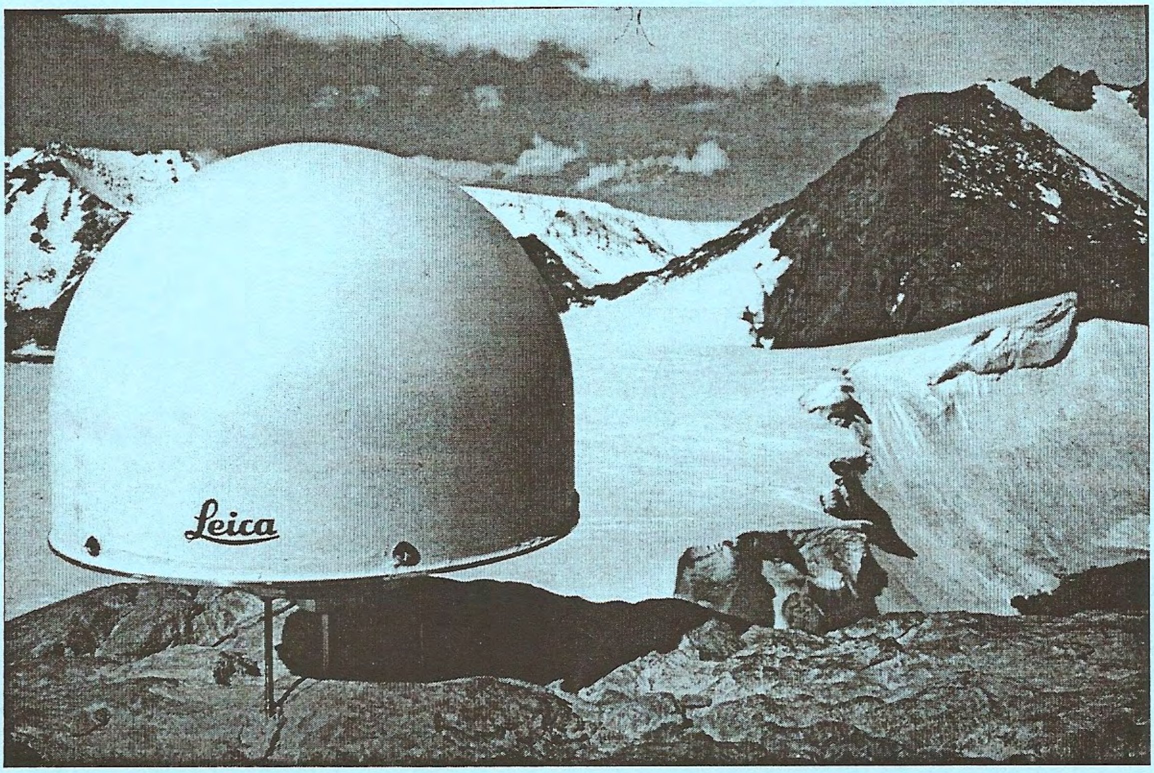
Geodetic and meteorological investigations in Dronning Maud Land, Antarctica



1999–2000 Field Report

Institute for Marine and Atmospheric research Utrecht (IMAU)
Utrecht University

Geodetic and meteorological investigations in Dronning Maud Land, Antarctica

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June 2000

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Cover Photo: The antenna of the new permanent GPS site installed at Svea, protected from snow accumulation by a plastic radome.

1. Introduction

EPICA (European Project for Ice Coring in Antarctica) is a long-lasting international project coordinated by the European Science Foundation. EPICA's main objective is to expand knowledge of global climate fluctuations by producing a high-resolution climate history of the Antarctic. To do so, it is planned to drill and analyse two deep ice cores from the East Antarctic ice sheet: one at Dome C and one in Dronning Maud Land (DML). Ten European countries participate in EPICA, which started in 1996 and is likely to continue for at least another 6–8 years. The IMAU expedition to Antarctica in 1999-2000 conducted work on two parts of the Dutch contribution to EPICA.

In the 1997-98 Antarctic season, six Automatic Weather Stations (AWS) were installed in DML as part of the first phase of Dutch involvement in EPICA (Bintanja et al. 1998). The purpose of these stations is to extend knowledge of the climate in this part of Antarctica in order to interpret the results of the EPICA core to be drilled in DML, and also to gain a better understanding of the spatial and temporal variations in the surface energy and mass balance components of the Antarctic ice sheet. Four of the sites were visited in 1999-2000 in order to replace sensors whose accuracy had deteriorated, rebuild masts which were being buried in snow, and replace the station at the site known to have developed faults.

In 1999 the Dutch Antarctic Programme approved the second phase of Dutch involvement in EPICA. This programme consists of three parts: a) geodetic measurements to constrain ice sheet history in DML; b) measurements of chemical and physical properties of medium deep firn cores from DML; and c) meteorological and climatological observations in DML. The geodetic experiment began in the 1999-2000 austral summer, with the installation of a permanent GPS site near the Swedish summer station Svea (74° 35' S, 11° 13' W) in the Heimfrontfjella mountain range. The aim of this station is to provide continuous GPS observations for a number of years, which can be used to accurately measure the vertical velocity of the earth's crust at this site, relative to other GPS sites closer to the coast in DML. These vertical velocities are the earth's response to changes in the thickness of the ice sheet, and can be interpreted to aid reconstructions of the changes occurring in the Antarctic ice sheet since the last glacial maximum. Such reconstructions are an essential contribution to interpreting the results of the EPICA ice core from DML.

2. Logistics

The logistics for the 1999-2000 Nordic Antarctic Research Programme (NARP) expedition to Dronning Maud Land were organised by the Finnish Antarctic Research Programme, FINNARP. The entire expedition consisted of Finnish, Swedish and Norwegian expeditions to their respective bases, an autonomous German geological party from the Alfred Wegener Institute, and the Dutch party, who operated as a part of FINNARP. The expedition used the Russian icebreaker r/v Akademik Fedorov for transport to and from Antarctica, and two Russian MI-8 helicopters for loading and unloading while the ship was at the ice edge. On the Antarctic continent, transport was by tracked vehicle, snow scooter, and Jet Ranger helicopter. The FINNARP party consisted of 23 people, including two Dutch. While in Antarctica we used the same local time as the Aboa and Wasa bases, which was GMT-1.

Below is a summary of the Dutch party's activities during the field season:

August 21-28:	Field training with FINNARP members on Okstindan Glacier, Norway
October 18-20:	Packing food and camping equipment in Helsinki
October 29:	Send equipment to Bremerhaven, to be loaded on Akademik Fedorov
November 27:	Depart for South Africa
December 1:	Akademik Fedorov departs Cape Town
December 14:	Akademik Fedorov arrives Rampen
December 15:	Attempt to fly to AWS 4; turn back in white-out conditions
December 20:	Dutch party fly to Aboa
December 23:	Visit AWS 5 by skidoo from Aboa.
December 26:	Attempt to fly to AWS 4; turn back in white-out conditions
January 2:	Visit AWS 4 by helicopter from Aboa.
January 6:	Depart Aboa/Wasa 2300 with Swedarp tracked vehicles.
January 7:	Arrive Svea 1300.
January 8:	Scharffenbergbotnen weather station (AWS 7) reconnaissance.
January 9:	Sveakorsett weather station (AWS 6) maintenance.
January 10:	GPS site reconnaissance. Swedarp vehicles depart for depot on plateau.
January 12:	Swedarp party return from plateau, and depart for Wasa.
January 14:	Rebuild AWS 7.
January 16-26:	Work at GPS site.
January 27:	NvL departs for Aboa by helicopter 1445.
January 29:	Close Svea. DZ departs 1300 for Aboa by skidoo with FINNARP glaciological party..
January 30:	Fly from Aboa to Akademik Fedorov at Rampen.
February 8:	Arrive Cape Town

The time spent in the vicinity of Svea was shorter than intended - approximately three weeks instead of five - because bad weather at the time the ship was unloading prevented the large helicopters flying us there directly. Instead, we flew first to Aboa, where we had to wait for overland transport. The kind cooperation of SWEDARP, with whom we traveled, allowed us to arrive at Svea as early as possible.

After the expedition, a report on the use of Svea by the Dutch party was submitted to the SWEDARP expedition Leader. This report is included here as Appendix A. Due to a misunderstanding at the start of our occupation, the toilet waste from Svea was not returned to Aboa/Wasa and removed from Antarctica at the end of the summer, as SWEDARP intended. Nevertheless, we are satisfied that the toilet waste (left at Svea in a field toilet to be used by the next expedition) constitutes no environmental risk. We also completed the NARP post-activity environmental report form, which is included as Appendix B.

3. Automatic Weather Stations

Background

Six Automatic Weather Stations (AWSs) were installed in Dronning Maud Land during the austral summer of 1997-1998. Data from these stations give us the opportunity to obtain a better knowledge of the near surface climate in this region of the Antarctic ice sheet. Understanding of the atmospheric processes near the surface is important for the interpretation of data from ice cores, which are, after all, a record of past conditions at the snow surface. To obtain past meteorological conditions from the ice core measurements, the surface conditions have to be related to the prevailing meteorological situation at the time of deposition of the snow. Measurements obtained with the AWSs enable us to get a better understanding of this relation between the surface and the atmosphere.

There are several reasons why the AWSs have to be visited once every two years. First, the stations in the regions where the net accumulation is positive become buried in the snow. The net accumulation (sum of precipitation, sublimation, snowdrift and melt) for the six station in the years 1989-1999 is given in Table 1. At the time when the stations were installed, the height of the sensors was approximately 3 m above the surface. After two years, the height of the sensors above the surface is reduced by the net accumulation during this period. For example, at the end of the year 1999, the height of the sensors of AWS 4 is approximately only half a meter above the snow surface. Another reason to visit the stations is to replace some sensors and the battery pack. This is necessary because various sensors lose accuracy during two years of operation. The batteries have a lifetime of 2 – 3 years.

The AWSs are located along a transect ranging from the coast to the plateau Amundsenisen (Figure 1). The northernmost station is located on the ice shelf and the southernmost station is located 600 km inland at an altitude of 2399 m. All stations were erected by Dutch and Swedish scientists during SWEDARP 1997-98, except for AWS 9 which was erected by scientists from the Alfred Wegener Institute under the supervision of Dr. H. Oerter.

Table 1: *Details of the 6 EPICA Automatic Weather Stations. The accumulation value for AWS 7 refers to ice surface lowering, not snow.*

site	installed	serviced	GPS position 1997-98	GPS position 1999-2000	altitude (m)	net accumulation (cm snow per year)
AWS 4 (1090)	19-12-97	02-01-00	72°45.156' S 15°29.931' W	72°45.052' S 15°30.254' W	34	106
AWS 5 (Camp Maudheimvidda)	02-02-98	23-12-99	73°06.320' S 13°09.878' W	73°06.344' S 13°09.947' W	363	46
AWS 6 (Svea cross)	14-01-98	09-01-00	74°28.89' S 11°31.01' W	74°28.901' S 11°31.097' W	1160	60
AWS 7 (SBB 01)	31-12-97	14-01-00	74°34.671' S 11°02.972' W	74°34.659' S 11°02.991' W	1173	-15
AWS 8 (Camp Victoria)	12-01-98		76°00.018' S 08°03.033' W		2399	22
AWS 9 (DML 05)	29-12-97		75°00.150' S 00°00.440' E		2892	26

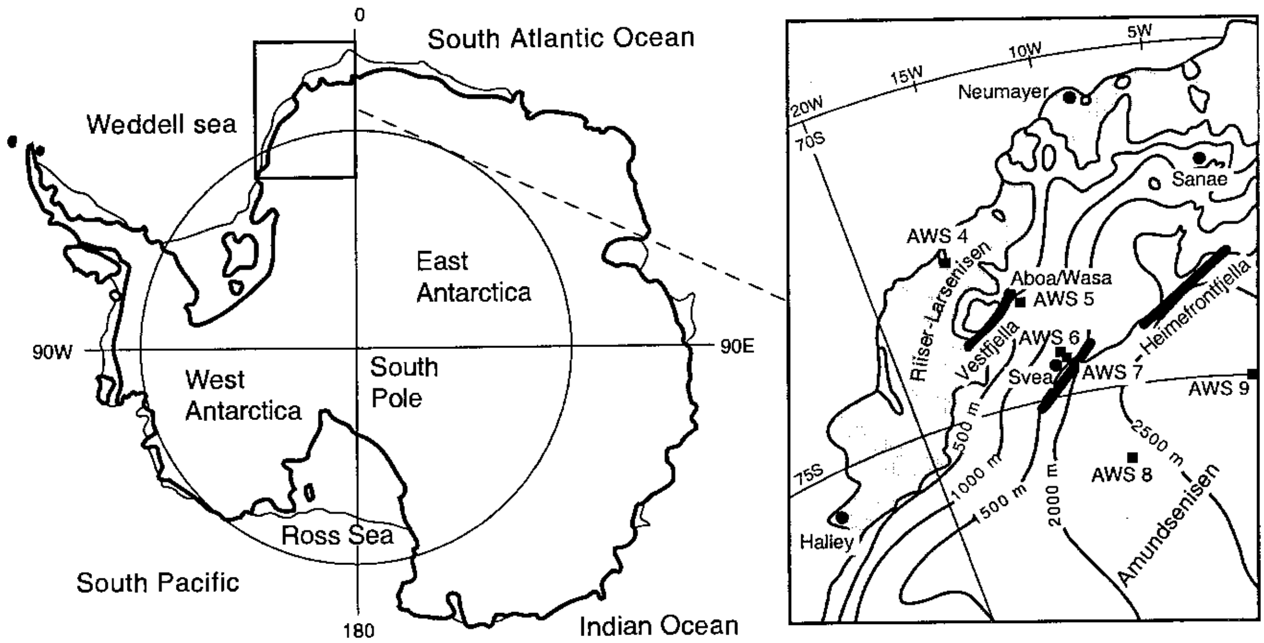

Figure 1: The locations of the six AWSs in western Dronning Maud Land, Antarctica.

A schematic illustration of an AWS on snow is given in Figure 2. The vertical mast is supported on four legs which are buried in the snow. AWS 7 is the only station over blue ice and stands freely on the surface, so that the height of the sensors above the surface remains constant. A horizontal yard on which most sensors are mounted is attached to the mast at appr. 3 m height. The sensors measure temperature, relative humidity, wind direction, wind speed, height of the sensors above the snow surface, air pressure, downward and upward shortwave radiation, and downward and upward longwave radiation. In addition, snow temperatures are measured at several depths. Initially, the shallow measurements are made at 5, 10, 20, 40 and 80 cm below the surface, but as the stations (except AWS 7) are buried in the snow, the depth of the sensors increases accordingly. AWSs 4 and 6 have an additional 15 m string measuring the sub surface temperatures at 2, 4, 6, 10 and 15 m depth, whereas AWSs 5, 7, 8, and 9 have a 100 m string with sensors at 2, 10, 15, 30 and 100 m. The bore hole near AWS 7 in the blue ice is only 51 m deep and therefore the lowest sensor of the 100 m string is at that depth. As for the shallow temperature sensors, the depth of these deep sensors changes with the net accumulation. Some characteristics of the various sensors, including the accuracy, are given in Table 2. Note that the Vaisala temperature/humidity sensor is not ventilated because of power supply limitations, which means that in periods with low winds and high insolation temperature measurements will probably be in error. Two-hourly means are stored locally in the AWS datalogger and are transmitted to Utrecht every two hours using an ARGOS transmitter.

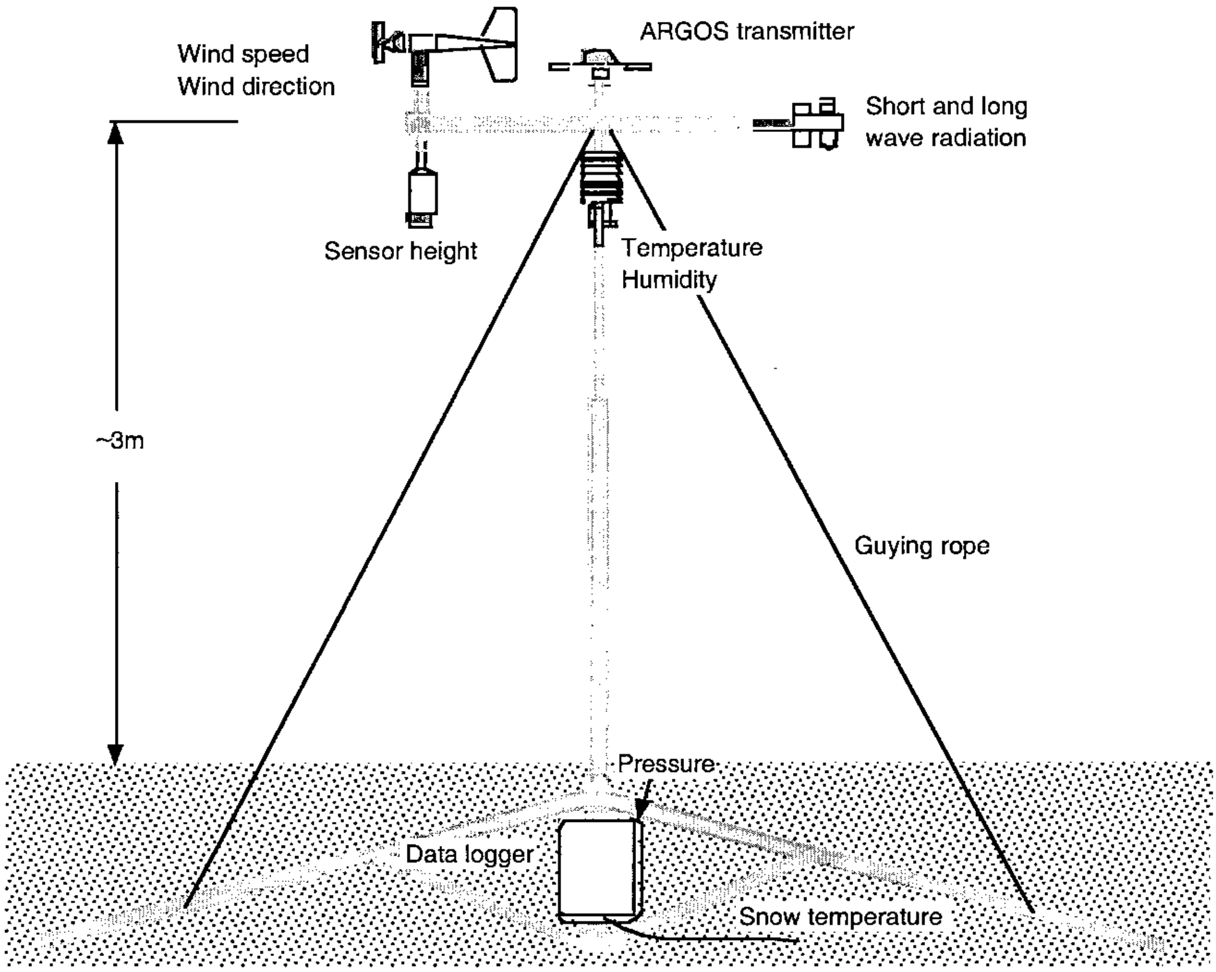

Figure 2: A schematic illustration of an AWS over snow.

Table 2 : Details of the sensors of the EPICA automatic weather stations

Sensor	Type	Range	Accuracy
wind speed	Young 05103	0-60 m s^{-1}	0.3 m s^{-1}
wind direction	Young 05103	0-360°	3°
temperature	Vaisala HMP35AC	-80-+56°C	0.1 °C
relative humidity	Vaisala HMP35AC	0-100 %	2 % (<90 %) 3 % (>90 %)
pressure	Vaisala PTB101B	600-1060 hPa	4 hPa
short wave rad.	Kipp CNR1	305-2800 nm	2 %
long wave rad.	Kipp CNR1	5000-50000 nm	15 W m^{-2}
snow/ice height	Campbell Scientific SR50	0.5-10 m	0.01 m or 0.4 %

Maintenance of AWS during FINNARP 1999-2000

General

During FINNARP 1999-2000, Dutch scientists visited AWS 4, 5, 6 and 7, whereas AWS 8 and AWS 9 were again kindly maintained by the group of Dr. H. Oerter (AWI). On arrival, the height of the sensors and the angles of the mast and the yard were measured (Table 4, appendix C). In order to get to the datalogger, a hole had to be dug in the snow that has to be at least 1.2 m wide and 2.5 m long in order to have enough space to reach the datalogger. The local net accumulation determines the depth of the hole. When the datalogger is retrieved, a data dump was made to a memory card, the memory of the datalogger was reset and a new program was loaded, compiled and started.

At all stations, the battery pack and the sensors for temperature, relative humidity, wind direction, wind speed, instrument height and shallow snow temperature were replaced. At AWS 4 and AWS 6, a new mast was built because the height above the surface of the sensor arm was very low due to high accumulation rates. At AWS 7 a complete new station was built and all sensors except the deep temperature string were replaced.

Working in the bottom of a snow hole, it was very difficult to undo the two lower nuts of the datalogger and battery pack boxes. When re-mounting the datalogger and the battery pack to the mast, these two nuts were not fixed to enable easier dismounting the next time. Cables were led between the datalogger and the battery pack so they are not so easily damaged by digging. At some stations, the accumulated snow load on the guying cables pressed them against a sensor wire that was attached to the side of the sensor yard. To prevent damage to these wires, they were now fixed on the underside the yard.

At the stations AWS 4, AWS 5 and AWS 6, a snow density profile was measured to a depth of 80 cm. At the end of a visit, the new height of the sensors and the angles of the mast and the yard were measured (Table 4). Further details of the work at the individual sites are given below.

AWS 4

On 2 January, 2000 9:30 GMT we arrived at AWS 4 after approximately half an hour flight from Aboa by helicopter (Jet Ranger). The sensor arm, originally installed at a height of about 3 m, was now only about half a meter above the surface (Figure 3). In order to recover the datalogger, a hole approximately 1.2 m wide, 2.5 m long and 3 m deep was dug. In addition, a cross was dug, in which the legs of the new station would be inserted. The configuration of the new station in relation to the old station is shown in Figure 4. As previously, the datalogger and the battery package were placed under the legs and not perpendicular to the yard in order to make the recovery of these boxes easier. After refilling and leveling the holes, measuring the height of the sensors and the angles of the new mast and yard we finished the work at 21:15 GMT and returned to Aboa.

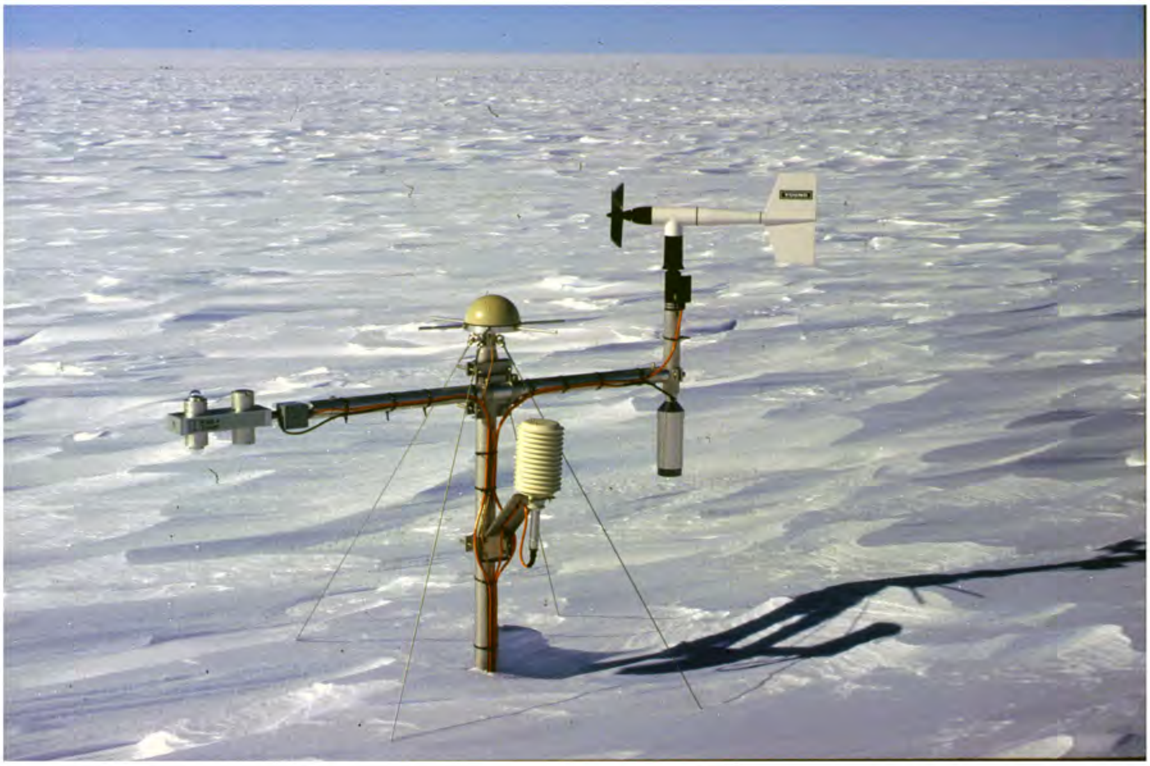

Figure 3: *The sensor yard of AWS 4, originally installed at a height of about 3 m, was only about half a meter above the surface after two years snow accumulation.*

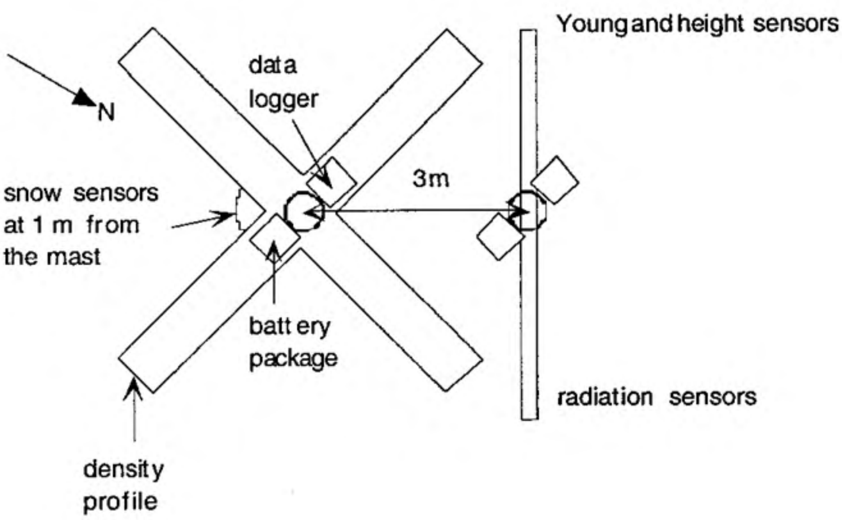

Figure 4: *Configuration of the new station of AWS 4 in relation to the old station (top view). The right side of the figure shows the old mast (circle), datalogger, battery package (boxes) and the yard. The left side shows the cross-shaped hole that was dug for the new station, the new positions of the datalogger, battery package and snow sensors and the location of the snow density profile.*

AWS 5

We arrived at AWS 5 on 23 December, 1999 12:00 GMT after approximately 1 hour drive from Aboa with 2 skidoos and a sledge. On arrival, it was noted that the yard was not mounted exactly between the mast legs, but was slightly rotated clockwise viewed from above.

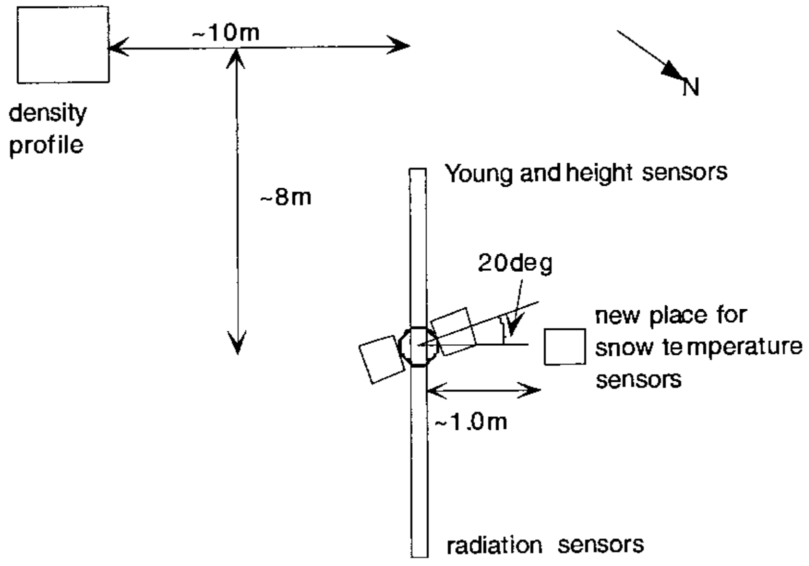

Figure 5: *Top view of the weather station AWS 5.*

The site of AWS 5 receives less accumulation than AWS 4, so that the sensor yard were still 2 m above the snow. For this reason, we did not build a new station, but only replaced the Young, Vaisala and the shallow snow temperature sensors. The position of the shallow snow temperature sensors is shown in Figure 5. The distance from the mast of the weather station to the new temperature sensors is approximately 1 m.

A hole was dug to the datalogger and the battery package. After reading the data from the two previous years, resetting the memory and loading and compiling a new program, the boxes were mounted on the mast above the legs to make the next recovery easier. The angle between the line connecting the datalogger and the battery package and the line perpendicular to the sensor yard is approximately 20°, because the cable of the long temperature string was too short to put it in the original position. A density profile was made at the place marked in Figure 5. After refilling the hole, the angles of the mast and heights of the sensors were measured again. The difference between initial and final angles is smaller than the accuracy of the compass. At 2200 GMT we finished the work and returned to Aboa.

AWS 6

We arrived at this station on 9 January, 2000 12:00 GMT after approximately an hour drive from Svea with a skidoo. The GPS location measured on arrival is 74°28.901'S and 11°31.097'W. It was noted that the reference notch of the Young sensor was not in line with the arrow on the yard: the sensor was rotated anticlockwise by 22° (viewed from above). This has an effect on the interpretation of the wind direction for the previous two years.

Two problems arose when digging to the datalogger and during installation of the new station, namely 1) the plug of the battery cable broke when we extracted the datalogger. The wire was resoldered to the plug; and 2) the thread in the lowest telescopic collar on the mast was stripped when tightening it with the allen key. A new bolt was used to fix this problem. The configuration of the new station in relation to the old station is shown in Figure 6. At 00:30 GMT (10 Jan) we finished the work and returned to Svea.

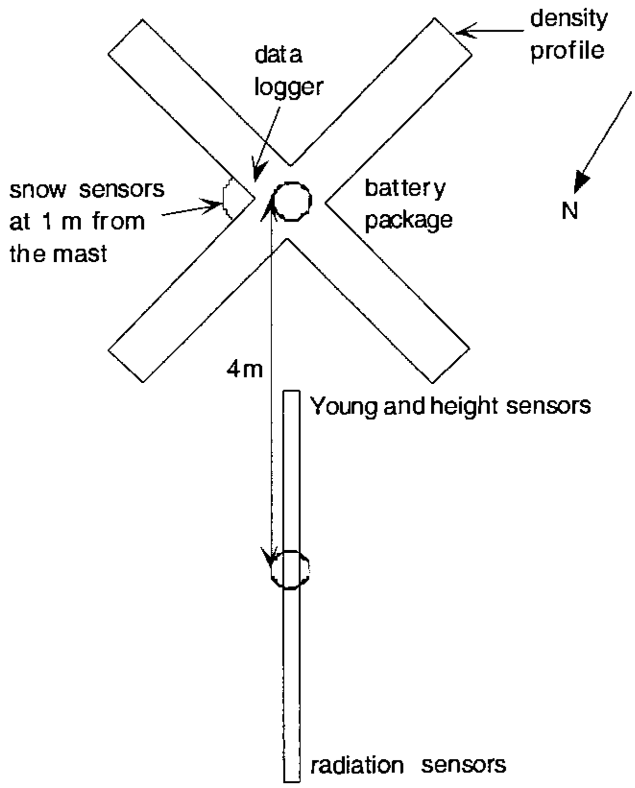

Figure 6: Schematic representation of the old and the new station at AWS 6 (top view). The old position of the mast and the orientation of the yard are shown below; the cross above indicates the leg positions of the new mast.

AWS 7

From the data returned by ARGOS to Utrecht University, it was clear that AWS 7, which is situated on blue ice, was not functioning properly. On 8 January, 2000 18:40 GMT we arrived at the station after approximately a quarter of an hour drive from Svea with a skidoo. The mast was lying on the ground with the Vaisala at the upper side. The mast was pointing (bottom to top) into the direction 133 (true bearing). One leg of the mast was broken and the anchor on the far end was pulled out of the ice (Figure 7a). The height sensor and the sensors that measure the temperature of the ice were the only sensors that were not damaged. The height sensor is mounted on a separate construction, because the net accumulation in a blue ice area is negative.

On 14 January 2000, the old station was removed from the blue ice and the new station was built approximately 5 m from the old site (Figure 7b and Figure 8a). Because the station is located on the blue ice it stands entirely above the surface. When building the new station, we noticed that the bolts on the struts connecting the legs with the mast (Figure 8b) were not tightened well. One of the struts became loose. We decided to insert spring washers from the old mast on as many strut joints as possible (this was possible for the upper bolts) and tightened all the bolts again. For a station that is not dug into the snow it is of vital importance that the leg construction is as firm as possible.

A) B)

__Figure 7:__ Photographs of A) the damaged station AWS 7, and B) the new mast at this site.

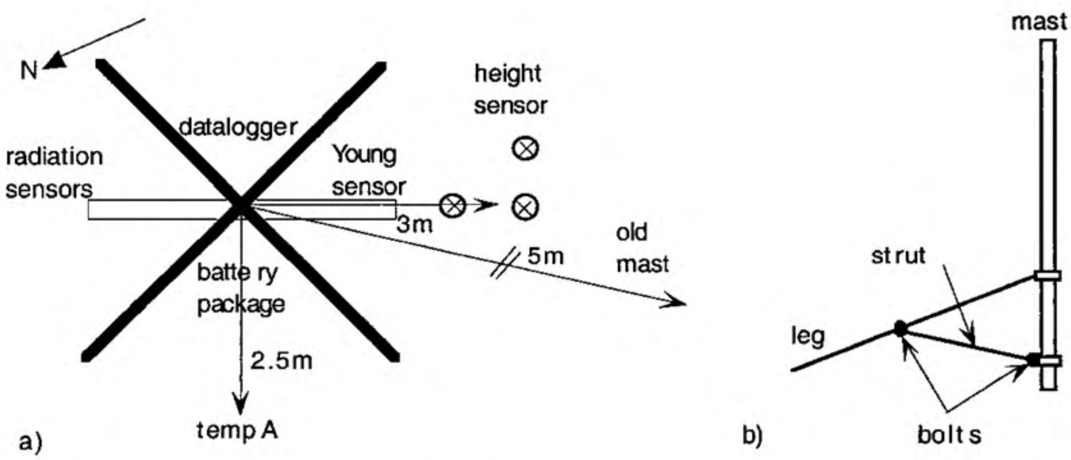

__Figure 8:__ Schematic representation of AWS 7 (top view). The height sensor is located at 3m from the mast on a construction of three stakes (indicated by ⊗). The legs of the mast are indicated by the cross. b) Schematic side view of the bolts connecting the struts to the mast and legs.

Lengths of chain were used to make anchors for the new mast. For this, a hole 1 m deep was drilled in the blue ice beside each leg. After inserting the chain, the hole was filled with water, which froze the chain in place. All sensors except the deep temperature string were connected. This temperature string was not connected until 23 January because the plug was damaged and required replacement.

Preliminary results

AWS 4 receives the largest net accumulation of all the EPICA AWSs. Figure 9 shows the distance between the height sensor and the snow surface (H). On 19 Dec 1997, when the station was installed, H was 263 cm. After a slight increase in distance, with a maximum of 269 cm on 23 January 1998, H starts to decrease, indicating net accumulation. On 2 January 2000 H is 50 cm, indicating that the net accumulation is 219 cm of snow during the two years 1999 and 2000. From the figure it is clear that the accumulation is not continuous, but occurs during several large precipitation events. The largest event occurs during the period from 20 March to 16 April 1999 in which the accumulation is 55 cm of snow (one quarter of the total accumulation during the two years). On 2 January 2000, a new height sensor was mounted on the new mast at a height of 306 cm above the surface. After this date, the distance between the sensor and the snow surface starts to decrease again as snow continues to accumulate.

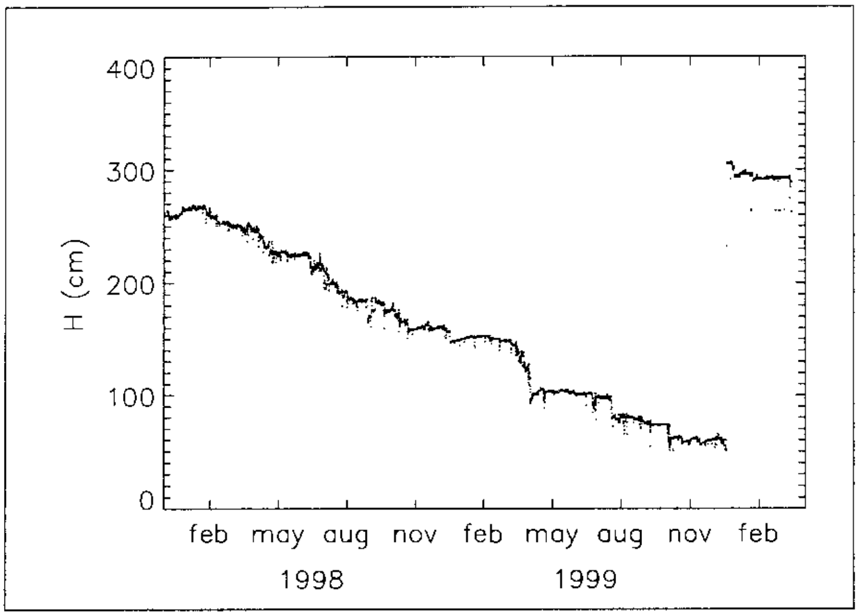

Figure 9: *Distance between the height sensor of AWS 4 and the snow surface (H) during 1998, 1999 and the beginning of 2000. At 2 January 2000, a new height sensor is installed on a new mast.*

Five temperature sensors were installed in the snow at AWS 4 at depths of 5, 10, 20, 40 and 80 cm. As described above, the sensors were slowly buried under the snow and by 2 January 2000, the depth of these sensors has increased by 219 cm. At this depth, there is hardly any daily cycle or day-to-day variation in the temperature. During December 1999, the temperature was slowly increasing. On 2 January, new temperature sensors were placed at the initial depths again. Near the surface, the summer temperature of the snow is higher and the daily cycle and the day to day variation are much larger than deeper in the snow. From the measurements of the five sensors it can be seen that the amplitude decreases with depth. In addition, there is a phase lag of the surface temperature signal which increases with depth. The amplitude of the daily cycle of the upper temperature sensor decreases during January 2000, probably because there has been some accumulation and the distance between the sensor and the snow surface had increased again.

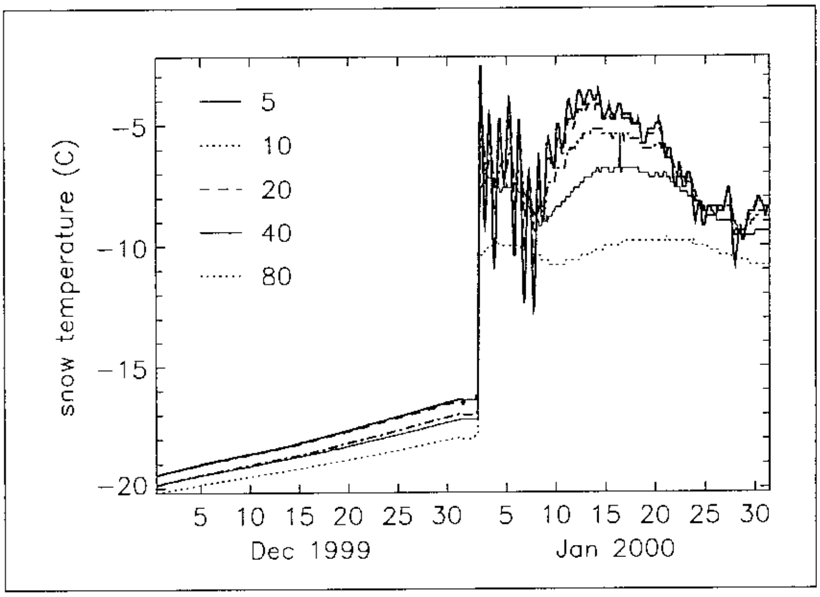

Figure 10: *The snow temperature at AWS 4 measured by the 5 sensors initially placed at 5 cm (thick solid line), 10 cm (thick dotted line), 20 cm (thick dashed line), 40 cm (thin solid line) and 80 cm (thin dotted line) during December 1999 and January 2000. On 2 January 2000, new temperature sensors were installed at the original depths.*

4. Permanent GPS Site

Background

Interpretation of the analyses from the EPICA ice core from DML will require knowledge of the history of the ice sheet in that region. Specifically, the age, and original location and elevation of the ice collected will determine the interpretation of isotopic analyses conducted on that ice. The geodetic component of the Dutch contribution to EPICA aims to provide a constraint on the ice sheet thickness through time independent of the numerical ice sheet models.

The use of geodetic observations to constrain the history of former ice sheets has been highly successful in Europe and North America. Such observations typically include geomorphological records of sea-level change over several thousand years, and modern tide-gauge and uplift observations. In Antarctica, sea-level and tide-gauge observations are sparse, due to the small number of rocky coastal 'oases' where they can be measured. Geodetic methods with wider coverage are therefore needed to provide continent-wide measurements of isostatic movements of the Antarctic crust. Planned satellite-based altimetry and gravity field observations offer one method of resolving the responses to former ice sheet thickness changes and modern mass balance (Bentley and Wahr 1998). Alternatively, ground-based measurements can be made where rock emerges from beneath the Antarctic ice. Long time-series of continuous GPS observations have successfully observed the pattern of isostatic rebound in Scandinavia (Scherneck *et al.* 1998), and predictions of rebound in Antarctica indicate that it should also be possible in several regions. Apart from the permanent sites at most Antarctic bases, there are three other networks of GPS receivers in Antarctica aiming to measure the isostatic rebound (Raymond et al. 1997, Donnellan et al. 1999, Zwartz et al. 1999). Establishing a network in DML will contribute to a continent-wide coverage of ground-based geodetic observations in Antarctica.

Equipment

The GPS receiver used at the new Svea site is a Leica CRS1000, which is specifically designed to operate as a continuous reference station. The receiver draws its power from six gel batteries, mounted in three pairs. The batteries are charged by six solar panels and a wind generator. Each solar panel and the wind generator is separately regulated to charge the batteries. The details of these components are listed in Table 3.

Table 3 : *Components of the Svea permanent GPS installation.*

Item	Specifications
GPS Receiver	Leica CRS1000
Antenna	Leica AT504 Choke Ring antenna and radome
Batteries	6 x Sonnenschein Dryfit A512, 12 V/85 A.h.
Solar Panels	Solarex, 3 x VLX-53, 3 x SX-50
Solar panel regulators	Solarex SRX-6
Wind generator	Southwest Windpower AIR Marine 12 V 403

The entire system is controlled by an electronics package "AntPac 2000" developed by the Research School of Earth Sciences at the Australian National University. This distributes power from the batteries to the GPS and other instruments that may be operated in the system. It monitors the temperature within the instrument box, and if necessary switches heaters on and off to maintain a pre-set minimum temperature. It also logs diagnostic data from the system, such as the solar panel voltages, charge and health status of the batteries, and temperature at 4 points inside and outside the box. Once per day a data logger is activated, which downloads the previous day's data from the GPS receiver and the system diagnostic data and stores them on a PCMCIA memory card.

The entire instrument package is mounted inside an aluminium box with 15 cm of Styrofoam insulation. The thickness of insulation was chosen to minimise the amount of heating required during winter, utilising the instruments' power consumption to heat the box, while also not causing the instruments to overheat during the summer.

Installation

The antenna was placed on an outcrop of solid bedrock at the south end of the knoll close to Svea Station (Figure 11). The site was chosen for stability of the mark (most of the ridge crest consists of glacial debris or frost-shattered bedrock), and because it should have minimal snow accumulation, located at the top of a cliff on the windward side of the ridge. The benchmark hardware was supplied by the Australian Survey and Land Information Group (AUSLIG), and was designed by them specifically for permanent GPS sites. A central bolt which supports the antenna is sunk approx. 200 mm into the bedrock and secured with epoxy. Three smaller posts level the mark and provide support, and are also drilled into the rock and secured with epoxy. The base of the antenna stands only approx. 150 mm above the rock surface (see Cover photo), in order to minimise the problems of reflected microwave signals (multipathing).

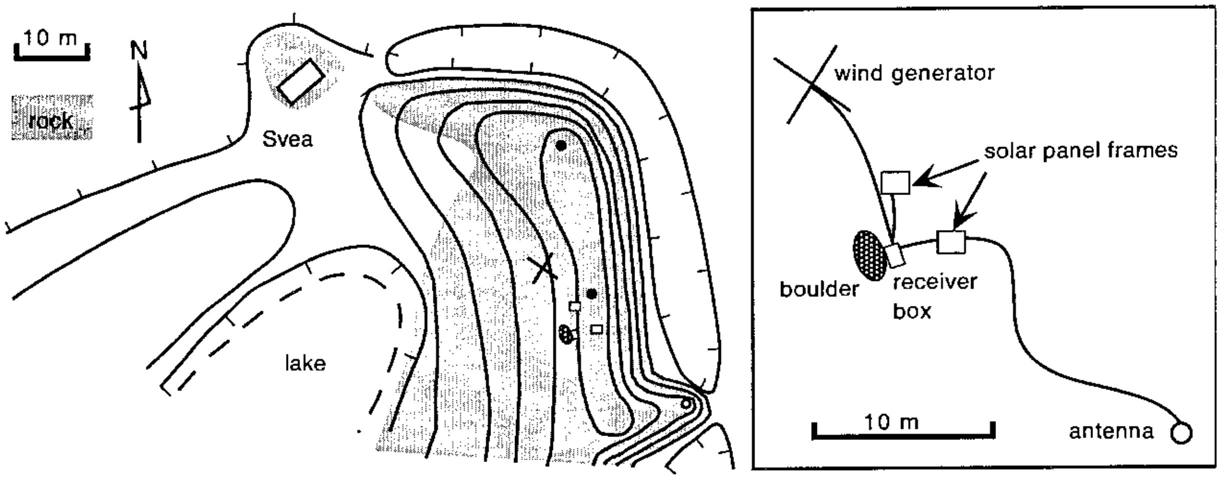

Figure 11 : Map of the site of the permanent GPS installation near Svea station. The contour map at left shows the site in relation to the field station Svea; an enlargement of the site showing the positions of system components and wiring is shown on the right. The solid black dots on the contour map represent GPS points installed by members of SWEDARP in 1991/92.

Mounted on the benchmark is a Leica AT504 Choke Ring antenna, with a plastic spherical radome to prevent snow accumulation within the antenna. Since other Antarctic GPS sites have had problems with ice accumulation within the radome, a silicone sealant was used to ensure that no snow can enter.

The solar panels are mounted in two arrays facing north, pointing 20° above the horizon. The frames supporting the panels are weighted down with rocks and anchored by steel cables.

The wind generator was mounted on a four-legged mast, similar to those of the Automatic Weather Stations. The mast is located slightly on the leeward side of the ridge, with the generator approximately 3.5 m above the ground, so that the generator is exposed to the wind while the mast remains somewhat more in shelter. The legs of the mast were adjusted so that the mast is vertical, and are weighted with rocks. Guy wires run from the mast to each leg, and also to four bolts placed in large nearby rocks.

Both the solar and wind charging systems had an initial design fault: a diode in the circuit intended to regulate the charging voltage prevented the regulators from properly sensing the battery voltage, and led to overcharging until the problem was noticed. The diodes were removed from the circuit. Although all batteries appeared to be operating normally after the overcharging, one which had leaked some liquid was removed from the system, since it could disrupt charging of the other batteries if it failed while still connected.

Preliminary Results

From the time of installation on January 19 until leaving Svea on January 28, the GPS recorded 10 complete days of data. While this is less than planned, because of the delay reaching Svea, it is sufficient to assess the data quality from this site as well as the best method of processing. Processing will be done in collaboration with DEOS, the Delft Institute for Earth-Oriented Space Research, at the Technical University of Delft.

Logged internal and external temperatures indicate that the insulation is sufficient to keep the instrument 35 - 40°C above the ambient temperature, depending on the amount of sun falling on the site. Even during summer, the site receives no sun for several hours during the night due to the surrounding mountains. On the basis of temperatures recorded at the nearby weather station AWS 7 in 1998, the temperature observations indicate that additional heating should be required on approximately 10 days during the winter.

While the solar charging system was being modified, the system operated for a few days with the wind generator as its only power supply. The generator easily fulfilled the power requirements of the system, as it must during winter when there is no solar power.

5. Conclusions

The main objectives of the expedition were accomplished - maintenance of the four AWSs and installation of the GPS site. Given the short time at Svea, we consider the expedition productive and successful. Our work programme suffered because of its dependence on the large helicopters for transport at the beginning of the season, but even in retrospect it seems that this could not have been avoided. Our small party did not have the resources for independent transport of all our equipment, and we were lucky to have the opportunity to travel to Svea with SWEDARP relatively early. Planned work that was not accomplished due to lack of time included investigations of changes in local ice thickness by studying the glacial geology. It is hoped that this work can be accomplished in the 2000-01 summer, when we hope to revisit the GPS site.

Maintenance of the 4 AWS's was successfully accomplished. The quality of the stations and data at the snow sites is an indication of the excellence of the original design and installation of the equipment. Minor improvements suggested by our experiences this year include a simpler method of mounting the data logger and battery boxes on the mast, and standard routing of the sensor cables to make recovery of the boxes safer and easier. At the site on blue ice, where the original station was destroyed, some of the weaknesses of the present station design were observed, but solutions are not obvious. The fundamental problem is that anchors holding the legs of the mast always become slack, because the surface is ablating, and this allows the mast to move in the wind. From the broken mast, and the installation of the new station, it is clear that the joints between the legs and the mast, and where the struts join the legs, are the weakest points of the construction.

The GPS site was installed as planned and left operating, and needs to be visited again to recover stored data and check the status of the system. It is planned to return to the site in the 2000-01 season. Ten days of data were recorded while we were at the site, and these will be used during 2000 to establish the method for processing the data we expect to recover in coming years.

Acknowledgements

We thank all members of the FINNARP and SWEDARP for their assistance and companionship during the expedition. In particular, Henrik Sandler and Mika Kalakoski worked extremely hard to coordinate the entire expedition, and Magnus Augner and Tomas Karlberg generously gave assistance whenever we requested it. We also thank the expedition staff and crew of the Akademik Fedorov for their logistic support with the ship and helicopters. We are also grateful to the following people and institutions:

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Bob Twilley (AUSLIG, Australian Surveying and Land Information Group)
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Keith Preston (Andrew Lusk & Co.)
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Appendix A: Report to Swedarp on occupation of Svea

<u>**Report on occupation of Svea Station, January 2000**</u>

To: Magnus Augner
Swedarp Expedition Leader 1999-2000

From: Dan Zwartz
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General

The Dutch scientific party, consisting of myself (DZ) and Nicole van Lipzig, and operating with FINNARP under the project EPICA-NL-2 of the Dutch Antarctic Programme, used the Swedish Antarctic station Svea as a base for our work during January 2000. We did this with the kind consent of the Swedish Antarctic Programme, and agreed to all of the conditions of use stated to us.

We occupied the base from January 7 to 29, and worked at the sites of two Automatic Weather Stations in Scharffenbergbotnen and at Sveakorsett, and installed a permanent GPS receiver for geodetic observations on the hilltop adjacent to Svea. A brief timetable of our stay is as follows:

January 6: Depart Aboa/Wasa 2300
January 7: Arrive Svea 1300. FINNARP glaciological party depart for Millorgfjella.
January 8: Scharffenbergbotnen weather station reconnaissance
January 9: Sveakorsett weather station maintenance
January 10: GPS site reconnaissance. Swedarp vehicles depart for depot on plateau.
January 11: Bad weather
January 12: Swedarp party return from plateau, and depart for Wasa.
January 13: Bad weather
January 14: FINNARP tracked vehicles arrive from Aboa. Scharffenbergbotnen weather station maintenance
January 15: FINNARP glaciological party return. FINNARP tracked vehicles depart for Aboa.
January 16: FINNARP glaciological party depart for Kibbergdalen. Begin work on GPS site.
January 17-22: Work at GPS site.
January 23: Work at GPS site and Scharffenbergbotnen weather station. FINNARP glaciological party return.
January 24: Work at GPS site
January 25: Work at Scharffenbergbotnen weather station.
January 26: Work at GPS site.

January 27: Work at GPS site. NvL departs for Aboa by helicopter 1445.
January 28: Work at GPS site.
January 29: Close station. Depart 1300 for Aboa.

Arrival

We arrived at Svea on January 7, after travelling from Aboa/Wasa with the Swedish tracked vehicles. We are grateful to Swedarp for allowing us the use of this transport for us and our equipment, enabling us to get to our work area as soon as possible after the delays caused by poor weather early in the season.

Svea was already open, having been occupied one week by the FINNARP glaciological party of John Moore, who left on the same day we arrived. They had turned on the gas system for cooking and brought the heater into working condition. They did not use any of the food already in Svea, and left the station clean and tidy.

When we arrived, Swedarp personnel installed the HF and VHF aerials, and the toilet drum in a tent on the snow below the station.

Residence

During our occupation of Svea, we had no problems with any of the facilities:

- We slept on the bunks, using our own sleeping bags.
- We used the existing gas cylinders for cooking and heating. In total, six 14 kg cylinders were used, including the gas used by the glaciological party before our arrival. Three empty cylinders were removed by the Swedarp party. Three used and six unopened 14 kg cylinders remain, as well as six new 18 kg cylinders brought by FINNARP.
- Initially we obtained drinking water from the Swedarp vehicles' supply. Later, from the lake behind the station.
- Waste water from the kitchen was poured into the snow near the toilet tent.
- The VHF and HF radios functioned well. Good communications with Aboa and the glaciological party were possible almost every day.
- We used the solar-charged battery (already at Svea) to power the radios, and also the GPS receiver (15 W) for three days while testing it indoors. The charge regulator for the solar panels remained on 'charge', and never indicated a low battery.
- In the construction of the guy wires for the mast of the wind generator at our GPS site, we used nine small cable clamps which were in the station. We will replace these before the 2000-2001 field season.

Departure

One person (NvL) left by Jet Ranger helicopter on 27 January, while the remaining 4 (DZ and FINNARP glaciological party) left with skidoos and sleds on 29 January. In closing the station, the following actions were taken:

- The gas supply was turned off at the valves inside and outside the station. Two used cylinders were left connected to the system, which were still supplying sufficient gas for cooking and heating. In addition, as mentioned above, six existing 14 kg cylinders and six new 18 kg cylinders remain at the station.
- Drinking water and waste water containers were emptied.
- The VHF and HF aerials were demounted from the roof and stored inside.

- The solar panels were left connected to the battery, as instructed.
- The generator was stored inside the station.
- The toilet waste was sealed in the 200 litre drum, and left in the snow close to the zero-accumulation line at the edge of the blue ice. It is also marked with a pole. The toilet tent was stored inside the station.
- The food-storage cupboard under one bunk was cleaned, where a glass bottle of soy sauce left on a previous expedition had frozen and burst.
- The station and cooking equipment were cleaned.
- The door was latched and secured with a pin.

The following items were left at the station:

- Three 20-day ration boxes, outside the station.
- Extra food (tinned and dried) was stored under the bunk or in the cupboard.
- Two 25 litre plastic jerry-cans of JET A-1 (for camping stoves), 2 litres Sinol (ethanol), and 10 litres 2-stroke engine oil were left in the station. (One container of JET was from the Dutch party, the remaining materials from the FINNARP glaciological party).
- A sealed gel-cell battery and a spare set of rotor blades for the wind generator were left in anticipation of a revisit to the GPS site.

We found Svea ideally suited to our requirements as a base for work in the area, and would like to thank Swedarp for their kindness and assistance throughout the season.

Dan Zwartz

Dan Zwartz
Dutch scientific party
3 February 2000

Appendix B: Environmental Report

This appendix contains a transcribed copy of the Environmental report of the EPICA-NL-2 expedition, which was submitted to FINNARP in May 2000:

POST-ACTIVITY REPORT

SCIENTIFIC ACTIVITIES IN ANTARCTICA

Finnish Institute of Marine Research
Finnish Ministry of the Environment
Norwegian Polar Institute
Swedish Polar Research Secretariat

1. General Information

Project Title: EPICA-NL-2A: Geodetic measurements to constrain ice sheet history in Dronning Maud Land

Project Leader: Dan Zwartz

2. Project Deviations

Describe any major deviations between activity as it was described... in advance of the activity and as it was actually accomplished (time period, area of field work, number of participants, transport and accommodation).

All work was conducted as planned. Because of adverse weather at the beginning of the season, the following changes to transport and accommodation were made:

1) We stayed at Aboa from 20 December 1999 to 6 January 2000, instead of flying from the ship directly to Svea.
2) Weather station AWS 5 (10 km from Aboa) was visited by snowmobile from Aboa, instead of by helicopter from Rampen.
3) Travel to Svea was overland from Aboa by Swedish tracked vehicle, instead of by helicopter from Rampen.

3. Environmental Impacts

3.1 Unexpected incidents with possible environmental consequences

Description of chemical or fuel spills.

None

Description of incidents leading to damage or loss of flora and fauna.

None

Description of damage to or removal of historic monuments.

None

3.2 Handling of waste and fuel deviating from given procedures

Description of disposal of waste not in accordance with Nordic Waste Management Plan (description of alternative handling method and reason for deviation).

Toilet waste at Svea was collected in a fuel drum for transport out of Antarctica, as required.

Description of fuel handling not in accordance with Nordic Fuel Handling Guidelines.

None

4. Special Permits

4.1 Specially protected areas

For each *Specially Protected Area* or *Site of Special Scientific Interest* visited, a SCAR Visitor Report form is to be completed.

No SPA's or SSSI's were visited.

4.2 Collection of fauna and flora

Specify use of permits.

None

4.3 Import of fauna and flora

Describe any deviations from conditions specified in permits granted for import of fauna and flora.

None

May 2000

Date **Signature**

Appendix C: AWS sensor heights and mast orientation

Before and after maintenance, the height of the sensors and the angle of the mast and yard of the automatic weather stations were measured. A definition of the variables used is given below.

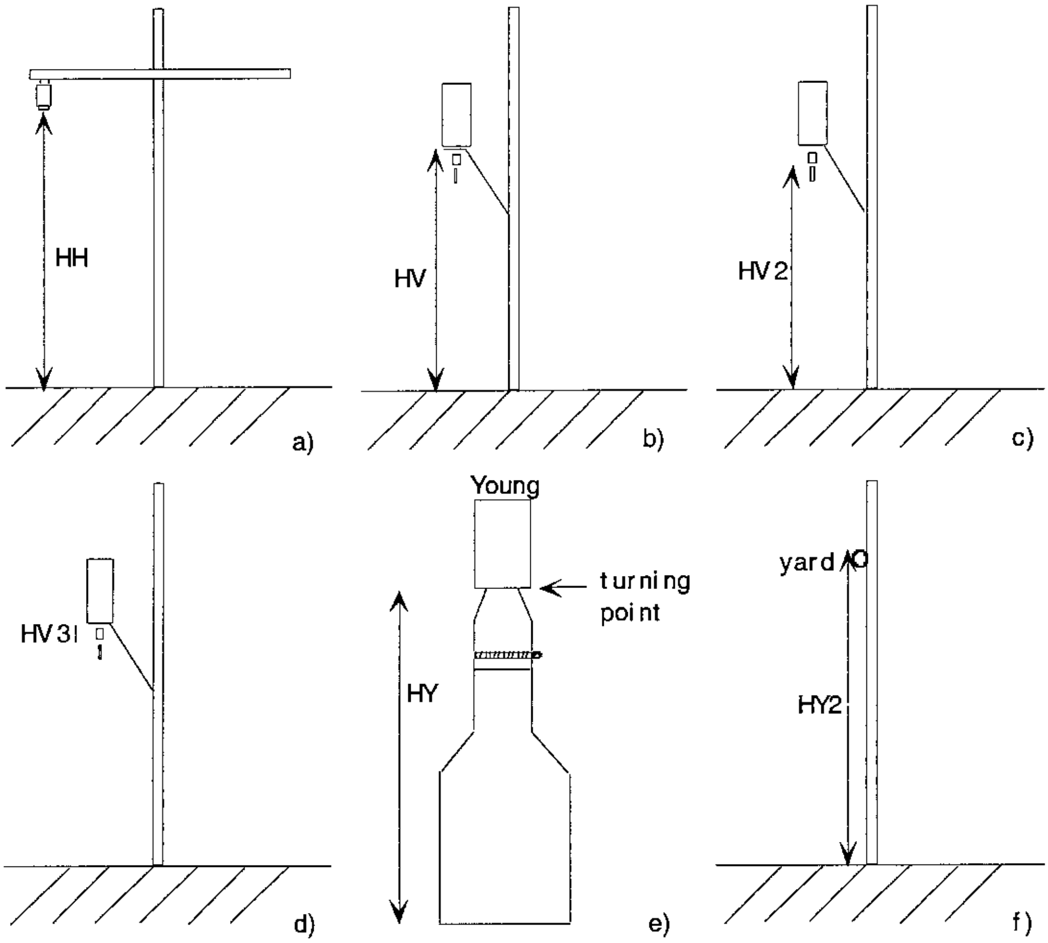

Figure 12: a) HH: height from the surface to the lowest part of the height sensor, b) HV: height from the surface to the plate of the Vaisala sensor, c) HV2: height from the surface to the top of grey/black part of the Vaisala sensor, d) HV3: height from the top of grey/black part of Vaisala sensor to the plate of the Vaisala sensor, e) HY: height from the turning point of the Young sensor to the bottom part of the height sensor and f) HY2: height from surface to the top of the yard.