Installation of two AWS on Larsen C Ice Shelf, Antarctica

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Field Report

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Institute for Marine and Atmospheric Research Utrecht (IMAU)

Contents

List of acronyms

AWS	Automatic Weather Station
BAS	British Antarctic Survey
CIRES	Cooperative Institute for Research in the Environmental Sciences (USA)
IMAU	Institute for Marine and Atmospheric research Utrecht
JPL	Jet Propulsion Laboratory (USA)
NERC	Natural Environment Research Council (UK)
SAR	Synthetic Aperture Radar
UU	Utrecht University

Photo on front cover: evening view from Rothera station over the iceberg-filled lagoon towards the north. Photo: IMAU

1. Background

For the cold Antarctic ice sheet, surface melt has long been considered of limited importance. This changed with the recent discoveries that surface melt occurs up to 2000 m elevation in West Antarctica, and that melt determines the viability of ice shelves. Ice shelves, the 200-1000 m thick floating extensions of the ice sheet, are situated at sea level where sustained surface melt may occur during summer (Fig. 1). The leading hypothesis that links ice shelf viability to ambient temperature identifies surface melt as a key process: pressure from infilling meltwater extends fractures in the ice shelf downward, and a 90% filling of crevasses is sufficient to completely penetrate the ice shelf. The geographical co-location of areas with meltwater ponds (dark streaks in left panel of Fig. 2) and the final area of disintegration provide support for the melt pond theory. Moreover, meltwater ponds appear to drain into the ocean just prior to break-up, indicative of crevasses that run through the entire ice shelf. If an ice shelf retreats past the stable ice front position, further retreat occurs in a catastrophic fashion through the capsizing of vertical ice shelf fragments (Fig. 2 right panel). Ocean warming and enhanced basal melt have likely thinned the ice shelves prior to break-up.

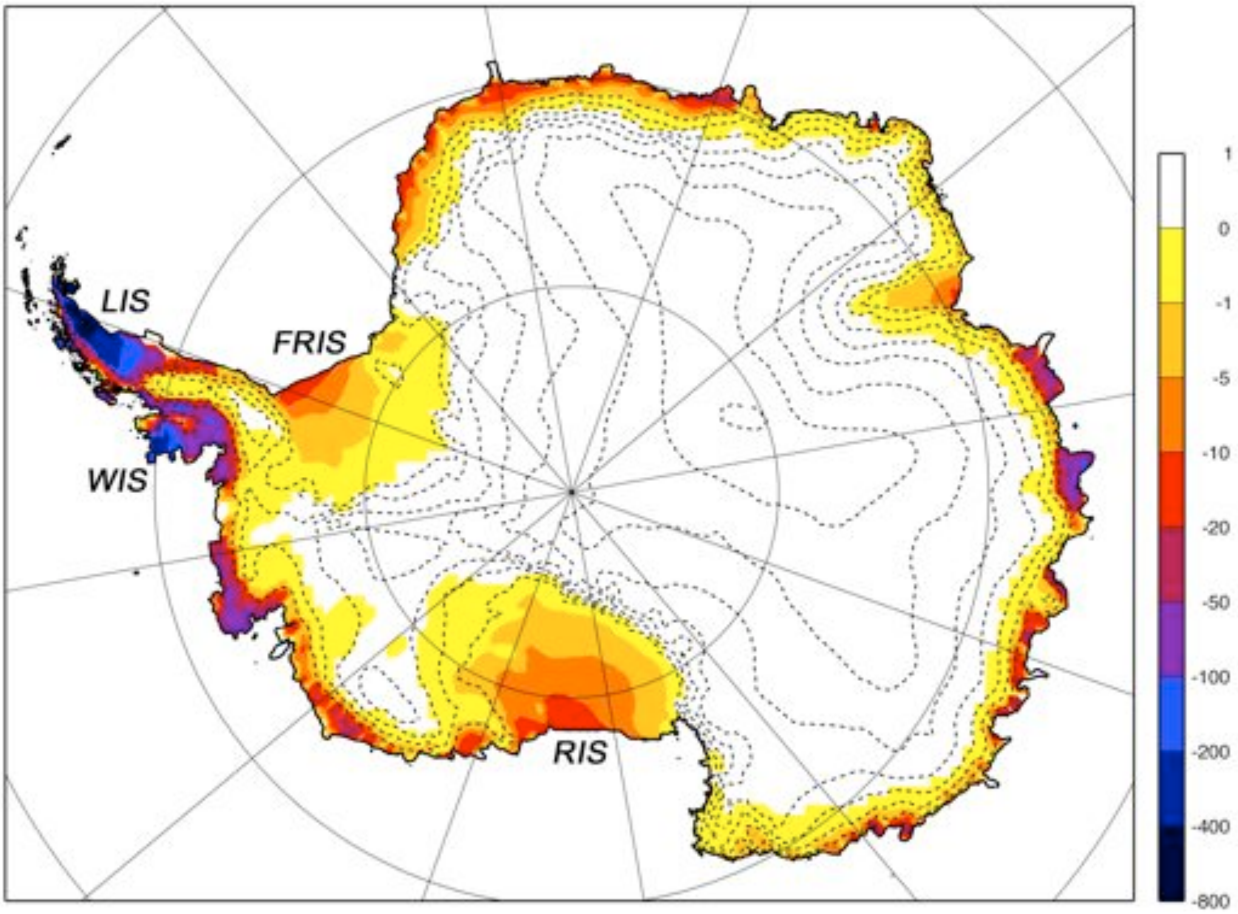

Figure 1. *RACMO2/ANT modelled surface melt in Antarctica (mm w.e. yr^{-1}, 1980-2004). LIS: Larsen ice shelf, WIS: Wilkins ice shelf; RIS: Ross ice shelf; FRIS: Filchner-Ronne ice shelf.*

According to Fig. 1, all ice shelves fringing the Antarctic coast experience some melt. It has been shown that the present-day -9 °C annual isotherm represents an approximate limit for Antarctic ice shelf viability. A 2 °C warming in the Antarctic Peninsula (AP) since 1979 has increased summer melting intensity and forced the limit of ice shelf viability southward by several latitudinal degrees. This was followed by a rapid retreat of the northernmost AP ice shelves, punctuated by the catastrophic collapse of the Larsen A ice shelf in January 1995. In February 1998, the front of the more southerly Larsen B ice shelf retreated behind its stable geometrical position, followed by its catastrophic collapse between 31 January and 7 March 2002, in which event over 3,200 km^2 broke away (Fig. 2). For this event, the calculated meltwater production of 400 mm per year closely matches the predicted amount needed to fill crevasses to the critical 90% level. If an annual melt of 400 mm indeed represents the threshold for ice shelf viability, Wilkins and Larsen C ice shelves are close to the limit (Fig. 1). Starting in May 2008, Wilkins has started to break up.

The break-up of ice shelves does not influence sea level, because they are afloat. However, ice shelves provide resistance to the grounded glaciers that feed them. After the break-up of Larsen B ice shelf, tributary glaciers accelerated with factors two to eight and thinned by tens of m per year. At present, AP glaciers are responsible for a net annual discharge of 51 +/- 47 km^3 into the ocean. Similar ice dynamical mechanisms may presently be active in the Amundsen Sea coast of West Antarctica, where satellite and airborne surveys also show rapid thinning and acceleration. Glaciers in the Amundsen Sea sector of West Antarctica are now discharging 106 +/- 60 km^3 of ice per year to the ocean, together with the Peninsula explaining >10% of present-day sea level rise. In combination with a grounding line that is situated far below sea level, there is concern that this catchment could drain into the sea, raising global sea level by 1.3 m.

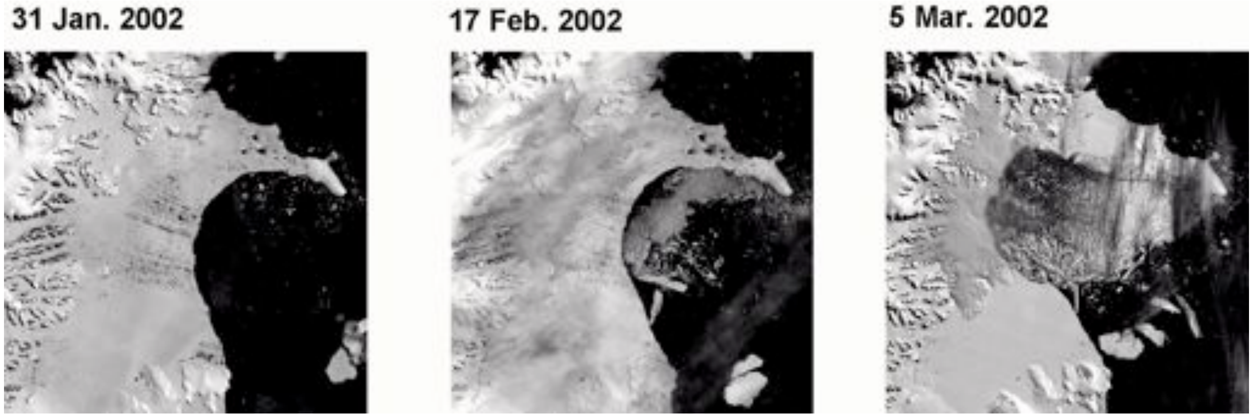

***Figure 2**. Disintegration of Larsen B ice shelf, January-March 2002. Image covers an area of app. 100 x 100 km. Note meltwater ponds on the ice shelf surface in the left and middle panel. Larsen A ice shelf, north of Larsen B, broke up six years prior to this date. Larsen C, south of Larsen B, is still intact. Image from http://nsidc.org/icebergs/.*

2. Research objectives and approach

It is clear that there is an urgent need to investigate melting in Antarctica in much greater detail than has been done thus far. The main objective of this project is therefore *to quantify surface melting in Antarctica using a combined observational and modelling approach.* We want to answer four research questions:

1. How strong is melting on Larsen C ice shelf and what are the feedbacks (albedo)?
2. What is the spatial and temporal distribution of melting in Antarctica?
3. How do these results compare to satellite-detected melting in Antarctica?
4. How does large-scale circulation variability affect melting in Antarctica?

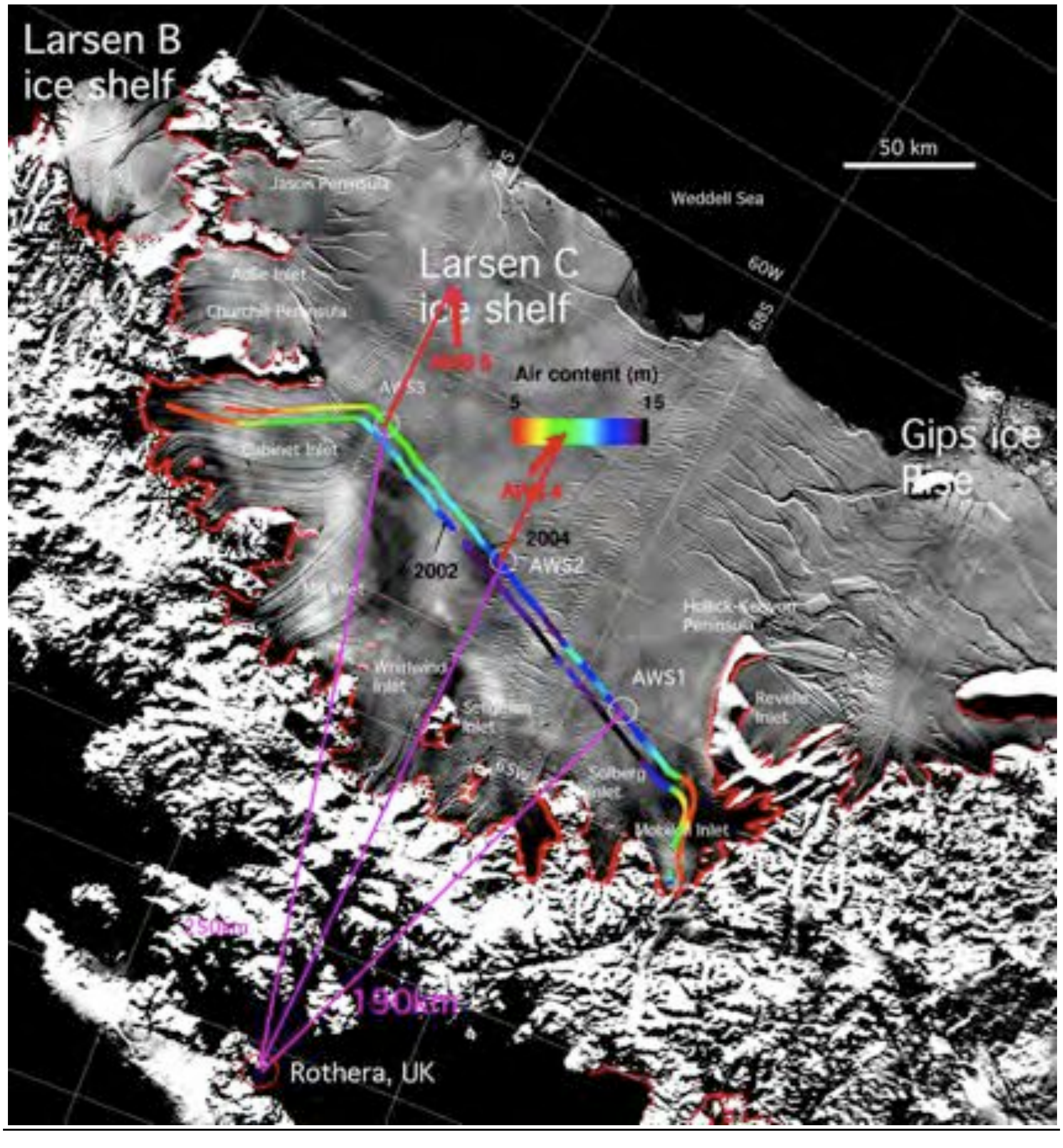

__Figure 3.__ Fieldwork locations; Background: SAR image of Larsen C ice shelf (Image: Konrad Steffen, CIRES).

Answering research question 1 involves initiating glacio-meteorological measurements on Larsen C ice shelf. To that end, UU/IMAU has built two dedicated automatic weather stations (AWS), equipped with sensors to measure the full surface energy balance (wind speed, temperature, relative humidity, shortwave and longwave downward and upward radiation and air pressure and snow temperatures). These AWS will provide the necessary data on the local timing and intensity of melt on Larsen C ice shelf as well as to quantify feedbacks through melt-related darkening of the surface (albedo). The AWS were installed on Larsen C ice shelf in January 2009, and these activities are described in this report. The AWS are equipped with 15 m long thermistor strings to detect meltwater penetration and refreezing in the firn. In addition, at one site an automatic digital camera monitors the characteristics of the ice shelf surface during the daylight period. A sonic height ranger has been fixed to the deeper snow/ice layers to measure surface accumulation and ablation in order to validate the AWS-derived melt flux. In addition to the meteorological measurements, low-cost stand-alone GPS receivers have been installed for year-round monitoring of ice velocity. Data from both AWS and GPS are relayed to Utrecht via ARGOS, depending on the data volume.

3. International framework

This work is part of three collaborative Antarctic research projects:

Melting in Antarctica: a combined modelling and observational approach Funded by NOW/ALW. PI: Michiel van den Broeke (UU/IMAU) postdoc: Peter Kuipers Munneke. Collaborators: John King (British Antarctic Survey), Konrad Steffen (CIRES, USA), Eric Rignot (University of Irvine and JPL, USA).

Long term monitoring of Antarctic climate using Automatic Weather Stations PI: Michiel van den Broeke (UU/IMAU).

Stability of Larsen C ice shelf in a warming climate PI: Konrad Steffen (CIRES, USA); Collaborators: Michiel van den Broeke (UU/IMAU), Eric Rignot (University of Irvine, Jet Propulsion Laboratory, USA), Dr. Anja Wendt, Mrs. Francisca Brown, Dr. Gino Casassa, Dr. Andres Rivera (Centro de Estudios Cientificos, Valdivia, Chile).

Table 1. *Approximate AWS locations, see Fig. 3.*

Station (BAS names)	Latitude	Longitude	Remarks	Distance to Rothera (km)
AWS1	68°31′53″S	64°21′50″W	US AWS	190
AWS2	67°54′58″S	63°32′56″W	US AWS	215
AWS3	67°25′59″S	62°52′36″W	US AWS	250
AWS4	67°29′18″S	61°44′04″W	IMAU AWS 15	260
AWS5	68°00′16″S	62°20′48″W	IMAU AWS 14	295
AWS6	69°30′00″S	66°36′00″W	Chilean AWS	240

4. Fieldwork locations

The two UU/IMAU AWS are part of a larger network of five AWS on the ice shelf. The three other AWS were to be installed by the group of Konrad Steffen in November 2008, but due to serious delays in the arrival of aircraft and equipment, the AWS were installed by BAS personnel in December 2008 instead, after Steffen had left Antarctica. Fig. 3 shows a map of the fieldwork area, including the location of and flight lines from Rothera research station (UK). The UU/IMAU AWS are located approximately 260 and 295 km distance from Rothera (see Fig. 3 and Table 1). Both AWS sites are equipped with a GPS receiver that transmits the AWS position to Utrecht via the ARGOS system every 6 days.

The activities described in this report coincide with enhanced research activity on Larsen C ice shelf. In 2008/09, groups from Swansea University (UK, dr. Bernd Kulessa), the University of Edinburgh (UK, dr. Andrew Shepherd) and CIRES (US, dr. Konrad Steffen) were active on Larsen C ice shelf, supported by BAS personnel. In 2009/2010, joint research flights between BAS and AWI will be conducted to study cloud microphysical properties.

Figure 4. *Embarking the British Antarctic Survey Dash-7 in Punta Arenas.*

A more extensive surface meteorological experiment will take place in 2010/11, for which a proposal has recently been submitted to NERC, and on which Michiel van den Broeke is a named collaborator (PI: John King, BAS). All these activities will be coordinated so as to get optimal scientific output and data exchange.

Figure 5. *View over Rothera research station towards the north.*

5. Travel itinerary

Equipment was sent to BAS in Cambridge before the July 31, 2008 deadline, from where it was shipped to Rothera research station. The original plan was for IMAU to install the automatic weather stations (AWS) in November 2008. However, the fieldwork was delayed at the latest moment because of problems with the certification of the Twin Otter aircraft in the UK. It was decided to postpone the fieldwork to January 2009. Fieldwork participants Michiel van den Broeke and Wim Boot travelled to Rothera via Madrid, Santiago de Chili, Punta Arenas (Chili).

Wednesday January 7, 2009 15h LT: Expedition members Boot and Van den Broeke leave for Santiago de Chili, via Madrid. Overnight in aircraft.

Thursday January 8, 2009 14h LT: Expedition members Boot and Van den Broeke leave for Punta Arenas. Overnight in Punta Arenas.

Friday January 9, 2009 10h LT: Expedition members Boot and Van den Broeke leave for Rothera in British Antarctic Survey Dash-7, arrival 14h. Tour of the station by station manager John Withers. Evening: collection and preparation of equipment. Overnight at Rothera.

Saturday January 10, 2009 Safety and health instructions. Vehicle and snowscooter instructions. Medical instructions, communications instructions. Walk around Rothera Point. In the evening: preparation of equipment. Overnight at Rothera.

Sunday January 11, 2009 Preparation of equipment, test of steamdrill, test of AWS, test of ARGOS transmitter. Provide weights for aircraft planning. Overnight at Rothera.

Figure 6. *Preparation of GPS receivers in the lab at Rothera.*

Figure 7. *Before deployment of scientists in the field, a field and safety training was completed in the hills in the direct vicinity of Rothera. Photo: Reuters.*

Monday January 12, 2009 Camera testing, field training start, overnight in tent at field training site.

Tuesday January 13 to Saturday January 17 2009 End of field training. Insufficient contrast over Larsen C ice shelf for landing, standby for field deployment. Overnight at Rothera.

Sunday January 18, 2009 Insufficient contrast over Larsen C ice shelf for landing, standby for field deployment. Boat trip to Sheldon Glacier. Deployment of IMAU GPS sensor on remains of Wilkins Ice Shelf by David Vaughan, British Antarctic Survey. Overnight at Rothera.

Monday 19 and Tuesday 20 January 2009 Insufficient contrast over Larsen C ice shelf for landing, standby for field deployment. Obtaining information from Utrecht that GPS on Wilkins Ice Shelf works.Overnight at Rothera.

Wednesday 20, January 2009 Field deployment of both AWS: 11h30-13h00 flying to AWS 15 site; 13h00 to 16h30 deployment of AWS, GPS; 16h30 to 17h00 flight to site AWS 14; 17h00 to 21h30 deployment of AWS, GPS and camera system; 21h30-22h15 skis of Twin Otter are frozen to the surface, which prevents take-off, the aircraft is freed after 45 minutes; 22h15-23h30 return flight to Rothera; storing leftover equipment. Overnight at Rothera.

Thursday 21 January 2009 Repacking of leftover equipment for sending to Utrecht. Obtaining information from Utrecht that AWS and GPS work.

Friday 22 January 2009 Clean-up activities, preparation for departure. Van den Broeke is interviewed by Reuters journalists about use of AWS and collaboration between UU/IMAU and BAS. Boot supports Italian researchers by performing reparation on their permafrost monitoring equipment.

Saturday 22 January and Sunday 23 January 2009 Waiting for departure. Gould party. Overnights at Rothera.

Monday 24 January Travel from Rothera to Punta Arenas with BAS Dash-7. Overnight in Punta Arenas.

Tuesday 25 January and Wednesday 26 January 2009 Travel Punta Arenas to Amsterdam via Santiago de Chili and Madrid. Overnight in plane. Arrival Amsterdam 18h.

Figure 8. *During the first week of our stay at Rothera, expedition members made a boat trip to Sheldon Glacier, in the vicinity of Rothera station.*

6. Future of the project

AWS data become scientifically more valuable if the time series are long (> 5 yr). That is why UU/IMAU has signed a Memorandum of Understanding with BAS that ensures that the AWS will be serviced by BAS personnel in the next five years, with the possibility to extend. If problems occur, there is also the possibility to send IMAU personnel to Rothera, for more substantial revisions. The data of the AWS can be viewed online at:

www.phys.uu.nl/~wwwimau/research/ice_climate/aws/antarctica_data.html

7. Acknowledgments

We would like to warmly thank all British Antarctic Survey staff for the excellent support and facilities offered, both in the UK and in Antarctica, which made our stay at Rothera very enjoyable. Without their help this work could not have been completed.

Figure 9. *The completed AWS15 on Larsen C ice shelf, next to the BAS Twin Otter. Right of the AWS a stand-alone height sensor is installed as well as a stand-alone GPS receiver (with red tape for enhanced visibility), with ARGOS antenna.*

Appendix: station specifications UU/IMAU AWS14 and AWS15

Equipment description: Aluminium mast with a single measurement level at app. 3.5 m at the date of installation. Data transmitted continuously through ARGOS and stored locally in Campbell CR10 datalogger with separate memory module.

Location: Larsen C Ice Shelf

Period of operation: 20 January 2009 to present.

Sampling frequency: pressure: 60 minutes, instantaneous; all other sensors: 6 minutes (instantaneous, except for wind speed, cumulative) after which 60 min means are stored. The snow thermistors are especially made and have 0.5 ºC accuracy. The thermocouple has been included to study radiation errors in the temperature measurement.

Sensor	***Type***	***Range***	***Accuracy***
Air pressure	Vaisala PTB101B	600 to 1060 hPa	4 hPa
Air temperature	Vaisala HMP35AC	-80 to +56 ºC	0.3 ºC
Air temperature	Campbell Chromel Constanta	-40 to +40 ºC	0.1 ºC
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 360º	3º
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%

At AWS14, an automatic photo camera has been installed that takes four images per day at 11 GMT, 13 GMT, 15 GMT, 17 GMT.

At both sites, a stand-alone GPS receiver was installed, that sends daily averaged positions each 6th day.