Technical Report 11-18

QASITEEX 2011
The Qaanaaq sea ice thermal emission experiment
Field report

Copenhagen 2011

DMI Technical Report

Colophon

Serial title:
Technical Report

Title:
QASITEEX - 2011

Subtitle:
The Qaanaaq Sea Ice Thermal Emission EXperiment
Field and data report

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Language:
English

Keywords:
Sea ice temperature, brightness temperature, microwave, thermal infra red, ocean, ocean salinity, ocean current, ice thickness, Qaanaaq, Inglefield Bredning.

Url:
www.dmi.dk/dmi/tr11-18.pdf

ISSN:
1399-1388

Version:
1.00

Website:
www.dmi.dk and ocean.dmi.dk

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Content:

Abstract ... 4
Resumé ... 4
Introduction ... 5
Motivation ... 7
Set-up, instrumentation and data ... 8
TIR radiometers ... 10
Program ... 10
Procedure ... 10
Data - temperaturs ... 11
Data - emissivity experiment ... 12
MW radiometers ... 14
Program ... 14
Data ... 15
THICK ... 17
Program ... 17
Procedure ... 17
Data - EM31 ... 19
Data – air borne ... 19
OCEAN ... 21
Program ... 21
Procedures ... 22
Data - CTD ... 23
Data – ADCP/Current mooring ... 24
Contacts ... 26
References ... 27
Previous reports ... 27

Abstract

The Qasiteex 2011 field work took place in April, at Inglefield Bredning by Qaanaaq in North West Greenland. The overall goal of QASITEEX was to investigate thermal properties of the fiord system, to improve and validate satellite based sea ice temperature algorithms and to collect data for subsequent modelling of heat transports between ocean, sea ice and atmosphere. The field work included measurements of water temperatures, salinity, ocean dynamics, sea ice surface and integrated snow/ice temperatures, ice thickness, ice growth and ice salinity and air temperatures. Finally, a range of technical and logistical issues were tested during the fieldwork. This report is a full record of the collected data during Qasiteex 2011.

Resumé

Introduction

QAanaaq Sea Ice Thermal Emission EXperiment (QASITEEX) took place at Inglefield Bredning fjord system by Qaanaaq from March 30 to April 6th, 2011.

The overall goal of QASITEEX was to investigate thermal properties of the fiord system, to improve and validate satellite based sea ice temperature algorithms and to collect data for subsequent modelling of heat transports between ocean, sea ice and atmosphere. The field work included measurements of water temperature and –salinity, ocean dynamics, sea ice surface and integrated snow/ice temperatures, ice thickness, ice growth, ice salinity and air temperatures.

The field campaign activities were divided into 4 themes. 1) A microwave theme (MW) using semi stationary radiometers to measure integrated surface and subsurface brightness temperatures. 2) A thermal infra red theme (TIR) with 1 semi stationary and 2 mobile radiometers to measure ice/snow/water skin temperatures and angular dependencies thereof. 3) An ice thickness theme (THICK) using a mobile EM-31 unit to measure transects of ice thickness and a thermistor string to measure the thermodynamic temperature profile throughout the field work 4) An oceanographic theme (OCEAN) equipped with CTD and ADCP instruments for temperature and salinity profiling and ocean current profiling, respectively. The OCEAN theme also included water sampling for chemical analysis.

QASITEEX was a joint field campaign between the main contributor Greenland Climate and Research Centre (GCRC) and The Scottish Association for Marine Science (SAMS), National Oceanography Centre, Southampton (NOCS), National Space Institute at the Danish Technical University (DTU-space) and the leading partner Center for Ocean and Ice at Danish Meteorological Institute (DMI).

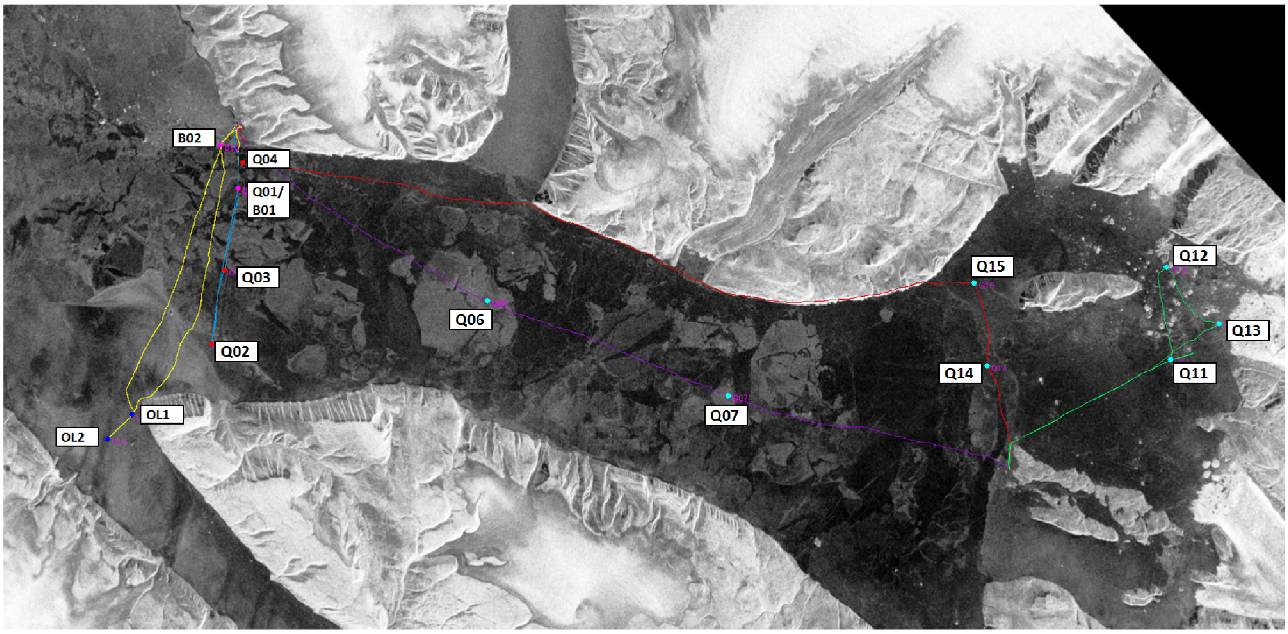


Figure 1 SAR chart of Inglefield Bredning from March 2011 with Qasiteex activities indicated by dots and lines. Dots named Q*xx* show positions of oceanographic stations and dots named BC1 and BC2 are BaseCamps 1 and 2, used for miscellaneous TIR and MW measurements. Lines are collocated TIR and ice thickness paths.

Beside the GCRC 'Satellite remote sensing of Greenland waters' project, also other research and development project will benefit from the experiment. Several national and international projects such as the Danish NAACOS, the EU MyOcean, the EUMETSAT OSI SAF, the ESA CCI SST and Sea-Ice project and the INUIT CLIMATE EXPERIMENT (Nordic Council of Ministers) have activities where the QASITEEX data are relevant.

This report is organised in three sections, a section briefly describing the motivation for the experiment, followed by a section where instruments and field set-up are described along with the physical, geographical and temporal sampling properties of the collected data. Finally, a list of contact details, where questions and requests for data can be posted.

The study received financial support from the Danish Agency for Science, Technology and Innovation and is a part of the Greenland Climate Research Centre

Motivation

A future perspective of the QASITEEX field work, and possible upcoming field works in the Inglefield Bredning fjord system, is to collect a comprehensive data set for thermodynamically modelling of the fjord. The data collected during this field work constitute central physical parameters responsible for the heat transport between ocean, ice and air and the integrated data are essential for model tuning and validation. However, each of the participating scientific teams also have immediate and individual purposes for their data and associated results.

The microwave (MW) emission from sea ice is a function of surface and subsurface properties and the MW experiment provided data for validation of models and for development of new models, for e.g. estimation of sea ice concentrations. The instruments are identical to past, present and future sensors on satellites like the SSM/I series and the objective is to exploit the satellite measurements better through and increased understanding of the emission processes.

The thermal infrared (TIR) instruments measure the thermal emission from the skin surface of sea ice, the Ice Surface Temperature (IST). The TIR experiment had 3 focus areas, one was to match the ground data to coincided satellite measurements, a second focus was on more technical aspects, namely to investigate the sensitivity/response of different sensors to band width and scan angle and estimation of emissivity. The third focus area was to investigate spatial variations of sea ice skin temperatures, to better understand distributed IST data from satellites. Finally, a fourth focus was to investigate the performance of the “state of the art” SST IR radiometer (ISAR) in extreme cold conditions.

The perspective of the ice thickness program was to obtain full seasonal ice thickness transects over dog sledge paths throughout the winter season or as long as the ice is safe for dog sledge transport. This information can be used for sea ice growth modelling and for direct use by the hunters and villagers that use the ice for transportation. This theme is still in its developing phase and it is presently focusing on finding practical and technical solutions to ensure the instrumentation autonomously operates throughout the winter.

The applications of the ocean field program were many fold but focussed on documenting the winter hydrography of the fjord supplying insight to the possible upper estuarine and intermediate circulation loops connecting the fjord with the open waters of the Baffin Bay. This also yields an important estimate of the upper layer stratification and vertical ocean heat flux across the sea-ice interface. Observations along the length of the fjord also allow an assessment of the available heat for glacier melt at the head of the fjord. Finally, tracer samples will be used to give direct evidence for subsurface glacier melt in the winter season.

Set-up, instrumentation and data

This section briefly describes the applied instruments along with the set-up in which they were working. An overview of recorded data is given and data samples are plotted. Detailed instrument description, field set-up and data access can be given by the responsible persons (see 'contacts', below).

The field program consisted partly of collocated measurements and partly of individual measurements. The science teams were grouped into two working groups, for both convenience and because of synergy of collocated measurement.

One working group was formed by the oceanographic and the ice thickness teams. This working group was convenient as both measuring programmes were scientifically strengthened by large geographical spread. This group jointly conducted 3 dog sledge trips, as indicated on figure 1 by coloured dots and lines. This group also brought a TIR instrument for collocating ice thickness and IST measurements.

Table 1 Approximate time line (UTC) for MW and TIR records. Grey fields represent continuous measurements of snow and ice surface and subsurface measurement, the red fields represent instrument failure of any kind (like the Ku instrument that broke down on day 3), blue fields is the period angular TIR dependency program and green fields represent the sea water freeze-up experiment.

Instrum.	site	Thursday March 31st				Friday April 1st				Saturday April 2nd				Sunday April 3rd				Monday April 4th				Tuesday April 5th				Wed.day April 6th			
Ku	BC1							h v	h v	h v	h v																		
	BC2																												
Ka	BC1						h v	h v	h v	h v	h v	h v	h v	h v	h v														
	BC2															h v	h v	h v	h v	h v	h v	h v	h v	h v	h v	h v	h v		
IR100	MIX										TRIP - END OF FJORD																		
IR120	BC1																												
	BC2																												
ISAR	BC1																												
	BC2																												

The other group was formed by the MW and the TIR teams. All measurements performed by this group took place at two 'base-camps' in the vicinity of Qaanaaq, at the positions BC1 and BC2 on figure 1. The MW and TIR radiometers were more or less deployed on full time at the 2 base-camp positions. A time table of all MW and TIR data that were collected is given in table 1.

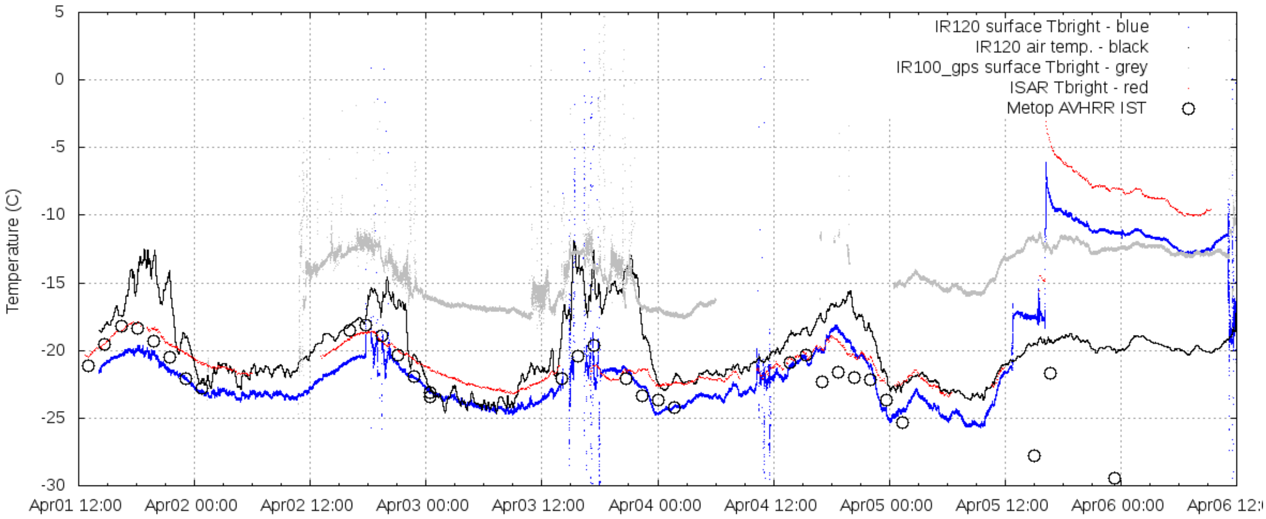


Figure 2 Plot of all collected IR data from the IR100, IR120 and ISAR sensors. Data are not calibrated. Grey and blue data refer to surface brightness temperatures from the IR100 and IR120 instruments, respectively and the black dots refer to the air temperature measured by the IR120 data logger. The red data dots are ISAR surface temperature estimated with sea water emissivity. Black circles are mean IST estimates based on the infrared AVHRR instrument on the Metop satellite.

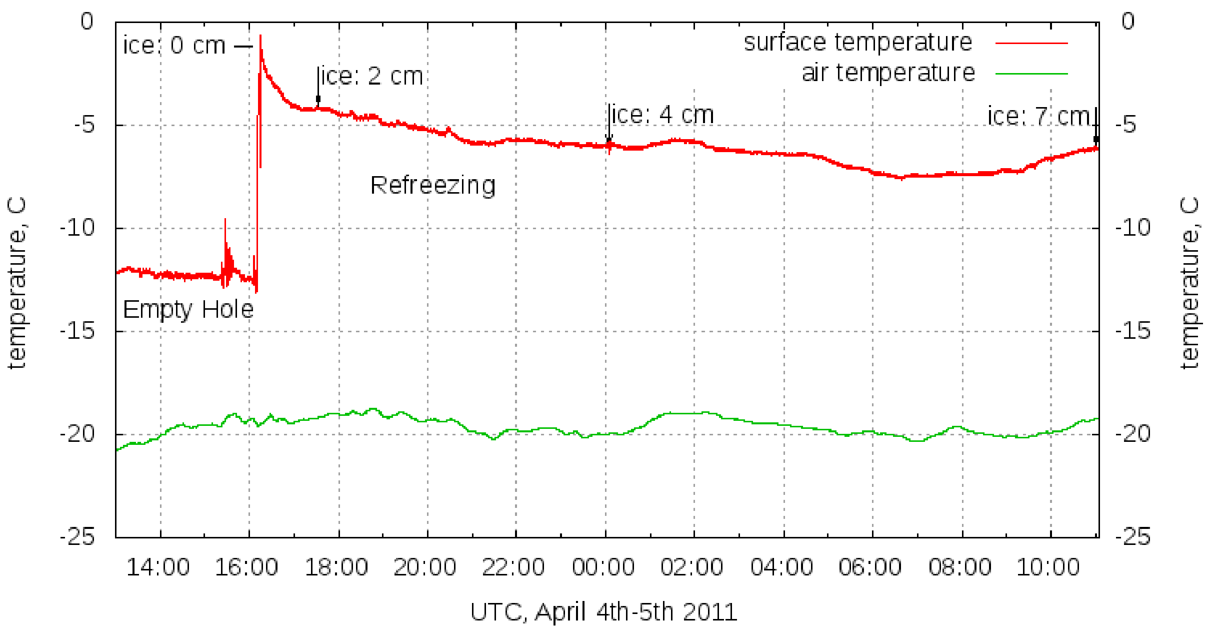


Figure 3 Water and ice skin temperatures from freeze-up experiment in red (rough calibration to thermodynamic temperature). Air temperatures are plotted in green.

TIR radiometers

The TIR experiments included measurements with 3 different TIR sensors, 2 broad band radiometers and a narrow band radiometer. The TIR sensors are:

- **ISAR** narrow band sensor (9.6 - 11.5 microns, view angle ~12 degrees), developed at NOCS.
- **IR100** broad band sensor (7 – 14 microns, view angle ~9 degrees), manufactured by Campbell Science.
- **IR120,** broad band sensor (8 – 14 microns, view angle ~40 degrees), manufactured by Campbell Science.

The ISAR instrument is a scanning self-calibration radiometer, with a heated and ambient black body, a sky and a target view (see Donlon et. al, 2008). The emissivity used to calculate ice surface temperatures were the sea water emissivity for the corresponding target angle (25 degrees for BC 1 and BC2 – emissivity of 0.9916, 55 for the refreezing experiment – emissivity of 0.985). Beside the TIR measurements corresponding thermodynamic measurement of snow/ice skin temperatures and air temperatures are recorded.

Program

1) Spatial variability measurements. IR100 with GPS mounted on dog sledge along with the ocean and ice thickness working group on 3 day journey along the fjord and back. See route on figure 1 and sample data in figures 2 and 5.
2) Temporal variability measurements. IR 120 mounted at BC1 and BC2 during most of the duration of the field campaign. ISAR was mounted at BC1 and BC2, respectively, for the duration of the campaign. See table 1 and figure 2.
3) Freeze up measurement. ISAR and IR100 ice surface measurements coincided with IR120 measurements in freeze up experiment. See Freeze up procedure and data in figure 3.
4) Angular dependency measurements. IR120 used as mobile radiometer for measuring temperature dependency of observation angle. See angular measurement in figure 4 and procedure description below.
5) Snow in situ measurements. For all stationary positions of the IR100/120 instruments snow parameters were measured. Measured parameters are grain size, salt content and thermodynamic temperature (the data logger of the in situ thermometer broke down and hence only few in situ temperatures are logged).

Procedure

Spatial variability: The IR100 was performed 'en-route' during the 3 day OCEAN-THICK-TIR programme to the bottom of the fjord (figure 1, 5 and 10). The IR radiometer was mounted on the same dog sledge as the EM31 ice thickness instrument to obtain optimal coincident measurements of thickness and IST temperatures. The IR100 dog sledge set-up (joint with the EM31) is seen on the photo in figure 9. The temperature transects from the dog sledge trips are plotted in figures 2 and 5

Temporal variability: The IR120 sensor was mounted on a tripod close to the ISAR sensor to test the broad/narrow band sensitivity to skin temperature variations. This procedure was followed at both BC1 and BC2. Occasionally the IR120 was used for angular dependency measurements. The IR120 and ISAR set-up is seen in figure 7 and all temperature profiles are plotted in figure 2, as brightness temperatures.

Freeze up: The freeze up experiment was of joint interest to the TIR and the MW measurement programmes. All TIR and MW radiometers were arranged around the constructed open water basin before the hole was inundated. An overview photo (figure 7) illustrates this set-up. The hole was 'drilled' using a Ø 25 cm ice drill to create an approximately 1 by 1 meter basin. The basin was cleaned for ice and snow and eventually inundated through a hole to the sea water below.

Angular measurements: The angular IR radiation pattern was mapped by using the IR120 instrument as a hand held radiometer. View angles between 0 and 60 degrees were recorded in 10 degree intervals. At appropriate intervals the sky temperature is recorded to handle the reflectance term for calculation of emissivity.

In situ measurements: Snow grain size, salinity and thermodynamic temperatures were recorded during all stationary IR measurements.

Data - temperaturs

An overview of the full TIR radiometer deployment record is shown in table 1, and all brightness temperature records from the ISAR, IR100 and IR120 instruments are plotted in figure 2. Thus the table show in which configuration the temperature data from figure 2 is recorded. The IR100 data (both air and surface brightness) are shifted approximately +8K relative to the other IR data, i.e. we seem to have an offset error. The reason for this offset problem is not yet found, but under investigation.

The spatial variability data (IR100) are clearly affected by day warming and large spatial variability and the night time data are more constant (figure 2). Extreme large fluctuations in the temporal variability data (IR120) during day time are caused by the angular measuring program, with sky measurements and moving the radiometer around in general. Data from the satellite based IST production, that is set up for the Inglefield Bredning and other Greenland fjords, are also plotted on figure 2. These data show fine agreement with the land based IR measurements during the first 3-4 days, hereafter the satellite and land based measurements diverge. This divergence is caused by clouds obstructing the measurements of the ice surface from satellite.

A colour plot of the IR100 data on route to the bottom of the fjord with the ocean and thickness teams is plotted on top of the coinciding SAR image in figure 5.

The 'freeze up' sections of the temperature records is zoomed into and plotted in figure 3. Here time of inundation and selected ice thickness data are superimposed. The freeze up data is coarsely calibrated to thermodynamic temperatures.

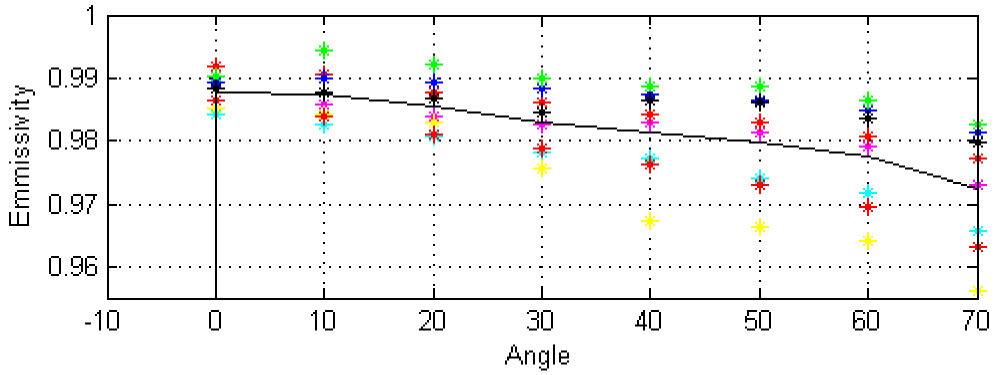


Figure 4 Angular measurements from IR120 and estimated emissivity.

Data - emissivity experiment

A series of experiments were carried out with the IR 120 radiometer to examine the angular dependence of the IR emissivity for the snow and ice (see table 1 for time of observations). In total, 12 angular measurements profiles (from 0 degrees zenith angle to 70 with step of 10 degrees) were performed at base camp 1 and 2, measuring the IR temperature, in situ air and snow temperature. The height of the radiometer was 130 cm and the last 8 profiles also included 0 zenith angle observations at 1 cm above the ice. 4 sites were used for the last eight angular profiles (two sites at BC1 and two sites at BC2). At each base camp, a site was chosen with a smooth snow surface and one with a more textured snow surface. Samples were taken of the snow on top of the ice and the snow grain size and the salinity were measured.

Clear sky was present for all observations with the solar elevation angles being about 15 degrees and mostly perpendicular to the line of sight of the IR instrument.

It was attempted to measure two angular profiles of the IR sky temperature, however, the sky temperature was too cold (colder than -100C) for the IR instrument to observe and no observations came out of this.

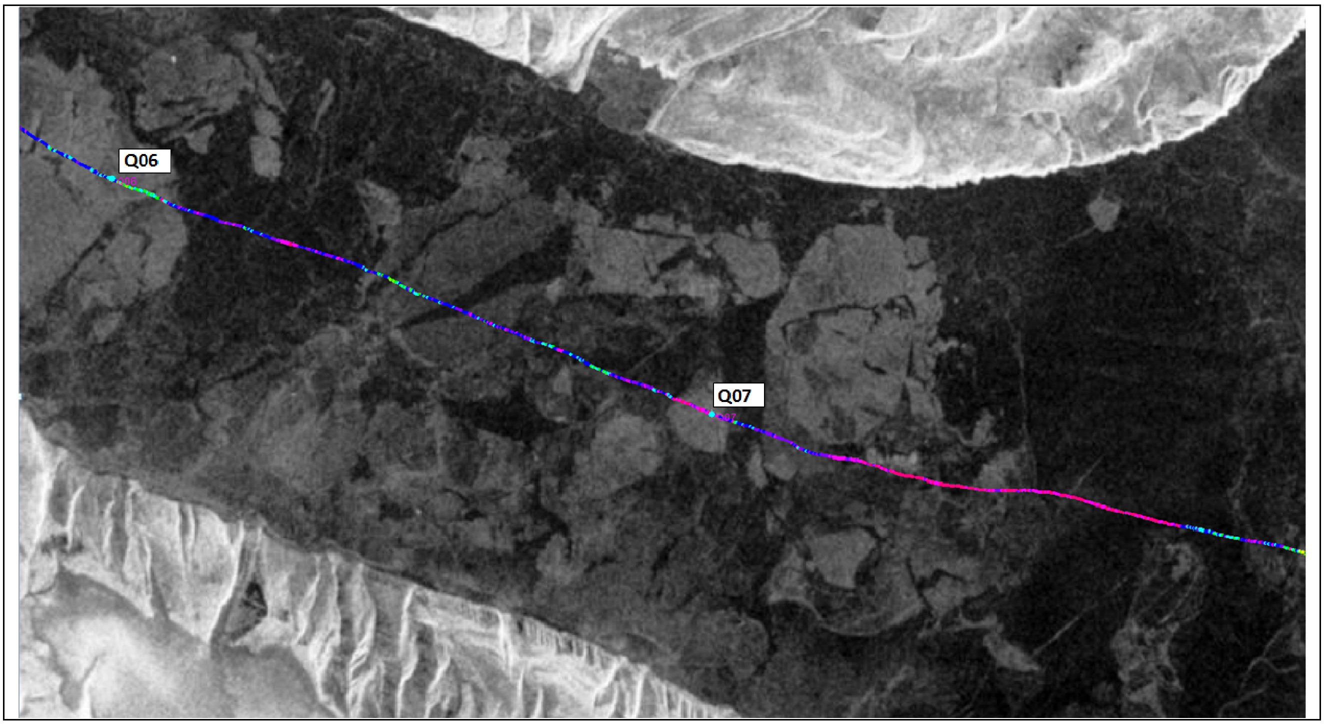


Figure 5 Measurement from dog sledge mounted IR120 radiometer. Data are superimposed a SAR image. The colour code is: blue is colder than red.

These observations were used to calculate the snow and ice emissivity for angles with an interval of 10 degrees and the results are shown in figure 4, indicating a clear angular dependence for all the angular profiles that were made, irrespectively of the surface conditions and the actual temperature.

MW radiometers

The microwave radiometer experiment measured the thermal emission from snow and sea ice in the Ku and Ka microwave bands, frequencies around 16 and 34 GHz, respectively. The Ku and Ka band radiometers measured at both vertical and horizontal polarisation. The Ku band radiometer operated only the first day, April 1st, due to a problem with the local oscillator.

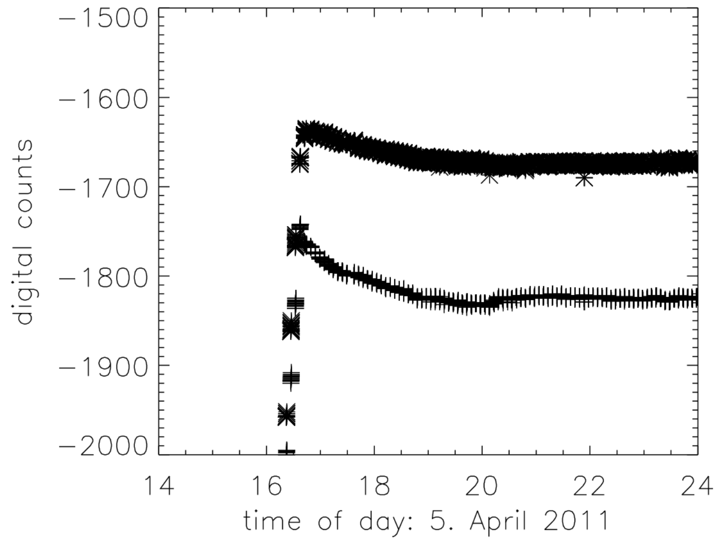


Figure 6 The Ka-band radiometer digital counts for channel 1 and channel 2 during the freeze-up experiment on 5. April 2011.

Program

The diurnal microwave emission cycle was measured on thick snow covered first-year ice at base camp 1. The temperature profile within the ice at BC1 was measured with a thermistor string from air to water during all 6 days. The upper 15-20cm of the string was above the ice and the thermistor spacing was 2 cm. The radiometer measurements were repeated at base camp 2 on a thicker snow pack. The freeze up experiment was conducted at base camp 2 without relocating the radiometers. The microwave radiometer set-up from site BC2 at the beginning of the freeze-up experiment is illustrated in figure 7.

Snow and ice properties were measured near the target including:

- Snow depth and stratigraphy using a ruler.
- Ice thickness using a drill or measuring samples in the freeze-up experiment.
- Snow grain size estimated with magnifying glass on mm- grid.
- Snow density measured with density shovel and scale.
- Salinity of snow and ice measuring the conductivity of melted samples
- Snow and ice temperature using a thermometer.

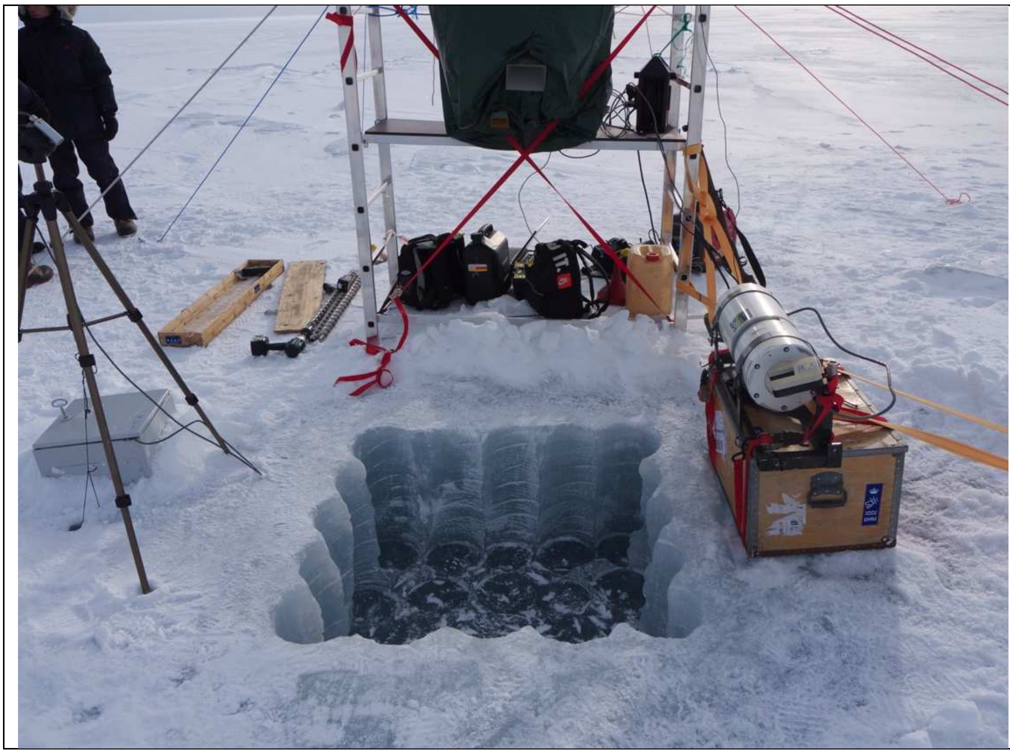


Figure 7 Open water/freeze-up experiment shortly before letting water into the hole. ISAR on the box on the right, IR120 on the tripod on the left and MW instruments on the scaffold

Data

The full deployment overview of the microwave (and TIR) data records is shown in table 1. Due to a defect power generator the microwave radiometer record is not complete. The following periods were covered by the Ka-band radiometer:
14.00 1. April to 6.00 2. April
15.00 2. April to 14.00 3. April
17.00 3. April to 8.00 4. April
14.00 4. April to 24.00 5. April
16.00 5. April to 9.00 6. April
The Ku-band radiometer operated only from 14.00 1. April to 6.00 2. April due to a problem with the local oscillator.
Sample data (as digital counts) from the Ka radiometer are plotted in figure 6.

The temperature profile data from the thermistor string is plotted in figure 8.

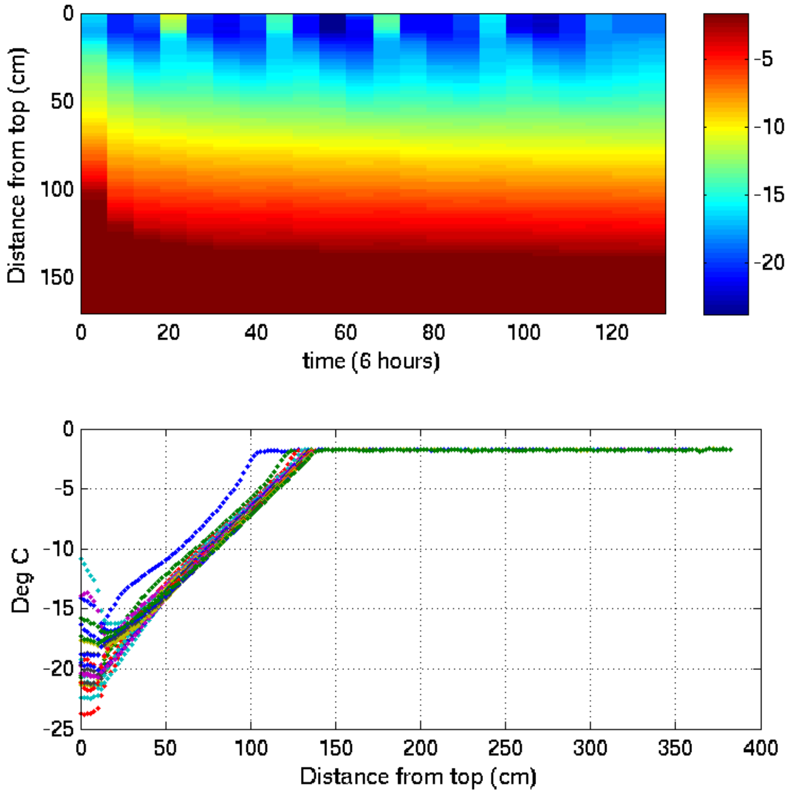


Figure 8 Temperature profile data from thermistor string frozen in at BC1. The approximately top 20 cm are in open air, and depth resolution (thermistor spacing) is 2 cm. The first axis of the top plot is hours from deployment, in 6 hours resolution.

THICK

The ice thickness program uses a mobile autonomous sea-ice thickness monitoring device that is currently under development by the Marine Technology group at SAMS. The device utilizes the commonly used EM31 conductivity probe by Geonics Ltd. In this instance we use the new shorter version, which is more easily mountable on a dog sled. This new prototype device includes a range of sensors, including a GPS to provide precise measurements with high spatio-temporal accuracy. A photograph of the sledge set-up is show in figure 9.
An over-flight with laser scanner and radar altimeter was completed approximately 2 weeks after the Qasiteex period to match up the EM31 data with airborne data.

Figure 9 Em-31 wrapped up on a dog sledge and ready to go. The IR100 radiometer is seen by the right handle at the back of the sledge.

Program

The goal of the THICK program was to test the new prototype EM-31 device in autonomous operation mounted on the hunter's sled. This is in anticipation of future deployments, when the system will be mounted on a sled for a full season.

By accompanying the OCEAN team, it was possible to survey a large area of the fjord. The instrument was continuously sampling during periods of sled travel. As well recording conductivity and GPS position we were also logging a range of physical parameters such as inclination, acceleration and temperature. This additional data will help us during the data analysis in identifying how the dynamics of dog-sled travel affect the conductivity signal quality, and ultimately improve the accuracy of the data.

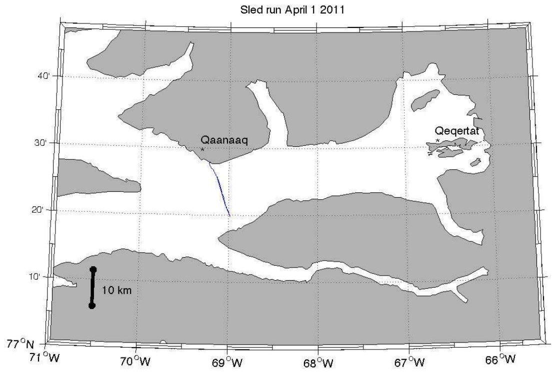
Procedure

The device was mounted on the hunter's sled during each of the trips carried out by the OCEAN team. It was important to distribute the loading of each sled so that the EM31 device was not cluttered with metallic (conductive) objects. Ideally the EM31 sled carried minimal personnel (driver + 1 passenger) and articles such as clothing and camping gear. Oceanographic equipment (winches, generators, CTD etc.) was carried on a separate sled, although this was not always possible and is reflected in the data.

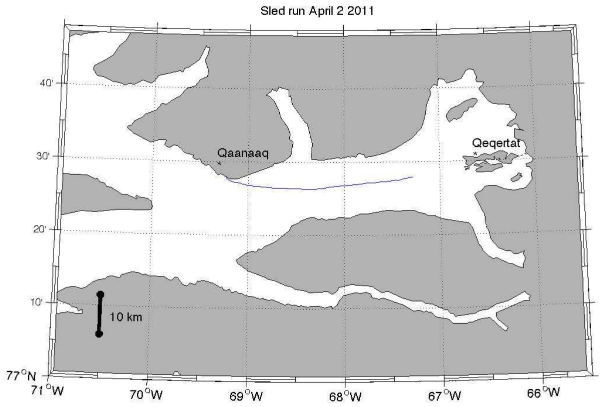
The sled track runs can be seen in figure 10. The first day was a short trip out and back across the mouth of the fjord. The purpose of this first day was to test the set-up and verify the operation of the prototype logger. This test proved successful and the device was setup for autonomous logging for subsequent trips. Stops were made at 2km intervals for manual ice thickness measurements, as well as the two stops made by the OCEAN team. Calibration of the EM31 instrument was also carried out during the OCEAN stops.

On days 2, 3 and 4 the trip went to the head of the fjord, overnight at Qeqertat and back. Stops were made for manual ice-thickness measurements only at the OCEAN team stops. The first day some damage was noticed on the instrument, although a repair was possible. As a result there is a gap in the data, as seen in the figure.

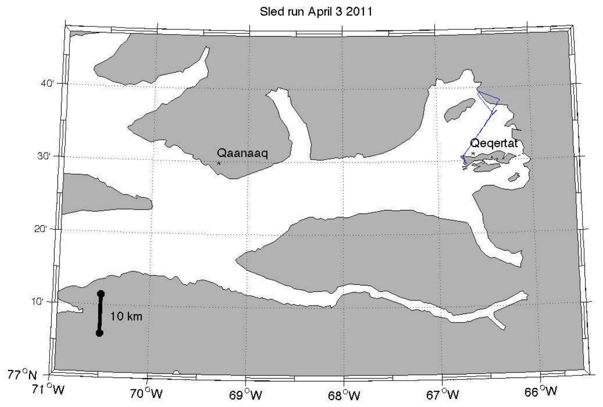
Day 5 was a run out to the centre of the Olrik fjord and back, again stopping only at the OCEAN team sites for manual ice thickness measurements, instrument calibrations were also carried out during these stops.



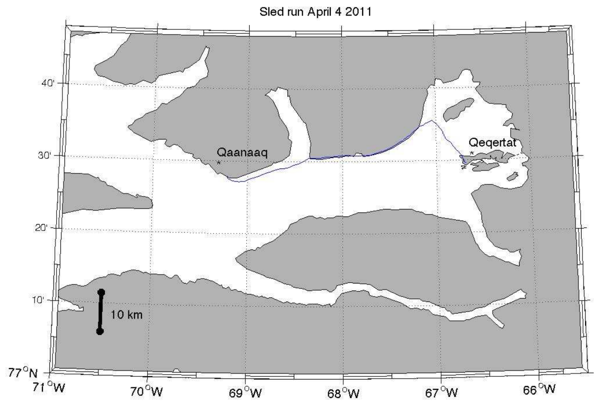
Test run



Fjord Run: Run up the centre of the fjord. Instrument stopped responding near the head of the fjord



Head run: Run around the head of the fjord



Fjord run2: Run along side of the fjord

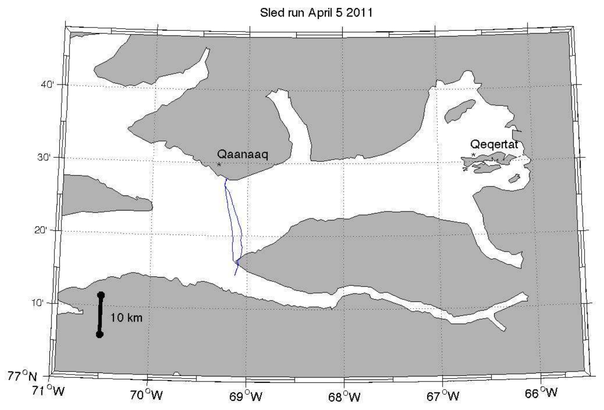
 Across run: Run across fjord .	

Figure 10 Paths of the five separate runs of the EM mounted sled system

Data - EM31

Data was collected from each of the sled runs on each day from the routes shown in figures 1 and 10. The data are currently being processed so that a full ice thickness data set can be determined for the entire trip. The system data is also being analysed to identify possible errors in the conductivity data, and correct for sled dynamics.

An example of one calibrated data set of sea-ice thickness from the return journey from Qeqertat to Qaanaaq can be seen in figure 11.

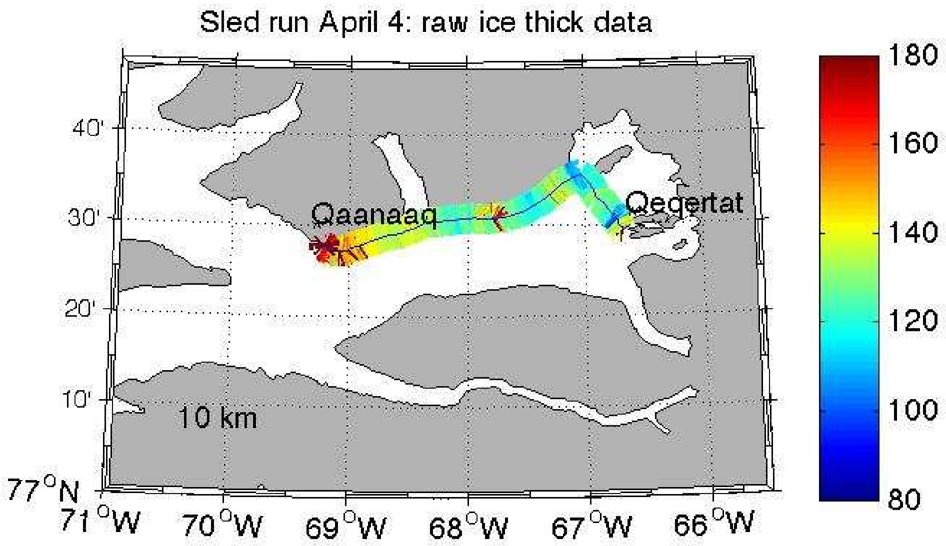


Figure 11 Ice thickness sample data from *fjord run2*. The colour bar indicate thickness in cm.

Data – air borne

The airborne CryoSat Cal/Val team was operating around Qaanaaq coincident with this field work. The Cal/Val team made an over-flight along the EM31 route along the fjord. The original plan was to fly the Qasiteex survey line, on April 9-10. However, the laser scanner was too cold and did not operate. A successful flight was completed on April 19, see green flight track in figure 12. During the survey flights high-resolution laser scanner data and 13.5 GHz radar altimetry data supported by vertical photography were obtained.

The airborne laser and radar data are not yet processed or calibrated, but are expected available from beginning of 2012.

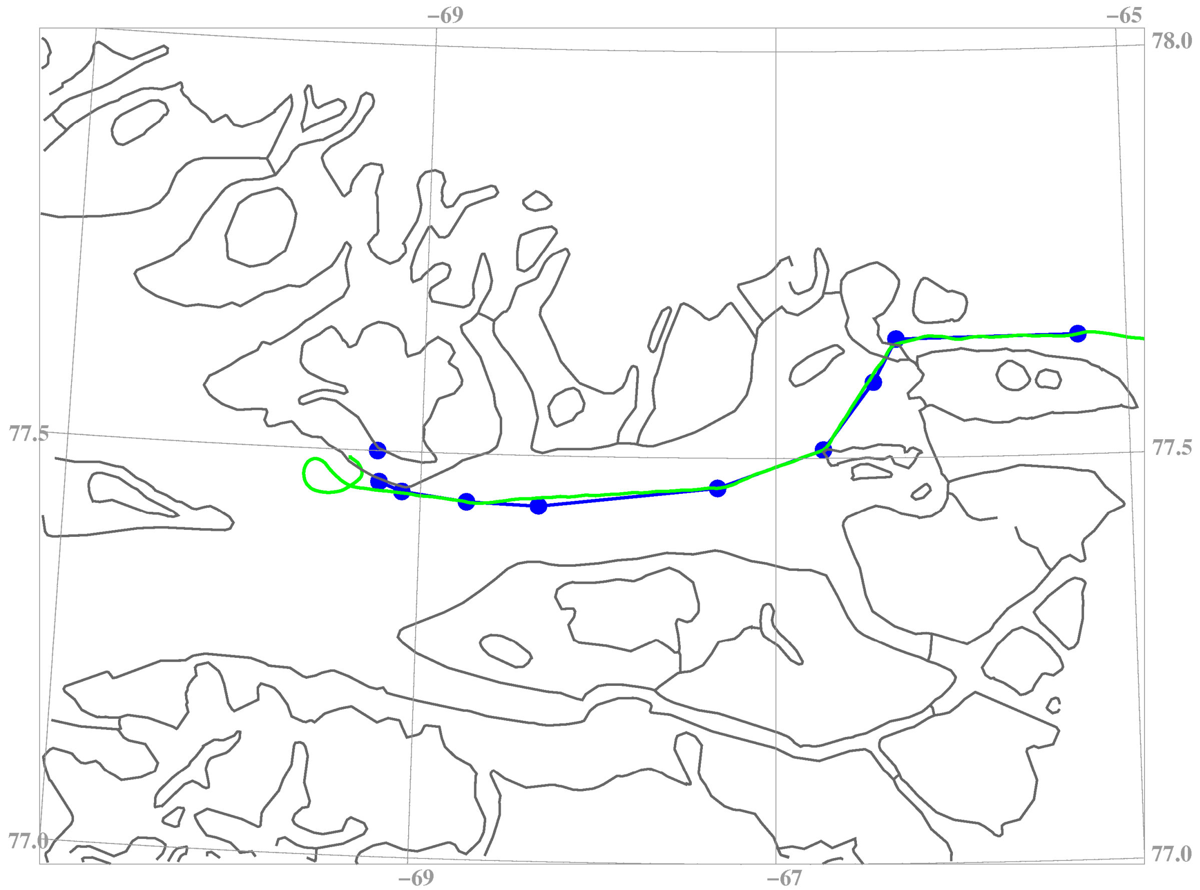


Figure 12 Flight paths on April 19th 2011, with laser scanner and 13.5 GHz radar altimeter. Blue dots on the fjord correspond to oceanographic and ice thickness survey route to the end of the fjord. The 2 dots on the glacier are way-points added for flight navigation.

OCEAN

Hydrographic data are obtained from a sledge based survey from the ice covered outer fjord region towards the head of the fjord with its calving glacier fronts (figure 13). Observations document the dominance of warmer intermediate waters from the Baffin Bay throughout the length of the fjord and in direct contact with the glacier fronts (figure 14). Observations show no sign of a cold halocline structure of Arctic origin below the winter mixed layer but, reaching a depth of 80-100m, the cold mixed layer does limit the melting rates at shallower depths throughout the year. The vertical water mass distribution resembles the conditions in the Baffin Bay though modified at the mixed-layer interface. Consequently only the deep reaching floating glaciers contribute to the observed melting and are vulnerable to warming of the Atlantic layer.

Figure 13 Oceanographic measurements in the bottom of Inglefield Bredning. The CTD is lowered into the water from the tripod on the left and the EM-31 is hidden on the sledge in the background.

Program

The program is planned as three section surveys supported by two to three Inuit hunters with dog sledges:

A two-day survey across the Inglefield Bredning ,
A one-day survey to the entrance of the Olrik Fjord and
A three-day journey along the Inglefield Bredning to the head of the fjord.

It was possible to occupy the cross fjord section and the Olrik Fjord opening on one-day journeys returning to the DMI facility in Qaanaaq overnight. During the longer journey along the fjord we planned to camp on the ice off the small settlement Qeqertat on the Harvard Øer. However, we were kindly offered use the combined school and Sunday church for sleeping. This also made it possible to download data and check instrument functionality in warm conditions.

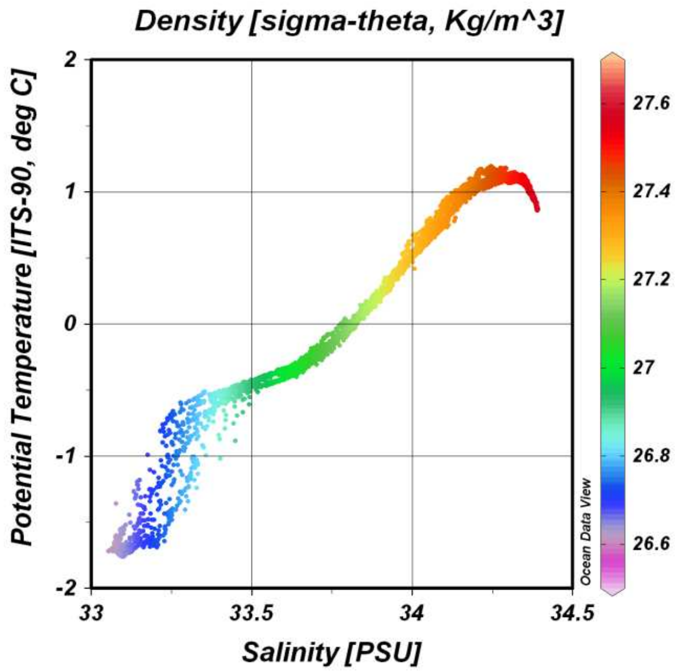


Figure 14 Water mass properties on the oceanographic survey sections off Qaanaaq across Inglefield Bredning and towards the head of the fjord.

Procedures

Measurements of water mass distribution were done at full depth at the defined sections, along and across the fjord making use of a portable CTD system. This system consists of a SBE19plusV2 pumped Seacat unit, a portable electric winch with 2000m synthetic rope and Niskin type water samplers attached to the line and triggered by drop messenger. Sensors include the built in Temperature-Conductivity package and an additional SBE43 oxygen membrane sensor. The ice was in general 80-120 cm thick, relatively flat and with no open water leads except very near the glacier front.

On station, the dog sledges were unloaded and the Honda EU20i (2kW) generator was powered up to heat the CTD box with the underwater unit. We used a 1.2kW hair dryer yielding good ventilation and tempered outlet temperature. Hereafter we drilled a 10 inch hole using a gas powered ice auger. Slush was removed from the hole by pulling up the auger fast frequently during the drilling. This was also necessary in order to avoid the drill from fastening. After assembling the portable winch, a weight was attached to the line and the depth logged using the digital meter wheel. With knowledge of the station depth, the heated CTD was deployed through the whole in a swift procedure to avoid cooling of the unit.

After deployment, the CTD rested in the subsurface layer for approximately 5 minutes waiting for the pump to turn on and allowing any slush ice from the drill hole to melt and in turn stabilizing sensor readings before the actual cast. Hereafter the CTD were raised to the base of the ice from

where the profiling of the water column was started. Profiles were retrieved with a descent rate of approximately 30 m/min in the upper 200m, roughly through the mixed layer and across the strongly stratified interface. Away from strong gradients, a descent rate of 50m/min was used. Water samples were taken at predefined depths, 5m and 100m after the termination of the up-cast part of the profile using the 2.5 l Niskin water sampler. Samples were drawn for isotopic composition (d18O) and nutrients; see Table 2 for a complete list of the distribution of samples at individual stations. Nutrient samples were frozen immediately while the d18O samples were stored warm inside the heavy Parkas. All samples collected will be analyzed after return to Copenhagen.
In total 13 full depth profiles were obtained during the field campaign (Table 2). SBE43 data are only available for station Q02. The oxygen membrane sensor failed after the first deployment due to the cold working conditions near or below -20^{o}C.

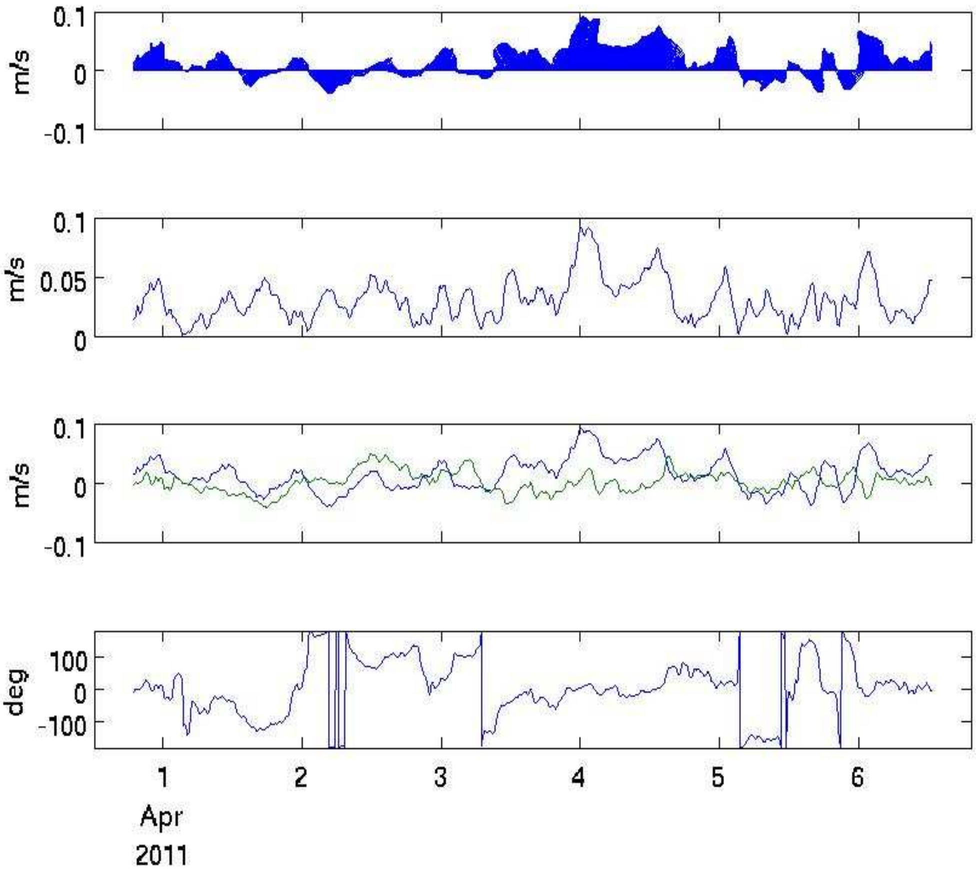


Figure 15 Lower mixed layer current variability at station Q01 (50-80m average) from the upward looking ADCP mooring. Upper stick plot shows the current components with the primary flow direction into the fjord directed upward. Below is shown the current magnitude, components and direction, respectively. The current direction is rotated so that zero degrees is eastward along the average flow direction

Data - CTD

No bottle data were drawn for salinity calibration and we rely on the very recent instrument calibration. After downloading the raw data from the CTD (HEX format), profile readings were converted to engineering units including pressure, in situ temperature, conductivity and oxygen concentration. Pressure readings are initially high pass filtered two ways in order to smooth high frequency data and to obtain a uniform descent history of the cast. The applied cut-off period for the SBE19plusV2 is 1.0 seconds. Inherent misalignment time delay in sensor responses and transit time delay in the pumped pluming line are corrected by advancing conductivity 0.5 sec relative to pressure for the SBE19plus. By this alignment, measurements refer to same parcel of water and the procedure eliminated artificial spikes in the calculated salinity which is dependent on temperature, pressure and conductivity. A recursive filter was hereafter applied to remove cell thermal mass effects from the measured conductivity according to the specifications for the individual sensors of the CTD system. This correction of salinity is significant in the upper layers with steep temperature gradients, but otherwise negligible. The last modification of the data removes scans with slow descent rate or reversals in pressure. Post processed data is averaged into 1m bins and includes derived parameters; salinity and oxygen concentration.

Data – ADCP/Current mooring

The current structure and tidal variability in the mixed layer under the sea ice was monitored on station Q02 (BC1) off the city of Qaanaaq (see table 2 and figure 15) on the section crossing the Inglefield Bredning. We used a 300 kHz RD-Sentinel Workhorse Broadband Acoustic Doppler Current Profiler (ADCP) moored at a depth of 92m below the surface looking upward. The ADCP was deployed 14:30 31-03-2011 and recovered again on 15:30 06-04-2011 yielding six days of observations. The ADCP was configured in moored profiling mode without bottom track. Using RD software (PlanADCP) the depth range was set to 110m, 2m cell size yielding 54 depth cells, 50 pings per ensemble and 2 min between measurements.

Measured velocities were generally less that 10cm/sec oriented roughly along the direction of the fjord when taking into account the negative magnetic declination of 52.50^{o}W. The field strength in the region is weak (5400 nT) and near the threshold of the internal flux gate compass. Thus, the average direction of the currents is associated with significant uncertainty. Measured currents show a mixed (weak diurnal and stronger semidiurnal) tidal current signal associated with reversals in current direction. Observed tilt and role of the instrument was negligible even though the unit was hanging freely in the water by its own weight. Interestingly, observed magnitudes of tidal currents are comparable to geostrophic estimates based on the cross fjord hydrography (not shown). Positioned near the mixed layer interface, the temperature time series from the mooring yields additional insight to the vertical movement associated with tides and internal waves. Amplitudes of 0.8^{o}C is observed and may be translated into isopycnal migration of up to 15m.

A reduced vertical coverage is observed during day time due to a low abundance of acoustic scatters in the water column. Only during nighttime, migration of zooplankton allows full profiling from the mooring depth the base of the sea-ice. Considering the tides and the duration of the mooring this makes it difficult retrieve a robust estimate of the average profile in the upper part of the mixed layer.

Table 2 CTD stations and bottle samples

Station	**Cast**	**Latitude**	**Longitude**	**Bottle samples**		**Date**
ID	*#*	*North*	*East*	*d18O*	*Nutrients*	*yyyymmdd*
Q01	2	77.428	290.864	5m	5m	20110331
Q03	4	77.377	290.943	5m/5m	5m	20110401
Q02	5	77.330	291.013	5m/5m	none	20110401
Q04	6	77.444	290.840	5m/5m	5m	20110401
Q06	7	77.439	291.678	none	none	20110402
Q07	8	77.464	292.442	none	none	20110402
Q11	9	77.604	293.595	5m/100m	5m/100m	20110403
Q12	10	77.657	293.462	5m/100m	5m/100m	20110403
Q13	11	77.639	293.679	5m/100m	5m/100m	20110403
Q14	12	77.548	293.105	5m/100m	5m/100m	20110404

Q15	13	77.593	292.960	5m	5m	20110404
OL01	14	77.266	290.905	5m/5m	5m	20110405
OL02	15	77.244	290.875	5m/5m	5m	20110405

Contacts

Following persons participated in the QAASITEEX field campaign. For information about the data, the fieldwork in general and access to data, please contact a person connected to the data you are interested in.

Table 3 Contact details and affiliations for all Qasiteex participants.

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