Field report of IMAU activities in Dronning Maud Land, Antarctica, in 2006/07

Aboa and Svea stations, December 2006 – February 2007

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Front cover: *Midnight sun over Antarctica. A view from Aboa station towards Plugen nunatak with low-level clouds over the ice sheet that formed during nighttime. On the right the Swedish station WASA. Photo by Paul Smeets.*

List of acronyms

ABL	Atmospheric Boundary Layer
AWI	Alfred Wegener Institute, Bremerhaven, Germany
AWS	Automatic Weather Station
CIO	Centrum for Isotope Research (Groningen University)
DML	Dronning Maud Land, East Antarctica
DROMLAN	Dronning Maud Land Air Network
FINNARP	Finnish Antarctic Research Program
FMI	Finnish Meteorological Institute
IMAU	Institute for Marine and Atmospheric Research, Utrecht University, the Netherlands
KNMI	Royal Netherlands Meteorological Institute, the Netherlands
NPP	Netherlands Polar Program
NAAP	Netherlands AntArctic Program
SL	Surface layer
SWEDARP	Swedish Antarctic Research Program

Introduction

This report describes Antarctic field activities of dr. C. J. P. P. (Paul) Smeets, scientist at the Institute of Marine and Atmospheric Research, Utrecht University (IMAU), during the austral summer of 2006/2007. The activities took place in the framework of two projects, financed by Utrecht University, the Netherlands Polar Program (NPP) and the Ministry of VROM. Main goals and plans for the 2006/07 field work are described below.

1) *"Long term monitoring of Antarctic climate using AWS (2005-2012)"*, IMAU, Dr. M. R. van den Broeke (PI). Regular maintenance of AWS 5 close to Wasa/Aboa and and AWS 6 close to Svea, respectively (see the map of DML in Fig. 1). A turbulence sensor was installed at AWS 5 to support interpretation of single-level AWS data and test the feasibility of year-round turbulence measurements. This is a follow-up test of the first successful year-round turbulence measurements by IMAU in Greenland during the period August 2003 to August 2004. These measurements enable us to directly quantify turbulent exchange of momentum and heat near the ice sheet surface, and to determine changes in surface characteristics over time. Our aim for the future is to make a turbulence sensor a common AWS component. During the fieldwork period we also installed an 11 m profile mast with 6 level wind speed and 5 level temperature measurements. Together with the turbulence sensor the lower 10% of the Atmospheric Boundary Layer (ABL), the so-called surface layer (SL), can be studied in detail.

2) *"Long term on-site isotope diffusion experiment"*, the Antarctic part of this project is integrated in the NAAP project *"Interpretation and measurements of isotopes and gas in Antarctica"*, a collaboration of the Centre for Isotope Research (CIO), prof. dr. H. A. J. Meijer (PI) and IMAU (dr. R. S. W. van de Wal). This project combines the experimental and glaciological expertise at CIO and IMAU. To improve the physical understanding of stable isotopes in ice cores, a layer of isotopically-enriched snow is to be sprayed on the snow in a controlled fashion near AWS 5. After deposition, the isotopic peak signal of the artificial snow will be gradually damped over the years as a result of

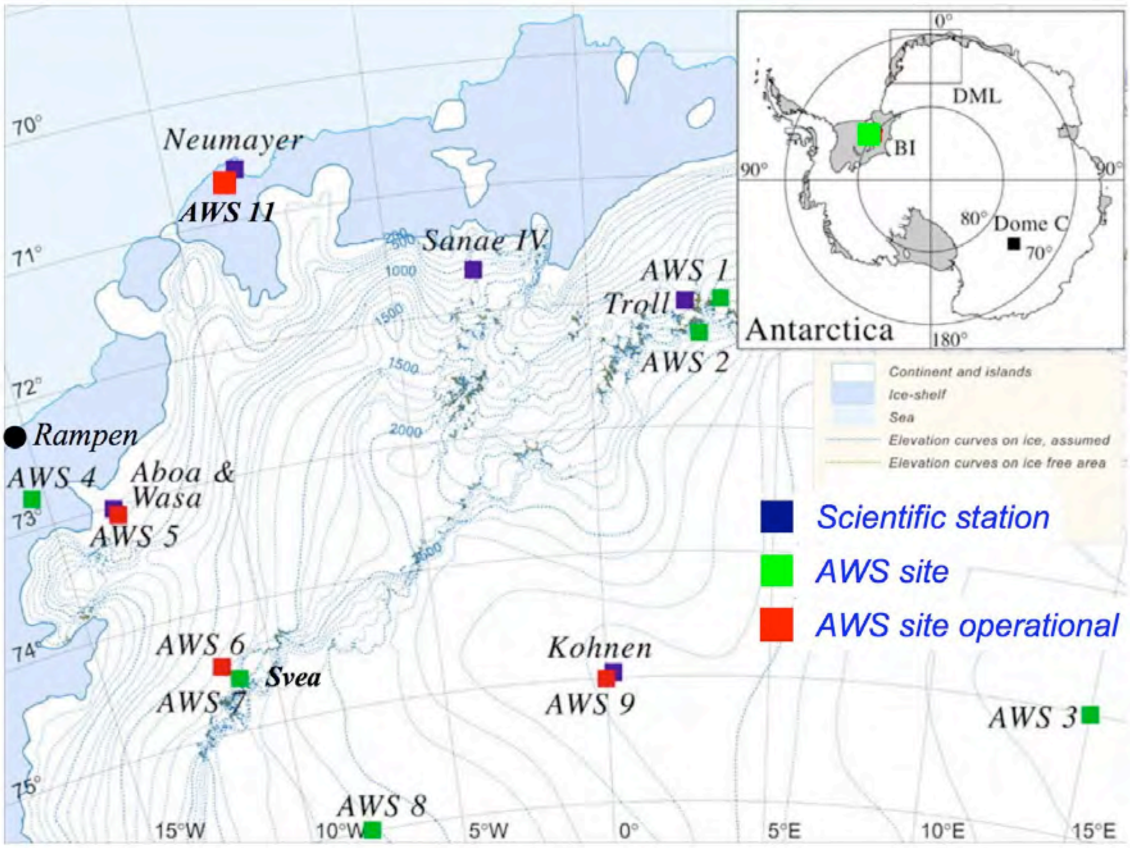

Figure 1. *Dronning Maud Land, East-Antarctica with the locations of manned scientific stations (dark blue squares), IMAU AWS currently in operation (red squares), locations of former IMAU AWS (green squares). AWS 11 is newly installed in January 2007 by AWI personnel. It is located on Halvfarryggen at the location of a potential ice coring site.*

diffusion in the firn. Regular sampling in the years to come will hopefully enable us to study the diffusion of this layer over time. Data from the nearby AWS 5 are used to monitor surface height and sub-surface temperature gradients, necessary for the correct interpretation of the results. Proper quantitative knowledge of diffusion is necessary to reconstruct the isotope signals of the original precipitation from the measured ones.

Travel itinerary

During the months preceding the expedition, Wim Boot, Henk Snellen (electronics department of IMAU) and Paul Smeets prepared, tested and packed all equipment in Utrecht and at Cabauw, the test site of the KNMI near

Utrecht. At 11 October 2006, the equipment was packed in a container and shipped to Oslo to be loaded onto the *Ivan Papanin*, a Russian icebreaker chartered by Norway, Germany, Belgium, Sweden and Finland. The *Ivan Papanin* sailed for Cape Town on 23 October 2006 and finally to Antarctica on 26 November 2006.

At first Paul Smeets was planned to be a SWEDARP member. He would however travel together with his equipment and the meteorological team of FINNARP on the *Ivan Papanin* to Antarctica. During the second half of September this plan was changed. Instead, Paul Smeets joined formally as a FINNARP member and was scheduled to fly via the DROMLAN network from Cape Town to Novo Air Base, close to the Russian *Novolazarevskaya* station in Dronning Maud Land, Antarctica, onboard an inter-continental flight in an Ilyushin 76TD cargo/passenger aircraft. From Novo runway onward, so-called feeder flights by Basler BT-67 aircraft connect the stations and field parties in Dronning Maud Land.

At 3 December 2006 Paul Smeets flew to Cape Town where he joined 3 other members of FINNARP. The official planning was to fly to Novo at the 7th, and onward to the Finnish station Aboa at the 11th. Due to envisaged bad weather, the flight to Novo was rescheduled to 5 December, and onward to Aboa at the end of the same day. 5 days ahead of schedule, the party arrived at Aboa on 6 December 2006, were Finnish expedition leader Petri Heinonen prepared the expedition members a warm welcome.

At about the same time the *Ivan Papanin* had reached the edge of the ice shelf close to the Norwegian base *Troll*. Unloading the Norwegian cargo lasted for about four days, after which the ship traveled onward towards *Rampen* (Fig. 1), the location where the Swedish, Finnish and IMAU cargo was to be unloaded. Within a day after departure the ship's progress was hindered by high sea ice concentrations. As a result, the vessel drifted along with the sea ice for over a week. Sea ice conditions improved on 18 December and on 19 December the *Ivan Papanin* arrived at Rampen. The area has a naturally shaped ramp in the ice shelf that provides easy access from the ice shelf to the sea ice, and lies about 130 km from Wasa/Aboa.

Figure 2. *Unloading of containers from the Ivan Papanin near Rampen. Photo by Siru Vartiainen, FINNARP.*

The Swedish and Finnish logistics crew that had waited for the ship had a hard time unloading, due to bad weather- and sea ice conditions. Unloading was finished in three days. After that, goods were transported to Aboa/Wasa where the first party arrived just after midnight on 24 December 2006. These were the Finnish logistics and boat travelers (2 scientists and a cook/logistician) together with food supplies. They arrived just in time to provide the expedition members with a well-catered Christmas dinner. At 25 December 2006 the Swedish party also arrived together with two containers with all scientific equipment. In the period between 27 December 2006 and 20 January 2007 all field activities of Paul Smeets concentrated near AWS 5 about 10 km from Aboa/Wasa.

At 21 January 2006, a SWEDARP traverse started out to Svea in which Paul Smeets joined in order to service AWS 6 (Fig. 3). AWS 6 is situated close to the Swedish station Svea, about 200 km south of Aboa and Wasa (Fig. 1). The traverse party returned to Wasa/Aboa on 26 January 2007. By this time the season had almost ended: the return flight was planned for 2

February. In order to make sure that everything was packed and ready for this flight temporary experiments were finished and everything was packed at 31 January.

Exactly as scheduled, the Basler BT-67 arrived on 2 February 2007 early in the morning to pick up 4 Finnish scientists, 2 Finnish logistics and Paul Smeets together with their equipment. After staying at Novo for two days, and having visited the Russian station *Novolazarevskaya* and the Indian station *Mithra*, they flew to Cape Town according to schedule on 5 February. In Cape Town they enjoyed a tropic and relaxed stay after the hectic last few weeks at Aboa. Here they also met with the Belgian team and had a chance to exchange their Antarctic experiences of the last two months. Finally, at 10 February 2007 Paul Smeets arrived at Schiphol after being away for 70 days.

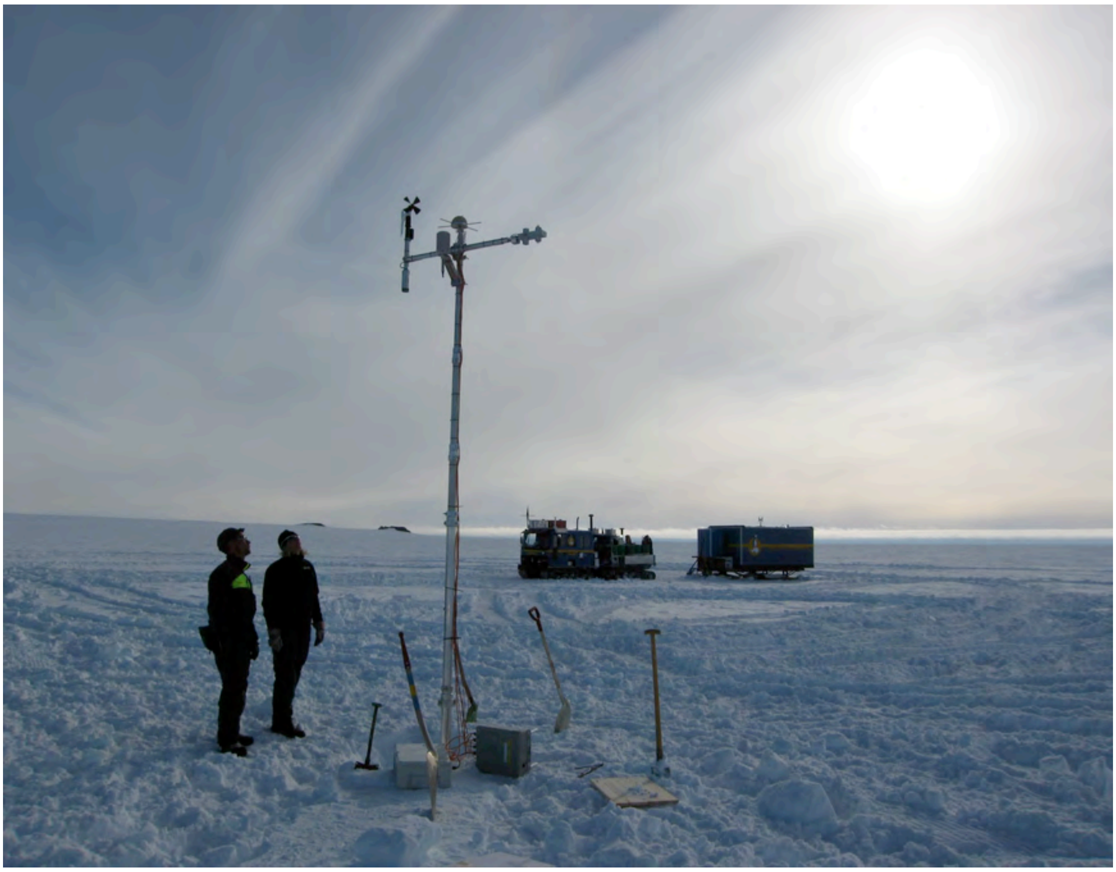

Figure 3. *Maintenance of AWS 6 is almost finished. In the background the SWEDARP traverse vehicles. Photo by Paul Smeets.*

Experiment timetable

The following timetable lists all activities during the fieldwork from 26 December 2006 to 30 January 2007. For location of sites see Fig. 1.

December 26th	*Equipment taken out of containers and organized at Aboa.*
December 27th	*Start building 12 m profile mast near AWS 5 together with SWEDARP member which also provided logistics.*
December 28th	*Finished profile mast, all slow response sensors installed, together with SWEDARP member.*
December 29th	*Fast response sonic anemometer mounted on profile mast together with FINNARP member.*
	No activities due to weather conditions.
January 4th	*Check profile mast measurements.*
January 5th	*Visit profile mast, collecting data, measuring sensor heights and various angles.*
January 6th	*Visit profile mast, calibration test temperature sensors, data collection, re-arrangement of datalogger boxes.*
January 7th	*Analysis of data.*
January 8th	*Visit profile mast, check heights, collect data.*
January 10th	*Testing of snow gun set-up at Aboa.*
January 11th	*Visit profile mast, check heights, collect data.*
January 12th	*Visit AWS, dug hole to datalogger and batteries of AWS 5 together with FINNARP member. AWS checked, data collected.*
January 13th	*Visit AWS, sensors replaced, batteries changed, extension placed, together with FINNARP member.*
January 15th	*Visit AWS, finished servicing of AWS 5 and mounted sonic anemometer on AWS. Data collection of profile mast and AWS. Radiation experiment with temperature sensors. Finnish meteorological site, close to Basen/Aboa: mounted a net-radiation sensor close to FMI experiment.*
January 16th	*Visit AWS 5 and Basen radiation site. Check and collect data.*
January 17th	*Snow gun and water container are transported to AWS 5 location by SWEDARP. Tested snow gun set-up. Calibration test temperature sensors.*
January 18th	*Snow gun experiment performed and snow sampled at three locations. Basen radiation site: data collection and check.*
January 19th	*Visit AWS 5 location. Check profile mast and AWS data and condition of snow layer. Preparation for trip to Svea..*
January 20th	*Start of trip to Svea with SWEDARP convoy late afternoon.*
January 21th	*Arrival at AWS 6 (Svea Cross, near Svea) late in evening.*
January 22th	*Maintenance of AWS 6 together with SWEDARP members.*
January 23th	*Arrival at Svea, helping unloading and loading of gear from sledges.*
January 24th	*Helping SWEDARP at Svea.*
January 26th	*Back at Aboa/Wasa.*
January 27th	*Visit AWS 5 location. Check all instruments and collect data. SWEDARP collects all snow gun equipment.*
January 29th	*Taking down profile mast and packing.*
January 30th	*Second time sampling of snow layer. Extensive calibration test temperature sensors. Digging out mast foot of profile mast. SWEDARP collects all equipment. Taking down radiation measurements near Aboa.*
January 31th	*Packing and preparing equipment for transport: weighing and inventory of boxes.*

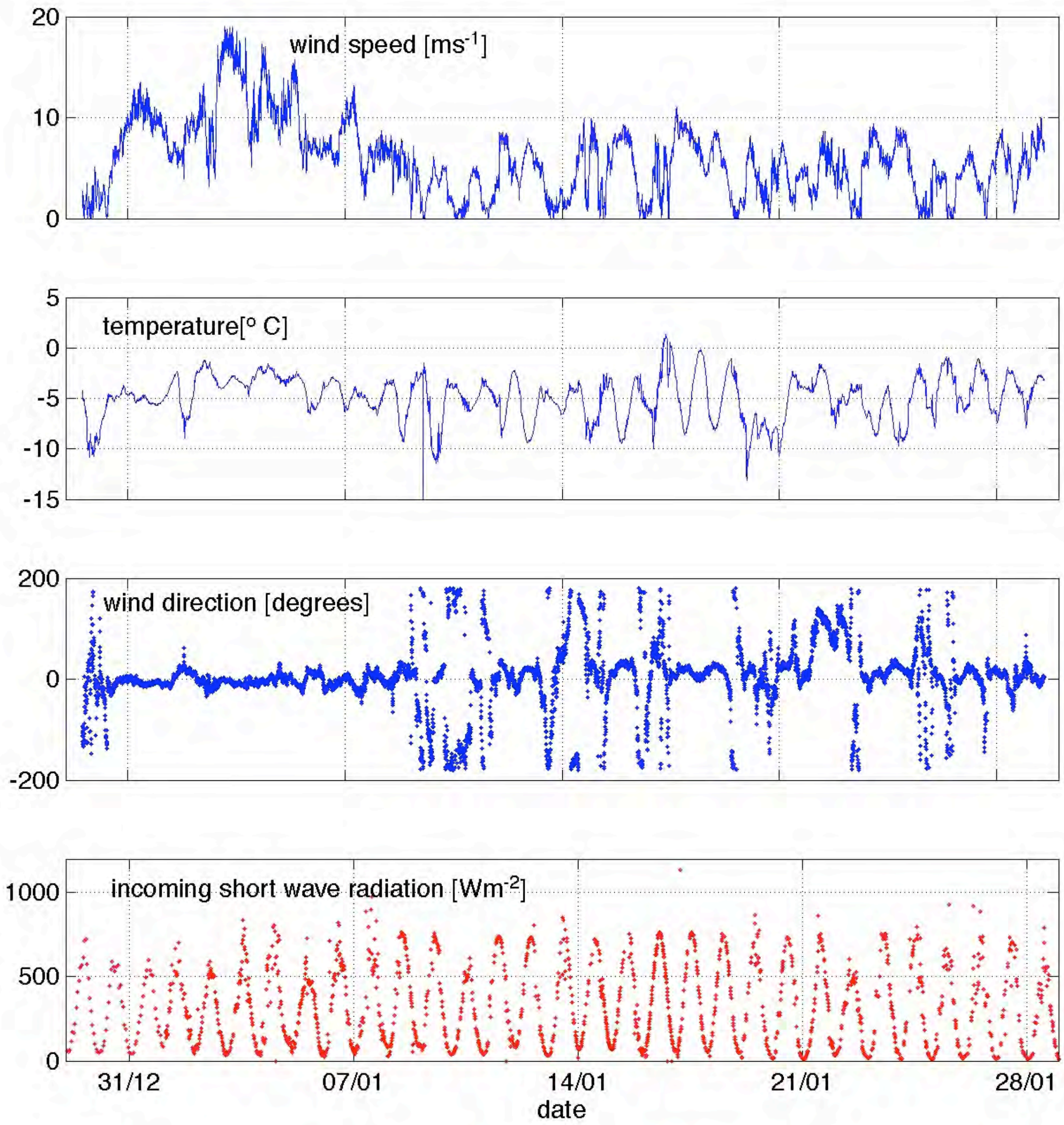

Figure 4. *Wind speed, temperature, wind direction and incoming short wave radiation from 28 December 2006 to 29 January 2007 near/at AWS 5 at 4 m height.*

Preliminary results

General meteorological conditions

Fig. 4 presents half hourly mean wind speed, wind direction, temperature and incoming short wave radiation for the experimental period using data from the profile mast and AWS 5. As can be seen, the fieldwork started just before the end of a fine weather period in which we managed to put up the profile mast and eddy-correlation sensor (27-29 December). Directly after this, a week of stormy weather occurred around New Year. Besides the high wind speed, this period is marked by persistent northerly winds and only small diurnal temperature variations. Thereafter the conditions were in general fair resulting in clear daily cycles of wind speed, temperature and radiation.

Most of the daily work of Paul Smeets took place at the location of AWS 5. The SWEDARP logistics put up a small shelter container near AWS 5 to be used in case of suddenly deteriorating weather conditions. It was also frequently used for a warm or sun-less lunch break. Fig. 5 shows the shelter on its sledge just after the storm period. Wind driven snow covered the shelter in sheets of ice, and a large drift formed in its lee.

Figure 5. *The SWEDARP shelter at AWS 5 after the New Year storm. Heavy snow drift produced a large dune of snow in the lee of the shelter. Photo by Paul Smeets.*

Profile mast and eddy-correlation measurements

At the location of AWS 5, an 11 m profile mast was erected to measure the wind speed/wind direction and temperature profiles at 6 and 5 heights, respectively. The heights were about 0.4, 1, 2, 3.5, 6.5, and 11 m above the surface. In addition, a sonic anemometer (sonic) was installed. At first this fast response sensor was mounted at the profile mast at approximately 4 m height. After maintenance of AWS 5 it was mounted on the AWS mast where it will remain for at least a year. It is expected to perform continuous turbulence measurements until the end of the austral summer next year, thereby hopefully collecting a unique data set of year-round direct flux measurements from Antarctica.

The sonic measures wind speed in three directions together with temperature at a rate of 10 Hz, and enables direct determination of turbulence fluxes of momentum and heat. Usually, empirical relations are used to calculate turbulence fluxes of sensible and latent heat in meteorological models or from single level AWS data. Combining the sonic with a multi-level profile mast enables testing these relationships for this specific region in Antarctica. Furthermore, we can study the lowest 10% of the atmospheric boundary layer (ABL), the so-called surface layer (SL), in detail. Fig. 6 shows some profile mast results for wind speed and temperature measured at 3 different heights during an interesting nighttime event.

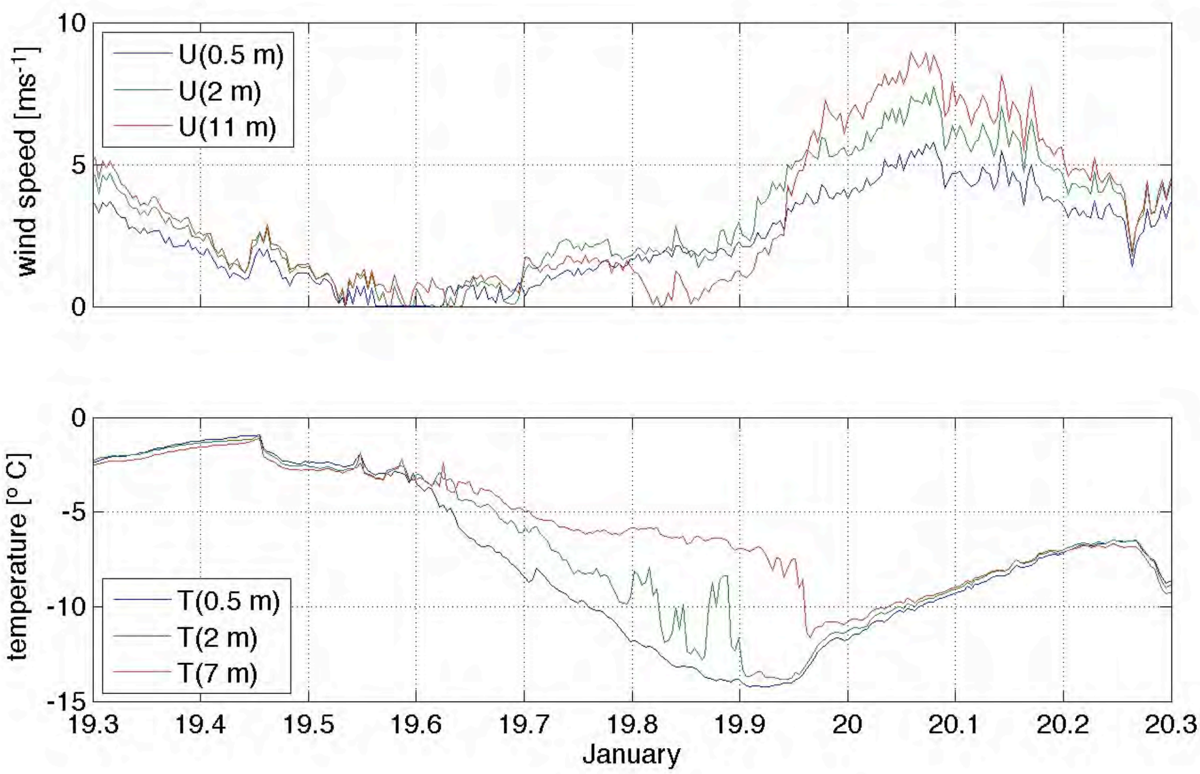

Figure 6. *Wind speed at 0.5, 2 and 11 m, and temperature at 0.5, 2 and 7 m data from the profile mast for a specific nighttime event 19-20 January 2007.*

In the beginning of the time series, from early morning until the beginning of noon, we observe a slowly declining wind speed. At the same time all temperatures are more or less equal and around -2 ºC. From January 19.55 (i.e. about 13.30 GMT) onward the wind is virtually absent and a very stable and shallow SL develops. The stable temperature gradient increases gradually up to 7 ºC between 0.5 and 7 m height. Around January 19.7 (i.e. about 17.00 GMT) the wind speed slowly starts to increase again. Note, however, that the gradient reverses resulting in a very shallow drainage flow only about 2 m thick between January 19.8 and 19.9. Within this time span the 2 m temperature signal clearly undulates indicating thickening and thinning of the layer in a regular pattern. Just before midnight the large-scale wind increases and quickly destroys the SL inversion giving way to near-neutral conditions again. Obviously, these observations are crucial for the right interpretation of single-level AWS data.

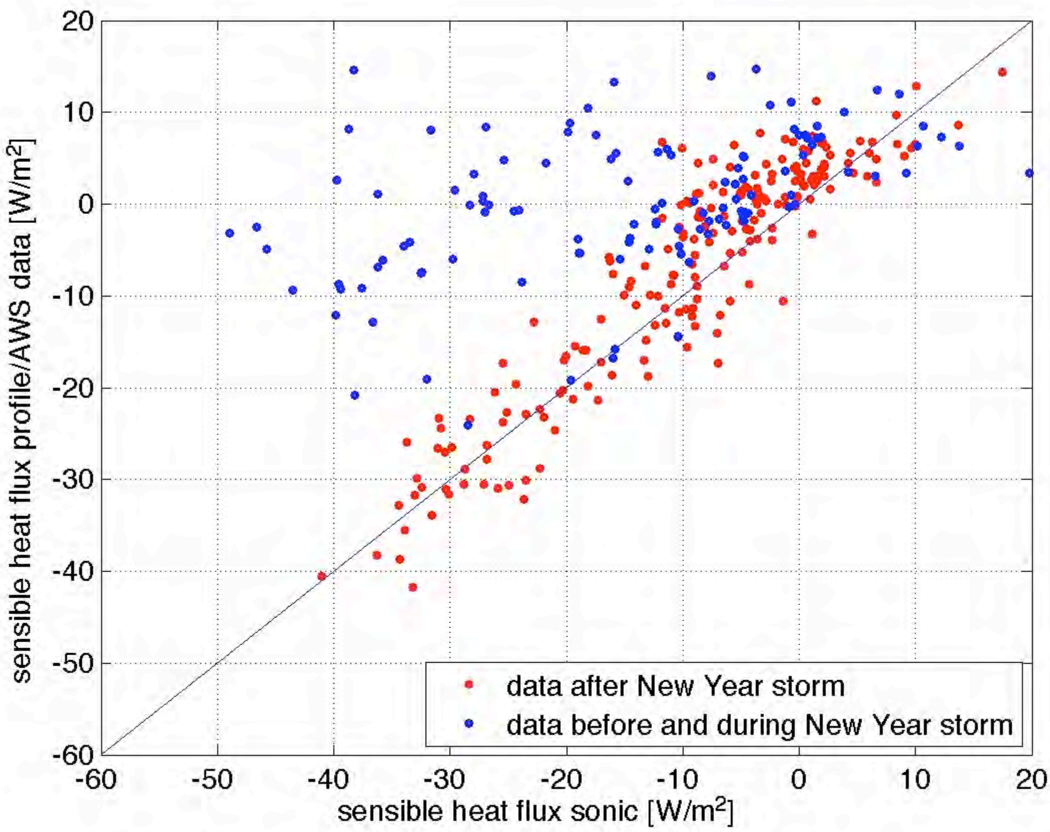

Figure 7. *Sensible heat fluxes from the sonic anemometer compared with those calculated from profile mast and AWS 5 data. Negative values indicate downward fluxes.*

Fig. 7 shows some preliminary results for sensible heat fluxes calculated from AWS versus sonic anemometer data. The results for AWS data were derived using a method that is commonly applied in models or to derive fluxes from single-level AWS data. The data are split in two periods. Data collected before and during the storm period show substantial deviations (blue dots). These data represent cases with heavy blowing snow (i.e. snow suspended in the air above eye level) that allow us to study its effect on the performance of the sonic anemometer. Figure 8 shows an example of blowing snow conditions during the first visit to location AWS 5 at the end of the storm period. The profile mast and attached sonic anemometer are clearly visible whereas the horizon and nearby AWS 5 and SWEDARP shelter are hidden in a layer of suspended snow particles.

After the storm period, blowing snow did not occur and both data sets in Fig. 7 nicely line up along the 1:1 line. However, when looking in detail we observe that the AWS derived fluxes are clearly offset from those of the sonic in cases where the sonic sensible heat flux exceed - 20 W/m^2.

Figure 8. *The profile mast and sonic anemometer at the location of AWS 5 during blowing snow conditions. Photo by Paul Smeets.*

While the sonic data indicate negative fluxes the AWS data partly result in positive values. This disagreement necessitates further study of the combined SL data from AWS, profile, and sonic.

Radiation measurements

Parallel with our meteorological measurements at AWS 5, the team from Finnish Meteorological Institute (FMI) concentrated their measurement campaign close to Basen nunatak where ABOA/WASA are located. Their site also contained a 5 level profile mast, and a sonic anemometer. They also deployed a radiation mast equipped with 4 ventilated radiation sensors allowing the separate measurement of the shortwave- and longwave incoming and outgoing radiation components (see picture on the left in Fig. 9).

During the second half of the measurement period Paul Smeets set-up a simple mast at the FMI site that was equipped with the net-radiometer that is also used on our AWS (Fig. 9). These measurements allow us to compare the performance of various sensors under typical Antarctic summer conditions, that is, a highly reflective surface and continuous light. In Fig. 10 a first comparison is made showing the net-radiation of the FMI and IMAU sensors. This first comparison affirms the good data quality observed in earlier validation results, with an average difference of only 4 W/m^2.

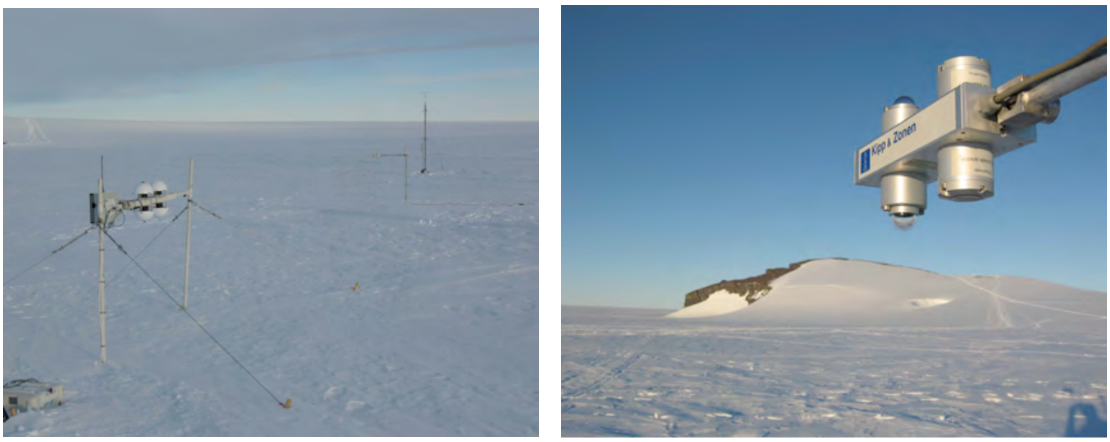

Figure 9. *On the left and on the foreground the high precision ventilated radiation measurements of FMI, in front of the IMAU radiation instrument, and in the background the sonic anemometer. On the right a close-up of the radiation sensor of the IMAU with Basen nunatak in the background. Photographs by Paul Smeets.*

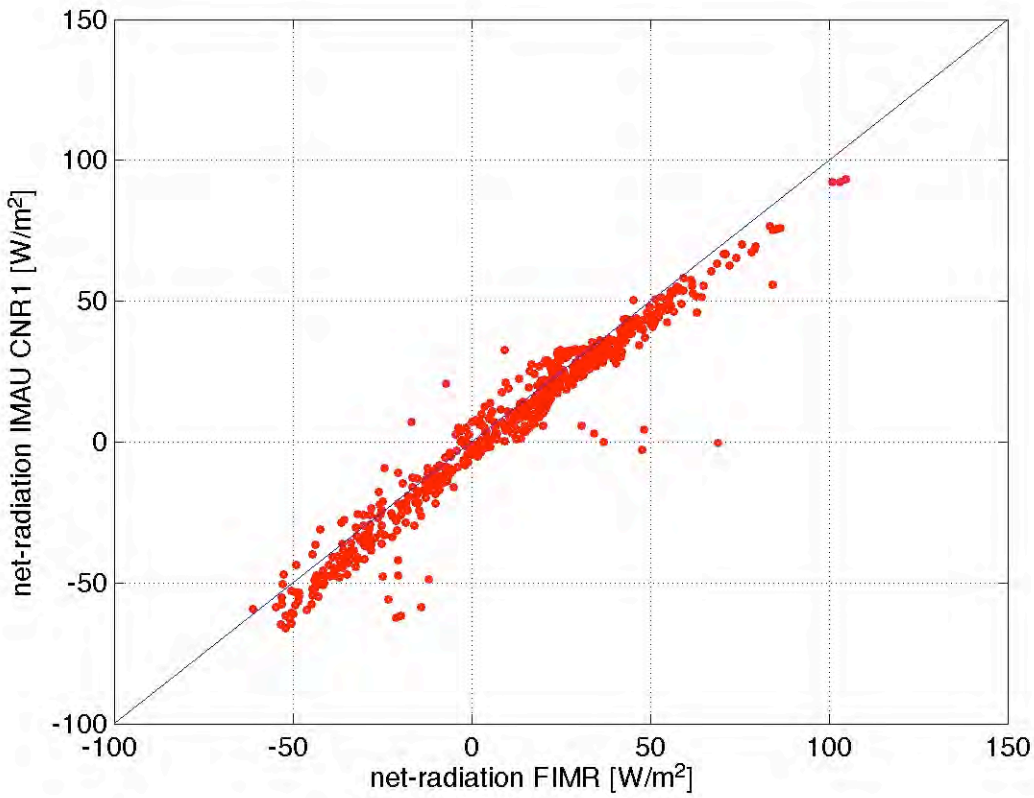

Figure 10. *The net-radiation measured by the FMI and the IMAU CNR1 near nunatak Basen. The data from FMI were kindly provided by Timo Vihma and Roberta Pirazzini, FMI.*

Maintenance of AWS 5 and AWS 6

The IMAU AWS in DML were placed in January/February 1998 as part of the European Project on Ice Coring in Antarctica (EPICA) drilling in Dronning Maud Land. A total of four AWS were placed along the SWEDARP 97/98 traverse, and at present AWS 5 and 6 are still operational (AWS 4, 7 and 8 have been removed from the area). In Fig. 4 a close up of AWS 6 is given. Maintenance of an AWS starts with digging up the datalogger and battery pack. In this case these were buried about 2 m deep at both locations. We replaced the datalogger memory module and the batteries. The wind speed/direction, temperature/humidity sensors were also replaced, and a 2 m long mast extension was mounted. Close to AWS 5, sub-surface temperature sensors were placed at 5, 10, 20, 40 and 80 cm depths. During the period between servicing moments, both AWS functioned flawlessly, with 100% data recovery.

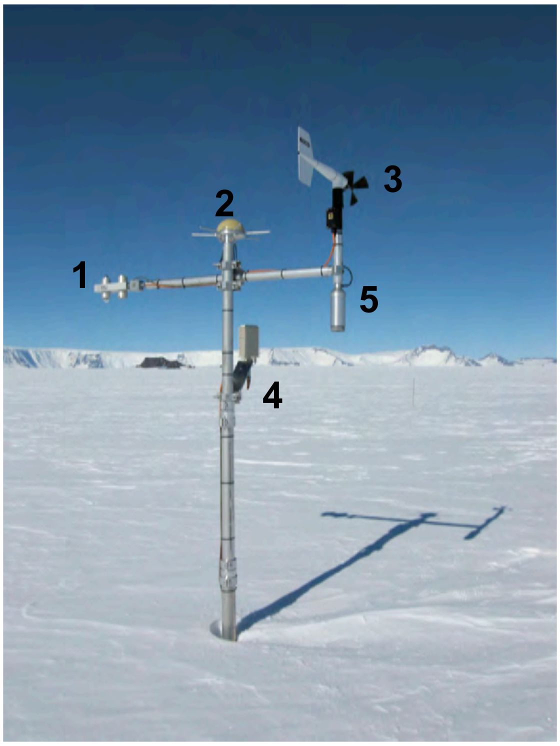

Figure 11. *AWS 6 in January 2007 with the Heimefront range in the background.* ***1:*** *radiation,* ***2:*** *ARGOS antenna,* ***3****: wind speed/direction,* ***4: t****emperature/humidity,* ***5:*** *snow height. Photo by Paul Smeets.*

As an example, Fig. 12 shows the full time series between the 2004 and 2006 servicing intervals of temperature and incoming short wave radiation at AWS 6 (note: the latter values are divided by 10 to allow use of the same axis). The seasonal variation of incoming solar radiation is closely followed by temperature, almost without time lag, with maximum and minimum values of +2 and -46 ºC, respectively.

Long-term on-site isotope diffusion experiment

At the location of AWS 5, a labeled water experiment was initiated intended to study isotope diffusion in a natural experimental setting. A layer of isotope-enriched snow was added to the snowpack in a controlled fashion, using a small snow gun (Fig. 11). The equipment needed for the production of the enriched snow layer consists of a generator/compressor/pump combination, a snow gun, 200-300 ml of enriched water, and a small additional generator with heat gun (for defrosting of vital parts such as the water pump), and 1 m^3 of ordinary ‘local’ water. All the transport of equipment and a tank containing the water was provided by SWEDARP. The snow layer was applied in a small field (6 x 6 m) marked with stakes that will provide a measure for future local snow accumulation, and thus, the depth of the enriched layer. The natural snow below and on top of the artificial layer has to be sampled regularly in the following years to track the progress and diffusion of the peak signal. At AWS 5, sub-surface temperatures at 5 depths are measured to provide temperature profiles close to the enriched layer.

After application, the fresh layer was sampled at three locations using small tubes of 1.5 cm diameter at alternating depths between 0 and 20 cm. This was done directly after application and again 12 days later. The samples were taken back to the Netherlands and will be analyzed at the CIO in Groningen.

Acknowledgements

First of all many thanks to all colleagues of the Finnish Antarctic Research Program (FINNARP) and the Swedish Antarctic Research Program (SWEDARP) in Helsinki and Stockholm and at the Antarctic research stations Aboa and Wasa, respectively. Without their support the activities described in this report could not have taken place. FINNARP provided local logistics and a very comfortable stay at Aboa, while SWEDARP took care of all transport between Aboa/Wasa and AWS 5 and AWS 6 near Svea in a very flexible way.

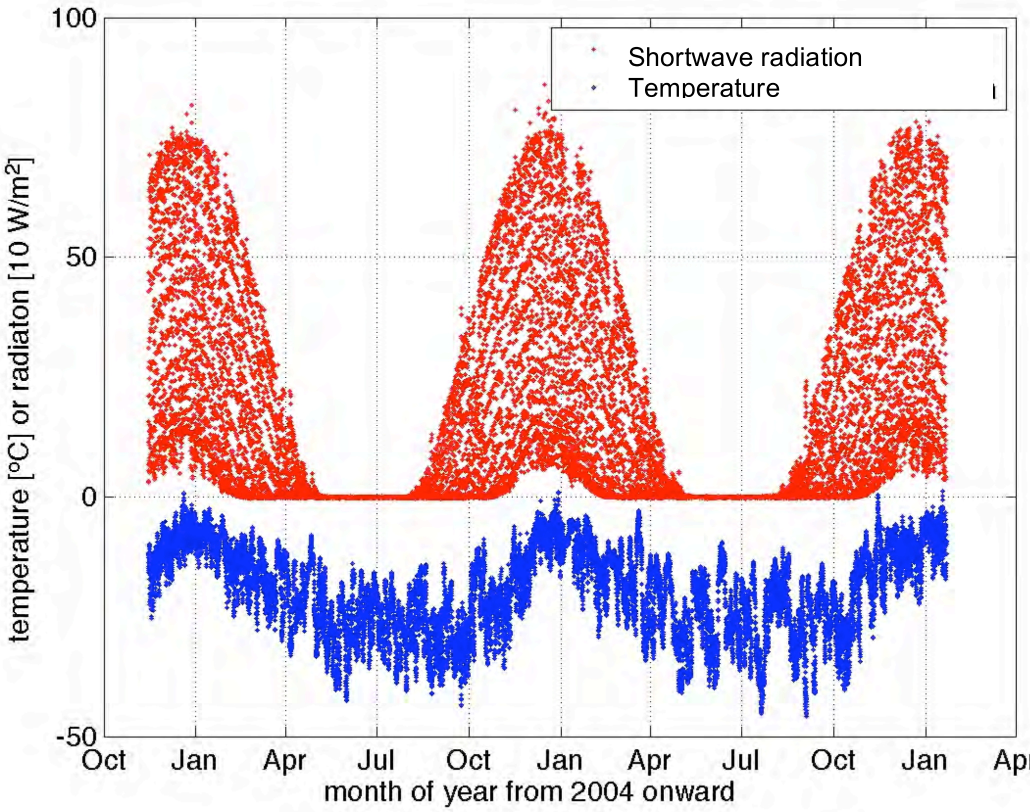

Figure 12. AWS 6 timeseries of temperature and incoming short wave radiation starting at the end of 2004.

Special thanks go to expedition leaders Petri Heinonen (FINNARP), and Ulf Hedman/Mikael Amlert (SWEDARP) for the very flexible support throughout the expedition. I would also like to thank Timo Vihma and Roberta Pirazzini (FMI) for their co-operation in and out of the field, and for kindly providing part of their radiation data.

At the IMAU I would like to thank Wim Boot and Henk Snellen for their invaluable help with the preparations, testing and packing of the equipment. During the experiment they provided quick response in case of technical problems and questions via regular Irridium phone and Email contact. Also many thanks to Michiel van den Broeke for sharing his experiences, giving advice and taking over some of the paperwork. He also provided the direct Email link between me and the IMAU and its staff, ensuring quick and informative response. This research is funded by Utrecht University, the Netherlands Polar Program and the Ministry of VROM.

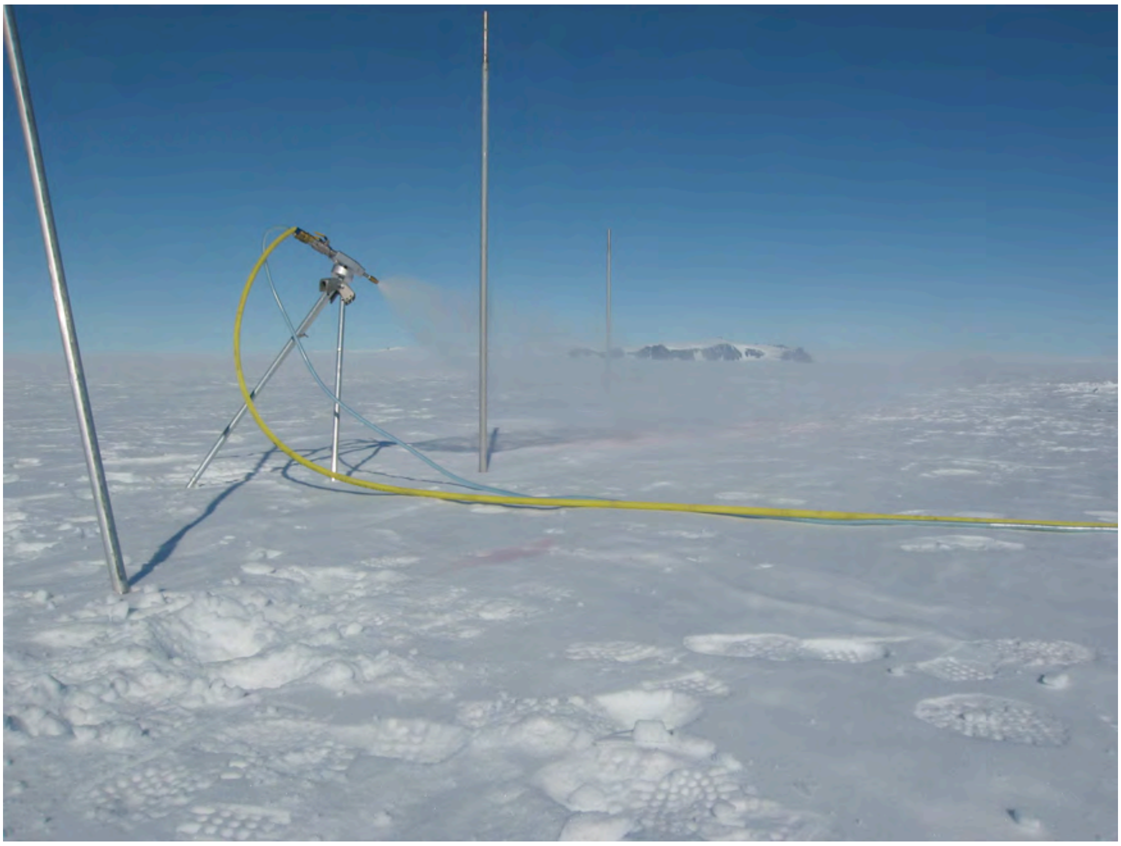

Figure 12. *The snow gun of the CIO in action near AWS 5. Photo by Paul Smeets.*