town on 12 April 2007 at 2 o'clock p.m. Under the influence of a belt of high pressure extending from the subtropical high towards the Cape Peninsula fine weather conditions with soft to moderate southerly winds predominated in the beginning. Shortly after having left the port basin, *Polarstern* encountered a long termed southwesterly swell with wave heights of about 4 to 5 meters at first, induced by cyclonic activities over the South Atlantic Ocean.

In the evening hours of the same day the southeast trade set in very soon, reaching wind forces up to 6-7 Beaufort throughout the whole next day. The reason for this development was a relatively sharp air pressure gradient between the subtropical high which was centred over the sea areas around Tristan da Cunha and a nearly stationary trough of low pressure along the coasts of Angola and Namibia towards the mouth of Oranje River. Leaving this "bottleneck" near the coast line behind, the trade wind evened out at moderate wind forces between 4 and 5.

These moderate wind conditions did not change very much within the next days along the further course of *Polarstern* over the northern flank of the subtropical high towards the equatorial trough. As the speed of the southeast trade was mainly some little bit higher than the ship's speed throughout this phase, the air chemistry measurements were influenced by winds coming from aft drifting the ship's plume of smoke above the Peildeck at times.

These conditions changed only after having crossed the equator in the confluence area to the Intertropical Convergence Zone (ITCZ) when the southeast trade decreased to less than 10 knots. Apart from some broken cumulus- and stratocumulus clouds mainly during the first few hours after sunrise, the sky was predominantly clear with only a few clouds throughout the whole cruise through the area occupied by the Southern Hemispheric trade wind.

Only in the immediate vicinity of the equator, when the water temperature rose to 28 degrees and the vertical growth of cumulus clouds was no longer suppressed by the trade wind inversion, some deep convection with isolated showers were observed in the vicinity of the ship. The water temperature rose constantly during 21 April reaching maximum values of more than 32 °C and air temperatures near 30 °C at the same time within the axis of the ITCZ along a latitude of about 5 degrees north. As the convective cells of the day before had dissipated or moved off westward, the weather within the axis of the ITCZ was mainly sunny with only a few banks of towering cumulus clouds during this day. The winds were light and variable. In the evening of the same day, however, strong vertical growth of cumulus clouds set in forming showers and thunder storms in the vicinity of the ship. A convective cell crossing the cruise line in the late evening caused 3 significant lightning strikes within a radius of less then 1 kilometre around *Polarstern* and 4.1 litres of precipitation per square metre were measured.

Shortly after having crossed this line of thunder showers *Polarstern* encountered the northern hemispheric trade wind. After a light to moderate ouverture the wind gradually increased reaching force 6 from north to northeast off the coasts of Mauritania on 24 April. Soon after the northern hemispheric trade wind set in reduced visibilities were observed affected by seaward drifting dust from the Sahel and the Sahara Desert. The temperatures of air and water dropped down by about 10 °C each within that time scale.

Along the south eastern flank of the North Atlantic subtropical high und thermal lows over the western and north western Sahara Desert the trade wind conditions continued also during the next days with wind forces between 5 and 6 from ahead and corresponding wave heights of about 2.5 metres constantly. The sky was mainly clear with only a few clouds below the trade wind inversion. While navigating towards the island of Gran Canaria, the wind increased to Beaufort 7 temporarily as a result of compression between the islands.

Due to logistical reasons *Polarstern* called at the harbour of Las Palmas on 27 April 2007 at 09 o'clock local time. The persisting fair and sunny weather was interrupted for some hours by many clouds and some light showers until noon. These conditions however improved soon into longer sunny intervals. The cruise to Bremerhaven was continued at 18 o'clock the same day.

Soon after having left the windbreaking harbour the trade wind quickly increased again, reaching wind forces between 6 and 7 from northerly directions associated with a rough sea about 3.5 metres between the islands and their northern approaches. When approaching the axis of the subtropical ridge of high pressure extending towards the Iberian Peninsula the wind decreased to forces between 4 and 5 until the evening of the following day.

The following passage of its axis marked the entrance into the North Atlantic frontal zone. The light to moderate wind shifted to westerly and south westerly directions. In the afternoon of 29 April the cold front of a north Atlantic low moving towards the gulf of Biscay crossed the cruise line with strong cloud cover and some rain. After the passage of the cold front the wind shifted to northwest rapidly. At the rear of the shallow depression - having reached the west coast of Brittany meanwhile - the northwest wind increased up to Beaufort

6 to 7 off the north west coast of Spain during 30 April. As the air mass was cool and unstable, frequent showers with gusts near gale force were observed especially in the late evening.

A spectacular development started in the morning hours of 1 May north of Cape Finisterre when - a little north of the cruise line of *Polarstern* - a very small but intense gale centre developed within a timescale of only a few hours. Associated by strong rain and heavy showers the wind rose up to gale force 8 – 9 and gusts up to 10 Beaufort for approximately two-and-a-half hours. The sea temporarily reached maximum heights of 6 metres. After having passed the occlusion of the low the wind collapsed very quickly while shifting to the north and the heavy rainfall stopped abruptly. Leaving behind a well-defined convective cloud band in the south, *Polarstern* continued its course with fine weather conditions and only a few clouds. The moderate wind gradually shifted from northeast to east and southeast later by reaching forces of up to 6 until the evening of the same day.

After a short period with soft winds during the following night the wind increased once again shortly after *Polarstern* came into the Channel. Between a low pressure system over Spain and Western France and a high north of Scotland the wind rose up till 7 Beaufort at times from northeast to east during 2 May. Approaching the strait of Dover in the morning of 3 May, the northeast wind blew with 7 Beaufort associated with rough sea. The sky was almost overcast by stratocumulus clouds for a while, improving from noon on. Along the remaining distance to Bremerhaven the wind remained strong from north to northeast, becoming moderate to fresh later on.

Polarstern reached the harbour of Bremerhaven in the afternoon of 4 May 2007.

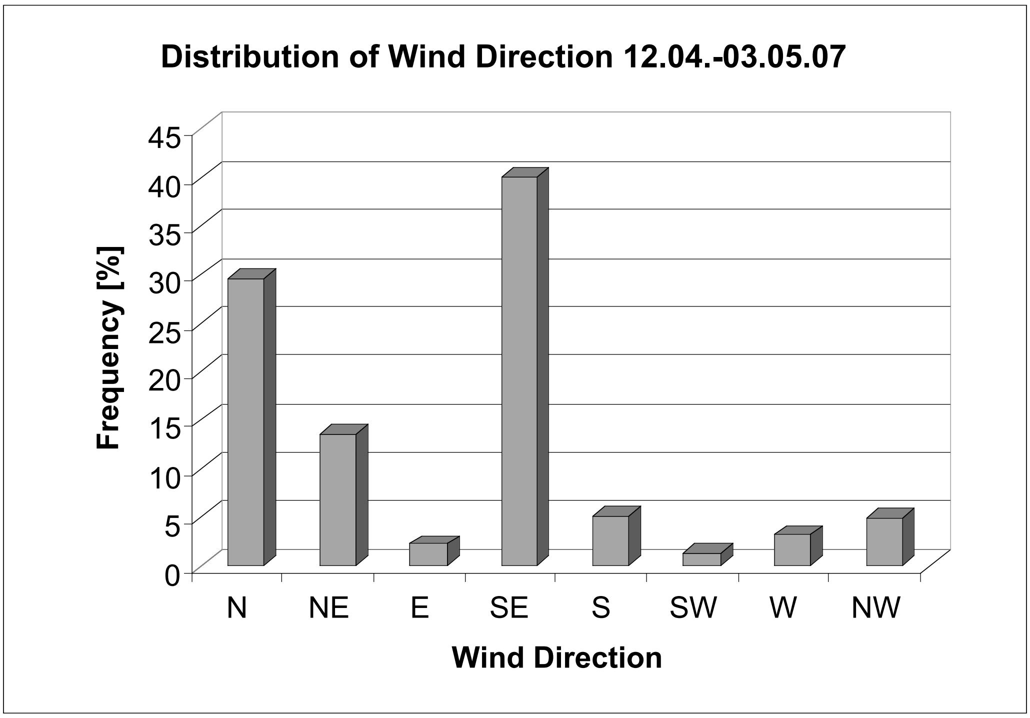

Fig. 2.1: Frequency distribution of wind conditions during the cruise (wind direction)

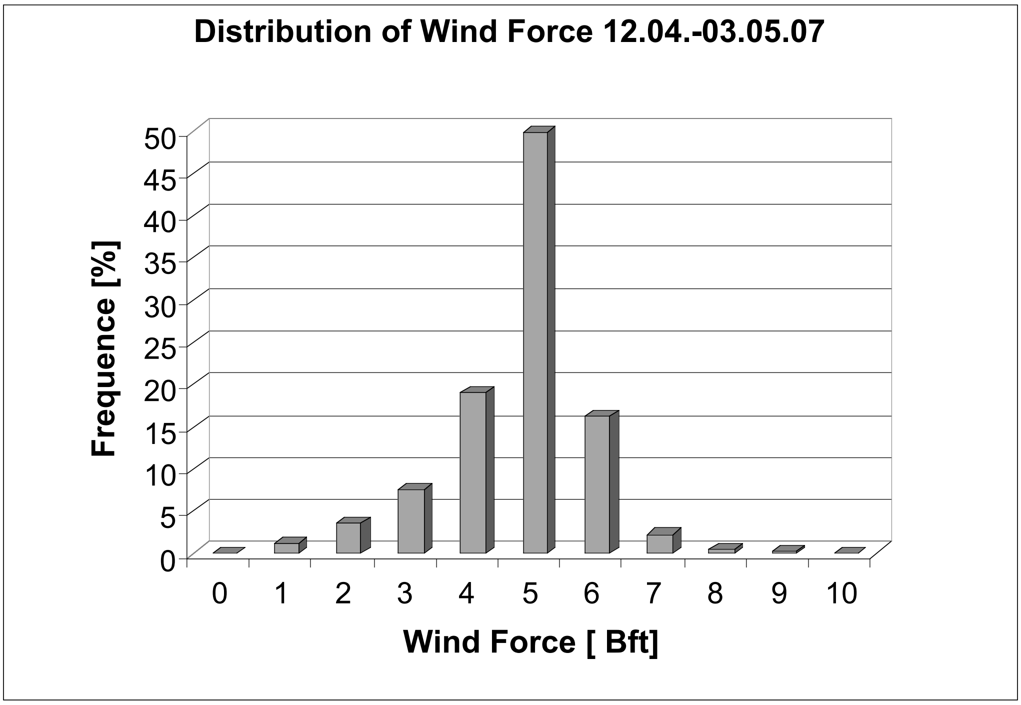

Fig. 2.2: Frequency distribution of wind conditions during the cruise (wind force)

3. NITRATLANTIK 07: STUDY OF THE ISOTOPE COMPOSITION OF MARINE AND ATMOSPHERIC NITRATE IN THE ATLANTIC OCEAN

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not on board: Joël Savarino

Objectives

The analysis of the isotopic composition of nitrate (NO_3^-) in various environments (marine, atmospheric, ice cores ...) is a fast-growing field of investigation. Isotope measurements complement concentration data, which by themselves do not allow for a thorough understanding of the intricate cycling of nitrogen oxides at the surface of the Earth, and in particular in the atmosphere. The discovery that ozone, one of the most prominent oxidant in the atmosphere, could transfer its isotopic anomaly ($\Delta^{17}O=\delta^{17}O-0.52x\delta^{18}O$, where $\delta=R_{sample}/R_{reference}-1$ and R is the $^{17}O/^{16}O$, $^{18}O/^{16}O$ or $^{15}N/^{14}N$ ratio in the sample and in a reference material) to nitrogen oxides (NO_x, the precursors of nitrate), has brought to light the potential for atmospheric nitrate isotopes to be a proxy for the oxidative capacity of the atmosphere. Nitrogen isotope ratios are generally considered to behave as tracers of the NO_x sources. Since the development of techniques able to accurately measure $\Delta^{17}O(NO_3^-)$ is very recent, few measurements are available for atmospheric nitrate. In addition, polar regions have been targeted first because of the potential for reconstructing past levels of ozone (thus, past oxidative capacity of the atmosphere) through the measurement of $\Delta^{17}O(NO_3^-)$ in ice and firn. $\Delta^{17}O(NO_3^-)$ was also measured in polar atmospheres and has given indications about atmospheric processes such as boundary layer ozone depletion events. Only one pioneering study was aimed at unravelling the seasonal cycle of $\Delta^{17}O$ in atmospheric nitrate in a mid-latitude, polluted marine boundary layer. The authors found that changes in $\Delta^{17}O$ values were best accounted for by changes in oxidation pathways over the course of the year: for instance, in winter, enhanced formation of nitrate through night time heterogeneous processes such as the hydrolysis of N_2O_5 leads to an increase in $\Delta^{17}O$ values. In summer, the gas-phase reaction between the hydroxyl radical OH and NO_2 leads to lower $\Delta^{17}O$ values. Coupled studies of all three isotope ratios of nitrate, i.e. $\delta^{15}N$, $\delta^{17}O$ and $\delta^{18}O$, have shown that considerable insight is given by the dual interpretation of $\delta^{15}N$ and $\delta^{17}O$ in atmospheric nitrate, in terms of sources and atmospheric processes, for atmospheric nitrate collected in the coastal Antarctica (Dumont d'Urville) over the course of a full year.

The ANT-XXIII/10 *Polarstern* cruise between Cape Town (Rep. South Africa) and Bremerhaven (Germany) therefore represented a unique opportunity to measure $\delta^{15}N$, $\delta^{17}O$ and $\delta^{18}O$ in atmospheric nitrate collected in a wide range of meteorological and photochemical conditions, in the marine boundary layer of the Atlantic Ocean. Coupled with measurements on dissolved nitrate in seawater samples collected during the cruise, this unique new data set will:

- enhance the global representation of the isotopic composition of atmospheric nitrate, both for oxygen and nitrogen,
- place new constraints on the processes responsible for the formation of atmospheric nitrate in the marine boundary layer, in relation with latitudinal variations in atmospheric concentration oxidants such as ozone and OH (due, for instance, to changes in air-masses origin, actinic flux, temperature, humidity),
- provide some new information about the air-sea interaction in terms of nitrogen input and output to the ocean.

Work at sea

Aerosol collection

Atmospheric particles (aerosol) were collected on the observation deck by means of high volume sampling (HiVol, see Fig. 3.1): a turbo-pump sucks in air through a filtering medium at a flow-rate of about 1 m^3 min^{-1}. The air flows through an assemblage of four slotted plates (four-stage impactor), each of them bearing a slotted pre-cleaned glass fiber filter, on which particles are selectively deposited depending on their aerodynamic diameter. This allows to separate larger particles (diameter > 1 μm), directly injected into the atmosphere such as sea spray, from smaller particles which can originate from a variety of pathways, including gas-to-particle conversions. Owing to generally calm and steady weather conditions, the sampling was carried out on a daily regular basis, hence the latitudinal resolution of these measurements is on the order of 4°. Over the course of the ANT-XXIII/10 cruise, 22 series of filters were obtained, representing 66 samples to be analyzed in our laboratory in Grenoble: indeed, the two slotted filters corresponding to the largest supermicron particles, SF1–2 (see figures 3.3(a) and 3.3(b)) are stored and analyzed together, as are the two slotted filters corresponding to the smallest supermicron particles (SF3–4, see figures 3.3(c) and 3.3(d)). During the cruise, 4 sets of blanks were performed, to assess the contamination induced by the handling of filters, during their cleaning, shipping, storage and analysis. Blanks were treated identically to the samples, i.e., the filter-holder was loaded with regular filters, except that the HiVol was not turned on.

Fig. 3.1: High-volume aerosol sampler during the ANT-XXIII/10 cruise onboard Polarstern

Sea-water sampling

Sea-water was sampled on a daily basis using the bow intake pumping system built into the ship, using pre-cleaned plastic and glass jars for the isotopic analysis of dissolved nitrate. Samples were also collected for the determination of the dissolved organic carbon (DOC) content of sea-water (M. Legrand, S. Preunkert and B. Jourdain, LGGE, Grenoble, not on board). The figure 3.2 shows the locations where the samples were collected, together with sea-water temperature at the sampling location.

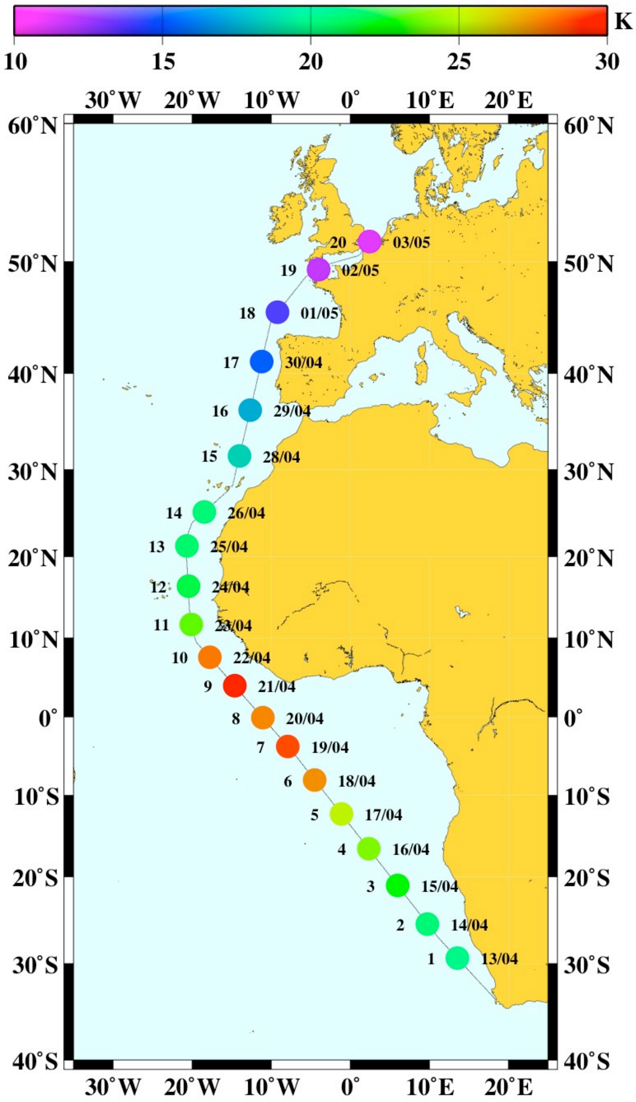


Fig. 3.2: Sea-water sampling locations

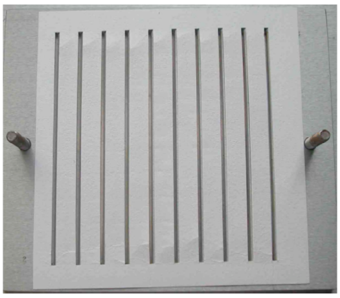
Surface ozone monitoring

Ozone was measured at a 10s resolution on the observation deck using a small UV-absorption ozone monitor (model 2020, 2B Technologies, Boulder CO, USA). Problems with the logging of data were experienced during the first week of the cruise, resulting in a few days without measurements. A solution was found later to obtain a continuous set of measurements during the remaining of the cruise. Zero levels were checked 3 times during the cruise using a zero-ozone cartridge, and showed no variation in the offset value. A calibration was performed before the cruise and repeated after the cruise to ensure the validity of the data acquired during the cruise.

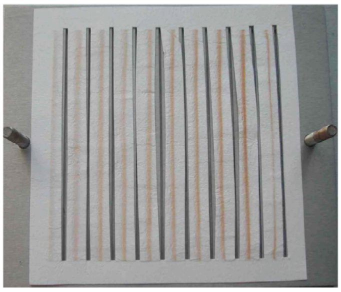
Expected results

This campaign is expected to yield the first comprehensive data set of $\delta^{15}N$, $\delta^{17}O$ and $\delta^{18}O$ in atmospheric nitrate in the marine boundary layer and at low latitudes. Complementary data from sea water will contribute to the representation of several Earth surface compartments in terms of nitrogen oxides cycling, with an unprecedented latitudinal resolution. To complement these observations, measurements of the concentration of major ions within the aerosol samples will be carried out (including Cl^-, NO^-_3 , SO_4^{2-}, Ca^{2+}, Na^+, Mg^{2+},K^+, NH_4^+).

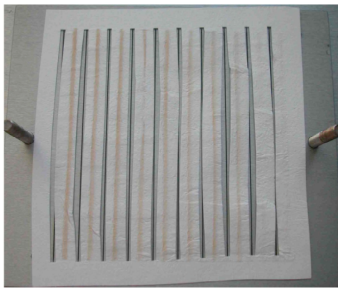
Previous investigations have shown that the chemical composition of aerosol varies greatly along a North-South transect in the Atlantic Ocean. In terms of nitrate, for example, levels in the submicron and the supermicron size vary from around 15 and 200 ng m^{-3} in the Southern Atlantic Ocean to concentrations higher than 50 and 1300 ng m^{-3} in regions influenced by European emissions, respectively.



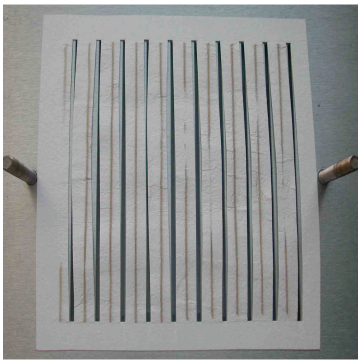
(a) SF1 (largest particles)



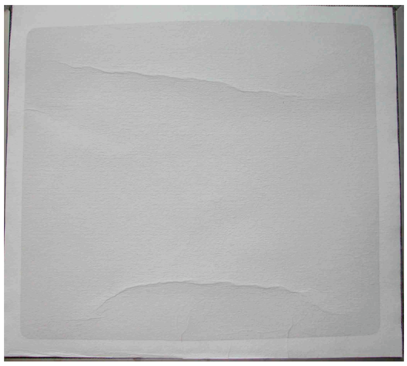
(b) SF2



(c) SF3



d) SF4 (smallest particles in supermicron range)



e) Submicton particles

Fig. 3.3: Example of slotted (SF1–4) and backup (3(e)) filters after 24 hours of sampling of aerosol containing dust from the Sahara

As one could expect, a wide range of types of air-masses and atmospheric conditions were observed during the cruise. The figure 1.2 shows the maximum daily temperature and total incoming solar radiation for each day.

During the first week, from 13 April to 21 April, relative and absolute wind were from behind the ship, with air masses closely following the ship track, as evidenced by real-time back-trajectories calculations provided by the German weather service (Deutsches Wetterdienst, DWD) on a daily basis. During this period of time, particles deposited on the filters were almost impossible to see (although the filters from the first day were a little dirtier, possibly due to dust and pollutants emissions from South Africa). Ozone levels during this part of the cruise were rather low (on the order of 20 n mol mol^{-1}). Such low values are compatible with the remote character of the air masses sampled during that time. However, the direction of the wind may have brought the ozone intake in contact with the exhaust plume of the ship's engine. Further studies will be aimed at determining whether NO emissions from the ship are sufficient to significantly destroy ambient ozone, hence, leading to an underestimation of surface ozone levels. It should be noted, however, that ship's exhaust is not likely to have contaminated the nitrate samples since the timescales for the conversion of NO_x to nitrate are on the order of 1 day typically, much longer than transport timescale from the ship's exhaust to the HiVol device (separated by 30 m approximately).

On 21 April the Equator was crossed and on the following day wind shifted to the North on a very abrupt manner; more waves were then encountered resulting in larger amounts of sea-spray being injected in the atmosphere. From 21 April to 26 April, filters exhibited brownish tints attributed to dust originating from North-African deserts. Ozone levels were then in the 40-50 nmol mol^{-1} range. The input of dust stopped on 26 April, but ozone levels remained in the same range.

On 27 April, the ship called at Las Palmas de Gran Canaria for a technical stop. A set of filter was put on one hour before entering the harbour, and was removed one hour after leaving it, i.e. about 12 hours later. As expected, the filters contained very dark particles (mostly soot) at all levels of the impactor. Ozone levels were lower in the harbour than in the surrounding sea, on the order of 20 nmol mol^{-1}, and tended to exhibit a diurnal pattern similar to urban areas (i.e., ozone levels are lower in early morning and late afternoon due to titration by NO emissions from cars at rush-hours).

From 29 April on, westerlies took over the trade wind (north-easterlies): in the area from Southern Portugal to the entrance of the English Channel (through the Gulf of Biscay), the air masses were predominantly originating from the Northern Atlantic Ocean. There, ozone levels were on the order of 50 nmol mol^{-1} and the filters did not exhibit significant coloration. During a few hours in the morning of 1 May, a storm was experienced (crossing of a low pressure system), with maximum wind speeds of 21.5 m s^{-1}. However, this storm only lasted a few hours.

On 2 May, the ship entered the British Channel: there, winds were mostly from the North-East. A new set of filter was put on when the wind direction shifted. Ozone levels were reduced during this period (levels in the 40-50 nmol mol^{-1} range). Steady conditions were then experienced until arrival in Bremerhaven. Aerosol filters in the British Channels showed soot particles in the smallest supermicron size range (Fig. 3.3: SF4) and on the back-up filter.

4. METOP & MORE 2007

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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 clear that subgrid-scale processes must be accounted for in radiative transfer parameterizations. Combined observations of cloud physical and radiative properties are a key to adjust or to validate such parameterizations.

In 2003 the Meridional Ocean Radiation Experiment (MORE) was initiated by S. Gulev and A. Macke as a joint initiative of the P. Shirshov Institute of Oceanology (IORAS) and the Leibniz-Institute for Marine Sciences IFM-GEOMAR. The research goal is to conduct long-term measurements of surface energy fluxes above the ocean at mid-latitude, subtropical and tropical conditions with an emphasis on the role of the cloudy atmosphere on the short wave (SW) and long wave (LW) radiation fluxes. Starting in 2004 regular Atlantic transects of the two Russian research vessels *Academician Vavilov* and *Academician Ioffe* have been used to perform surface energy flux and atmospheric measurements. As a result improved parameterizations of the SW- and LW fluxes based on standard meteorological observations for different cloudy sky conditions have been developed. A further objective is to provide validation data for temperature and humidity profiles from the new infrared sounding radiometer IASI onboard the first European polar orbiting operational weather satellite MetOp.

Work at sea

In April 2007 the *Polarstern* cruise ANT-XXIII/10 from Cape Town to Bremerhaven was utilized for the 6th MORE cruise. *Polarstern* is well equipped for meteorological research as well as for routine meteorological services. The meteorological observatory is permanently manned with a weather technician/-observer from the German Weather Service (DWD) who perform the routine 3–hourly synoptic observations and the daily upper air soundings. The meteorological observations also include pyranometer- and pyrgeometer measurements of the downwelling solar and thermal broadband irradiances. In addition, a Kipp&Zonen Net Radiometer CNR-1 with up and down looking pyranometer and pyrgeometer operated by IORAS was used on this cruise. As already started on the 5th MORE cruise onboard *Academician Ioffe* in autumn 2006 sky images had been obtained from a total sky imager manufactured at IFM-GEOMAR every 15 seconds. This enables a detailed analysis of the role of cloud cover and cloud type on the radiation budget at the sea surface.

For the first time a multi-channel microwave radiometer (HATPRO, Radiometer Physics) for continuous observations of atmospheric temperature and humidity profiles as well as liquid water and precipitable water path has been operated on the open ocean (see Fig. 4.1).

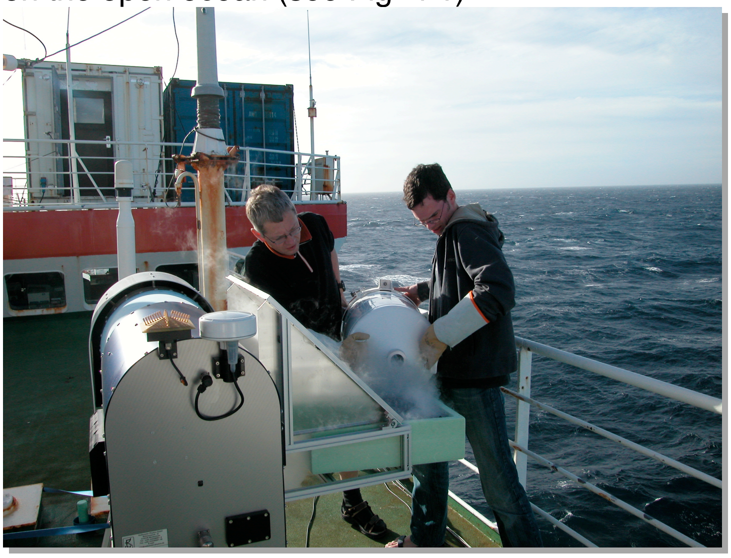

Fig. 4.1: Filling of liquid nitrogen for calibration of the HATPRO microwace radiometer after departure from Cape Town

Three resp. seven independent information on the humidity and temperature profiles up to 10 km height are measured with a temporal resolution of one second. Under calm sea conditions boundary layer scans can be performed to increase the vertical resolution substantially within the lower 1,000 m height. Together with ceilometer measurements of cloud bottom height, 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. Unfortunately, problems with the data acquisition software had disabled HATPRO measurements until 19 April, 2007, leading to a 7 day gap of data in the Southern Atlantic.

In addition to the continuous profiling by means of the HATPRO microwave radiometer, additional radiosondes were launched whenever Polarstern was in the field of view of the IASI instrument. Due to calibration problems all MetOp instruments have been shut down by EUMETSAT on 20 April. On 27 April IASI started working again; the extra soundings are continued.

Preliminary results

Figure 5.2 shows a time series of liquid water path and temperature and humidity profiles from 20 April, 2007 (near the equator). The sky was mostly cloudy with occasional shallow cumulus clouds below altocumulus and cirrus clouds. Because of retrieval errors, the microwave radiometer shows positive LWP of about 50 gm^{-2} even for clear sky conditions. These errors were expected as the current retrieval was designed for mid-latitude atmospheres over land. With the help of the auxiliary data (cloud camera, ceilometer) it will be possible to correct for such biases in the ongoing analysis.

The early afternoon was dominated by cirrus clouds which show no signal in the microwave radiometer but reduce the downwelling solar radiation. This emphasizes the importance of continuous sky observations for the interpretation of cloud-radiation measurements.

Interestingly, the time series of the relative humidity profiles shows small scale horizontal variabilities both in the vicinity of clouds (LWP > 100 g m^{-2}) and under clear sky conditions. The latter may have a significant effect on satellite based humidity retrievals.

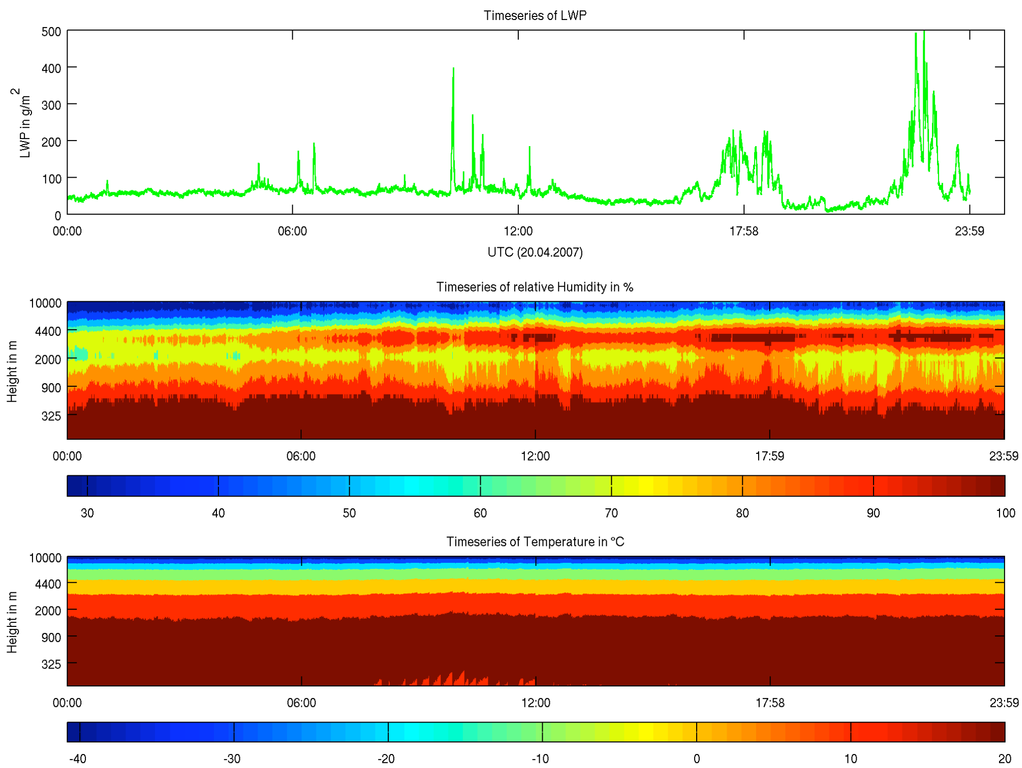

Fig. 4.2: Time series of relative humidity (middle plot) and temperature profiles (lower plot), as well as vertically integrated cloud liquid water (upper plot)

Figures 4.4 and 4.4 show the LWP and SW-radiation time series for all days with functioning microwave radiometer. The sinosuidal diurnal cycle of the SW radiation for clear sky conditions is modulated by shadowing from clouds passing the solar disk and by excess diffuse scattering by clouds outside the solar disk (broken cloud effect). As soon as a liquid water cloud passes *Polarstern* the microwave radiometer shows a clear LWP signal on top of the clear sky noise mentioned above. Dips respectively peaks in the SW-radiation and LWP time series mostly do not coincide simply because the overhead clouds observed by the microwave radiometer are not the same as the clouds that are blocking the sun. Visual inspections of the full sky imager reveals that the clear peaks in the LWP time series result from moderately large cumulus clouds (Cu mediocris). Within the subtropics the sky was mostly clear with occasional shallow cumulus clouds (Cu humilis) which show almost no signal in the microwave radiometer but strongly effect the solar irradiation.

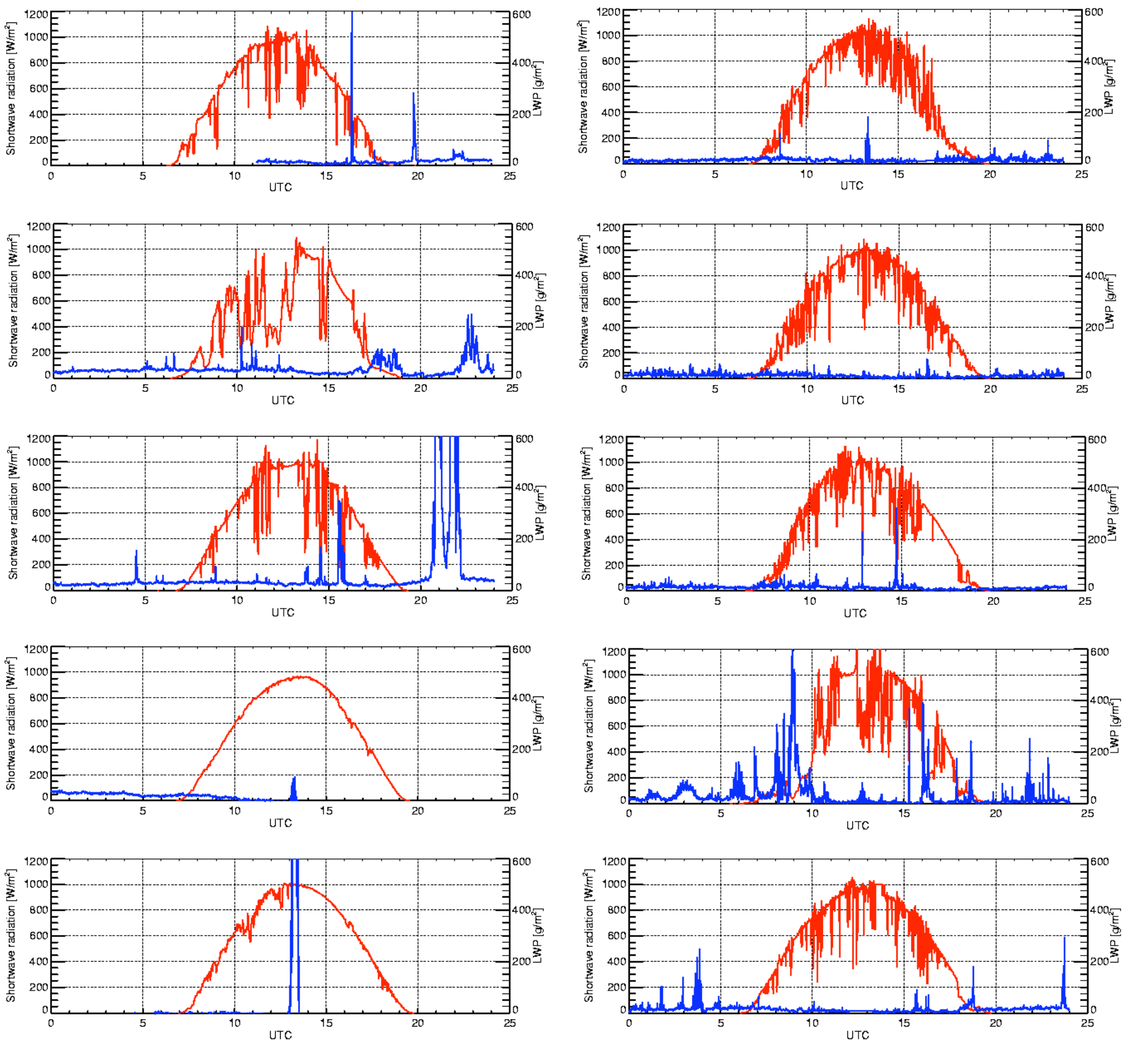

Fig. 4.3: Daily time series of downwelling broadband solar radiation (red) and liquid water path (blue) for April 19 - 23 (left column) and April 24 - 28 (right column)

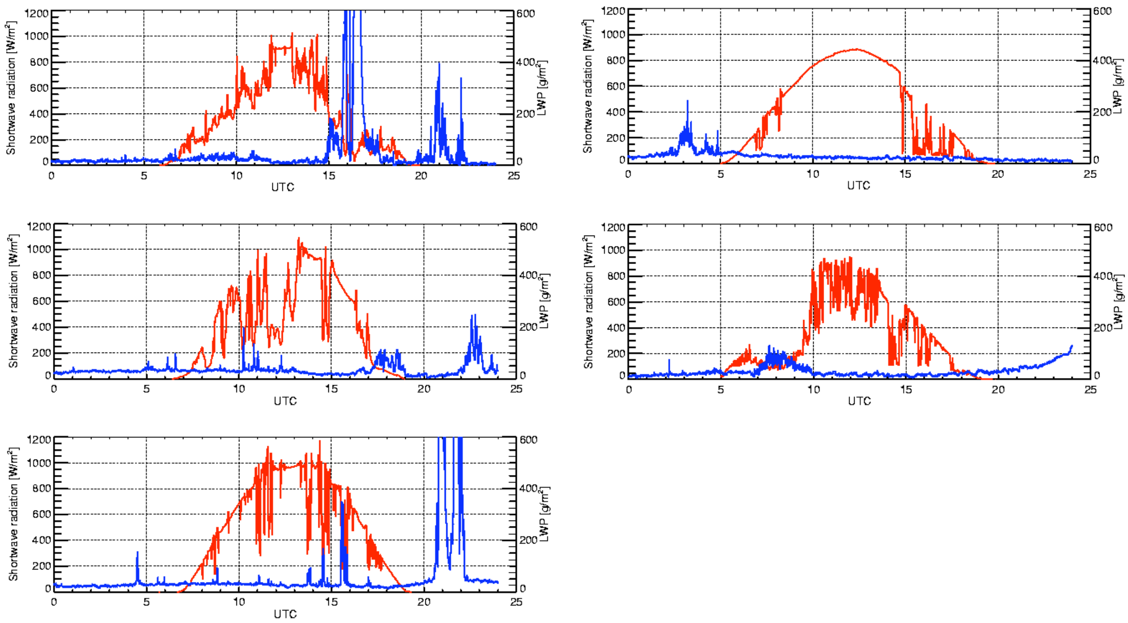

Fig. 4.4: Daily time series of downwelling broadband solar radiation (red) and liquid water path (blue) for April 29 - May 1 (left column) and May 2 - 3 (right column)

Figure 4.5 shows the time series of optical thickness at wave lengths of 340 nm, 675 nm and 870 nm measured with the Microtops sun-photometer along the entire cruise. Thanks to the full sky images the strong spikes in the diagram can be explained by the occurrence of haze or cirrus clouds. The real aerosol optical thickness is seen in the slowly varying background signal. From 22 April to 28 April *Polarstern* was passing through extended Sahara dust aerosol clouds. This was nicely observed in the Meteosat SEVIRI data and is also visible in the optical thickness data. The Sahara dust event can be regarded as a stroke of luck because the ship based observations allow for a quantification of the satellite based dust retrievals.

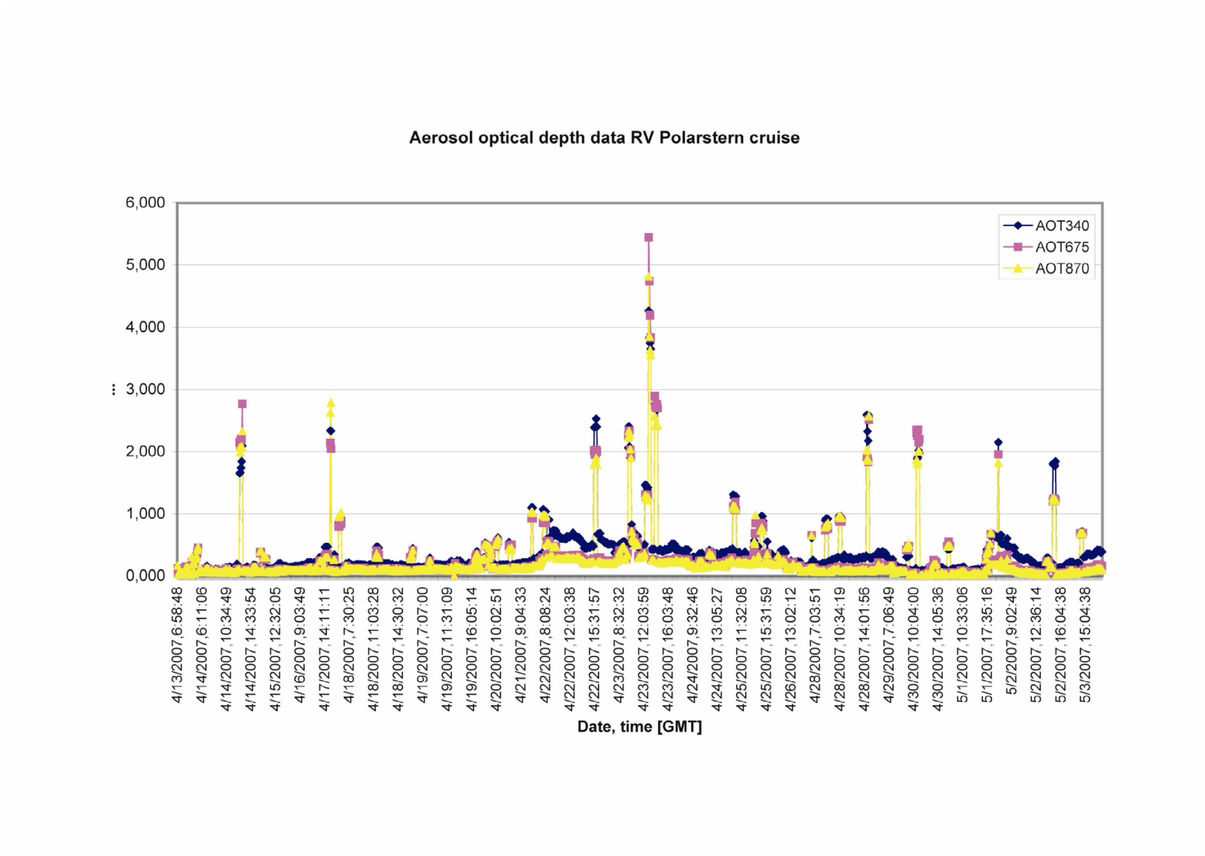

Fig. 4.5: Time series of optical thickness along the entire cruise derived from the Microtops sun-photometer at wavelengths of 340 nm, 675 nm and 870 nm

5. ADCP MEASUREMENTS

Peter Brandt
IFM-GEOMAR

During ANT-XXIII/10 current velocity measurements were carried out using the shipboard 150 kHz Ocean Surveyor ADCP. Data were acquired from 13 April to 25 April 2007. The equatorial current system was crossed at about 15°W.

The velocity data obtained after processing are of good quality. Depth range is 200 to 250 m for the whole cruise. Thanks to frequent purposeful deviations from a straight cruise track, the transducer misalignment - which is an essential factor in data processing - could be determined quite well. Those purposeful deviations prove most suitable if the time intervals between course changes are 10 minutes at least and course changes are 10 degrees at least. Heading data were available from the Laser-navigation-platform. This heading resulted in slightly lower data quality compared to previous cruise when the heading from the ASHTECH array were used. The obtained uncertainty in the calculated transducer misalignment was 0.5 degrees compared to 0.3 degrees if the heading from the ASHTECH array were used.

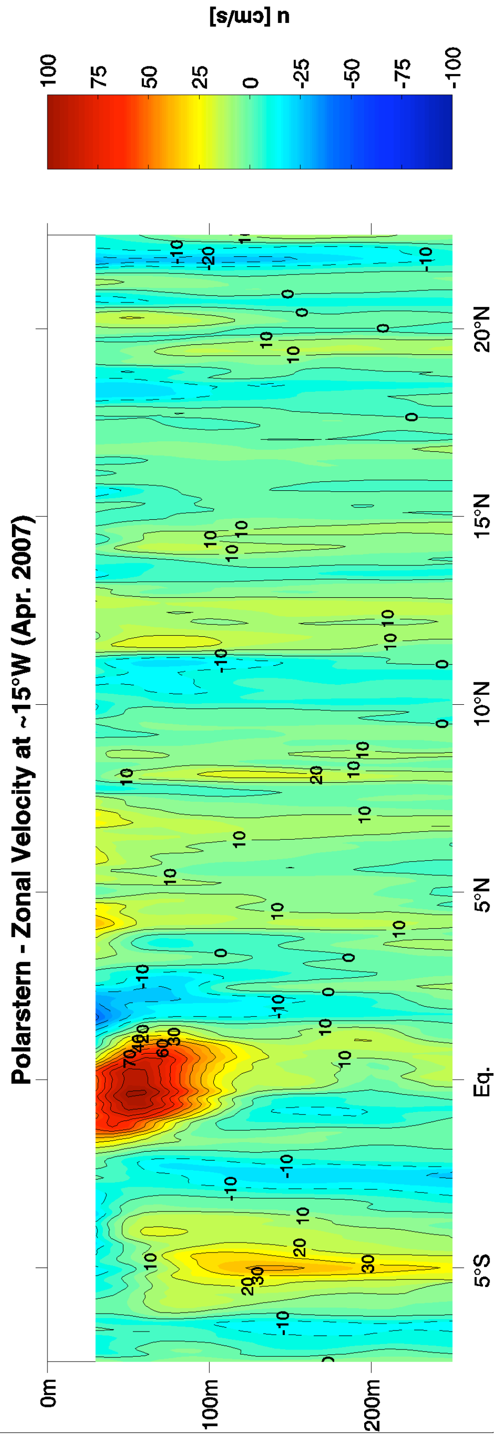

Fig. 5.1: Zonal current velocity along a meridional section at 15 to 20 degrees W. Most prominent the equatorial current system with the Equatorial Undercurrent (EUC) at 50 m depth at the equator (up to 1 m/s) and the South Equatorial Undercurrent (SEUC) at 100 to 200 m depth at 5S (up to 0.4 m/s). Further north there are several eastward and westward current bands mainly associated with the enhanced eddy field in the region.

APPENDIX

A.1 PARTICIPATING INSTITUTIONS

A.2 CRUISE PARTICIPANTS

A.3 SHIP'S CREW

A.4 STATION LIST

A.1. PARTICIPATING INSTITUTIONS

	Adresse /Address
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft Postfach 12 01 61 27515 Bremerhaven / Germany
DWD	Deutscher Wetterdienst Seewetterdienst Bernhard-Nocht Str. 76 20359 Hamburg / Germany
IFM-GEOMAR	Leibniz-Institut für Meereswissenschaften IFM-GEOMAR Düsternbrooker Weg 20 24105 Kiel Germany
IORAS	P.Shirshov Institute of Oceanology Academy of Sciences Krasikova 23 Moscow, 117218 Russian Federation
LGGE	Laboratoire de Glaciologie et Géophysique de l'Environnement (UMR 5183) 54, rue Molière 38402 - Saint Martin d'Hères cedex France
University Heidelberg	Institut für Umweltphysik Universität Heidelberg Im Neuenheimer Feld 229 69120 Heidelberg Germany
IUB	International University Bremen GmbH Postfach 750561 D-28725 Bremen Germany

A.2 CRUISE PARTICIPANTS

Name	Vorname/ First Name	Institut/ Institute	Beruf / Profession
Buldt	Klaus	DWD	Technician
Haerendel	Gerhard	IUB	Scientist
Kalisch	John	IFM-GEOMAR	Meteorologist
Knuth	Edmond	DWD	Meteorologist
Macke	Andreas	IFM-GEOMAR	Meteorologist
Morin	Samuel	LGGE	Student
Sinitsyin	Alex	IORAS	Technician
Wassmann	Andreas	IFM-GEOMAR	Student, meteorology

A.3 SHIP'S CREW

Name	Rank
Schwarze, Stefan	Master
Spielke, Steffen	1.Offc.
Farysch, Bernd	Ch.Eng.
Fallei, Holger	2. Offc.
Peine, Lutz	2.Offc.
Niehusen, Frank	3.Offc.
Geisler, Stephanie	Doctor
Hecht, Andreas	R.Offc.
Minzlaff, Hans-Ulrich	1.Eng.
Westphal, Henning	3.Eng.
Sümnicht, Stefan	3.Eng.
Scholz, Manfred	ElecEng.
Nasis, Ilias	ELO
Verhoeven, Roger	ELO
Muhle, Helmut	ELO
Himmel, Frank	ELO
Loidl, Reiner	Boatsw.
Reise, Lutz	Carpenter
Vehlow, Ringo	A.B.
Lamm, Gerd	A.B.
Winkler, Michael	A.B.
Guse, Hartmut	A.B.
Hagemann, Manfred	A.B.
Schmit, Uwe	A.B.
Bäcker, Andreas	A.B.
Wende, Uwe	A.B.
Preußner, Jörg	Storek.
Ipsen, Michael	Mot-man
Kusch, Thomas	Mot-man
Voy, Bernd	Mot-man
Elsner, Klaus	Mot-man
Hartmann, Ernst-Uwe	Mot-man
Grafe, Jens	Mot-man
Müller-Homburg, Ralf-Dieter	Cook
Silinski, Frank	Cooksmate

Name	Rank
Völske, Thomas	Cooksmate
Jürgens, Monika	1.Stwdess
Wöckener, Martina	Stwdss/Kr
Czyborra, Bärbel	2.Stwdess
Silinski, Carmen	2.Steward
Gaude, Hans-Jürgen	2.Steward
Möller, Wolfgang	2.Stwdess
Huang, Wu-Mei	2.Steward
Yu, Kwok Yuen	Laundrym.
Felsenstein, Thomas	Apprent.

A.4 STATION LIST PS 69

Station	Date/Time	Position Latitude	Position Longitude	Gear
PS69/10-track	2007-04-12T00:00	-33.80000	18.40000	
PS69/27455	2007-04-13T11:12	-30.01000	14.19000	Radiosonde
PS69/27456	2007-04-14T10:49	-25.86000	10.03000	Radiosonde
PS69/27457	2007-04-15T11:10	-21.26000	6.23000	Radiosonde
PS69/27458	2007-04-16T10:59	-16.87000	2.56000	Radiosonde
PS69/27459	2007-04-17T10:58	-1.258000	-0.90000	Radiosonde
PS69/27460	2007-04-18T09:17	-8.59000	-4.06000	Radiosonde
PS69/27461	2007-04-18T11:20	-8.25000	-4.33000	Radiosonde
PS69/27462	2007-04-19T10:49	-4.08000	-7.63000	Radiosonde
PS69/27463	2007-04-19T21:27	-2.32000	-9.17000	Radiosonde
PS69/27464	2007-04-20T10:56	-0.07000	-11.13000	Radiosonde
PS69/27465	2007-04-21T09:31	3.76000	-14.47000	Radiosonde
PS69/27466	2007-04-21T16:53	4.88000	-15.45000	Radiosonde
PS69/27467	2007-04-22T10:47	7.58000	-17.81000	Radiosonde
PS69/27468	2007-04-22T22:15	9.40000	-19.41000	Radiosonde
PS69/27469	2007-04-23T10:47	11.74000	-20.15000	Radiosonde
PS69/27470	2007-04-24T10:48	16.46000	-20.50000	Radiosonde
PS69/27471	2007-04-25T10:44	21.33000	-20.68000	Radiosonde
PS69/27472	2007-04-26T10:59	25.32000	-18.39000	Radiosonde
PS69/27473	2007-04-28T10:29	31.06000	-14.13000	Radiosonde
PS69/27474	2007-04-28T21:50	33.38000	-13.49000	Radiosonde
PS69/27475	2007-04-29T10:10	35.86.000	-12.79000	Radiosonde
PS69/27476	2007-04-29T21:29	38.12000	-12.14000	Radiosonde
PS69/27477	2007-04-30T10:54	40.84000	-11.32000	Radiosonde
PS69/27478	2007-05-01T14:11	45.98000	-8.89000	Radiosonde
PS69/27479	2007-05-01T20:54	47.14000	-7.55000	Radiosonde
PS69/27480	2007-05-03T11:09	51.42000	2.10000	Radiosonde
PS69/27481	2007-05-03T20:08	52.75000	4.14000	Radiosonde

Die "Berichte zur Polar- und Meeresforschung"
(ISSN 1866 - 3192) werden beginnend mit dem Heft Nr. 377 (2000) in Fortsetzung der früheren "Berichte zur Polarforschung (Heft 1-376, von 1982 bis 2000; ISSN 0176 - 5027) herausgegeben. Ein Verzeichnis aller Hefte beider Reihen befindet sich im Internet in der Ablage des electronic Information Center des AWI (ePIC) unter der Adresse http://epic.awi.de. Man wähle auf der rechten Seite des Fensters "Reports on Polar- and Marine Research". Dann kommt eine Liste der Publikationen und ihrer online-Verfügbarkeit in alphabetischer Reihenfolge (nach Autoren) innerhalb der absteigenden chronologischen Reihenfolge der Jahrgänge.

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