EPICA-Netherlands Atmospheric Boundary Layer Experiment (ENABLE)

Kohnen and Neumayer stations
December 2001-March 2002

Institute for Marine and Atmospheric Research
Utrecht University, The Netherlands

Contents

***Front cover**. Emperor penguin rookery in Atka Bay, near Neumayer station, East Antarctica (photo by Robert Metzig, AWI). This picture was taken on 15 May 2001, one week before the beginning of the polar night at Neumayer.*

List of acronyms

ABL	Atmospheric Boundary Layer
AWS	Automatic Weather Station
CIO	Centre for Isotope Research (Groningen University)
DML	Dronning Maud Land
ENABLE	EPICA-Netherlands Atmospheric Boundary Layer Experiment
EPICA	European Project for Ice Coring in Antarctica
GISP	Greenland Ice Sheet Project
GPS	Global Positioning System
GRIP	Greenland Ice Coring Project
GTS	Global Telecommunication System
GOFISH	GPS Observations for Ice Sheet History
HM	Height Meter (stand-alone sonic height ranger)
IMAU	Institute for Marine and Atmospheric Research (Utrecht University)
m asl	Meters above mean sea level
KNMI	Royal Netherlands Meteorological Institute
NWO	Netherlands Organization for Scientific Research
SL	(Atmospheric) Surface Layer (lowest 10% of the ABL)
VU	Free University of Amsterdam
w.e.	water equivalents

Map of Dronning Maud Land, East Antarctica

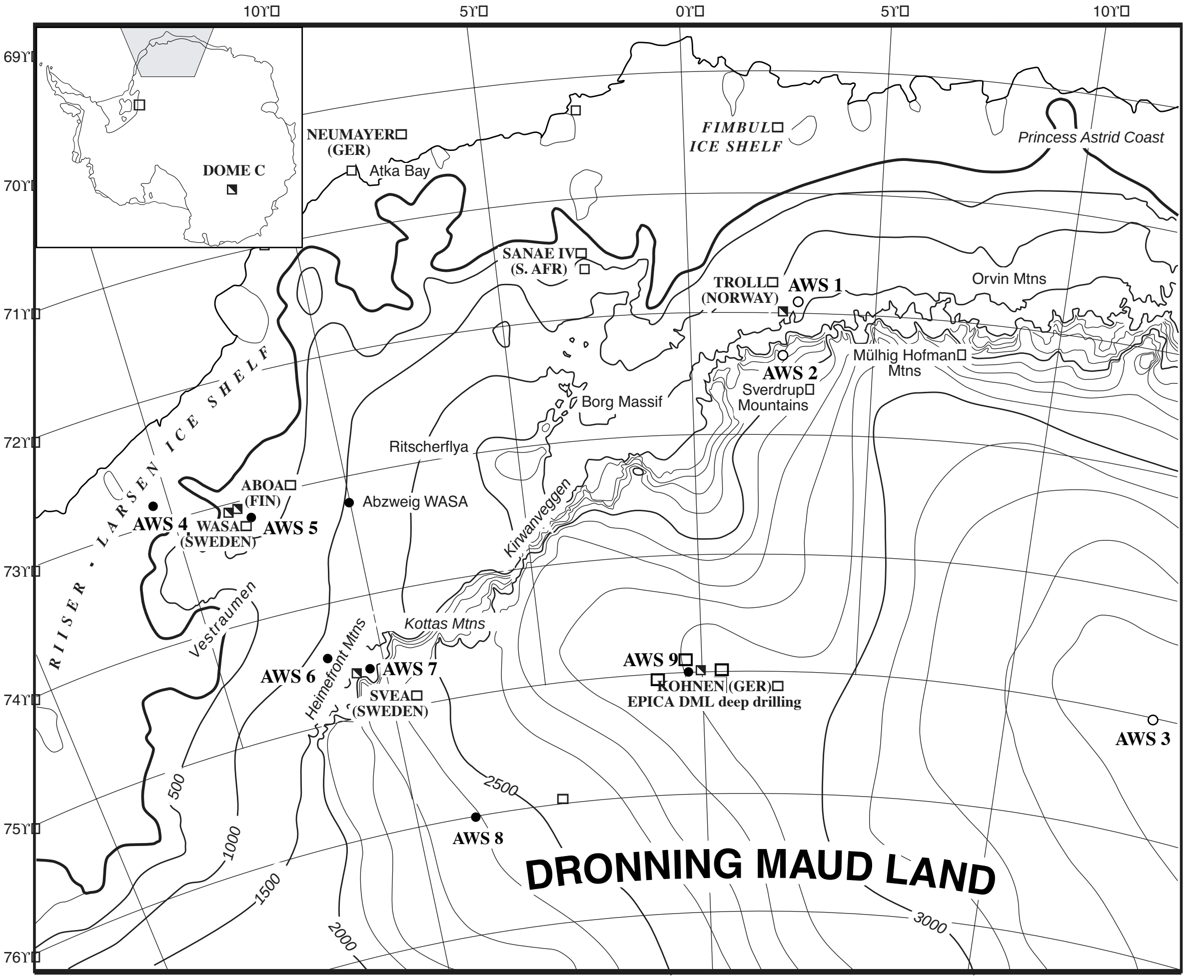

Fig. 1. Dronning Maud Land, East Antarctica, with the locations of summer stations (half-filled squares), year-round stations (open squares), IMAU AWS in operation (black dots), IMAU AWS no longer in operation (white dots; AWS1, AWS2 and AWS 3 were removed in the 2000/2001 season). A new AWS is planned near Troll at the old location of AWS 1.

Introduction

This field report describes Antarctic field activities of scientists from the Institute for Marine and Atmospheric Research, Utrecht University (IMAU) in the austral summer of 2001/2002. These activities took place in the framework of the Netherlands contribution to the European Project for Ice Coring in Antarctica (EPICA), a scientific programme funded by the European Commission and by national contributions from Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom. In EPICA it is envisaged to retrieve two deep ice cores from the East Antarctic plateau: one from Dome C in the Pacific sector of Antarctica and one from Dronning Maud Land (Fig. 1). The age of the ice from the Dome C drilling, which reached 2871 meters at the end of the 2001/02 season, is already the oldest ice seen by man to date. With improved analysis techniques this core should support and expand the interpretation of the Vostok and other deep Antarctic ice core records. The Dronning Maud Land (DML) core, drilled in a region where the annual accumulation is considerably higher than at Dome C (71 vs. 30 mm w.e.), will hopefully yield details of the transition between the last glacial period and the Holocene. Being situated in the Atlantic section of Antarctica, it should also make a connection with climate records from ice cores drilled on the Greenland Ice Sheet (GISP/GRIP).

The present Netherlands contribution to EPICA, EPICA-NL-2, consists of three components:

- GPS observations for ice sheet history reconstruction (EPICA-NL-2A, project acronym GOFISH, 1999-2002). This component had its first field season in 1999/2000 and its second field season in 2001/02 (for logistical reasons one year later than planned). Apart from the GPS related work and a paleoclimatological reconnaissance, GOFISH also acted in support of the maintenance of AWS's 4 to 7 in the Wasa/Aboa area.
- In the season 2000/2001, two medium deep ice cores and several shallow firn cores were drilled along a traverse line from the coast via the Norwegian station Troll to the inland plateau in eastern DML (EPICA-NL-2B, 2001-2004). This traverse was a follow-up of the 1996/1997 Norwegian EPICA pre-site survey (Van den Broeke *et al.*, 1999). No field activities took place in 2001/02.
- In the season 2001/02, a meteorological experiment was performed at Kohnen station, the site of the deep EPICA drilling in DML (EPICA-NL-2C, project acronym ENABLE, 2001-2004). This component, originally planned for the season 2000/2001 as a collaboration between IMAU and the VU, has been modified with respect to the original proposal for logistical constraints. EPICA-NL-2C includes the maintenance of IMAU AWS in DML.

Because ENABLE and GOFISH activities in 2001/02 took place in different parts of Dronning Maud Land, each having logistic support from different countries, they are described in separate reports.

EPICA-Netherlands Atmospheric Boundary Layer Experiment (ENABLE)

Kohnen and Neumayer stations, December 2001-March 2002

Michiel van den Broeke, Dirk van As, Willem Boot, Henk Snellen

Travel itinerary

After a period of comprehensive pre-site surveys, including detailed accumulation and bedrock-topographic studies (Steinhage *et al.*, 1999; Oerter *et al*, 2000), the location of the EPICA deep drilling in DML was fixed at 75° 00.15’ S, 0° 04’ E at an elevation of 2892 m asl. To accommodate the drilling operation, Kohnen station was built and officially opened on January 11^{th}, 2001 (Fig. 2). The station consists partly of living containers from the former Filchner station, that was evacuated from an iceberg that broke off the Filchner Ice Shelf in 1998. As part of the first drilling season in 2001/02 and in accordance with the original EPICA proposal, IMAU carried out a meteorological experiment at Kohnen station in support of the interpretation of the DML deep ice core.

Fig. 2. Kohnen station (Germany) at the site of the EPICA deep drilling in DML, East Antarctica. (photo Wim Boot).

During the months preceding the experiment, Henk Snellen (equipment and electronics at IMAU) prepared, tested and packed the meteorological equipment in Utrecht, after which it was shipped to AWI in Bremerhaven on October 17th, 2001 and loaded onto the research vessel Polarstern. On November 7th the Polarstern left for Cape Town, South Africa, where the expedition participants from IMAU, Michiel van den Broeke (field leader), Willem Boot (equipment and electronics) and Dirk van As (PhD student) boarded on December 1st. At 20 UTC the same day, Polarstern left Cape Town heading for Atka Bay, the unloading site near the German Antarctic station Neumayer (70° 39’ S, 08° 15’ W, Fig. 1). This marked the start of the first leg of cruise FS "POLARSTERN" ANT XIX/2 from Cape Town to Punta Arenas. On board were 74 scientists, mainly from Germany, but also from Denmark, France, Iceland, Italy, Japan and the Netherlands. Of these, 27 had Kohnen station as destination.

Fig. 3. R/V Polarstern unloading on sea ice on December 21st, 2001. Photo: Sepp Kipfstuhl, AWI.

Already on December 4th the first large icebergs were spotted, and three days later the sea ice edge was encountered at 58° 30' S. This is unseasonably far to the north, and it proved a harbinger of the difficult sea ice conditions ahead. On the envisaged day of arrival, December 10th, the first real icebreaking action took place, in which Polarstern had to move back and forth to break the ice. During the following night, progress has slowed to a crawl, with 100 km still to go to Atka Bay. Not before a southerly wind broke up the coastal ice on December 18th could Polarstern reach the ice shelf, close to but not in Atka Bay. After unloading fuel on the shelf, Polarstern reached a sea ice harbour some 40 km to the northeast of Neumayer, and on December 20th unloading activities could finally start (Fig. 3).

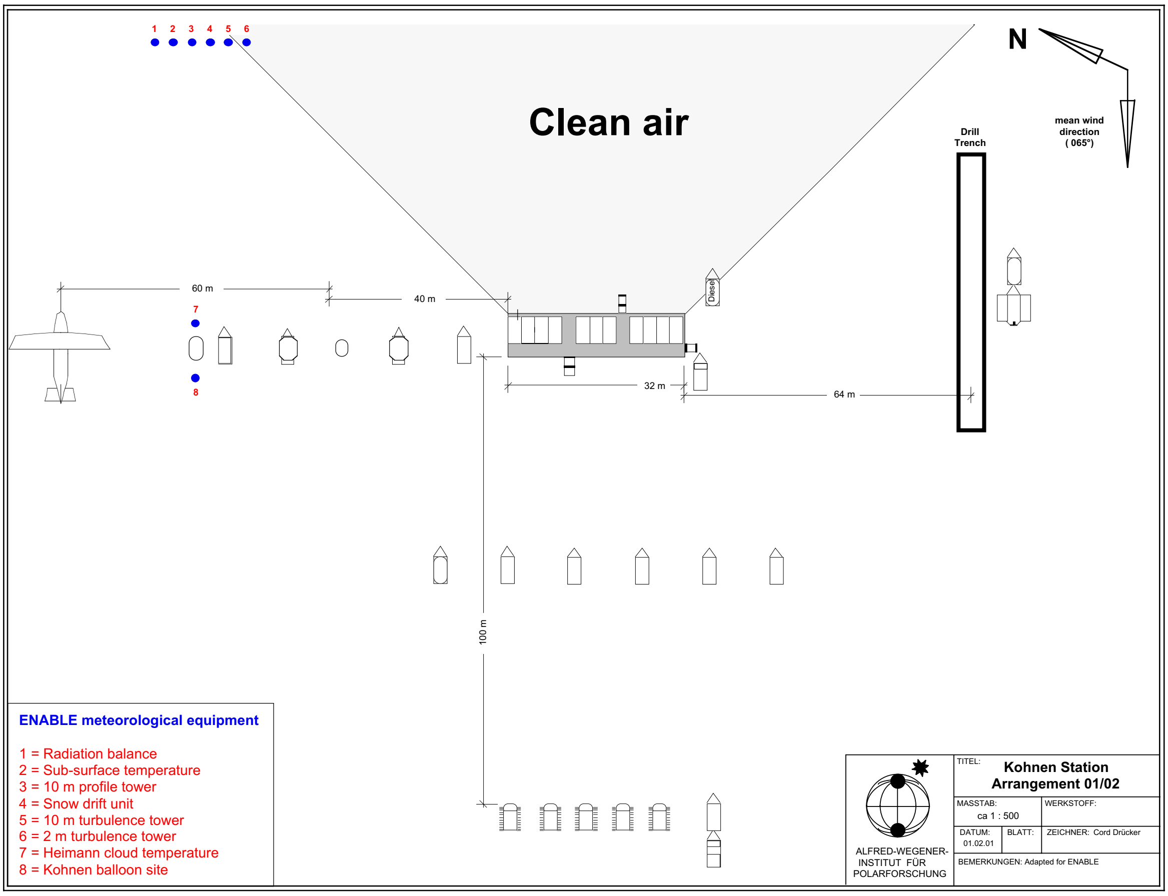

Fig. 4. Layout of Kohnen station and the various measurement sites of the meteorological experiment, highlighted in colour. Adapted from the original drawing by C. Drücker, AWI.

On December 22nd, all Kohnen personnel was flown to Neumayer by helicopter. The ground traverse to Kohnen (700 km, 9 –10 travel days) left Neumayer on December 26th, 2001; among the 10 traverse personnel was Dirk van As who installed a meteorological station and snowdrift unit close to Abzweig WASA, 270 km south of Neumayer (Fig. 1). The activation of Satellite Station 1 in the night of December 29th, 2001, marked the official start of ENABLE 2001/02. Van As, together with a German colleague, also measured 1005 accumulation stakes (bamboo poles) that mark the route between Neumayer and the Kottas Mountains, as part of a long-term accumulation study. The traverse arrived at Kohnen station on January 3rd after which the station was quickly made operational. Wim Boot and Michiel van den Broeke were flown in from Neumayer by Dornier aircraft POLAR 4 on January 4th and 5th 2002, respectively.

After the experiment at Kohnen ended and all equipment was packed, the participants were flown back to Neumayer on February 13th. At Neumayer, Satellite Station 2 was re-installed with a snowdrift unit to measure until February 27th. The South-African vessel S/A Agulhas picked up the expedition members on March 3rd, and Cape Town was reached on March 12th. The participants arrived back in Amsterdam on March 14th, where they were reunited with their families and friends after an absence of 105 days.

Experiment timetable

The following timetable lists the sequence of activities during the meteorological experiment at Kohnen, January 6th to February 13th, 2002. For the location of the various measurement locations, see Fig. 4.

January 6th	*Equipment taken out of transport container and stored in tent.*
January 7th	*10 m profile tower, radiation set-up at Kohnen operational. Start of synoptic observations (clouds, weather and snow drift).*
January 8th	*Heimann cloud temperature sensor at Kohnen site operational. Test of radiosonde system and start of radiosonde program.*
January 9th	*Installation of snowdrift sensors at Kohnen site. Low sonic mast operational. Start with erection of 10 m turbulence mast.*
January 10th	*Bad weather, no outdoor activities.*
January 11th	*Bad weather. Installation of snow temperature sensors at Kohnen site.*
January 12th	*10 m turbulence mast at Kohnen site operational.*
January 13th	*Installation of Satellite Station 2 close to new site of AWS 9, about 1.7 km east of Kohnen. This set-up includes a snowdrift unit. Start with sampling program for oxygen isotope studies, 1.20 m pit close to new site of AWS 9.*
January 16th	*Test of cable balloon system.*
January 17th	*Installation of wind generator at new AWS 9 site for heating the Argos transmitter. 1.20 m pit sampled at old location of AWS 9 for isotope studies.*
January 20th	*Excavation of AWS 9 and relocation to new, less disturbed site app. 150 m NE of old site. New sensors fitted and new datalogger software installed.*
January 21st	*Memory modules of stand-alone height meters no.'s 1 and 2 exchanged. Sampling for oxygen isotopes at these sites (down to 0.4 m) for isotope studies.*
January 22nd	*Memory modules of stand-alone height meter no. 3 exchanged. Sampling at this site (down to 0.4 m) for isotope studies.*
January 23rd	*Computer repairs.*
January 25th	*Last pit,1.5 km NW of Kohnen, 1.2 m depth; end of sampling program.*
January 26th	*Start of intensive cable balloon program.*
January 28th	*Final installation of new AWS 9 at new site.*
February 4th	*Satellite Station 2 taken down for transport to Neumayer.*
February 9th	*Last full measurement day at Kohnen site.*
February 10th	*Intercomparison of sensors at Kohnen site for profile masts and tethersondes.*
February 11th	*Start of packing scientific equipment.*
February 12th	*Tent taken down and packed.*
February 13th	*All equipment in container, participants flown to Neumayer.*
February 14th	*Re-erection of satellite station 2 at Neumayer.*
February 19th	*Satellite station 1 at Abzweig Wasa taken down by traverse personnel.*
February 26th	*Satellite station 2 at Neumayer taken down.*

Preliminary results

General meteorological conditions

Fig. 5 shows 2 m temperature and wind chill, 10 m wind speed and direction, cloudiness and occurrence of drifting/blowing snow (snow suspended below/above eye level, respectively). Shortly after the start of the experiment, Kohnen was hit by a storm on the 10th and 11th of January, bringing strong northerly winds, high temperatures and whiteout conditions. After that the weather improved but winds remained generally strong for another week. The third and fourth week brought calmer weather and continued cooling. The last week at Kohnen was variable with occasional clouds and snowdrift. During the experiment the lowest 2 m temperature was –43 °C on February 7th. However, –46 °C was measured on the day of departure from Kohnen, February 13th.

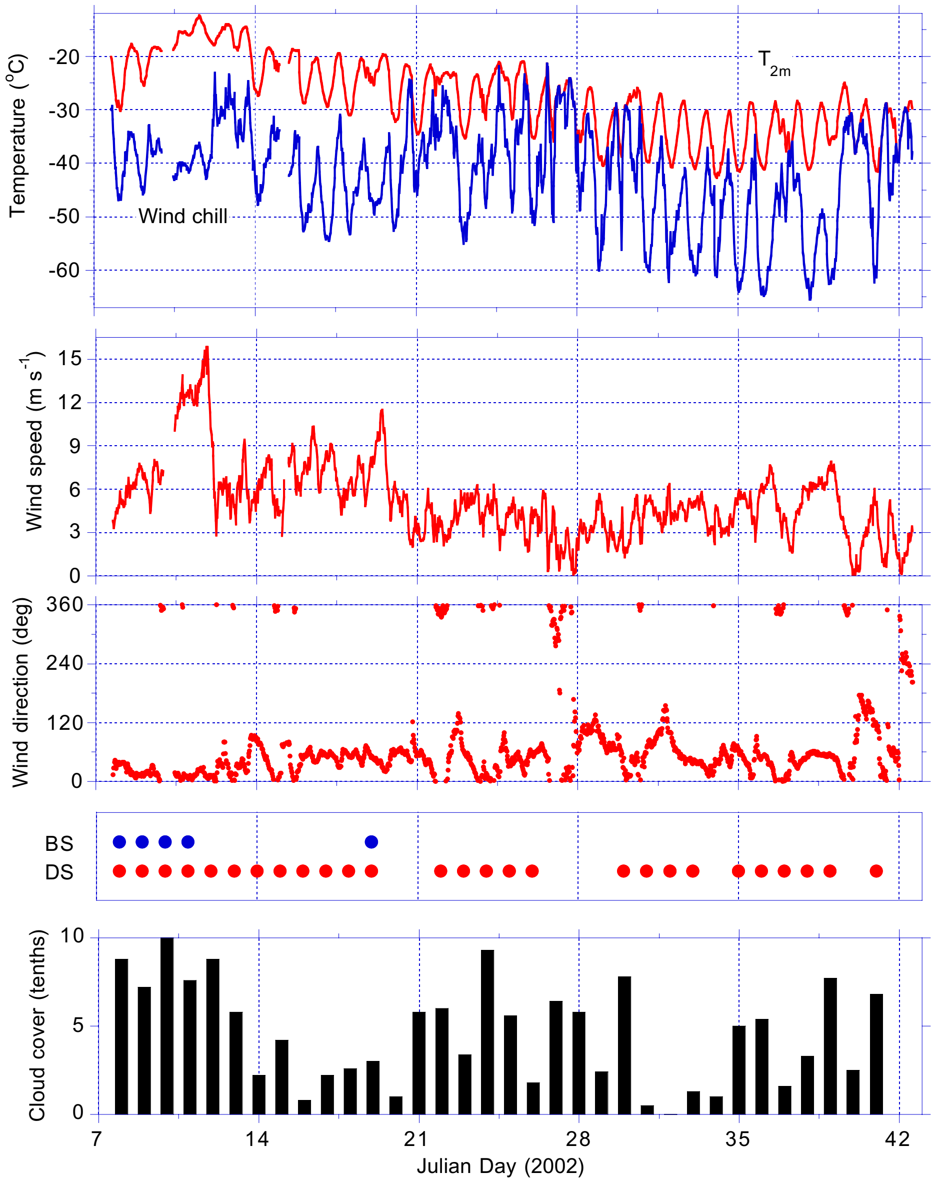

Fig. 5. Temperature at 2 m, wind chill, 10 m wind speed and direction, cloudiness and occurrence of drifting (DS) and/or blowing snow (BS) at Kohnen, 7 January to 10 February 2002.

Profile tower

A 10 m profile tower was erected at Kohnen to measure wind speed, temperature and relative humidity at app. 0.5, 1, 2, 5 and 10 m above the surface. These data show the structure of the surface layer (the lowest 10% of the ABL) and can be used to calculate the surface turbulent fluxes of sensible and latent heat and to validate and improve the SL representation in mesoscale/regional/global meteorological models over Antarctica.

An example of wind and temperature observations at 0.5, 2 and 10 m for some clear days is shown in Fig. 6. The surface-based temperature inversion that develops at night makes the SL more stable and partly decouples the upper atmosphere from the near surface air. As a result, friction is reduced at higher levels and at 10 m the wind speed increases. Close to the surface, the air decelerates as a result. Around noon, the temperature inversion is briefly destroyed, resulting in a well mixed surface layer in which the wind speed profile is less curved.

The profile tower instruments generally worked well. Datalogger problems caused a data gap of half a day on January 10th. On several occasions icing hindered correct functioning of the sensors, while power failures caused ventilation of the temperature/relative humidity sensors to cease on two occasions.

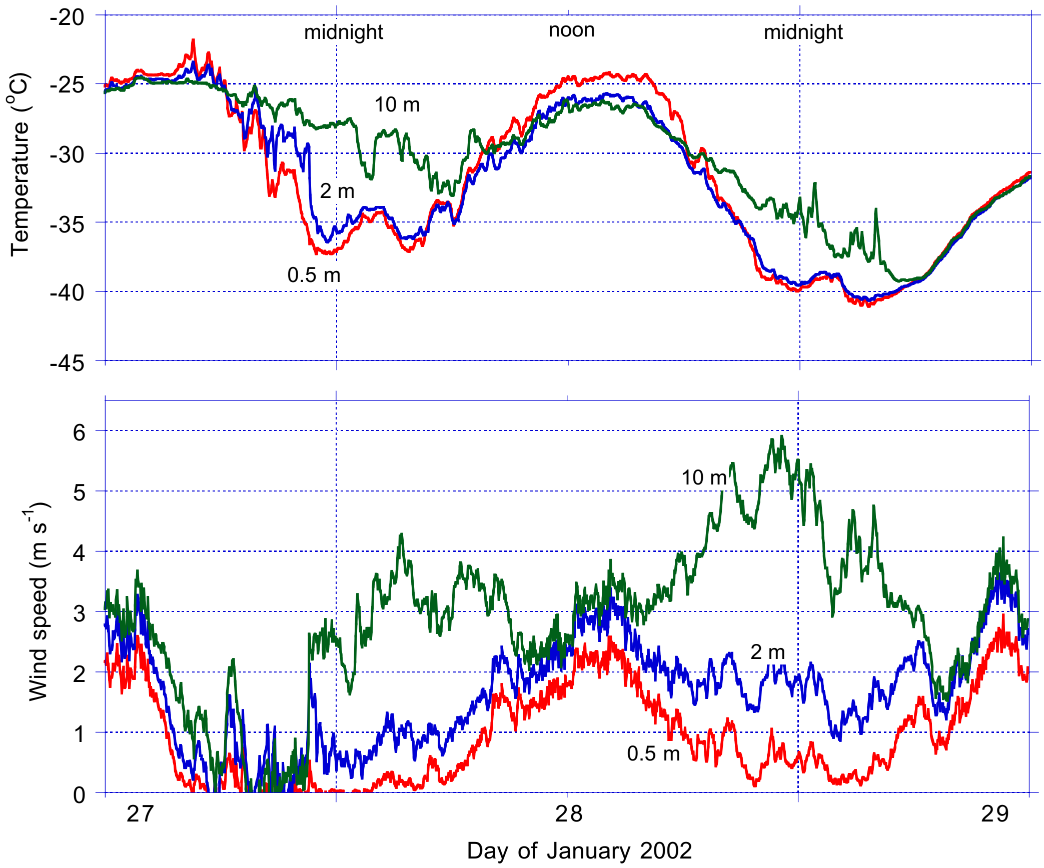

Fig. 6. Temperature and wind speed at 0.5 m, 2 m and 10 m (uncorrected) from the profile tower at Kohnen site, 27 to 29 January 2002.

Radiation balance

The radiation balance at Kohnen site was measured using a Kipp en Zonen CM14 albedometer for incoming and reflected shortwave radiation and two Eppley PIR2's for longwave radiation. These measurements serve two purposes: direct observation of the surface radiation balance and testing of the performance of the Kipp en Zonen CNR1. The latter sensor combines measurement of all four radiation components in one housing and is used in the IMAU AWS in Antarctica.

An unexpected problem occurred with the upward looking sensor of the CM14, which appeared to be very susceptible for rime formation on the outer glass dome. The problem was probably caused by the lower temperature of the dome compared its surroundings, enhancing ice crystal growth on its surface under moist conditions. The problem did generally not affect the downward looking sensor or both shortwave sensors of the CNR1 (which have a single dome). If the Kipp en Zonen CM14 is to be used as a reference on the Antarctic plateau in the future, heating and ventilation must be therefore be applied.

Fig. 7 compares incoming and outgoing longwave radiation as measured by the Eppley PIR2 and the Kipp en Zonen CNR1 for sunny and cloudy conditions. The CNR1 performed well under cloudy conditions. Errors are larger when the direct solar beam hits the CNR1 incoming radiation sensors, but under all conditions the absolute difference remained smaller than 10 – 15 W m^{-2}. Given this and the fact that icing did not strongly affect the Kipp en Zonen CNR1 this sensor appears to be a good choice for application on Antarctic AWS.

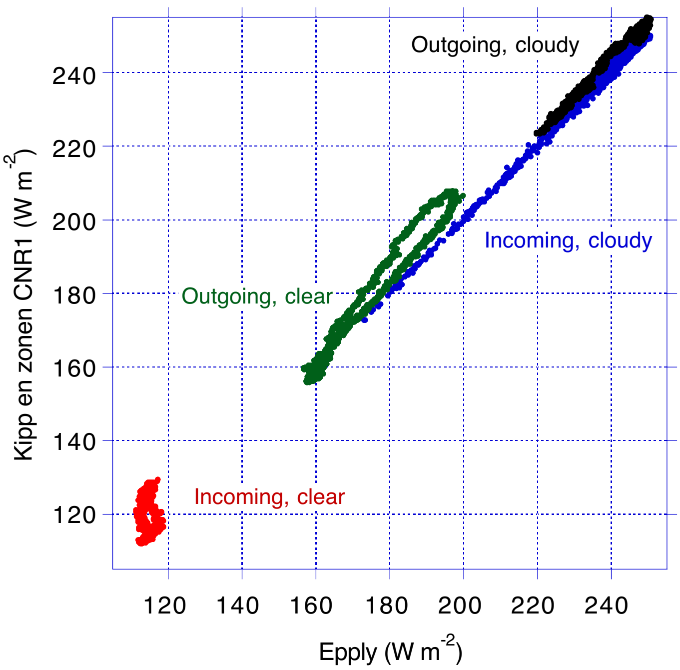

Fig. 7. Comparison of measured longwave radiation by two sensors (uncorrected data): Kipp en Zonen CNR1 (vertical axis) and Eppley PIR2 (horizontal axis), for a sunny day (January 31st) and a cloudy day (January 10th, 2002) during ENABLE.

Tethersondes

A system consisting of a zeppelin balloon filled with Helium 4.6 carrying a maximum of 5 tethersondes was used to gauge the atmosphere between the surface and 400 to 600 m. The tethersondes measure air pressure, temperature, relative humidity, wind speed and direction. The wind speed limit for this system is about 15 m s^{-1}, so it could be used in an intensive fashion only during the last weeks of the experiment. During the period January 26th to February 9th, every three hours at 03, 06 09 UTC etc. a vertical profile was measured with one tethersonde. In between these soundings, five tethersondes measured simultaneously at vertical spacing of 20 to 40 meters, depending on weather conditions and time of day. The balloon of type AIR TSB-9 (9 m^3) was found unsuitable because of helium loss; fortunately, the Cameron 12 m^3 blimp performed much better in that respect. Its more limited lifting power (because of its greater weight) posed no serious problems and heights up to 500 m could usually be attained with a single sonde, which is sufficient to probe the thin Antarctic ABL.

An example of tethersonde-measured vertical profiles of temperature and wind speed is given in Fig. 8. The thickness of the lines represents the difference between ascent and descent, either caused by sensor hysteresis and/or real tendencies. Clearly visible is the surface based nocturnal temperature inversion and the associated katabatic flow which has a well defined wind speed maximum in the lower ABL. At noon the temperature inversion decreased in strength under the influence of heat input from the surface, and so does the katabatic wind. Note that when the cold ABL air is mixed upward through the ABL top, the layer above it cools by several degrees.

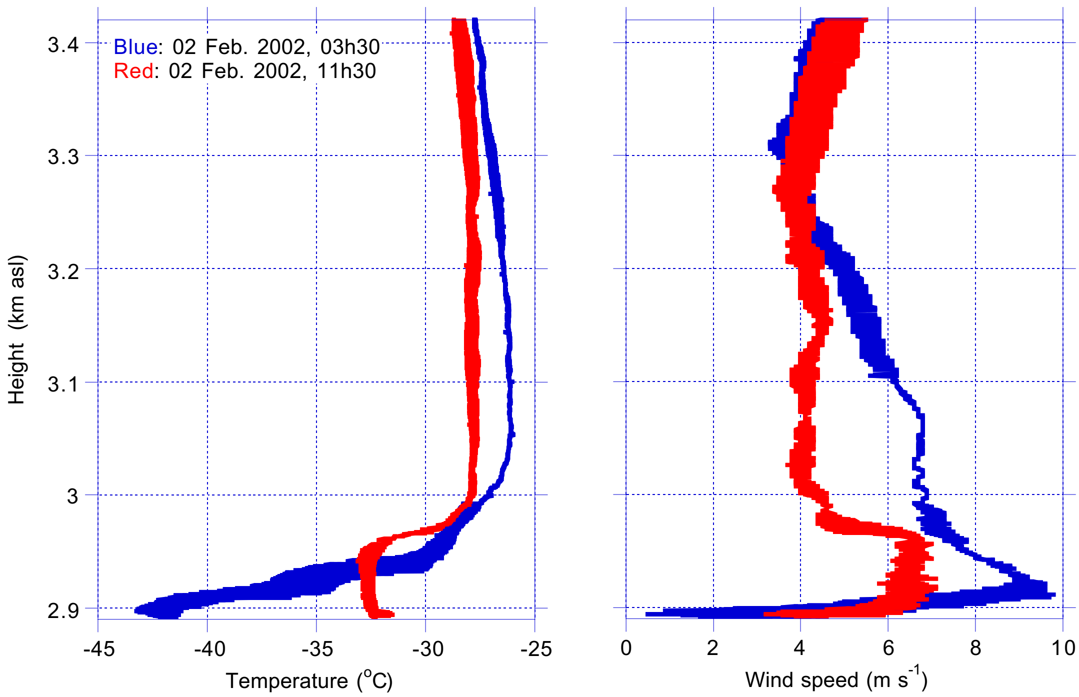

Fig. 8. Tethersonde profiles of temperature (left) and wind speed (right) for a nocturnal (03h30 UTC) and a daytime sounding (11h30 UTC), February 2nd, 2002.

Radiosondes

Radiosondes were released twice a day at app. 10h30 UTC and 22h30 UTC to monitor the vertical structure of the lowest 10-20 km of the atmosphere. Radiosonde profiles enable a correct interpretation of the large scale weather situation and play a major role in the validation of numerical weather prediction models. We used the Vaisala Digicora MW15 in research mode, i.e. without data editing, in combination with the RS-90 AG radiosonde (analogue sonde with GPS wind finding). To carry the balloon, 200 g latex balloons were used, filled with app. 1.5 m^3 He. In general the system worked well with stable reception of the radiosondes up to 23 km. In total, 68 balloons with radiosondes were released in the period January 8^{th} to February 11^{th}, 2002. It was found that the frequency at which the radiosondes operate (app. 403 MHz) interferes with the tethersonde system, leading to loss of radio contact when both systems operate simultaneously. That is why changes in the above mentioned time schedule were made during the period in which both systems were in use.

An example of radiosonde-measured profiles of temperature and humidity during three consecutive days (9-11 January 2002) is given in Fig. 9. This was a period of strong winds and snow drift at Kohnen; it is clearly visible how during this event the large scale northerly winds warmed and moistened the troposphere. Note the lower specific humidity in the lowest km, associated with dry air advection in the ABL.

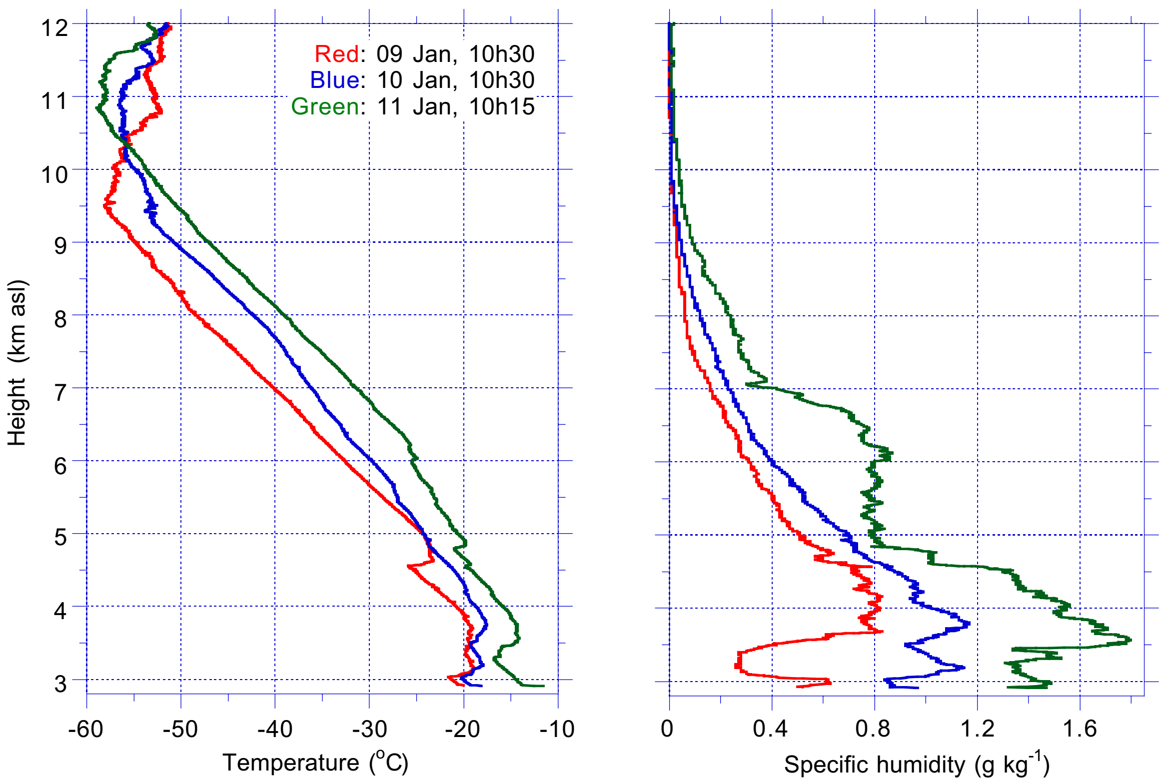

Fig. 9. Tropospheric temperature and specific humidity profiles for a 3-day period of strong northerly advection at Kohnen, 9-11 January 2002.

Turbulence masts

The 10 m mast at Kohnen was equipped with sonic anemometers at 2 and 10 m, 2 Lyman-α humidity sensors at 2 m (of which one was adapted for dry Antarctic conditions) and thermocouples at app. 0.5, 1, 2, 5 and 10 m. All sensors were sampled at 20 Hz by a Campbell 9000 datalogger, yielding 81 Mb of data per day. On the low mast was mounted at 2 m an identical sonic anemometer with thermocouple, sampled at 8 Hz with an ordinary Campbell CR10 datalogger; this logger uses a dedicated turbulence routine that directly calculated and stored 10 minute averages of all flux components.

Two of the three sonic anemometers were sent to the factory in the USA for low-temperature calibration. In spite of this, all three sonic anemometers stopped working below –37 to –40 °C (software controlled), which meant considerable data loss at the end of the measuring period. One Lyman-α was especially adapted for the very dry Antarctic atmosphere by increasing the distance between the measuring arms; this sensor proved capable of measuring specific humidities down to 0.05 g kg^{-1}. The unadjusted Lyman-α was not able to measure well below specific humidities of 0.12 g kg^{-1}. The thermocouples were found to be susceptible to icing. Even though the ice usually could be carefully shaken off, it was hard afterwards to tell when exactly which sensor had been iced, rendering the use of these data for flux calculations uncertain.

Fig. 10 shows an example of measured flux of sensible heat at 2 m from the ‘fast’ turbulence mast. In this period of weak winds, the flux is small but has a pronounced daily cycle, with a downward directed flux in the night and convection around noon. This enables the formation of a shallow mixed layer as observed with the tethered balloon (see p. 12). These data will be compared to fluxes measured by the ‘slow’ sonic and fluxes calculated from the profile measurements. This comparison will hopefully tell us whether the ‘slow’ set-up is sufficient for flux observations at Antarctic AWS.

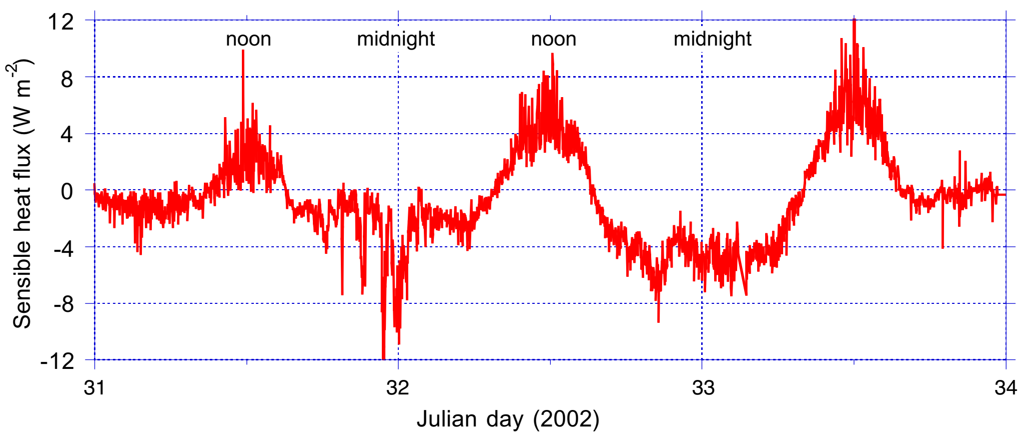

Fig. 10. Sensible heat flux observed with sonic anemometer at 2 m, sampled at 20 Hz.

Snowdrift observations

Three snowdrift units, each consisting of three particle impact sensors mounted at app. 20, 50 and 100 cm above the surface, were installed at the Kohnen meteorological site and at the locations of the two satellite stations. The snowdrift units, developed at AWI and IsiTec, measure total amount as well as impact strength of snow particles cumulated over a period of 30 s. Based on these measurements and an extrapolated wind speed profile, horizontal drifting snow flux can be calculated. Because of the relatively large power requirement of the snowdrift units (0.5 A), three dedicated solar panels with battery buffer were installed at both satellite locations. In the beginning of the season repairs were needed due to a loose connection in one of the sensors and a malfunctioning datalogger unit. Otherwise, the snowdrift equipment worked well and produced interesting data, more so because snow drift appears to be a frequent phenomenon at Kohnen (Fig. 5).

Fig. 11 shows the number of particle impacts per 30 s at Kohnen site during the first week of the experiment, together with 1 m wind speed from the profile tower. Clearly, snow drift increases exponentially with wind speed once a threshold value (in this case about 5 m s^{-1} at 1 m) is passed. This event produced large sastrugis in the camp.

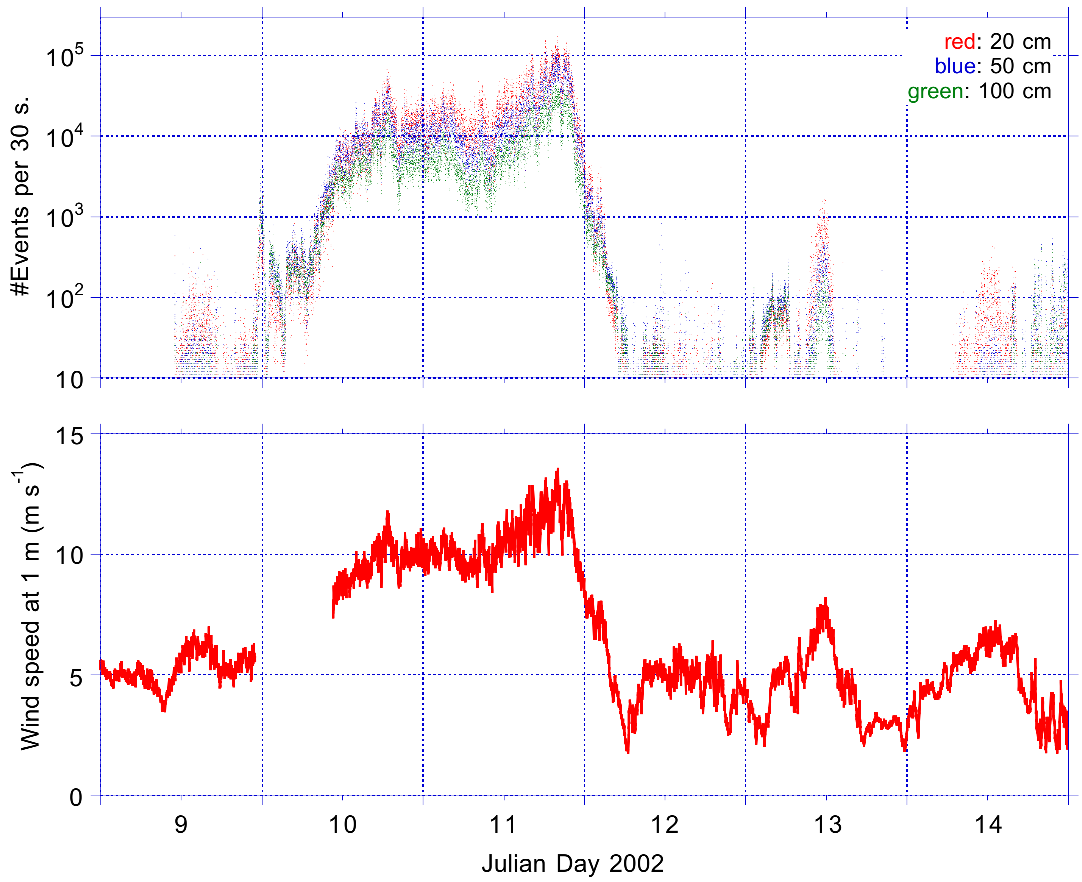

Fig. 11. Number of particle impacts per 30 s at Kohnen at 20, 50 and 100 cm (upper panel) and 1 m wind speed (lower panel). Note logarithmic scale in upper panel.

Sub-surface temperatures

A potentially important component of the surface energy balance is the sub-surface heat flux. In a homogeneous medium (which is a good approximation for the top few cm of the Antarctic snow pack) this flux is mainly driven by vertical temperature gradients. At Kohnen site, temperatures in the snow pack were measured initially at depths of 5, 10, 20, 40 and 80 cm. Later in the period, this was changed to 5, 10, 20, 30 and 40 cm. Unfortunately, it was discovered quite late that a faulty datalogger recorded erroneous temperatures; during the period January 16-27th 2002, sub-surface temperatures below 10 cm are therefore unreliable.

An example of successfully measured sub-surface temperatures is presented in Fig. 12. They clearly show how the upper snow layers respond to the daily cycle of the surface temperature, while the deeper layers respond more slowly and rather reflect the gradual cooling of the snow pack.

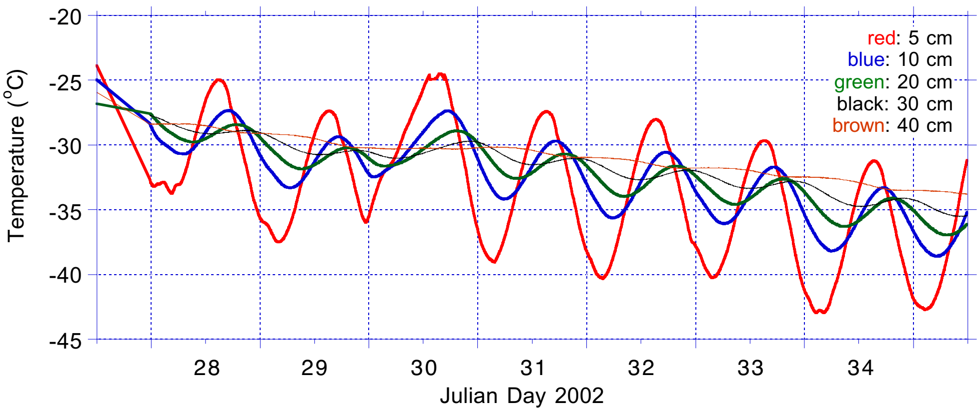

Fig. 12. Sub-surface temperatures for the period January 27th to February 4th, 2002.

Satellite stations

Two meteorological stations were installed outside of the direct surroundings of Kohnen. One was erected on December 29th, 2001, at 72° 48' S, 9° 30' W. This is 17 km north of Abzweig Wasa, a waypoint along the traverse between Neumayer and Kohnen at an altitude of app. 1050 m asl (Fig. 1). This station should improve the interpretation of the differences between the climates of the coast and the plateau. Satellite Station 2 was set up in between the old and the new locations of AWS 9, app. 1.7 km west of Kohnen. This station replaced the AWS during the period that it was out of order for excavation and relocation. Both satellite stations were equipped with two wind speed levels in support of snow drift observations. At February 4th Satellite Station 2 (including the snowdrift unit) was taken down and flown to Neumayer a few days later. There it was erected again on February 14th, where it measured until February 27th. Satellite station 1 was taken down by traverse personnel on February 19th.

Cloud radiation temperature

A Heimann sensor that measures radiation temperature in the wavelength band of the atmospheric window was borrowed from KNMI and installed close to the Kohnen balloon site (Fig. 4). Although the equipment worked generally without problems, a disadvantage was that the data logger had to be restarted after each power cut that lasted longer than 15 seconds; these power cuts were frequent (once every one or two days) in relation to generator maintenance. Because no equipment was brought to download the memory cards, no data were available for inclusion in this report.

Maintenance of AWS 9

AWS 9, situated approximately 1.7 km east of Kohnen base, has been in operation since December 1997 when it was installed by AWI personnel. Since then, AWI yearly changed sensors, updated datalogger programs and read out the data from the internal logger. In the 2001/02 season, after four years of operation and about 1 m of accumulation, the highest beam of the AWS protruded only 1.5 m above the surface, and it was decided to excavate the station and move it app. 150 m to the NNE. This was necessary to keep the AWS away from the artificial accumulation effects of two radar reflectors at the old AWS site. New sensors were fitted and the logger program updated.

In addition to the regular maintenance, a wind generator was installed to produce heat for the ARGOS transmitter, which stops working when the temperature in the logger box drops below –55 °C. Temperatures measured in the logger encasing (Fig. 13) suggest that the heating system works well: when wind speeds at the AWS exceed about 4 m s^{-1}, the wind generator produces sufficient heat to quickly heat up the internal part of the datalogger box to about + 5 °C. After that, excess heat is dissipated in open air in a resistance module fitted to the wind generator mast. With the new setup we hope that data of AWS 9 will soon be available from GTS for year-round logistic operations and forecasting applications.

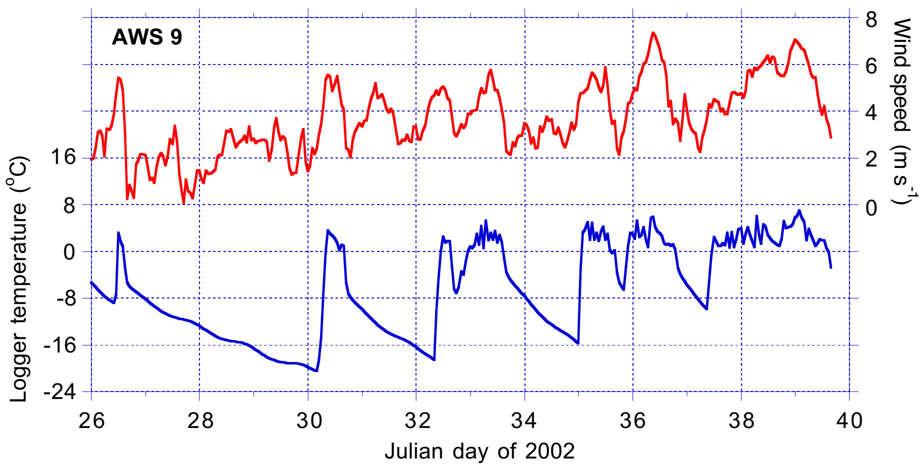

Fig. 13. Wind speed and logger temperature at AWS 9.

Maintenance of HM's1-3

To quantify the variability in space and time of accumulation events, three stand-alone sonic height meters (HM's) were installed in the season 1999/2000 by AWI personnel, each with a distance of 1 km from the old position of AWS 9. In 2001/02 the memory modules of these stations were exchanged for the second time. A first look at the data revealed data gaps during the 2001 winter. No obvious cause could be found, so the problem could not be solved on the spot. It is considered to have new sensors installed next year if it is decided that the measuring program should continue.

Sampling for isotope studies

Linking isotope values of oxygen and deuterium in the snow pack to atmospheric parameters could help us understand how isotopic information of infrequent snowfall events is stored in the deep DML ice core. In January 2002, AWS 9 had been operational for 4 years during which close to a meter of snow had accumulated; we dug three snow pits of 1.20 m depth -one directly underneath the height meter of AWS 9- to penetrate these four year layers. The same was done underneath the three stand-alone height meters; here, 40 cm pits were sufficient to reach the horizon of their installation date in January 1999. In all snow pits samples were taken every 1.5 cm to obtain over 10 samples in an annual layer. One profile was taken at higher resolution (1 cm). The samples will be sent to the CIO in Groningen for analysis. Density was measured at 2.5 cm resolution using a hollow pipe of 5 cm diameter at alternating depths.

Fig. 14. Snow sampling for oxygen isotope studies (photo Wim Boot).

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Appendix A: Equipment and sensor specifications

10 m profile tower

Equipment description:	10 m aluminium mast with 5 measurement levels. Local data storage on Campbell CR10 data logger with memory card.
Location:	Kohnen meteorological site.
Period of operation:	January 7th 2002 to February 11th 2002.
Measurement height:	Wind speed, temperature and humidity sensors at app. 0.5, 1, 2, 5, 10 m. Wind direction at 2 and 10 m.
Sampling frequency:	Temperature, humidity, wind direction: instantaneous, every 2 min. Wind speed: every 2 min, cumulative (pulse counting).

Sensor	*Type*	*Range*	*Accuracy*
Air temperature	Vaisala HMP35AC	-55 to +49 °C	0.2 °C
Relative humidity	Vaisala HMP35AC D probe	0 to 100 %	2 % (RH < 90 %) 3 % (RH > 90 %)
Wind speed	Vector A100R	0.2 to 60 m s^{-1}	0.1 m s^{-1}
Wind direction	Vector W200P	0 to 360°	2°

Radiation balance

Equipment description:	Low mast with two sensor beams. Local data storage on Campbell CR10 data logger with memory card.
Location:	Kohnen meteorological site.
Period of operation:	January 7th, 2002 to February 11th, 2002.
Measurement height:	Sensors mounted at app. 1.3 m.
Sampling frequency:	Instantaneous, every minute.

Sensor	*Type*	*Spectral range*	*Accuracy*
Pyranometer	Kipp en Zonen CM14	305 to 2800 nm	2%
Pyrradiometer	Eppley PIR2	±3000 to 60000 nm	10 W m^{-2}
Pyranometer	Kipp en Zonen CNR1	305 to 2800 nm	2%
Pyrradiometer	Kipp en Zonen CNR1	5000 to 50000 nm	15 W m^{-2}

10 m turbulence tower

Equipment description:	10 m aluminium mast with 5 measurement levels. Local data storage on Campbell 9000 logger with 85 Mb memory card.
Location:	Kohnen meteorological site
Period of operation:	January 13th 2002 to February 11th 2002.
Measurement height:	2 x Lyman-α: 2 m. Sonic anemometers: 2, 10 m. Thermocouples: 0.5, 1, 2, 5 and 10 m.
Sampling frequency:	20 Hz.

Sensor	*Type*	*Range*	*Resolution*
Sonic anemometer	Campbell CSAT3-3D	u: 0 - 32 m s^{-1} v: 0 - 64 m s^{-1} w: 0 - 8 m s^{-1}	u, v: 1 mm s^{-1} w: 0.5 mm s^{-1} c: 1 mm s^{-1}
Lyman-α	KOH-3	0.12 – 3 g kg^{-1}	< 0.2 %
	KOH-3 adjusted	0.05 – 3 g kg^{-1}	< 0.2 %
Thermocouples	Campbell Chromel Constantan 75 micron	-40 to + 40 °C	0.01 °C

2 m turbulence mast

Equipment description:	2 m aluminium mast with 1 measurement level. Local data storage on Campbell CR10 data logger with memory card.
Location:	Kohnen meteorological site.
Period of operation:	January 10th 2002 to February 11th 2002.
Measurement height:	App. 2 m.
Sampling frequency:	8 Hz, storage of 10 min means.

Sensor	*Type*	*Range*	*Resolution*
Sonic anemometer	Campbell CSAT3-3D	u: 0 - 32 m s^{-1}	u, v: 1 mm s^{-1}

		v: 0 - 64 m s^{-1} w: 0 - 8 m s^{-1}	w: 0.5 mm s^{-1} c: 1 mm s^{-1}
Thermocouple	Campbell Chromel Constantan 75 micron	-40 to + 40 °C	0.01 °C

Tethersondes

Equipment description: Vaisala Tethersonde Meteorological Tower (TMT).
Receiver: AIR-5a-RCVR 395-410 MHz.
Balloons: 2 x AIR TSB-9 (9 m^3) and 2 x Cameron Blimp (12 m^3).
2 x winch: Braams Techniek, 750 W with 2 km twaron/kevlar cable.
6 x tethersonde: AIR TS-5A-SP for pressure, temperature, humidity, wind speed and direction (specifications below).

Location: Kohnen balloon site.

Period of operation: January 26th to February 9th 2002, during which 3-hourly vertical profiles were measured with 1 sonde; in between 2-hr periods in 5-sonde configuration.

Sampling frequency: In 1-sonde profiling mode: 0.5 Hz; in 5-sonde configuration, each tethersonde is sampled about every 15 seconds.

Sensor	*Type*	*Range*	*Accuracy*
Air pressure	AIR TS-5A-SP	600 to 1050 hPa	1 hPa
Air temperature	„	-40 to +50 °C	0.5 °C
Relative humidity	„	0 to 100 %	3 %
Wind speed	„	0 to 20 m s^{-1}	0.5 m s^{-1}
Wind direction	„	0 to 360°	10°

Radiosondes

Equipment description: Vaisala Radiosonde System.
Receiver: Digicora MW15 in research mode.
Balloon: 200 g Totex TA200 filled with Helium 4.6.
Radiosondes: RS-90 AG with GPS wind-finding (specifications below).

Location: Kohnen balloon site

Period of operation: January 8th 2002 to February 11th 2002.

Sampling frequency: Twice daily soundings at 10h30 UTC and 22h30 UTC.
Radiosonde sampling frequency: 0.5 Hz.

Sensor	*Type*	*Range*	*Accuracy*
Air pressure	Vaisala Barocap	2-1080 hPa	0.2 hPa
Air temperature	Vaisala F-Thermocap	-90 to + 60 °C	0.1 °C
Relative humidity	Vaisala heated Humicap	0 to 95 %	2%

Satellite stations

Equipment description: Aluminium mast with two levels at app. 1 m (wind speed only) and 3 m.

Locations: Sat. Stat. 1: Abzweig Wasa, 72° 48.505' S, 9° 30.268' W, 1050 m asl.
Sat. Stat. 2: 1.7 km west of Kohnen.

Period of operation: Sat. Stat. 1: December 29th 2001 to February 18th 2002.
Sat. Stat. 2: January 13th to February 4th 2002.

Sampling frequency: Pressure: 30 minutes, instantaneous; all other sensors: 6 minutes (instantaneous, except for wind speed, cumulative) after which 30 min means are stored.

Sensor	*Type*	*Range*	*Accuracy*
Air pressure	Vaisala PTB101B	600 to 1060 hPa	4 hPa
Air temperature	Vaisala HMP35AC	- 80 to + 56 °C	0.3 °C
Relative humidity	Vaisala HMP35AC	0 to 100 %	2 % (RH < 90 %) 3 % (RH > 90 %)
Wind speed	Young 05103	0 to 60 m s^{-1}	0.3 m s^{-1}
Wind direction	Young 05103	0 to 360°	3°
Pyranometer	Kipp en Zonen CNR1	305 to 2800 nm	2 %
Pyrradiometer	Kipp en Zonen CNR1	5000 to 50000 nm	15 W m^{-2}
Snow height	Campbell SR50	0.5 to 10 m	0.01 m or 0.4 %

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Equipment description:	Aluminium mast with one measurement level at app. 3 m. Data transmitted through ARGOS and stored locally in Campbell CR10 datalogger with separate memory module.
Location:	New location: 75° 00’ 05.5’’ S, 000° 00’ 12.5’’ E, 2892 m asl.
Period of operation:	December 29th 1997 to present.
Sampling frequency:	Pressure: 30 minutes, instantaneous; all other sensors: 6 minutes (instantaneous, except for wind speed, cumulative) after which 60 min means are stored.

Sensor	*Type*	*Range*	*Accuracy*
Air pressure	Vaisala PTB101B	600 to 1060 hPa	4 hPa
Air temperature	Vaisala HMP35AC	- 80 to + 56 °C	0.3 °C
Relative humidity	Vaisala HMP35AC	0 to 100%	2 % (RH < 90 %) 3 % (RH > 90 %)
Wind speed	Young 05103	0 to 60 m s^{-1}	0.3 m s^{-1}
Wind direction	Young 05103	0 to 360°	3°
Pyranometer	Kipp en Zonen CNR1	305 to 2800 nm	2 %
Pyrradiometer	Kipp en Zonen CNR1	5000 to 50000 nm	15 W m^{-2}
Snow height	Campbell SR50	0.5 to 10 m	0.01 m or 0.4 %

Cloud radiation temperature

Equipment description:	Tripod with separate logger and sensor housing, the latter kept at app. + 30 °C. Rain detector for automatic sensor protection. Data stored on Skipper datalogger memory cards.
Location:	Kohnen balloon site.
Period of operation:	January 8th to February 12th, 2002.
Sampling frequency:	1.2 seconds, after which 10-min. averages are stored.

Appendix B: Radiosonde landing sites

For reasons of environmental monitoring, we present here the probable landing sites of the radiosondes after being released at Kohnen during ENABLE 2001/02.

To calculate the horizontal displacement of radiosondes, the average balloon horizontal speed components were multiplied by the duration of the sounding. A sounding ended when a) the sounding program terminated automatically after two hours (green dots in the figure below), b) the balloon burst followed by a rapid descent of the sonde (blue dots) and c) radio contact with the sonde was lost (red dots).

As can be seen, 90 % of the balloons released at Kohnen came down to the west and south of the station; a similar majority did not travel further than 50 km from the station, which is due mainly to the relatively weak stratospheric circulation in the Antarctic summer. Note that in cases a) and c) the endpoint of the balloon trajectory was not yet reached. However, given the similar distribution of green and blue dots in the figure below, there is no reason to assume that these balloons travelled much further.