Initial Environmental Evaluation
Science Projects
On the Filchner-Ronne Ice Shelf, Antarctica

The IEE is an appraisal of the work during the period 2014 to 2018.
This document has been updated to reflect the situation at the start of the 2016/17 season

Includes Grant reference: NE/L013770/1. Ice shelves in a warming world: Filchner Ice Shelf system, Antarctica

BAS Environment Office

September 2016

British Antarctic Survey,
High Cross, Madingley Road,
Cambridge, UK, CB3 0ET.
&
The Alfred Wegener Institute,
Helmholtz Centre for Polar and Marine Research
Bremerhaven
Germany

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
AWI

Contents

NON-TECHNICAL SUMMARY

Initial Environmental Evaluation
Science Projects
On the Filchner-Ronne Ice Shelf, Antarctica

1. Introduction

This Initial Environmental Evaluation (IEE) has been carried out by the British Antarctic Survey (BAS) for proposed science projects on the Filchner-Ronne Ice Shelf (FRIS) and its five tributary ice streams. It covers activities for the main science campaign in the 2014/15 to 2017/18 field seasons and any later field visits to maintain and remove the science equipment deployed. This IEE updates and complements the IEEs produced for the 2014/15 and 2015/16 field seasons and includes more information on these later field seasons that has become available since the start of the project.

The IEE has been prepared in accordance with Annex I of the *Protocol on Environmental Protection to the Antarctic Treaty* (1998).

2. Description of the Proposed Activity

The science intends to gain a better understanding of the interaction of the FRIS and the ocean shelf seas in order to improve the numerical models that can predict the future behaviour of the ice shelf.

During the 2014/15 field season, the science objectives were to drill (using hot water techniques) three holes through the ice shelf and deploy oceanographic instruments to gather data over an estimated 10 year period. A seismic survey was also carried out.

The 2015/16 and 2016/17 field seasons involved hot water drilling and recovery of marine sediment cores, deployment of oceanographic instruments, seismic surveys, installation of up to 15 ApRES radar sites, an airborne survey, the installation of 10 GPS stations on Foundation Ice Stream and up to six on Recovery Ice Stream, and during 2015/16 only, surface snow measurements and shallow firn cores collection.

The 2017/18 field seasons will involve the recovery of the ApRES and GPS stations, and the servicing and data collection from the drill sites.

The science is supported by logistics involving ship, vehicle traverse and air input, and the depoting of fuel and equipment using a combination of UK and German logistic components.

3. Description of the Environment

The FRIS is an ice shelf south of the Weddell Sea, divided into Eastern (Filchner) and the larger Western (Ronne) sections by Berkner Island. The whole ice shelf covers some 430,000 km² and is the largest (by volume) in the world.

There are no significant concentrations of wildlife and no ice-free ground at the vicinity of the transportation route, depots or drill site surface. There are no Antarctic Specially Protected Areas (ASPAs), Antarctic Specially Managed Areas (ASMAs), Important Bird Areas

(IBAs), or Historic Sites and Monuments (HSMs) in the area to be visited. The work site for the 2014/15 season was previously visited so had already been subject to minor human disturbance.

4. Alternatives to the Proposed Activity

Alternatives to the proposal have been examined as follows:

i) Do nothing
ii) Conduct the science elsewhere in Antarctica
iii) Use alternative technologies or methodologies
iv) Use alternative logistics

All alternatives were considered not viable for scientific, technical, logistical or environmental reasons.

5. Impact Assessment

Environmental impacts associated with this science campaign include the emissions from ships, aircraft and tractor train used in the logistics, and from skidoos and generators used for science, which will have an unavoidable impact on air quality. There is the potential for fuel spills to contaminate the ice at traverse or work sites. Waste will be generated which if handled incorrectly has the potential to contaminate the ice and impact the wilderness and aesthetic value. It is not feasible to recover all science equipment, and that remaining in Antarctica will impact the wilderness value. Given that the activities are proposed on an ice shelf there is little potential to affect flora and fauna.

6. Mitigating Measures

An environmental briefing, based upon this IEE, will be given by the BAS Environment Office to all those taking part in the proposed activities.

Appropriate measures are recommended to mitigate any adverse impacts. These include:

- Logistics being planned with maximum efficiency.
- Worksites and traverse routes avoid environmentally sensitive areas (e.g. Emperor penguin colonies, ASPAs). Some drill and depot sites have been subject to previous visitation.
- Planned retrieval of surface scientific equipment (e.g. GPS and ApRES stations) wherever feasible.
- The science utilises hot water drilling techniques which use no drill fluid.
- All equipment will be checked prior to deployment to ensure that it is free of soil and non-native biota, as set out in the BAS Biosecurity Handbook.
- All waste, other than grey water/urine and explosives packaging, will be correctly packaged and labelled in accordance with the BAS Waste Management Handbook, and removed from Antarctica.
- The potential for fuel spills will be reduced by using robust and reliable equipment. Staff are trained in oil spill response and spill response equipment provided.
- Efficient, well maintained equipment e.g. generators, skidoos will be used, and maintenance will be undertaken as required.

- The location of all activities (traverse, camps, worksites and equipment deployed) will be recorded in the BAS Operations GIS so as the operational footprint is apparent and understood.

7. Environmental Monitoring and Management

Compliance with the BAS environmental policy and the mitigation measures outlined in this IEE will be the responsibility of all personnel, but will be overseen by a BAS Field Leader nominated by the Principal Investigator.

8. Conclusion

This IEE indicates that the proposed science activities on the Filchner-Ronne Ice Shelf are likely to have no more than a minor or transitory impact on the Antarctic environment, provided the recommended mitigation measures identified in this report are carried out. It is therefore concluded that this activity should be allowed to proceed, and that a Comprehensive Environmental Evaluation (CEE) is not required.

CHAPTER 1. INTRODUCTION AND SCOPE

1.1. Introduction

This Initial Environmental Evaluation (IEE) has been carried out by the British Antarctic Survey (BAS) for a proposed science project on the Filchner-Ronne Ice Shelf (FRIS), Antarctica. It has been prepared in accordance with Annex I of the *Protocol on Environmental Protection to the Antarctic Treaty*. The Revised Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1, 2016) were also consulted during its preparation.

This IEE covers activities for the 2014/15 to the 2017/18 field seasons. This report is the update for the 2016/17 field season onwards.

The work in 2014/15 contributed to the objectives of the Polar Oceans group at BAS whilst the field work in 2015/16 formed part of Grant reference: NE/L013770/1: Grant title: Ice shelves in a warming world: Filchner Ice Shelf system, Antarctica. Hereafter referred to as the FISS Programme, with participants from two NERC centres (BAS and National Oceanography Centre [NOC]), the Met Office Hadley Centre [MO], University College London, the University of Exeter and Oxford University. A European partner, Alfred Wegener Institute (AWI, Germany), bring scientific knowledge and expertise to the proposal. In addition AWI and BAS are partners in the fieldwork: both logistical and scientific. For the 16/17 season the oceanographic component of the work (deployment of instruments through the Filcher Ice Shelf) include the Uni Research, Bergen, Norway as a project partner.

1.2. Statutory Requirements

To ensure the protection of the Antarctic environment, the Antarctic Treaty nations adopted the Protocol on Environmental Protection to the Antarctic Treaty (hereafter referred to as the Environmental Protocol) which came into force in 1998. The UK enforces the provisions of the Protocol through the 'Antarctic Act 1994 and Antarctic Act 2013' and 'Antarctic Regulations 1995/490 (as amended).

1.2.1 Annex I – Environmental Impact Assessment (EIA)

One of the guiding principles of the Environmental Protocol is that an EIA be carried out before any activity is allowed to proceed. It states that activities should be planned and conducted on the basis of *'information sufficient to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment'* (Article 3, Environmental Protocol).

Annex I of the Environmental Protocol sets out the detailed regulations for EIA in Antarctica, and establishes a three-stage procedure based on different levels of impact. The levels are:

- Preliminary Assessment;
- Initial Environmental Evaluation (IEE); and
- Comprehensive Environmental Evaluation (CEE).

An IEE is for activities, which are likely to have a minor or transitory impact on the Antarctic environment. It is considered that an IEE is appropriate for this programme of work on the FRIS. In the UK the IEE is subject to review by the Foreign and Commonwealth Office (FCO), which also makes the final decision on whether the activity should proceed. As this is a collaborative project with AWI there will be full consultation with AWI and Federal

Environmental Agency of Germany (the German Competent Authority).

1.2.2 Permits

The Antarctic Act states that certain activities within Antarctica require a permit before being undertaken. Those activities relevant to this programme include the mineral resource activities for scientific research i.e. sediment sampling. The Principal Investigators will apply to the FCO for the necessary Antarctic Act permits for scientific research.

All other activities carried out by BAS staff and our collaborators is covered by the BAS Operating Permit which is organised directly between BAS and the FCO.

Any activity carried out exclusively by AWI with no BAS involvement, will also be subject to the German Permitting regime.

1.3. Purpose and Scope of Document

The purpose of this IEE is to provide information on the proposed activities on the FRIS, their potential environmental impact, and a description of how impacts will be avoided or minimized.

The document has been split into the following sections;

- Section 2 describes the proposed activities;
- Section 3 describes the local environment;
- Section 4 describes the alternatives considered;
- Section 5 describes the environmental impacts and the measures proposed to minimise or avoid them; and
- Section 6 provides the conclusions of the IEE.

A non-technical summary has been included at the beginning of the document to provide an overview of the IEE in a clear, concise and non technical manner as well as outlining the conclusions achieved.

CHAPTER 2. DESCRIPTION OF THE PROPOSED ACTIVITY

2.1. Location of the Proposed Activity

The science and associated logistical activities are on the Filchner-Ronne Ice Shelf and its five tributary ice streams, which spans sections of both the East and West Antarctica Ice Sheet. The location of the FRIS and its tributaries are shown in the figures below.

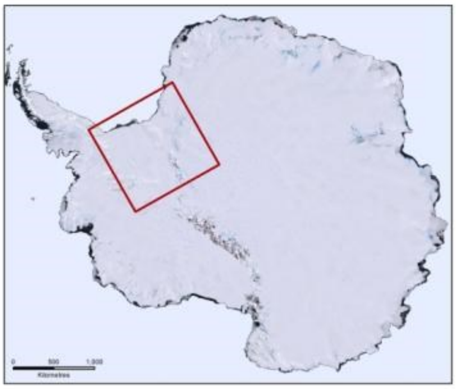


Figure 1 – the location of the Filchner-Ronne Ice shelf in Antarctica

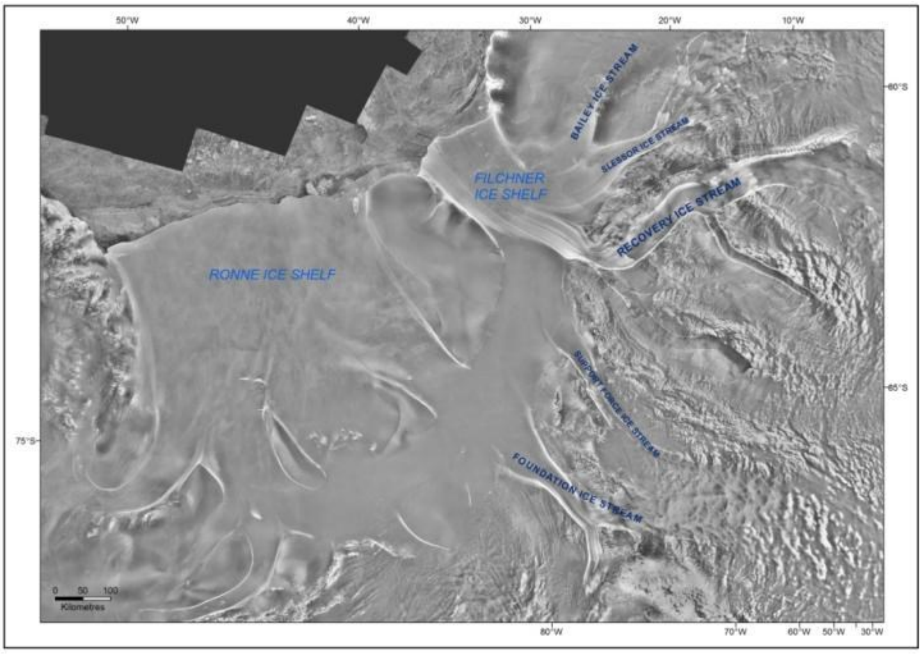


Figure 2 – The FRIS and tributary ice streams

2.2. Science Aims and Objectives

The primary aim of the project is to determine how a large sector of the Antarctic Ice Sheet will evolve in a warming world. In response to rising global temperatures, the potential exists for abrupt and irreversible ice loss from the ice sheet. The result would be a rise in global sea-level and changes in the ocean's deep circulation. We propose to gather the observations necessary to understand the system and make a quantitative assessment of the risk to Filchner Ice Shelf and its inland catchment, an area of the Antarctic that is four times the size of France.

The prospect is for atmospheric and oceanic forcing to reduce the thickness and extent of floating ice shelves as a result of increased melting at their base. A thinned ice shelf has a lowered ability to buttress the flow of its grounded tributary ice-streams. Removal of an ice shelf therefore allows the restrained ice to flow faster, drawing down the vast interior reservoir and resulting in global sea-level rise. However, the rate, pattern and timing of the ice-shelf melt and the associated sea-level rise are uncertain. We propose a carefully targeted observational programme, in support of a comprehensive modelling activity. The sector to be studied is the Filchner Ronne Ice Shelf and its five tributary ice streams, which spans sections of both the East and West Antarctica Ice Sheet. Specifically, projections will be made out to the end of this century of the contribution to global sea-level rise from this sector.

The proposal's aims are encompassed by the following deliverables:

Deliverable 1: Gather in 14/15, more detailed oceanographic data from three closely spaced locations on the SW coast of Berkner Island (within a couple of kilometres from each other), so we can see how the variability beneath the ice shelf correlates with observed changes north of the ice front (e.g. seasonal and interannual changes in sea ice production).

During the last 25 years, BAS has been studying the interaction between FRIS and the ocean shelf seas. One of the field campaigns during that 25 year period involved making an access hole using a hot water drill at a site off the SW coast of Berkner Island. The access hole was used to deploy oceanographic instrumentation which gave a few years of data and demonstrated that of the handful of sites that have been drilled, that particular area was oceanographically highly responsive to changes in the condition at the ice front, and appeared to be able to indicate changes in conditions beneath the ice shelf in general.

During the 14/15 field season BAS and Uni Research revisited the area and deployed another set of oceanographic instrumentation with a planned life of approximately 10 years. The spread of three nearby sites will help determine whether any long term changes are a result of motion of the moorings as the ice flows, or from real changes at the ice front. The site is oceanographically upstream of the ocean cavity beneath Filchner Ice Shelf, which is to be instrumented in future seasons. This will show how the variability observed at the SW Berkner site propagates around the sub-Filchner cavity.

Deliverable 2: New datasets from the Filchner region, and validated simulations of the present-day system and its variability.

- Determine the geometry of the model domain (ice-bed elevation, ice thickness and sub-ice shelf bathymetry) in several key areas that lack data coverage.
- Collect datasets designed to supply a physical understanding of Filchner Ice Shelf, its tributary ice streams and the sub-ice shelf ocean, in the present atmospheric and oceanographic regime.
- Numerical simulation of the complete system will demonstrate the various interconnected physical processes and importantly, their sensitivities to a change in climatic forcing.

Deliverable 3: Reliable projections on how the Filchner region will contribute to sea-level rise over the 21st century.

Deliverable 4: An assessment of the uncertainties in the projections, and a broadening of the study to encompass all of Antarctica.

2.3. Methodologies

<u>2.3.1 2014/15 Season Outcome</u>

Science

During the 2014/15 field season BAS and Uni Research deployed oceanographic instrumentation on the SW coast of Berkner Island with a planned life of approximately 10 years. Three boreholes were drilled at the following locations:

S5A (*Site 1),* S80° 20.00' W054° 46.43'
S5C (Site 2), S80° 17.20' W054° 42.50'
S5B (Site 3), S80° 20.40' W054° 37.00'

The project used a hot water drill, pumping 90l of water per minute at around 90 °C amounting to around 0.5 MW of heating power. The drill made a 30 cm diameter hole through the ice around 750 m thick, underlain by a few hundred metres depth of water. Three access holes were drilled within a few kilometres from each other and three sub-ice shelf moorings of varying degrees of complexity deployed. Much of the data is being returned to the UK using satellite communications; full data sets are stored in memory of the equipment on site to be retrieved at later time.

The drill itself used petrol-fuelled generators, and water-heaters powered by aviation fuel. Approximately six thousand litres of aviation fuel were burnt, and around 800 litres of petrol. The generators are commercially-built units that comply with normal emissions protocols. The water-heaters are purpose-built, and have heat-recovery units mounted in the exhaust path to maximise their efficiency.

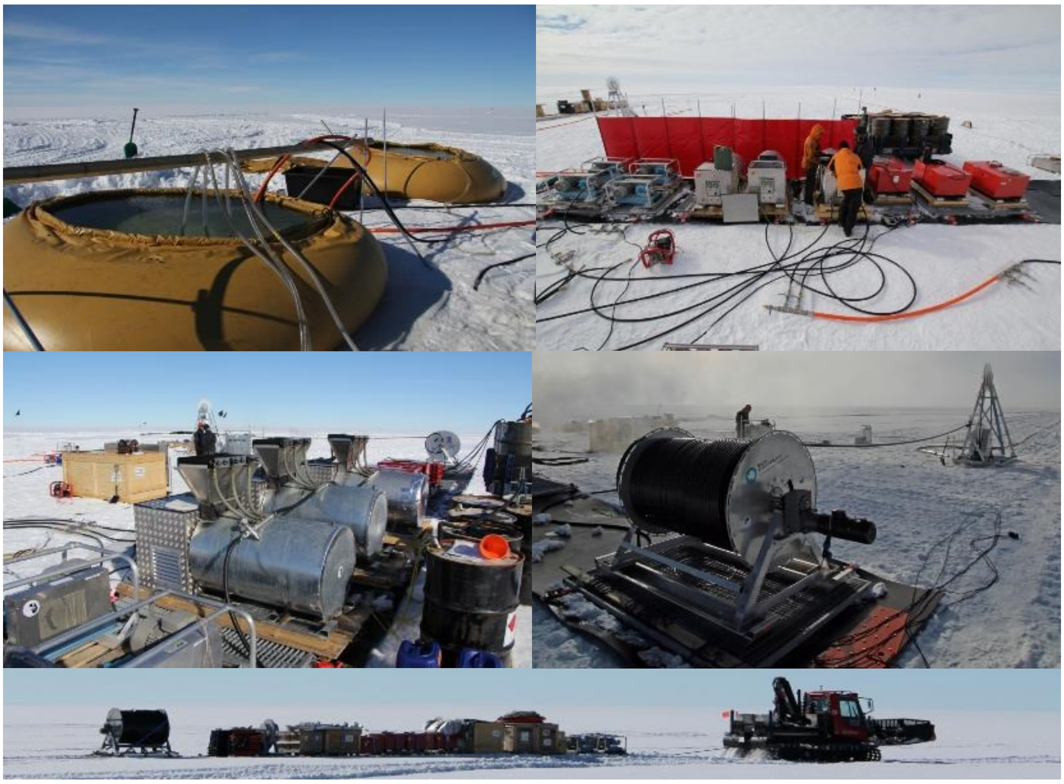


Photo collage of the equipment used for the hot-water drilling of boreholes

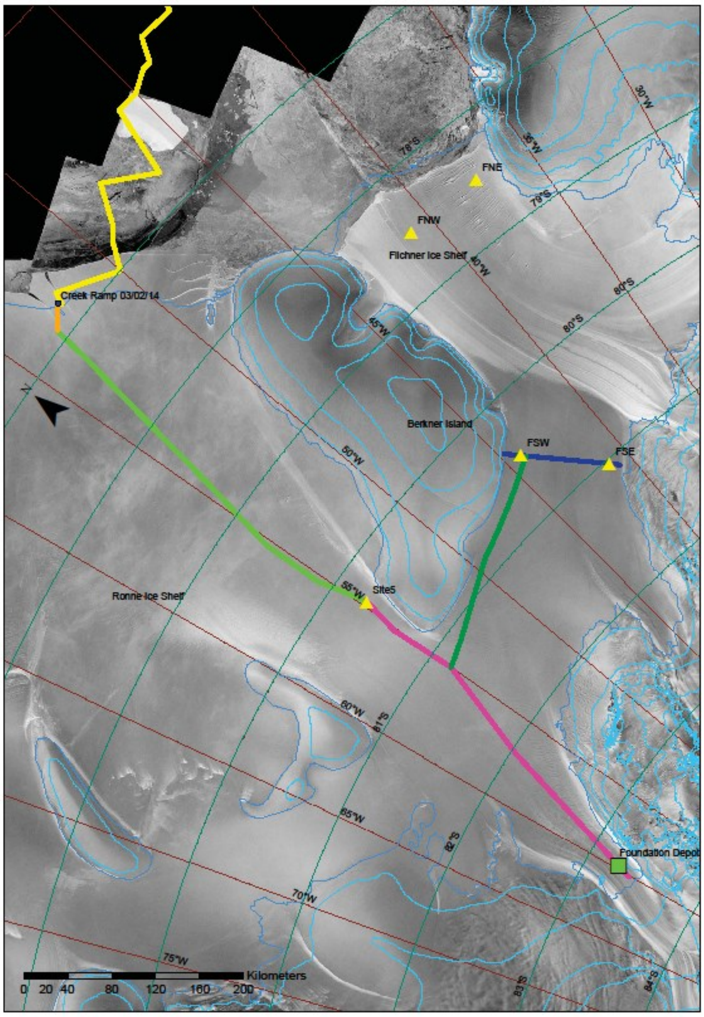
After the borehole was made, a standard oceanographic conductivity-temperature-depth (CTD) instrument was deployed to obtain a series of CTD profiles. A microstructure profiler was then used to investigate the turbulence regime in the ice-ocean boundary layer to study oceanographic controls on the basal melt rate. Both profilers were recovered as part of their normal use.

Sediment samples were collected from the sea floor using a simple gravity corer deployed via the borehole. This was the first time seabed samples were recovered from beneath the FRIS and it is anticipated they will reveal important information about the long term history of the ice shelf which can be used to place the recent changes in the area into a long term context. A total of seven cores were obtained with a combined total length of 2.65 metres.

Finally, instruments were deployed on moorings beneath the ice shelf. One mooring consists of battery-powered current meters and temperature-conductivity instruments, communicating via inductive modems to a controller on the ice shelf surface. Another, located about 2 km downstream, consists of four instruments connected to the surface controller by a cable that will provide power and data communications. A third mooring, located 2 km cross stream, consists of a cable with a conducting element and also optical fibres. That cable reaches to the ice shelf base, and then back to the ice surface providing an inductive transmission line. The optical fibre, when used with an appropriate spectrometer, will yield an ice temperature profile. A 24-channel thermistor cable extends from the bottom of the optical fibre cable loop to near the sea floor. That cable is connected to a battery-powered logger, which is itself inductively linked to the fibre-optic cable loop. A controller at the surface communicates with the thermistor cable logger.

The instruments tethered beneath the ice shelf will not be retrieved. All equipment on the surface will be removed at the end of the (up to ten-year long) experiment.

In addition to the deployment of the oceanographic equipment, seismic data was gathered for later field seasons. The survey consisted of one line of 14 sites running across the southern Filchner Ice Shelf (see Fig 3). Each site entailed the drilling of a 5-m metre hole using a petrol-powered auger, loading it with 150-300 g of Pentolite explosive, backfilling and detonating. The shot was recorded using a 24-channel Georod array, with each geophone shallowly buried.



`

Figure 3 showing the location of the activities undertaken in 2014/15
Light green is the Pistonbully traverse from the ice front depot (TRD) to the drill site (site 5). The mauve line is the route taken by the tractors to establish a fuel cache near the grounding-line of the Foundation Ice Stream. Light green is the skidoo route taken by the two person seismic party who undertook a survey along the blue line. The yellow triangles show the location of the boreholes.

<u>2.3.2 2015-16 Season Plan + Outcome</u>

For the 2015/16 field campaign 12 primary activities were undertaken. The following gives an overview of the planned activity and what was actual achieved, for each of the 12 activities. Detailed descriptions of the activities is as described for the previous field season, or in the text below. The location of the activities are as shown in Figure 4.

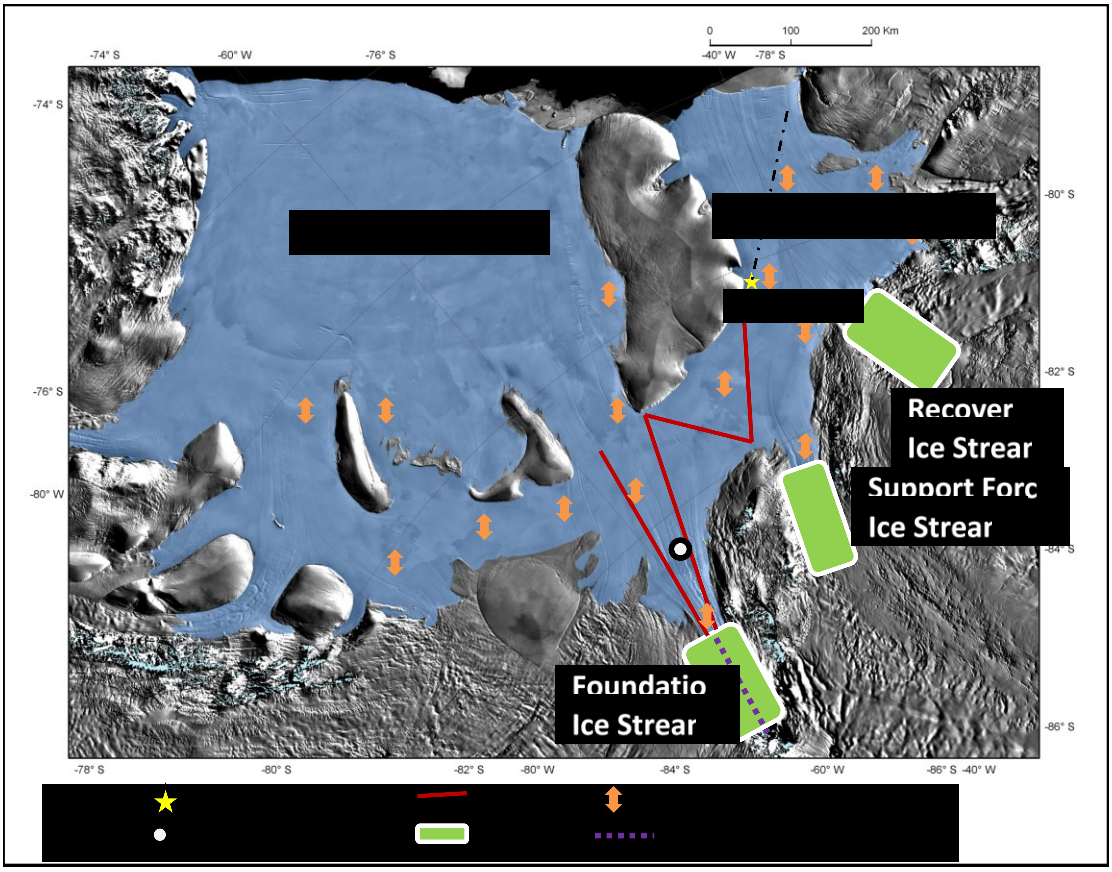


Figure 4. Overview of planned work areas in 2015/16

Plan 1. Hot water drilling and deployment of instruments through the ice shelf at four locations: two at FSE and two at FSW.

- Nine people are attached to this activity (5 BAS and 4 AWI).
- Science equipment weighing 1,200 kg is required at each of the two sites.
- Sediment cores from the ocean floor are planned to be recovered: the aim is for four cores each of 3 metres length
- Water samples will be taken at discrete heights in the water column
- The oceanographic instruments will be logged at the surface and are expected to record for a minimum of five years.

Outcome 1. All objectives were met. The four holes through the ice shelf were successfully drilled at the locations given in the following table. The access holes permitted the retrieval of shallow sediment cores from the sea bed and recovery of water samples at specific depths in the water column.

Name	Latitude	Longitude	Ice thickness (m)	Bathymetric depth* (m)	Water column thickness (m)
FSW1	-80.43531	-44.43134	853	1215	471
FSW2	-80.48122	-44.18861	872	1233	472
FSE1	-80.97393	-41.44864	891	1306	528
FSE2	-81.07583	-40.82747	837	1142	442

The access holes permitted the retrieval of shallow sediment cores from the sea bed and recovery of water samples at specific depths in the water column. A sketch for the mooring strategy for each of the four sites, with respect to bathymetry and ice thickness, is given in Figure 5 below. Full details of each instrument can be found in the Tango1516 filed report. Sediment cores were recovered at all sites with the exception of FSW2. In total, 2.9 m of sediment was recovered with a maximum penetration of 0.78 m at FSE1. At FSW1 two cores were recovered with core recovery 0.14 m and 0.33 m using the mini-corer (MiC) and gravity corer (GC) respectively. At FSE1 three cores were recovered, with two MiC (0.73 m and 0.78 m respectively) and one short GC (0.08 m). Two cores were recovered at FSE2 measuring 0.55 m (GC) and 0.36 m (MiC).

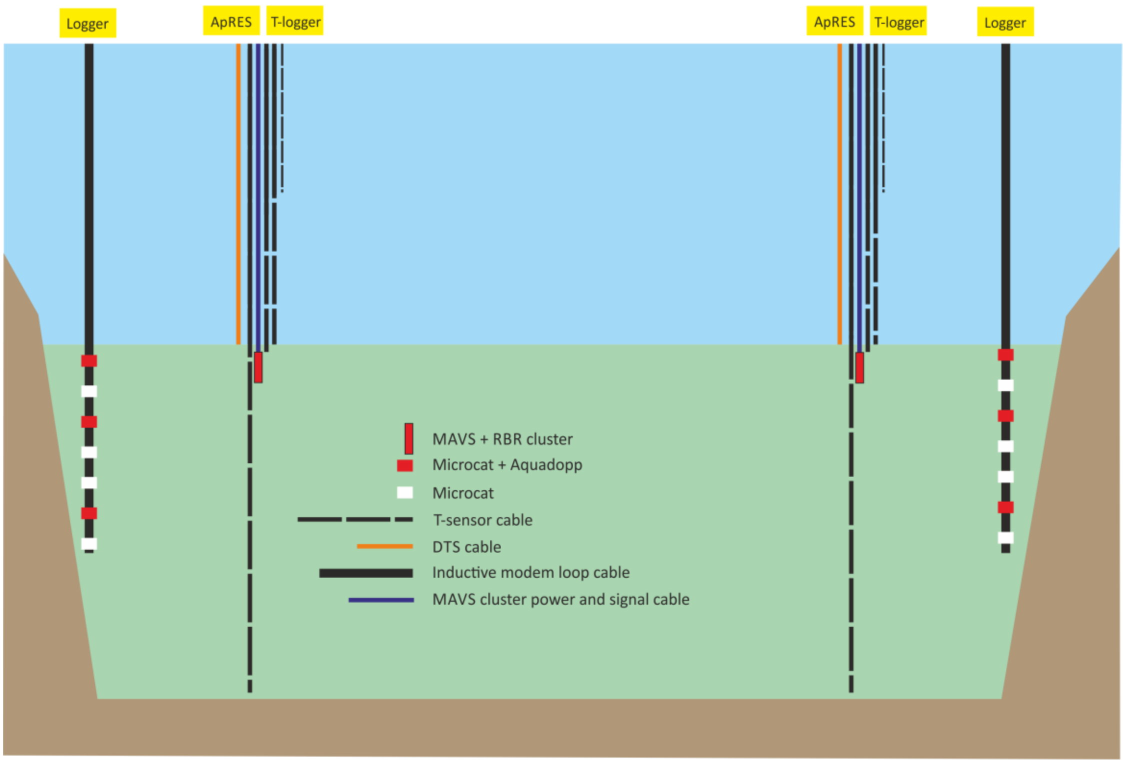


Figure 5 showing the mooring strategy for each site

<u>Plan 2</u>. Oversnow seismic that would do an estimated 1,500 km traverse.

- A standard two person field team (scientist and Field Assistant) will work to acquire approximately 125 point measurements of bathymetry.

<u>Outcome 2</u>: The total distance travelled by skidoo was approximately 2,800km. A total of 104 bathymetry measurements were successfully acquired. In addition, radar measurements *(pRES*) were made at 13 points along the route. These will be re-visited during the 2016/17 season to obtain ice-shelf melt rates. The route and measurement points (radar and seismic) are shown in Figure 6 below.

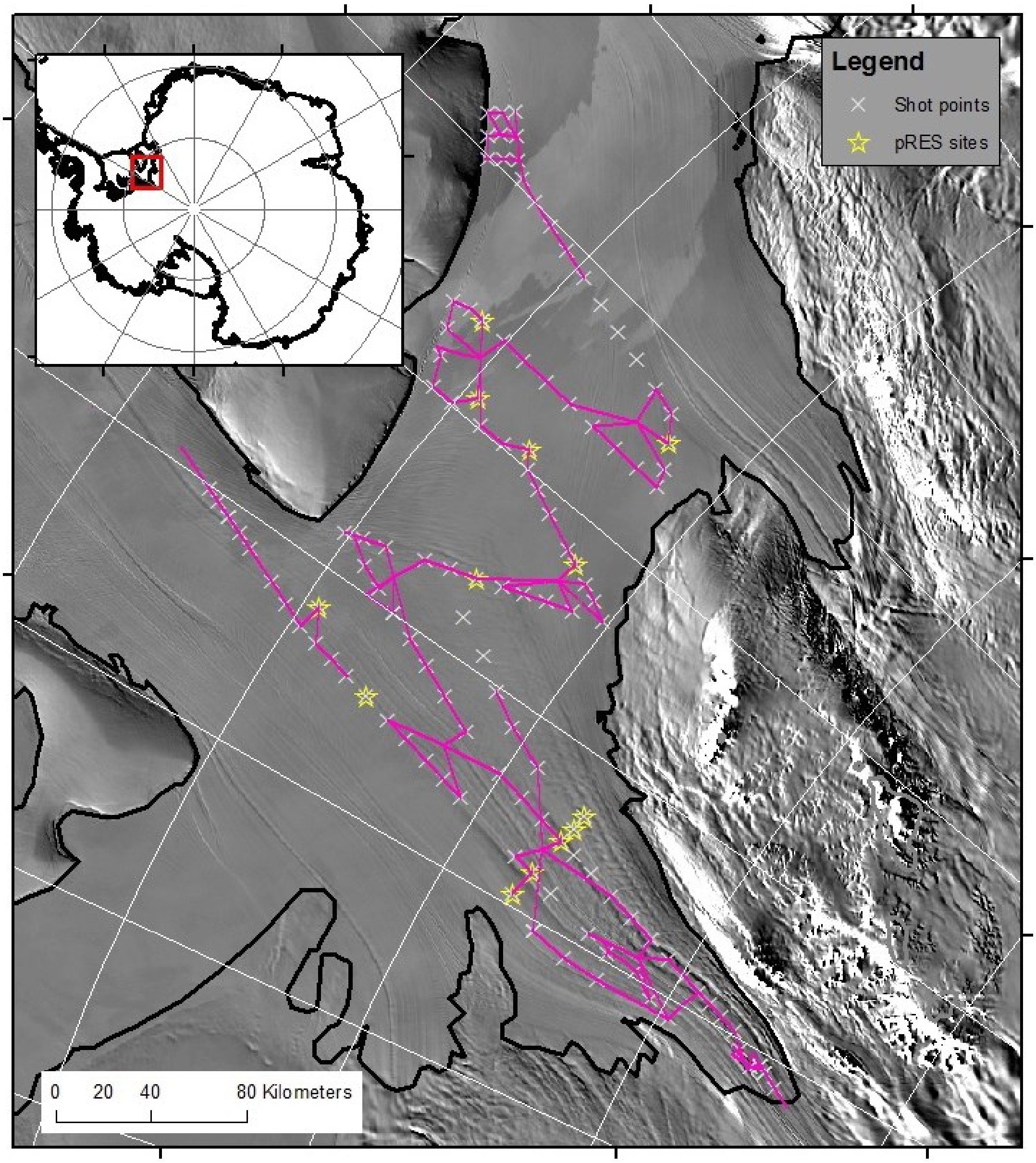


Figure 6 Route map for the traverse, showing each shot point (crosses), pRES site (stars) and skidoo

Plan 3. The installation of 15 ApRES radar sites – these would occupy a specific location for a nominal 12 months giving a detailed time-series

- Each unit weighs 50kg and can be installed in two hours, and consists of a ApRES radar system powered by a 200 AH 6Volt battery
- These are spread across the Filchner-Ronne Ice shelf.
- Each unit would be revisited in 2016/17 and a number will be relocated.

Outcome 3: A total of 14 ApRES radar sites were established. The 15th was not deployed due to safety concerns of the surface. The table below and Figure 7 detail their locations.

Site	Latitude	Longitude	Date
S0115	S75 53.4683	W59 08.8143	24th Dec 2015
S0215	S76 22.2710	W61 51.9676	23rd Dec 2015
S0315	S77 02.3714	W66 58.0777	23rd Dec 2015
S0415	S77 04.8655	W73 33.4894	5th Jan 2016
S0515	S78 51.9780	W71 20.4834	4th Jan 2016
S0615	S79 56.171	W72 08.176	19th Dec 2015
S0715	S80 41.530	W73 31.875	19th Dec 2015
S0815	S80 49.7303	W65 17.9203	4th Jan 2016
S0915	S82 49.4301	W60 56.1462	10th Jan 2016
S1015	S82 51.5646	W58 22.4871	10th Jan 2016
S1215	S79 00.4677	W38 25.2503	15th Jan 2016
S1315	S78 30.3077	W37 27.8990	15th Jan 2016
S1415	S78 44.7108	W51 06.7387	4th Jan 2016
S1515	S76 59.8748	W58 58.3234	23rd Dec 2015

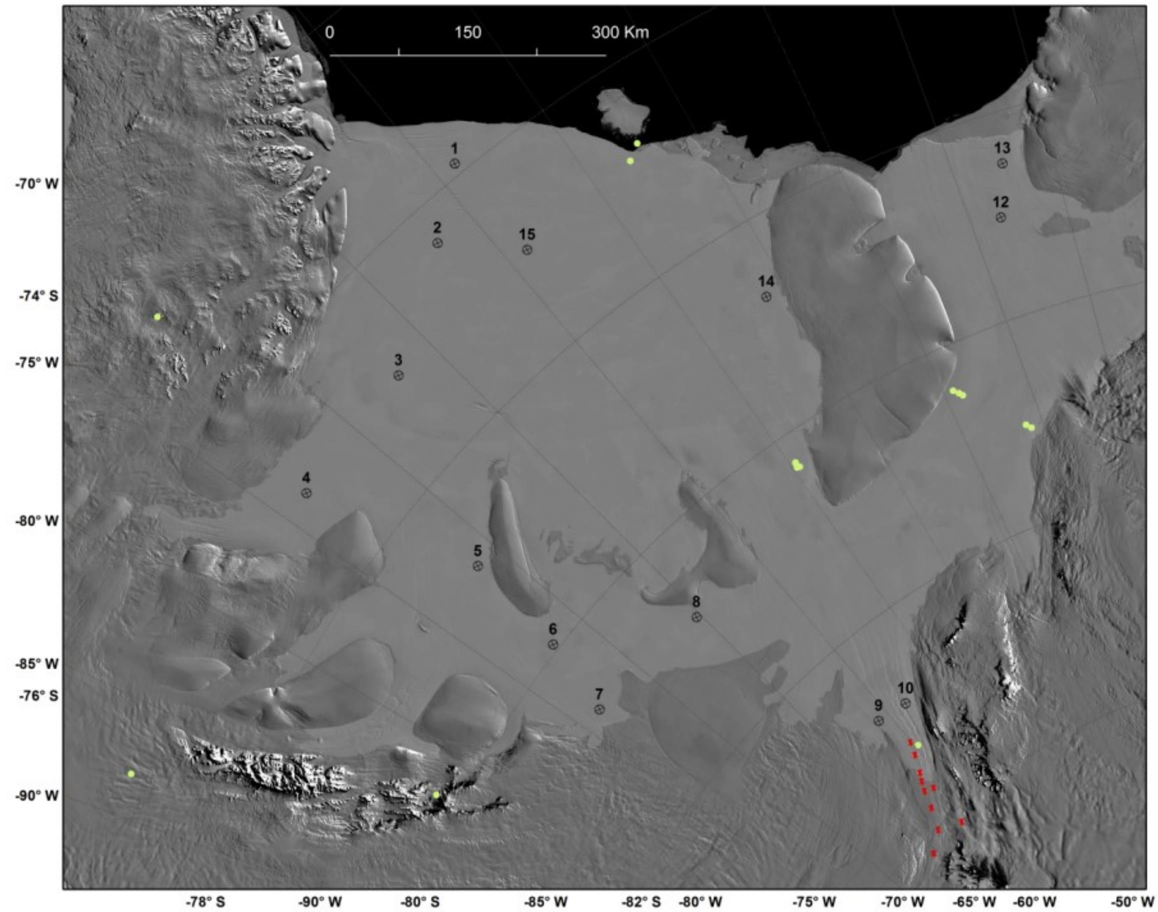


Figure 7 Location map of the 14 ApRES sites. Yellow dots were the main depots and the red thumbtacks are Hotel's GPS sites on the Foundation Ice Stream

Plan 4. pRES point measurements to give an average (over a year) melt rate

- It is envisaged that an oversnow party would establish a number of sites (approximately 15) that would be marked by bamboo stakes and would then be revisited in 2016/17.
- The establishment of a site and the measurement takes approximately 20 minutes.

Outcome 4: A total of 14 ApRES sites were established along the seismic traverse route. Please refer to Figure 6 for a map of the locations.

Plan 5. An airborne survey to measure the ice thickness of the Foundation, Support Force and Recovery Ice Streams.

- Each of the ice streams would have a targeted 20 hour (20,000 line km) survey with a nominal line spacing of 2km and terrain clearance of 1,000' (300 metres).
- Four personnel would be involved operating from two fuel caches.

Outcome 5. Because of time and equipment constraints only the Foundation Ice Stream was surveyed. Figure 8 below shows details of the six sorties: each had a nominal endurance of 950 km and across glacier line-spacing of 2.5 km.

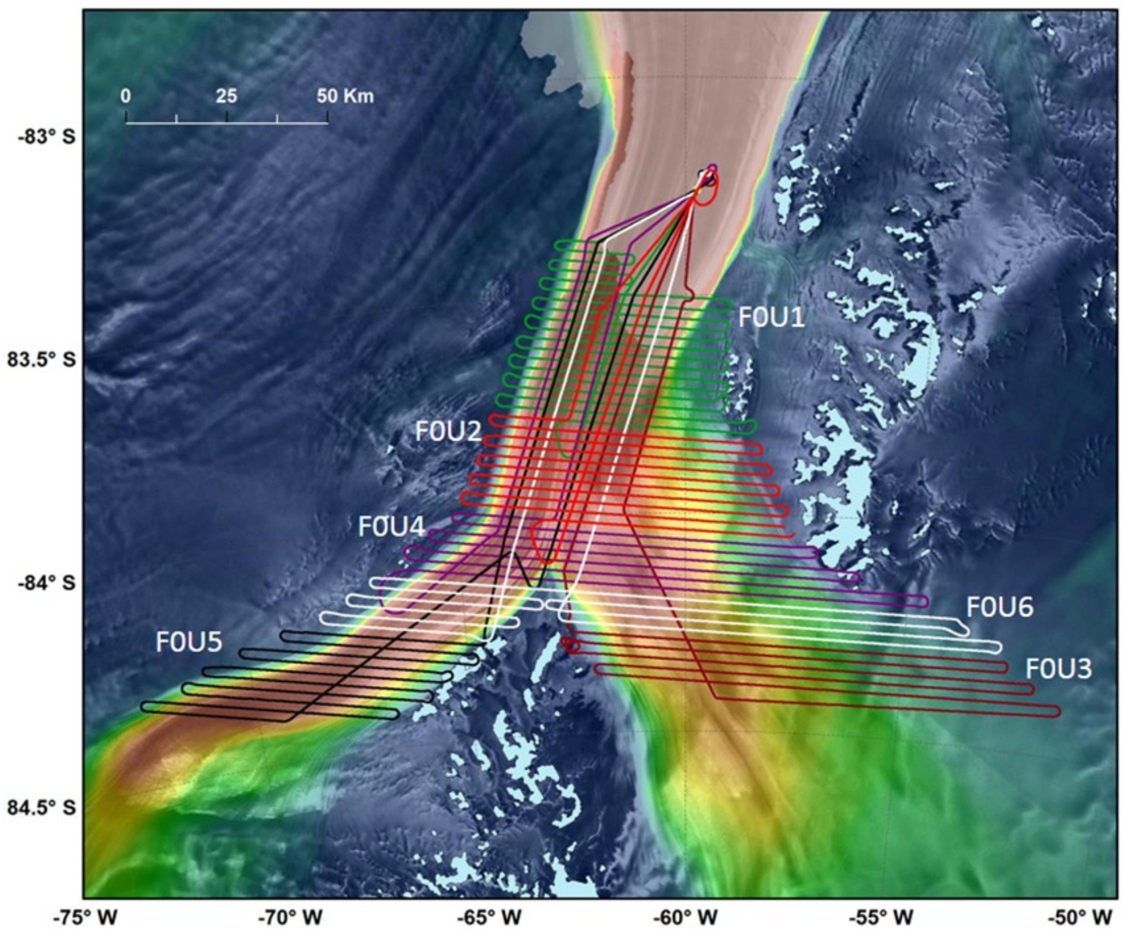


Figure 8: showing location of the airborne surveys

Plan 6. The installation of 10 GPS stations recording tidal movement and flexure.

- The Foundation Ice Stream would have one unit established 20km downstream of the grounding line, then the remaining nine at 10 km intervals upstream of the grounding line.
- Each of the stations weighs a maximum of 300 kg, and primarily consists of a Leica GPS receiver, solar panel, two 100 AH sealed-lead-acid batteries and associated pipe work to mount the solar panel and GPS aerial.
- The stations will be removed and redeployed in the 2016/17 season.

Outcome 6. The only departure from the plan was the installation of one of the units at the 'Pillar Knob' depot (W115 in the table below).

Site	Latitude	Longitude	Date
H0115	S83 33.745'	W061 35.083'	27th Dec 2015
H0215	S83 39.112'	W061 58.821'	27th Dec 2015
H0415	S83 49.530'	W062 33.073'	27th Dec 2015
H0515	S83 58.361'	W063 11.476'	27th Dec 2015
H0715	S84 05.36'	W061 40.920'	10th Jan 2016
H0815	S83 19.65'	W060 33.29'	10th Jan 2016
H0915 (Johnny Cache)	S83 15.3072'	W059 44.943'	10th Jan 2016
H1015	S83 41.62'	W061 13.19'	10th Jan 2016
H1115	S83 29.560'	W061 12.703'	28th Dec 2015
W115	S83 37.82'	W059 06.64	17th Jan 2016

A finished site, each marked with at least two flagged bamboos. The solar panel is mounted on 2 m glacio poles. The zarges box containing the GPS unit, solar regulator and batteries is buried directly behind the solar panel.

Plan 7. Static GPS on Recovery Ice Stream.

- Six AWI GPS stations are to be established along the ice stream: one seaward and five at various intervals along the ice stream. These are to work year round. Input will be by Twin Otter.
- The stations will be removed in the 2016/17 season

Outcome 7: Because of extensive crevassing along the lower reaches of the Recovery Ice Stream only four GPS stations were established. The remaining two were established close to the grounding line of Support Force Glacier. Figure 9 below details their locations.

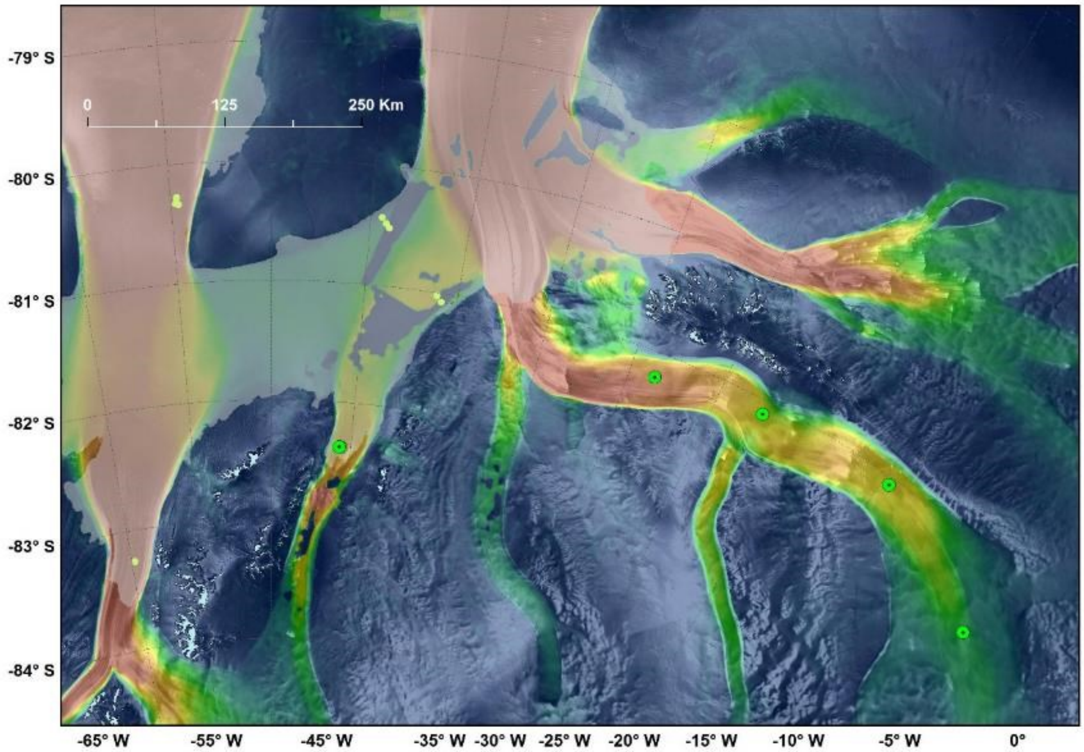


Figure 9: location of GPS stations

Plan 8. Shallow firn-cores

- Three firn-cores each 14.4 metres depth, will be taken on the Filchner Ice Shelf along the flow line of the Support Force Ice Stream
-

Outcome 8. Under permit 'II2.8-94003-3/365 (German Umweltbundesamt)' one 10 m firn-core was successfully retrieved from near FSE-1, in the extension of the flow line of the Support Force Ice Stream, and shipped to AWI.

Plan 9. Radar measurements (pRES and snow-accumulation)

- A three person party (1 field unit) will work along on an area of the Filchner Ice Shelf between the grounding-line of Support Force Ice Stream and the southern drill sites.
- Up to 200 pRES sites (for average melt rates) will be established. These will be re-measured in the 16/17 season.

Outcome 9. A total of 132 sites were established across the seaward extent of the Support Force Glacier. Bamboo flags were set-up to mark each measurement location for repeat measurements in season 2016/17. The locations for these measurements are shown in Figure 10 below.

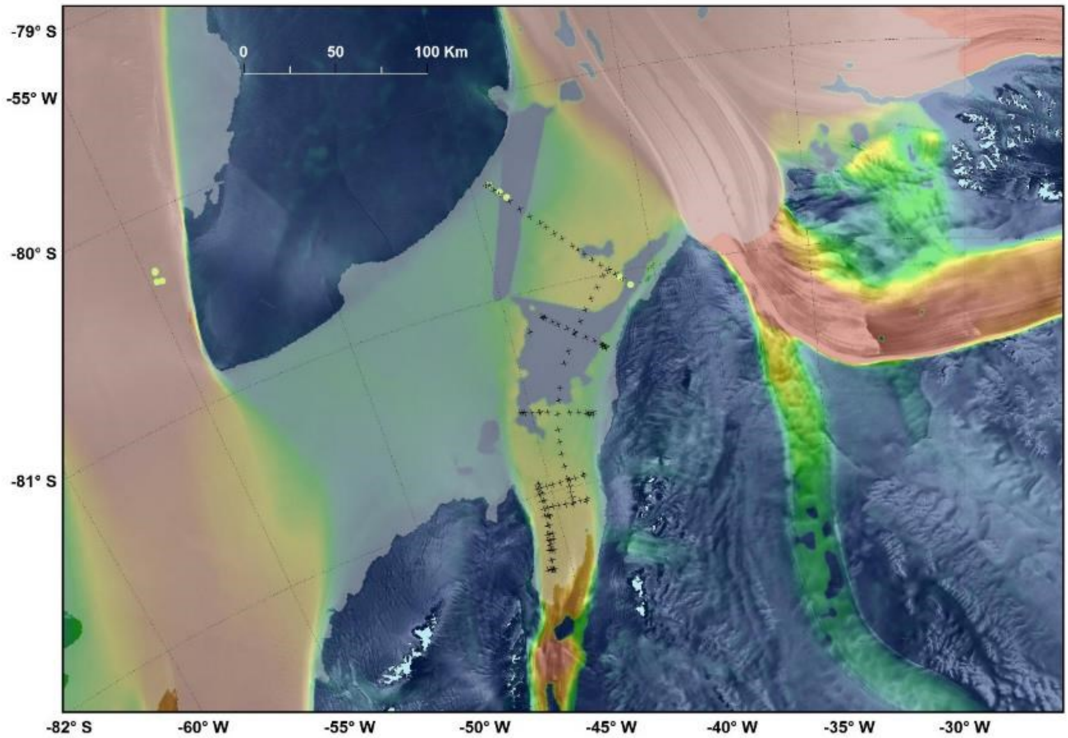


Figure 10 showing locations of the radar measurements

<u>Plan 10</u>. Deployment of wave buoys including AWS

- Three wave buoys with automatic weather stations (AWSs) will be deployed in the southern Weddell Sea from the *Polarstern*. The data from these buoys will be used to validate a regional climate model.

Deployment of a wave buoy.

- It is envisaged that the buoys will move clockwise in the Weddell Sea gyre and eventually enter the Southern Ocean north-east of the top of the Antarctic Peninsula after 1- 2 years. It is highly unlikely that they will be recovered.
- The weight of each buoy is approximately 250 kg and they are about 1.5 m tall without the AWS on top, which will add a further 2 m. The meteorological instruments, which will measure pressure, temperature, humidity, wind and short- and long-wave radiation, will be powered by a combination of rechargeable (from solar panels) lead-acid Cyclon E cells (42) and alkaline Duracell Procell D type cells (248). The data will be transmitted back to BAS via Iridium satellite connection.

Outcome 10. The three wave buoys with automatic weather stations (AWSs) were successfully deployed. The data is being automatically logged via an Iridium system.

Plan 11. Recovery of marine sediment cores from the Antarctic continental shelf and slope.

This will allow the reconstruction of changes in environmental conditions and ice-sheet dynamics during the geological past and will identify driving mechanisms of ice-sheet melting.

- Long sedimentary sequences will be recovered with gravity cores (up to 30 No. 6 m long cores with a diameter of around 125mm). In addition, sediments from the seabed surface will be recovered with box and multiple corers (up to ca. 0.6 m long).
- Up to 30 box cores (each 0.5 m x 0.5 m and up to 0.6 m in length); and up to 30 multiple cores (each with 12 sub-cores up to 0.5 m long and with 67 mm diameter) will be collected.
- The samples will be collected on the *Polarstern* between 60°S and 79°S and 62°W and 0°. The target area is the Weddell Sea embayment between 70°S-78.5°S and 20°W-62°W but in case of unsuitable sea-ice conditions an alternative study area within the specified region will be targeted.

Outcome 11. A total of 27 samples were recovered on Polarstern Cruise PS96. The amount of material recovered was 1505 cm equating to a volume of 194647 cm^3.

Plan 12. Surface snow measurements

A transect of surface snow measurements will be taken during the traverse, to gather data in an area of Antarctica that is rarely accessible. A small volume of snow (3 No sample pots of around 50 ml each) will be taken at 40 – 50 km intervals across the Ronne Ice Shelf.

These samples will be analysed for iodide and bromide concentrations in the snow to assess gradients inland and signals of post-depositional processing. This builds up a BAS dataset and the results will be used to assess impurities of ice cores as markers of past sea ice extent.

Outcome 12. Samples were collected at a 40km interval along the iBeam traverse. A map of the traverse by the PistonBully tractors is shown in Figure 11.

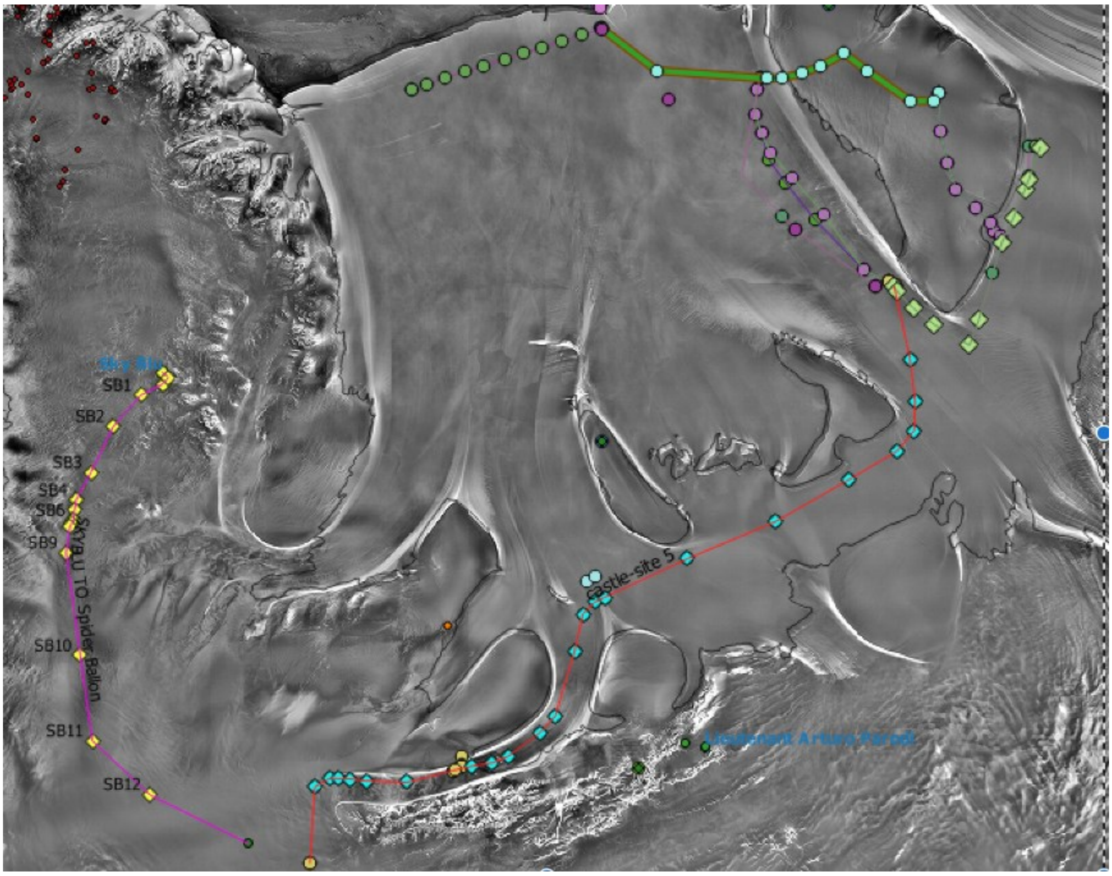


Figure 11 showing the location of snow samples collected on the iBEAM route

2.3.3. Science methods 2016/17 (fieldwork) -plan

The field component for this season can be loosely described as more of the same in that there is planned to be a continuation of the tasks and associated logistic requirements that were outlined for the 2015/16 season.

The following outlines the basic fieldwork requirements for the eight planned tasks.

1. *Hot water drilling and deployment of instruments through the ice shelf at three locations on the northern Filchner Ice Shelf*
2. *Oversnow seismic.*
3. *The servicing of 14 BAS ApRES radar sites across the Filchner Ronne.*
4. *Revisit established pRES points for a measurements to give an average (over a year) melt rate.*
5. *An airborne survey to measure the ice thickness of the Support Force, Recovery, Bailey and Slessor Ice Streams.*
6. *The servicing/movement of 10 GPS stations recording tidal movement and flexure on Foundation Ice Stream.*
7. *Servicing of equipment at the ice-shelf bore holes. There are seven sites (3 at Site 5, FSE1, FSE2, FSW1 and FSW2) at each site there are oceanographic and associated data loggers. This includes the AWI AWS at FSW1.*
8. *Two of the AWI GPS instruments are to be removed. The remaining four GPS sites and two three ApRES sites are to be serviced.*

1. Hot water drilling

Figure 12 shows the approximate locations for the three hot-water drilled access holes that are proposed this season.

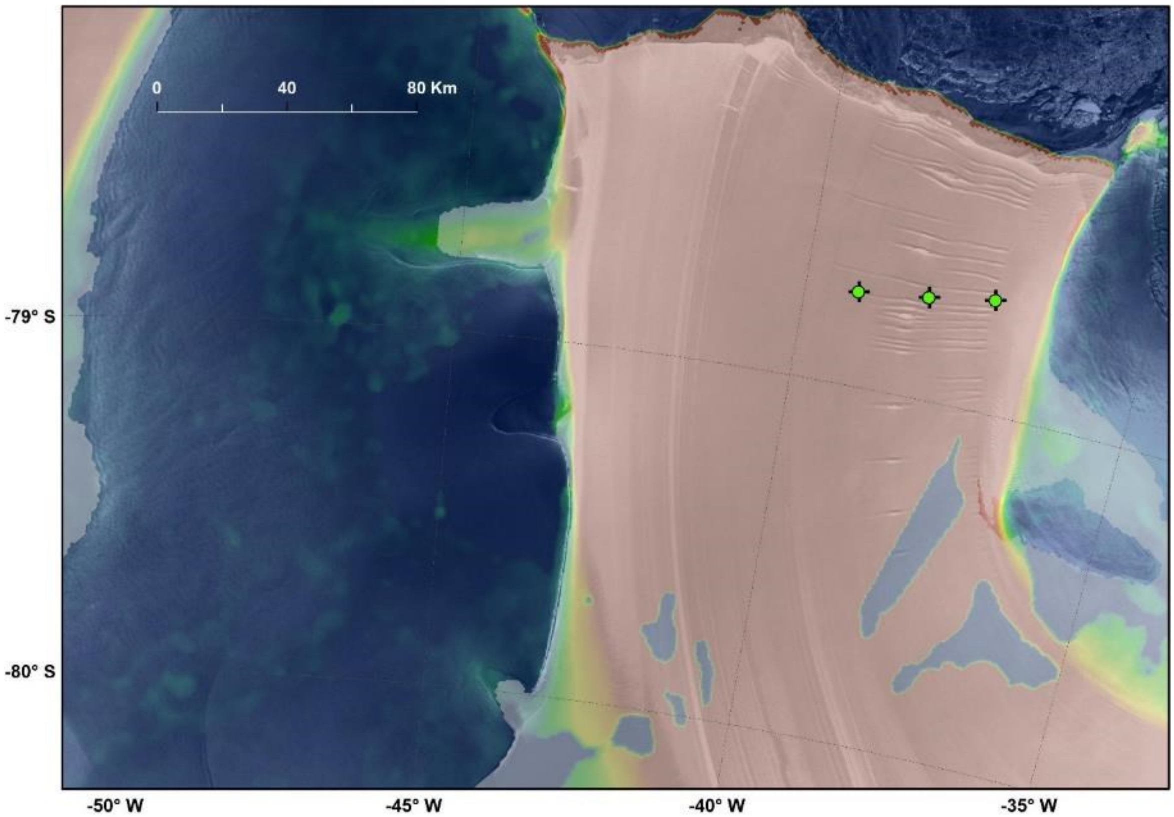


Figure 12 The approximate location of the three hot water drill holes

- Eight people are attached to this activity (3 BAS and 5 AWI).
- Science equipment weighing 1,200 kg is required at each of the three sites.
- Sediment cores from the ocean floor are planned to be recovered: the aim is for 4 cores each of 3 metres length
- Water samples will be taken at discrete heights in the water column
- The oceanographic instruments will be logged at the surface and are expected to record for a minimum of five years.

The drilling methodology is as described for the 2014/15 field season (see Section 2.3 of this report)

The boreholes are separated by 20km. The equipment, which includes living units, staff and equipment (drill and scientific) will be moved between the drill sites by skidoo. As each Skidoo can tow 600 kg (on two, wide siglins), approximately 17 skidoo rotations skidoo will be required, amounting to 17 rotations x 2 (there and back) x 20 km distance between sites.

2. Oversnow seismic survey
This is an AWI task and has three components: *i*. conventional spot depths for bathymetry at 104 locations, *ii*. The revisit of 13 pRES sites established by sledge Victor in 15/16, *iii*. A focused, high resolution seismic-study of the geomorphology of the ocean bed forms.

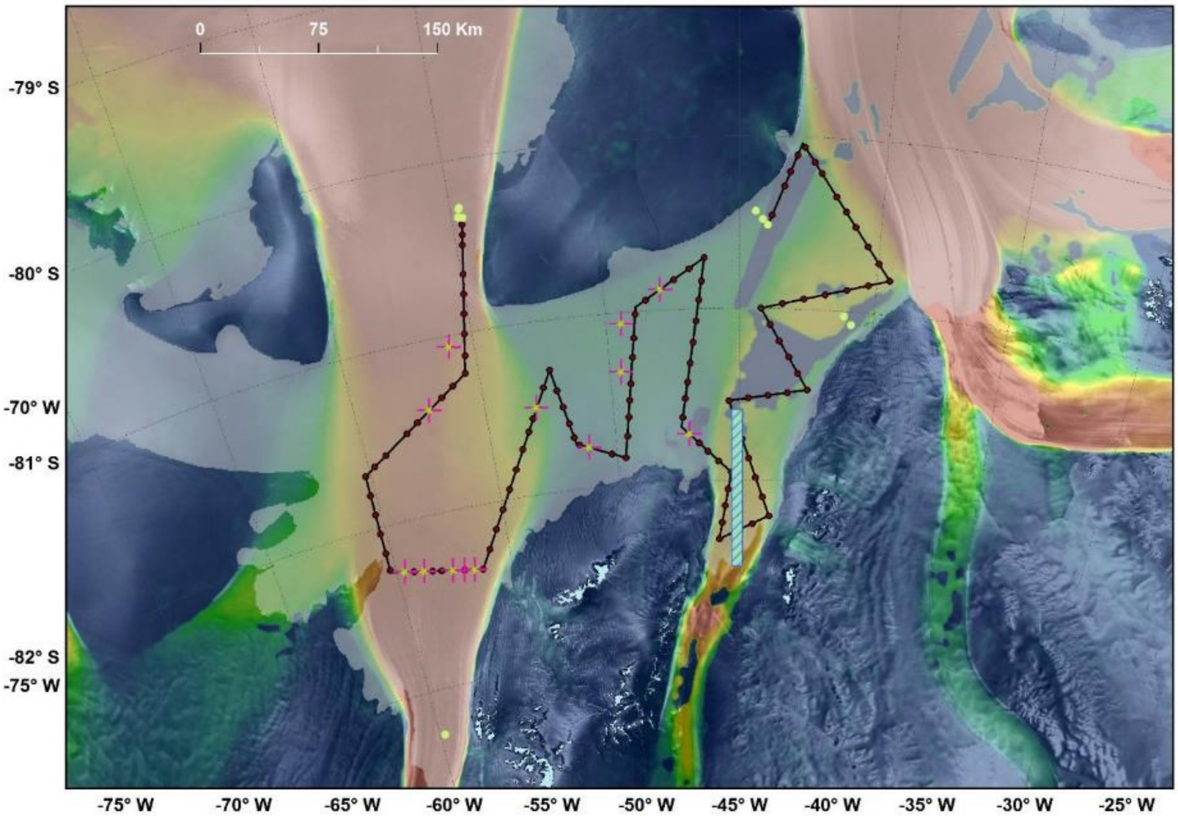


Figure 13 The planned seismic-traverse route. The black filled points are the locations of bathymetry spot-depths, the crosses are the pRES locations and the hatched zone contains the area for the high-resolution seismic survey. Note: intermediate depots are not shown.

Starting at Site 5 (where the 2015/16 traverse ended) the intention is for a two person party to undertake an estimated traverse of some 2,500 km (this figure is estimated from sledge Victor in 2015/16).

i. The explosive material required to carry out this activity will be come from supplies at Rothera and that depoted at FSW2 in 2015/16.

3. Servicing of ApRES radar sites

The ApRES units record the ice thickness every two hours. For each of the 14 sites the units require servicing. Briefly this entails: raising the radar unit (to just below the surface) and replacing the data card. If the battery is suspected to be in a poor condition it will be replaced with a fully-charged 12 V 100 Ahr unit. A small solar panel (15 Watt) will be installed on the existing mast. The replacement batteries are currently depoted on Berkner Island.

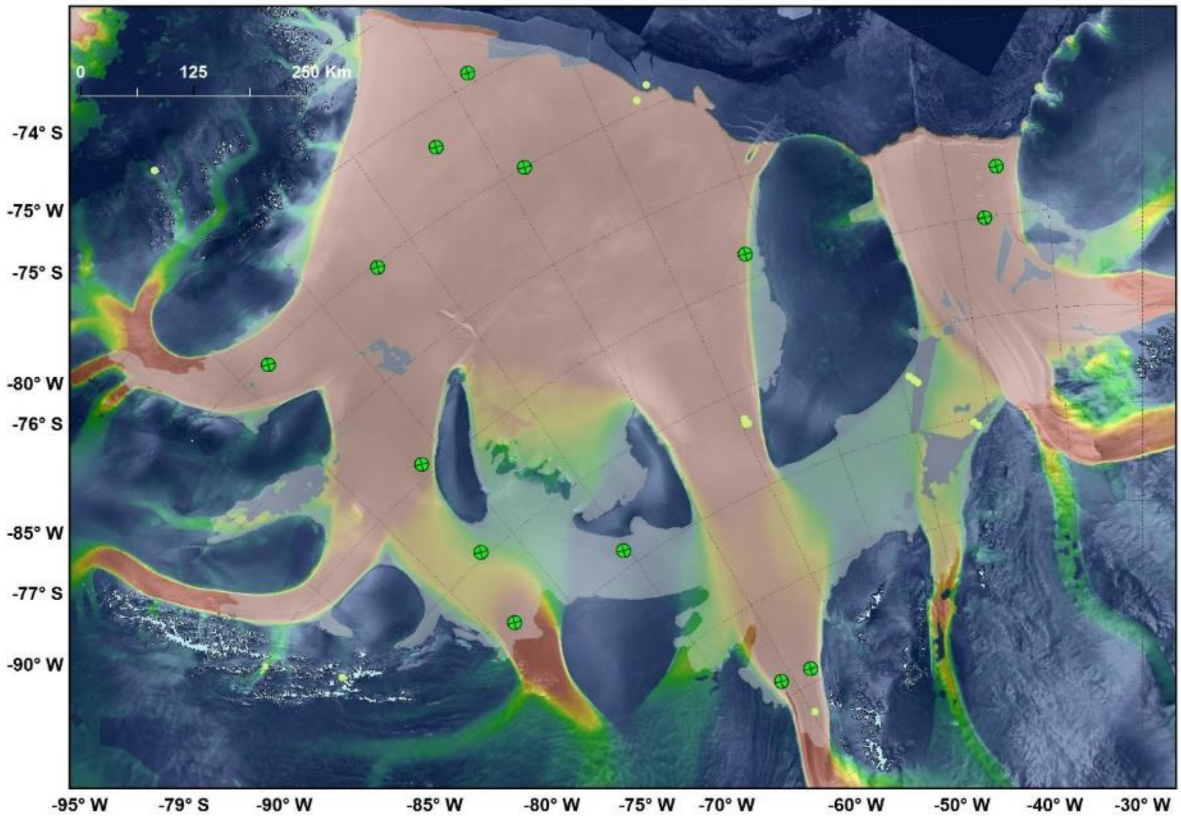


Figure 14. The location of the 14 ApRES sites across the Filchner-Ronne Ice Shelf

4. Revisit established pRES points (AWI)

Please refer to Figure 15 for the scope of the work. A total of 132 pRES sites were established in the 2015/16 season. Each site is required to be reoccupied so that an average melt rate can be determined. It is envisaged that the work would be undertaken by a 'standard' two person travelling party. The distanced to be travelled is estimated to be 1,000 km. In addition it is anticipated that AWI's AWS at FSW1 would also be serviced by the pRES team.

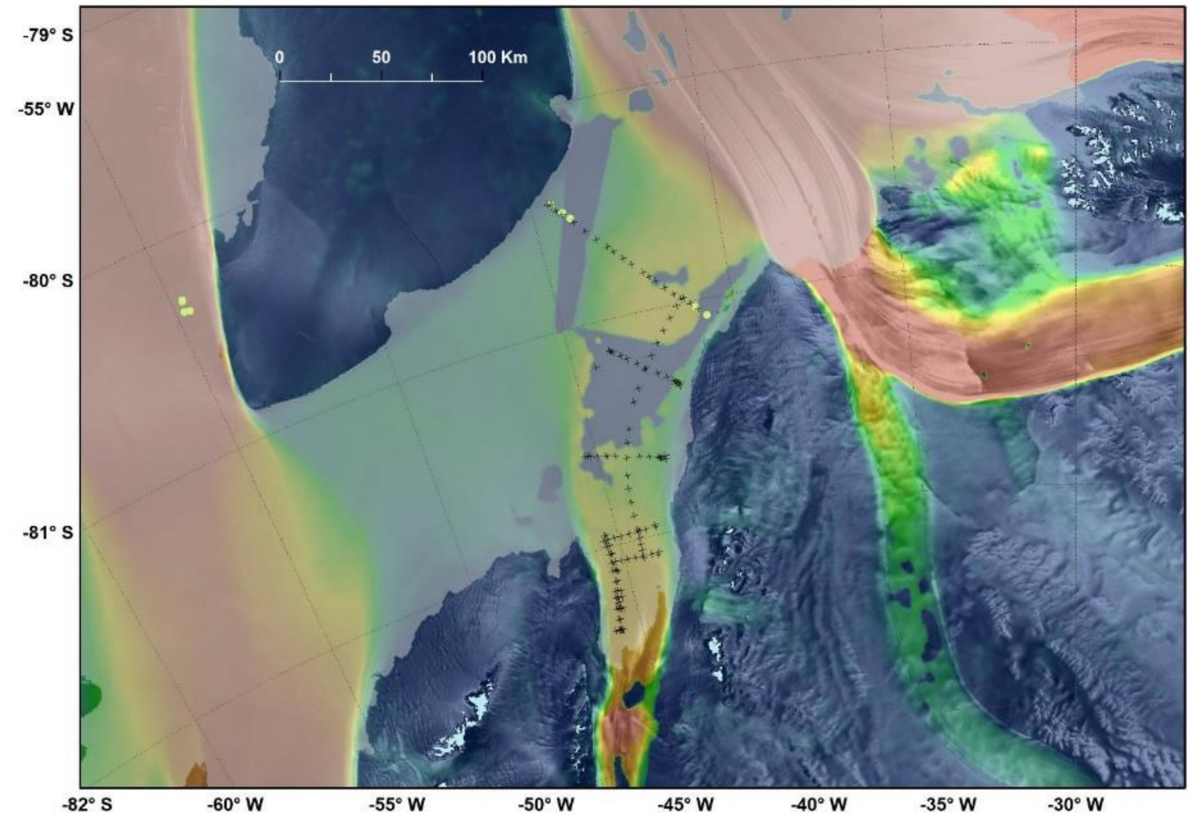


Figure 15 The 132 points to be revisited for pRES measurements.

5. An airborne survey of the Support Force, Recovery, Bailey and Slessor Ice Streams.

The airborne geophysics platform (VP-FBL) equipped with: radar, magnetics, lidar and strap-down gravity sensors will survey the grounding-line regions of each of the four ice streams. The spacing between crossing lines is 2km and the upstream extent of each area is approximately 110 km of the grounding line. The following distances are the total line kilometres for each area.

Bailey 2650 line km
Slessor 3680 line km
Recovery 5600 line km
Support Force 2300 line km

<u>NOTE</u>: The distances include the turns for each line (which equates to approximately 20% of the total), however, it does not include transits to and from depots. It is estimated that a total of 16 sorties are required.

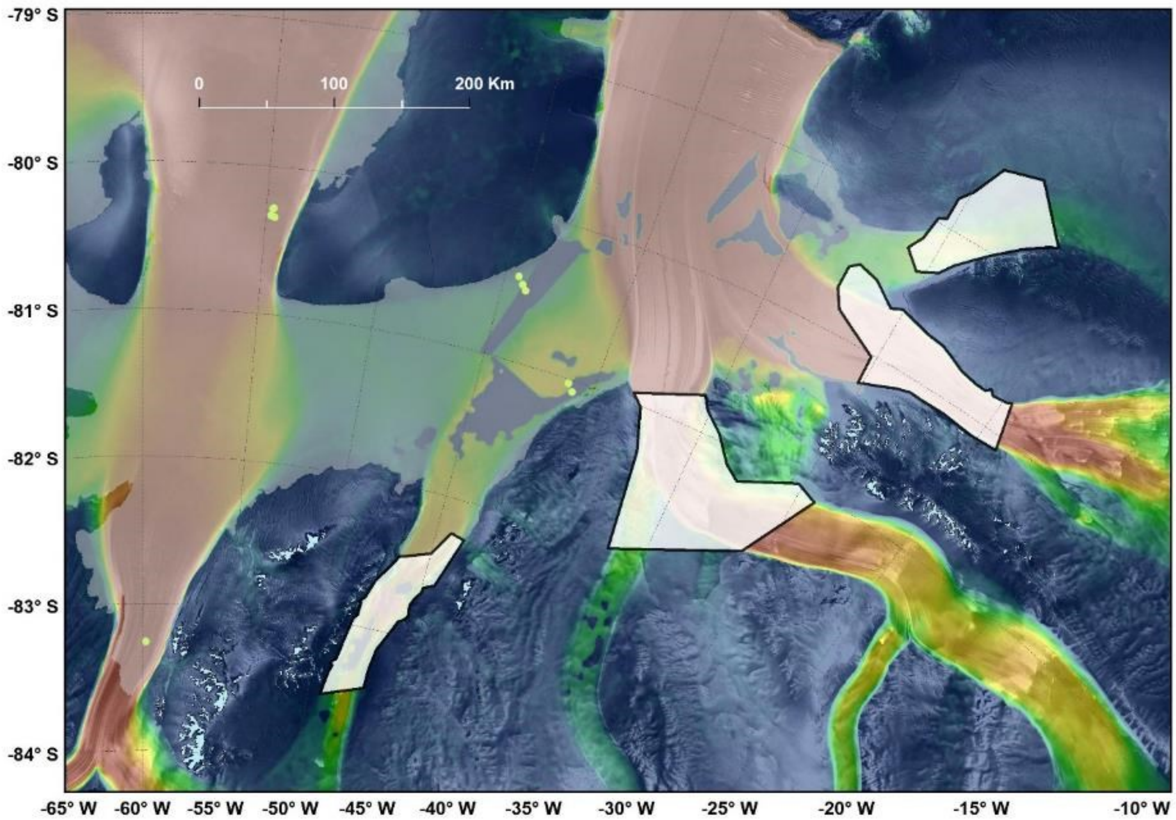


Figure 16. The polygons outline the targeted areas for the airborne survey

6. The servicing/movement of GPS stations on Foundation Ice Stream.

Nine GPS stations were installed along the ice stream in 2015/16, a tenth, used as a fixed reference was installed on a 'local' rock outcrop near Pillar Knob. It is anticipated that five of these stations would be moved to Moller Ice Stream, four would be either serviced (i.e. raised and data recovered) or relocated on Foundation Ice Stream. All ten GPS units are to be removed in the 2017/18 season.
Each unit weights approximately 100 kg.

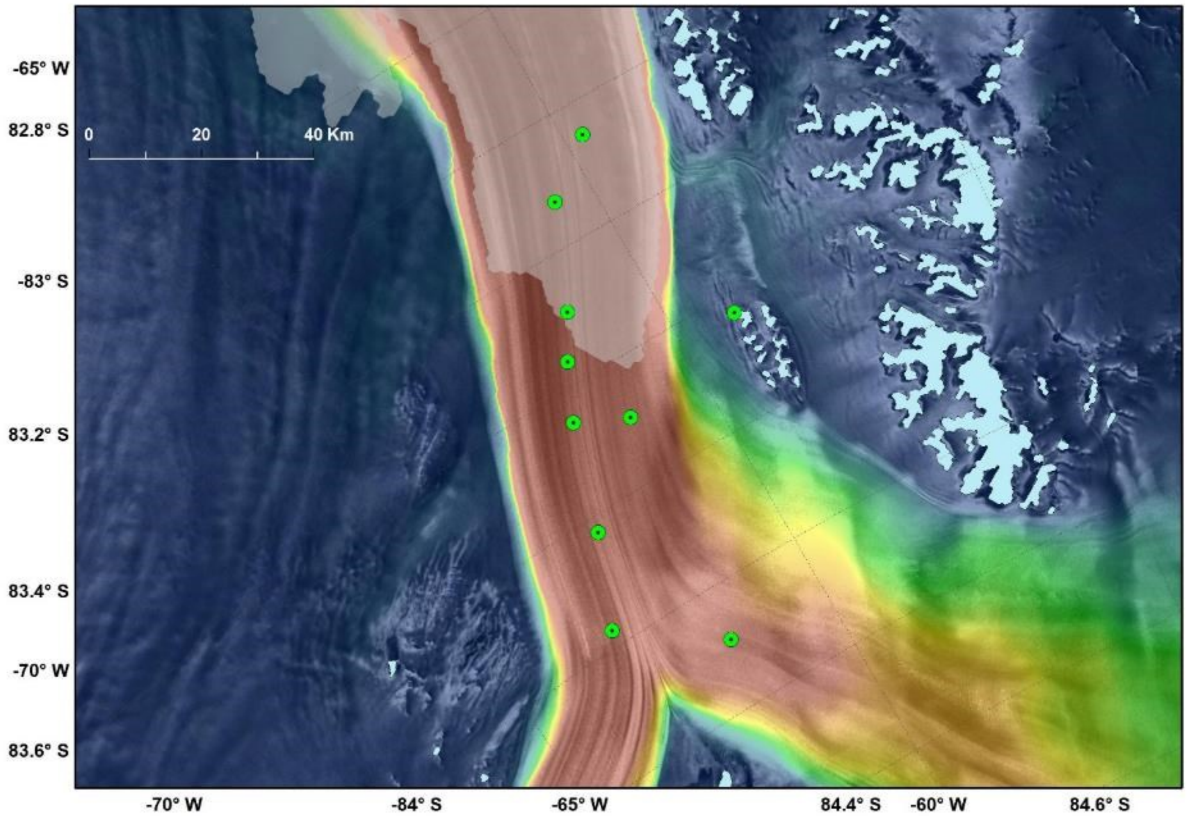


Figure 17. The location of the 10 GPS stations on Foundation Ice Stream. The downstream unit is co-located with Jonny Cache depot.

7. Servicing of equipment at the ice-shelf bore holes.

The FSW and FSE drill sites will be visited by travelling unit towards the end of the season. Equipment required will be modest: 1kw Honda generator, DTS spectrometer, zarge with tools.

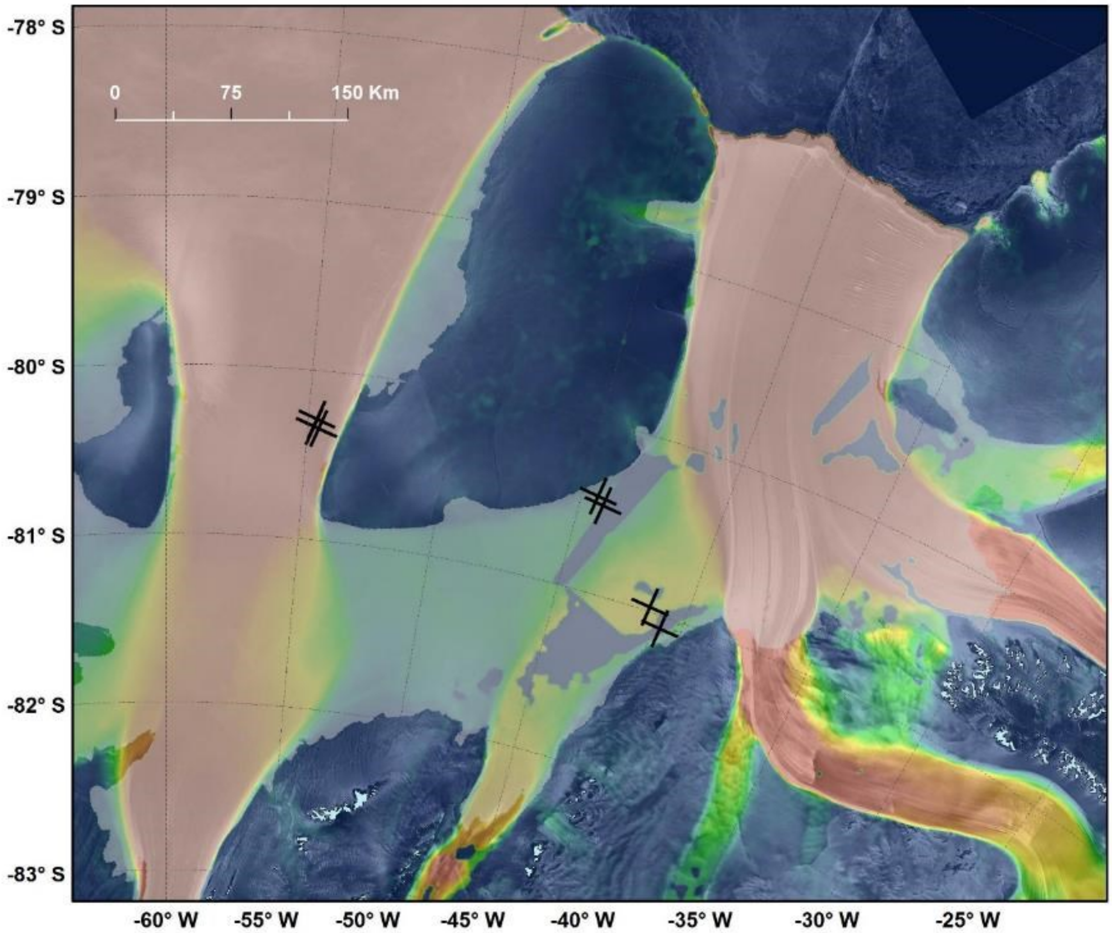


Figure 18. Location of the seven instrumented bore holes.

8. Servicing/Removal of (AWI) GPS and ApRES stations

There are a total of six GPS and three ApRES instruments in place from the previous field seasons. Please refer to Figure 13 for locations. Each GPS site consists of:

- wind generator (130 kg)
- solar panels (30 kg)
- GPS box (90 kg)
- An ApRES unit weighs an extra 10 kg.

Because of issues with the wind generators at each of the GPS stations it is assumed that power will have been interrupted and recording stopped. Therefore two stations on Support Force Glacier and two of the four on Recovery will be serviced. The two stations closest to the grounding line of recovery are to be removed.

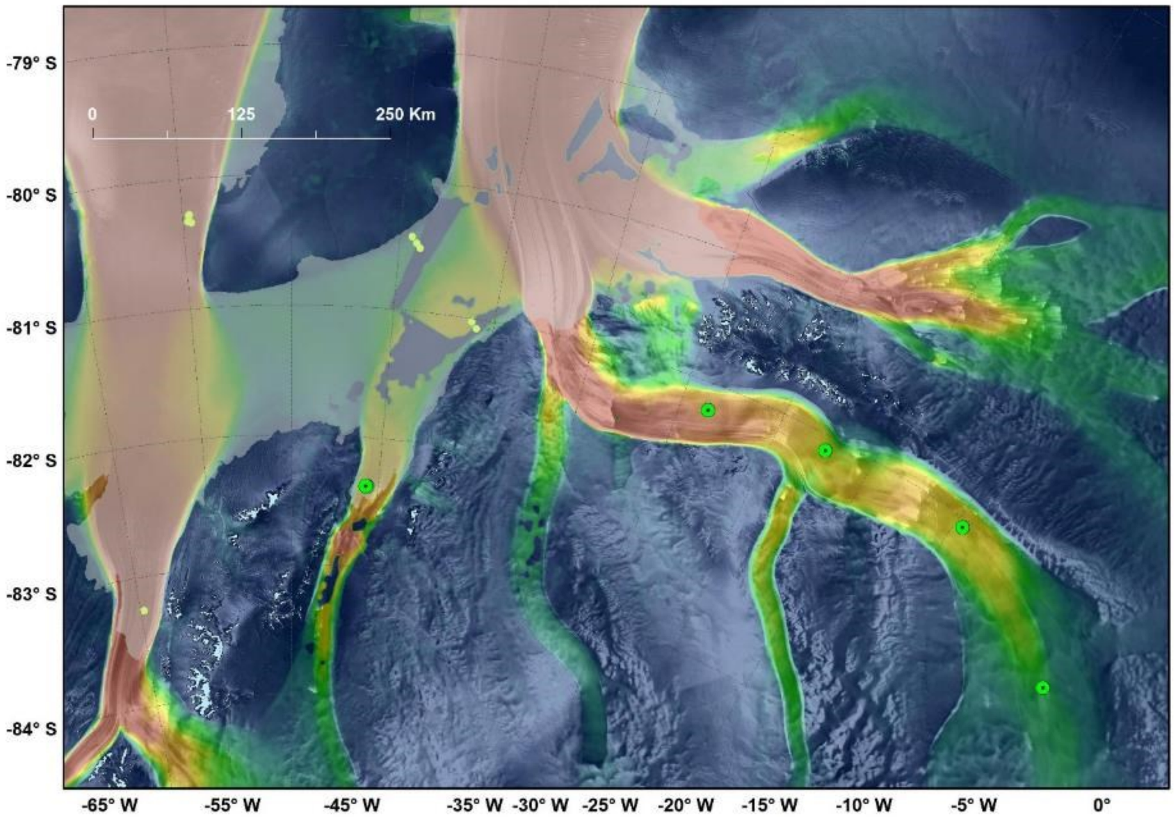


Figure 19 Location of the six GPS stations. The two near the grounding line of Support Force are 1.3 km apart. There are three co-located ApRES sites: two at Support Force and the third on a subglacial-lake on the upper reaches of Recovery Glacier.

2.3.4. Science methods 2017/18 (fieldwork)

The third and final fieldwork component for the project is to recover the 15 ApRES stations and the 10 GPS stations. If a science case can be argued and funding can be obtained these instruments would ideally be either moved to new sites or reestablished at their existing locations.

The four drill sites established in 2015/16 (FSE, FSW, FNE and FNW) and three in 2016/17 will be serviced and data collected. In addition the ApRES will be visited to complete a second measurement so that the average melt-rate can be determined. The AWI GPS and ApRES instruments are to be removed. The depot locations from which the required support aircraft would be based have yet to be determined.

Logistics, Depots and Field Camps

Fuel and equipment was inputted using the Ernest Shackleton at the end of January 2014. This activity and subsequent depoting was subject to a separate Preliminary Environmental Assessment (although the associated impacts are also included in this IEE) and is described in detail in the Ronne Deployment 2013/14 report (J Wake Feb 2014).

The fuel and equipment offloaded included:

- 2 x Kassbohrer Pisten Bully vehicles
- 2 x Lehmann sledges

- a container living unit
- 205 litre drums of aviation kerosene up to a maximum of 240 drums.
- 46.4 m^3 of aviation fuel in bladders (5800 litres per bladder)
- 80 drums of aviation fuel F34
- 24 drums of petrol for generator and skidoo use
- Oils, lubricants and cooling fluid for the tractors.
- Batteries for power systems on the living caboose 4 x 100 AHr gel cell batteries.
- Hot water drill hoses

The offloaded equipment and fuel was moved using a combination of the vehicles and BAS Twin Otters to the Three Ronne's and Berkner depots. The Three Ronne's is a new depot established to support this science (although is adjacent to the existing Ronne depot). The Berkner depot is long established, serving as a general fuel cache for transiting aircraft between Halley and Rothera.

All cargo and equipment was left on 2m berms and where possible, sledges. 20 berms were placed at 50m intervals and squared off to promote wind scouring. A 4m site marker was established at each depot to allow it to be found by aircraft radar.

The depots will be in place for a minimum of two years. During this time ~90 empty aviation fuel drums will be generated for removal from the site.

Photos showing depoted hot water drilling equipment and berms 13-20 containing fuel bladders

The scientists and any remaining equipment not on the traverse were flown into and out of the field by BAS Twin Otter.

Various camp arrangements will be used at the different stages of the project.

During the traverse and depoting operations, an accommodation caboose provides sleeping accommodation, cooking facilities, and general storage. It consists of a modified shipping container mounted on one of the Lehmann sledges, and is fitted out with a kitchen, snow melting system, generators, batteries, and communications equipment. Further details on the caboose arrangements are given in the Traverse Operations Manual (2014).

Static field camps will be set up to support the science activities, and comprise Weatherhaven and pyramid tent accommodation.

The 2014/15 hot water drill camp consisted of three pyramid tents for accommodation, a toilet tent, and two Weatherhaven work tents for messing and equipment repair.

The hot water drill winch system is electrically powered and consists of a hose reel and tower mounted on skis and placed on sheets of marine plywood.

Three 15 kVA petrol generators were installed at the field camp to operate the hot water drilling equipment and to supply power to the field camp. Further 2 kVA and 1 kVA petrol generators were kept on site to service low power requirements when the main generators were not running.

Three 250 kW water heaters (fueled on a mixture of Avtur and 2-stroke oil at a ratio of 100:1) were installed at the field camp to heat the drill water used to melt the hole.
The drill equipment was depoted for overwintering at Site 5 at the end of the 2014/15 season.

The logistics fieldwork also included:

- Resupply of fuel depots, including Therons depot (to support the aerogeophysics), Foundation Depot and Jonny Cache Depot
- Investigation of route to southern drill site South, FSE

Photograph of the over-wintering depot at Site 5

2.3.5. 2015/16 field work

The Tractor traverse was de-winterised at Site 5 then traversed to the southern Ronne where AWI Basler brought cargo in from Union Glacier. The traverse then moved to the first drill site and science staff were brought out from Rothera via BAS twin otter.

Drilling was carried out at the four sites using the same methodology as the 2014/15 season. Upon the completion of the drilling, science staff were uplifted by AWI Basler and the traverse continued to the depot Berkner South to over winter alongside the iBEAM traverse.

Sledge Victor the overland seismic traverse was input by air to the first drill site and completed the traverse down to Site 5. Field equipment was depoted here and staff uplifted by air.

Sledge Uniform the overland radar traverse were input to the first drill site by air before traversing down the support force carrying out radar work and deploying two GPS stations. They traversed back to the tractor traverse at the end of season, where their equipment was taken up to Berkner South by tractor.

Airborne survey was carried out from Johnny Cache depot with field equipment and fuel remaining in place to support further work next year.

ApRES instruments were deployed by air across the Ronne and Filchner. GPS were also deployed on the foundation and support force ice streams

2.3.6. 2016/17 field work

Berkner South Depot will act as the hub for this year's campaign, and will be the site of the field camp for the first half of the season.

Personnel will be flown from Berkner South to the work sites in either the BAS twin Otters or AWI Basler, and once mobilised, will travel by skidoo. The location of the different worksites and the routes that will be taken between them are shown in Figure 20.

Staff will be housed in pyramid tents. The existing depots (Jonny Cash, FSE2, Therons and Berkner South) will be used to refuel the aircraft.

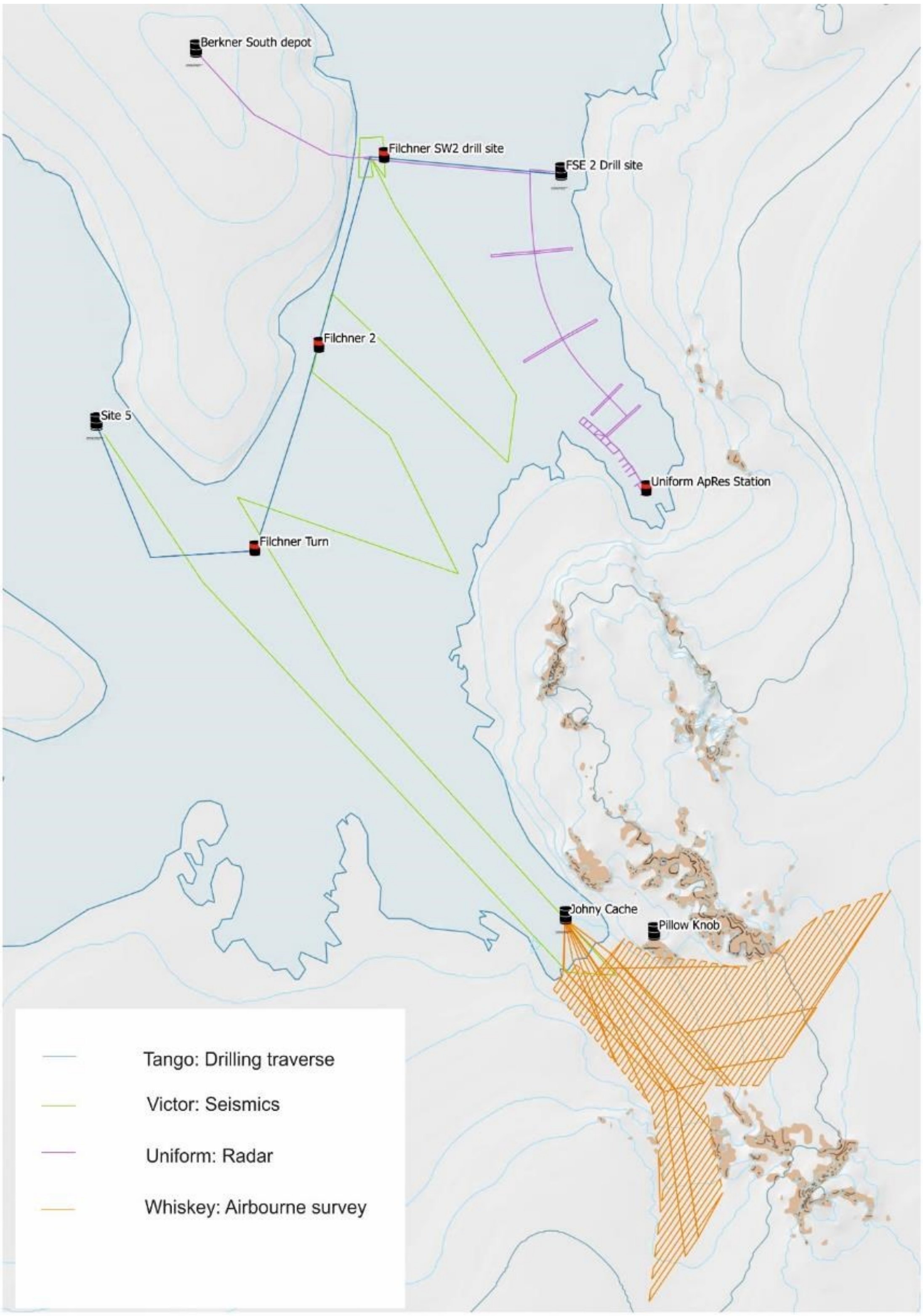


Figure 20 showing the logistics routes between the work sites

2.4. Duration and Intensity of the Proposed Activity

Preparations for the science activities on the FRIS started in January 2014 when the fuel and equipment was input.

The main science campaign will take place over the following three field seasons, with additional follow up visits to remove science equipment until it is recovered from the Antarctic.

It is envisaged that in the 2016/17 field season up to 11 personnel will be deployed for a typical duration of 8 – 12 weeks.

CHAPTER 3. DESCRIPTION OF THE LOCAL ENVIRONMENT

The FRIS and its tributary ice streams lie to the south of the Weddell Sea. The FRIS is divided into Eastern (Filchner) and the larger Western (Ronne) sections by Berkner Island. The whole ice shelf covers some 430,000 km² and is the largest (by volume) in the world.

Along with the Ross Ice Shelf, the FRIS makes up Environment P in the Antarctic Environmental Domains Analysis. This domain consists entirely of ice shelf land cover, apart from the only mapped area of rumples (known as Doake Ice Rumples) located on southern Ronne Ice Shelf. The environment contains no mapped geology. Climatically the environment is cold when compared with other environments with an average air temperature of –22.23°C and the third largest seasonal range at –26.39°C. The wind speed for the environment is moderate at 11.70 m/sec. As one would expect within this large ice shelf environment the slope is quite flat at an average slope across 926 631 km² of only 0.97°, making it the flattest environment on the continent.

There are no significant concentrations of wildlife and little ice-free ground at the vicinity of the transportation route, depots or drill site surface. Three emperor penguin colonies are known to be present on the FRIS (LaRue et al 2014) but each is over 50 km away from the traverse route. The very occasional seal and emperor penguin was observed during the four days the RRS Ernest Shackleton was at the edge of the ice shelf offloading equipment and fuel. Little is known of the benthos at the ice edge but the Biogeographic Atlas of the Southern Ocean lists 14 species having been recorded on the FRIS within 50 km of the Three Ronnes Depot. An Important Bird Area (IBA) (No 101 NW Berkner Island) is present on the Ronne but is approximately 100 km away from any work or traverse site.

The nearest protected area is Antarctic Specially Protected Area (ASPA) 119: Davis Valley and Forlidas Pond, Dufek Massif, Pensacola Mountains (51°4'53"W, 82°29'21"S) which were designated for protection as they contain some of the most southerly freshwater ponds known in Antarctica, and are examples of unique near pristine freshwater ecosystems and their catchments. They provide unique opportunities for the scientific study of biological communities near the extreme limit of the occurrence of these environments.

This ASPA is approximately 50 km from the work sites and traverse routes, there is no reason to enter this site and we envisage no over flights of the protected area. There are no Antarctic Specially Managed Areas (ASMAs) or Historic Sites & Monuments (HSMs) on FRIS.

The work sites for the 2014/15 field season were previously visited when oceanographic equipment was deployed and logistic depots established, so has therefore already been subject to minor human disturbance prior to this project commencing.

CHAPTER 4. ALTERNATIVES TO THE PROPOSAL

4.1. Do Nothing

This alternative has been considered and rejected on the grounds of the highly important scientific benefit that will be gained from carrying out the project.

Understanding the behaviour of the FRIS and its vulnerability to a shift to warmer conditions is of global importance given the FRIS' large volume and potential to significantly affect sea levels.

4.2. Conduct the Science elsewhere in Antarctica

This alternative has been rejected on the basis that the 2014/15 science was of most interest at the chosen drill / equipment deployment site to build on data collected previously from the same location.

Undertaking science and depoting activities at a site which has already been subject to visitation is preferable environmentally than working in an area not previously visited.

There are no sensitive environmental receptors at the proposed site, so there is little to be gained in conducting the activity elsewhere.

4.3. Use Alternative Technologies or Methods

Hot water drilling has been selected as a method as it is the only viable option. It is quick, allowing the holes to be drilled in a matter of days. The alternative is to use a mechanical core drill, which would require multiple seasons to achieve the same boreholes, and would require the use of drilling fluids that are potentially harmful to the environment.

There presently exist no alternatives to the proposed *in situ* oceanographic moorings to obtain long-term measurements of the conditions beneath the ice shelf.

4.4. Use Alternative Logistics

Alternative logistical options were considered such as the input of fuel and equipment by aircraft, however this was deemed impractical as some of the equipment to be used in the area is too large to fit into the aircraft.

The use of a tractor train to transport fuel and equipment is more efficient than using aircraft, requiring less fuel, generating reduced atmospheric emissions, and frees up the BAS aircraft to undertake science survey flying.

The sharing of logistics between BAS and AWI is far preferable to both organisations conducting their science separately and results in much reduced cumulative environmental impacts.

CHAPTER 5: IDENTIFICATION AND PREDICTION OF IMPACTS, AND MEASURES TO MINIMISE OR MITIGATE THOSE IMPACTS

The following predicted impacts and mitigating measures are based upon BAS experience of operating logistics and other deep field science projects.

5.1. Impact To Air

Air pollution will result from the input of the field party and equipment/fuel by aircraft, ship and tractor train, the use of generators at the field camps and aircraft and skidoos for survey works. Emissions will include carbon dioxide, carbon monoxide, nitrous oxides, sulphur dioxide, heavy metals and particulates.

Emissions will generally be rapidly and thoroughly dispersed by the strong and regular winds. There will be some fallout of pollutants in the local area. Heavy larger particles, such as soot, are likely to have relatively short maximum transport distances, with background levels in surface snow samples probably being reached within 2 km downwind of the drill site. Metals would have greater transport distances.

Whilst it is acknowledged that the emissions resulting from the logistics, running the field camp and drilling all contribute to a reduction in air quality, the impacts are minor and unavoidable.

5.1.1 Mitigating Measures

The proposed science and associated logistics will be planned with maximum efficiency by minimising the number of journeys and transporting equipment of fuel and equipment by tractor train rather than aircraft. The collaborative nature of the BAS & AWI science using shared logistics further minimises emissions.

Equipment (such as generators and skidoos) used on site will be well maintained to enhance efficiency and will be shut down when not required to save fuel.

The greenhouse gas emissions associated with this project will be incorporated into the BAS Annual Environmental report and submitted to the FCO.

5.2. Impact To Ice

The depots, traverse route, drill sites, sampling locations, seismic surveys and establishment of GPS and ApRES sites will be situated on ice, which could be impacted by fuel spills, waste disposal and loss of equipment.

The collection and removal of firn ice, and shallow snow samples is not envisaged to have a measurable impact on the environment.

A further, but localised possible impact, could be ice or snow contamination caused by minor spills and leaks of fuel. The maximum quantity of fuel that is likely to be spilled at any one time is approximately 5800 l, due to a punctured fuel bladder or when moving fuel from ship to shore. Unless recovered quickly spills would be partially absorbed by the surface snow, although most will pass quickly through the surface layer to hard ice. At this depth fuel spilt will remain within the ice for decades. There would be little biological effect of a minor fuel spill or leak close to the drill or depot sites. Fuel spills occurring at ship to shore fuel transfer would have a greater impact as the receiving environment is more sensitive due to the greater (albeit still limited) presence of wildlife.

Fuels spills and leaks are most likely to occur through overfilling and splashes when transferring from the drum or bladder to the equipment, or as a result of equipment leaking through faults. The most likely spill volume, should they occur, would be around 5 l. Should a drum split then the maximum that could be lost is the 205 l drum volume.

A minor increase in the quantity of hazardous and non-hazardous waste produced by BAS in Antarctica is expected as a result of the project. This waste, if handled incorrectly, could negatively impact the environment. The waste streams generated will include:

- Hazardous wastes such as empty fuel drums, oily rags, oils, batteries etc.
- Sewage
- Grey water
- Waste food
- Non-hazardous packing wastes e.g. paper, glass, plastics and metal.
- Explosives packaging

5.2.1. Mitigating measures

BAS makes every effort to prevent accidental fuel spills through careful attention to fuel management, at its stations, on ships, and in the field.

Spill response equipment, including booms and skimmer pumps, is available on board the RRS Ernest Shackleton during the transfer of fuel from ship to shore which would have been deployed in response to a spill. This bulk transfer of fuel in the 2014/15 season occurred without incident.

Further depoting of fuel from the *Polarstern* was carried out during the 2015/16 field season in accordance with the method statement included in the previous IEE. This refuelling occurred without incident.

Fuel and equipment that is depoted has been clearly marked with 4m site markers to allow it to be found by aircraft radar to prevent depot loss. The depots will be in place for a minimum of two years and will be visited annually to raise the equipment and fuel.

Only light refined fuels such as AVTUR and petrol will be depoted and used at the science camp. The majority of fuel depoted is in 5800 l bladders which are constructed from high-tenacity woven fabrics which are coated and impregnated with speciality synthetic rubber compounds. They are manufactured with heat and pressure seams, heavy duty flange connections and reinforcements at all corners and openings. They exhibit excellent resistance to sun light (UV), temperature extremes, abrasion and corrosion and have been successfully deployed in the Antarctic for a number of years.

Members of the field party will be expected to take all reasonable precautions to ensure that minor fuel leaks and spills do not occur such as by using drum funnels when refuelling.

Spill response procedures are documented in the BAS Heavy Vehicle Traverse Oil Spill Contingency Plan. Any minor fuel spills will be stopped as quickly as possible such as by rotating a split drum and sealing it with repair putty. Contaminated snow will be scooped up and drummed for return to Rothera where it will be consigned for appropriate disposal. Absorbent mats and pads will be provided for immediate response to minor spills. Used absorbents will be drummed and removed to Rothera for safe disposal. Any petrol spilt will be left in-situ and left to evaporate or disperse due to the health and safety risks in handling petrol.

All operatives will be trained in fuel handling, refuelling and the use of spill kits to reduce the occurrence and impact of spills.

A log of any fuel spills is to be kept and returned to the BAS Environment Office (and ultimately the Foreign & Commonwealth Office) at the end of the season. Wherever feasible, the scientific equipment (dataloggers, GPS stations etc.) will be retrieved from the field.

Staff involved in the proposed project will comply with BAS waste management policy and will follow the procedures outlined in the BAS Waste Management Handbook (BAS, 2016). The camp will be cleared of any rubbish or debris each day. All waste (other than grey water/urine and explosives packaging) will be packaged appropriately such as in colour coded waste sacks, UN approved drums or boxes for hazardous wastes, and UN approved clinical waste drums for solid human waste.

Once packaged correctly, the wastes will be removed from the site to Rothera, for later treatment or removal from Antarctica for safe and controlled disposal. Open burning of waste is prohibited, except for the disposal of the small amount of explosives packaging which will be burnt in situ as per the BAS Explosives Policy.

Removal of wastes from Antarctica reduces the impact on the Antarctic environment, however a low risk remains from windblown wastes becoming lost and impacting the receiving environment. Whilst lightweight materials are most likely to be lost in this manner all materials including fuel drums are at risk. This will be mitigated by emphasising the need for staff to fully secure waste.

5.3. Impact to Native Flora and Fauna

High intensity visitation may lead to trampling of vegetation and soils and disruption of animal behaviour and breeding activities; however, there are no significant concentrations of wildlife, and no ice-free ground (with the exception of Pillow Knob – a previously visited site) at or in the vicinity of the transportation route, depots or drill site surface that could be affected by this programme.

Inter and intra-continental transport provides the opportunity for the introduction of non-native species associated with importing contaminated cargo, scientific equipment, fresh food, clothing and personal possessions. Of increasing concern is the homogenisation of spatially distinct biodiversity through redistribution of Antarctic biota associated with human activities.

The survival of any species inadvertently introduced to the science site or along the transportation route is unlikely given the severe climate and lack of appropriate habitat for colonization.

<u>5.3.1. Mitigating Measures</u>

All staff will be briefed on environmental matters including the BAS Wildlife Viewing Guidelines and informed of the requirements of the BAS Biosecurity Handbook to prevent the potential deposition of non-native species.

The biosecurity procedures followed will be in line with best practice and will entail boot washing, cleaning personal and scientific equipment and providing dried food only, as is standard BAS practice.

5.4. Impact on Wilderness and Aesthetics

The field activities including depoting, traverse, and the mobilisation and demobilisation of all equipment, materials, wastes etc. will have a will have a low visual and noise impact due to the minor nature and duration of the activity.

The transportation route and science work will however increase the footprint of BAS operations.

There is the low potential for equipment or wastes to become lost in the field, reducing the wilderness potential of the area, with the exception of some of the oceanographic equipment (three instrumented buoys as Automatic Weather Stations (AWS), moorings and instrument strings) deployed through seven hot-water drill access holes on the Filcher Ice Shelf, which are non-recoverable and will remain within the Antarctic convergence zone.

<u>5.4.1 Mitigating Measures</u>

The science and depot sites that were selected for the 2014/15 field season have been visited previously so have already been subject to minor human disturbance. The co-ordinates of the transport route, depots and all work locations will be logged and recorded on the BAS Operations GIS for future reference.

All equipment and waste materials will be securely fastened to prevent loss by windblow.

Wherever feasible science equipment is to be removed from the field, and the programme includes provision to retrieve the GPS units, data loggers etc.

Any materials left in the field, either by accident or design, will be reported to the BAS Environment Office for inclusion in the “lost equipment log” and their position noted on the BAS Operations GIS.

5.5. Cumulative Impacts

A cumulative impact is the combined impact of past, present and future activities. These impacts can be cumulative over time and space.

Previous field work has been carried out by the BAS in the area, which had impacts of less than minor or transitory.

The use of the tractors will have cumulative impacts beyond the scope of this IEE given that they will, at the end of this science campaign, be used in further projects in Antarctica. Likewise the maintenance of the depots which support this and other projects/logistics slightly increase the impacts beyond those described in this IEE.

The co-operative nature of BAS / AWI logistics undoubtedly reduce the impacts of this science campaign (compared to both Operators conducting the work in isolation).

5.6. Environmental Education

It is BAS policy to brief all new recruits on Care of the Antarctic Environment before they travel to Antarctica. An environmental briefing has be given by the BAS Environment Office to those personnel involved in the project.

5.7. Assessment and Verification of Impacts

All personnel involved with this project are responsible for the implementation of the measures required to minimise or mitigate the adverse environmental impacts which may otherwise result from the FISS Programme (Table 1). The Principal Investigator will nominate a site leader for each phase of the works that will be responsible for the daily on site supervision of each phase of the project. Photographs will be taken of the site and activities at all major stages of the project, including the clean up and removal of the camps and equipment. The PI will report back to Environment Office on the implementation of the mitigation measures discussed within this IEE (as is the case with all BAS Environmental Impact Assessments) at the end of each field season.

5.8. Impact Matrix

Table 1 shows a summary of how the predicted environmental impacts which may result from the proposed science on the FRIS, and how the FISS Programme plans to minimise or mitigate these impacts.

Table 1.

Activity	Issue	Possible Impact	Probability of impact occurring	Severity of impact	Preventative or mitigating measures
Science Traverse	• Increased footprint of BAS operations • Potential to introduce non native species (nns)	• Reduction of wilderness and pristine nature of localities • Wildlife / habitat disturbance	Medium	Low	• Some locations have previously been visited. • Log of depots, camps and traverse routes to be kept at BAS for future reference • Log to be kept of all equipment deployed and any equipment which is not retrieved • Biosecurity practices reduce the risk of nns being introduced and the environment encountered on the traverse is not likely to support their establishment. • There is very little wildlife to be disturbed.
Fuel transfer and storage depots	• Fuel spills and leaks • Failure to re-locate after winter storage	• Contamination of snow/ice • Loss (undamaged) to the environment	Low	Medium -low	• All staff will be trained in documented fuel handling and spill response procedures. • Only robust, reliable fuel storage and transfer equipment will be used. • Spill equipment to be carried on specially allocated sledge travelling with tractor train and will include spare bladder to be used in the unlikely event a bladder ruptures. • Fuel spills to be reported to BAS Environment Office. • Depots marked so as visible on aircraft radar. Depots to be raised annually to reduce risk of fuel or equipment becoming buried and lost.
Field camps (at science site and on traverse)	• Waste (hazardous and non/hazardous) • Atmospheric emissions	• Contamination of snow/ice. • Minor but cumulative contribution to regional and global atmospheric pollution inc.	Low	Very Low	• Environmental briefing for all staff. • All wastes (including human) to be correctly packaged, labelled and removed for safe disposal, in line with BAS Waste Management Handbook. Only urine and grey water will be disposed of on site. Explosives packaging waste to be burnt in situ for H&S purposes. • Site to be cleared each day and waste materials secured to prevent wind scatter.

		greenhouse gas emissions			
Ship, aircraft and tractor train operations.	• Fuel use and associated emissions	• Minor but cumulative contribution to regional and global atmospheric pollution inc. greenhouse gas emissions	High	Low	• Most efficient logistics planned to reduce fuel burn (and cost). • Traverse by tractor train is more fuel efficient than the use of aircraft. • Use of well-maintained and regularly serviced equipment. • Shut down of vehicles and generators when not in use.
Science					
Hot water drilling & Sediment Sampling	• Fuel use and spills • Possible loss of drill • Atmospheric emissions	• Contamination of ice • Reduction in wilderness values • Minor but cumulative contribution to regional and global atmospheric pollution inc. greenhouse gas emissions	Medium	Low	• The drilling method requires the use of fuel to heat water, but this method prevents the need for drilling fluids which can contaminate the environment.
Oceanographic Equipment	• Some equipment (e.g. AWS) is irretrievable	• Source of waste at sea • Reduction in wilderness values	High	Low	• Equipment will be retrieved where feasible (e.g. dataloggers) • The location of equipment is to be recorded on the Ops GIS • The position of any equipment remaining in the field will be logged and reported to FCO.
Seismic survey	• Fuel use and associated emissions from skidoos • Explosives use	• Fuel spill • Local snow contamination. • Excess explosives remaining once fieldwork completed	Low	Low	• All batteries sealed and installed inside bespoke containers. • Staff briefed on spill response • Excess explosives removed from area or destroyed by controlled detonation

					• Packing burned to comply with Health & Safety requirements. Minimise impact using small pit dug in the snow and covered with fresh snow afterwards.
Airborne survey	• Fuel use and associated emissions	• Minor but cumulative contribution to regional and global atmospheric pollution inc. greenhouse gas emissions	High	Low	• Most efficient logistics planned to reduce fuel burn (and cost).
GPS & ApRES station installation, maintenance and service	• Minor spills from batteries. • Equipment loss	• Contamination of snow • Reduction in wilderness values	Low	Low	• All batteries are of 'Non-Spillable' type and are sealed and installed inside bespoke containers. • Equipment to be retrieved at end of project. • Equipment location recoded in Ops GIS (and lost equipment log if non-recoverable).

CHAPTER 6. CONCLUSIONS

This Initial Environmental Evaluation indicates that the FISS Programme is likely to have no more than a minor and transitory impact on the Antarctic environment, provided the recommended mitigation measures identified in this report are carried out. It is therefore concluded that this activity should be allowed to proceed, and that a Comprehensive Environmental Evaluation (CEE) is not required.

REFERENCES

British Antarctic Survey (2014). The British Antarctic Survey Traverse Operations Manual Version 2, Cambridge.

British Antarctic Survey (2014). The British Antarctic Survey Heavy Vehicle Traverse Oil Spill Contingency Plan, Cambridge.

British Antarctic Survey (2016). The British Antarctic Survey Waste Management Handbook, 9th edition, BAS, Cambridge.

British Antarctic Survey (2016). The British Antarctic Survey Biosecurity Handbook, 4th edition, BAS Environment Office, Cambridge.

British Antarctic Survey (2014). Initial Environmental Evaluation: Science Projects on the Ronne-Filchner Ice Shelf, Antarctica. BAS Environment Office, October 2014.

British Antarctic Survey (2014). Initial Environmental Evaluation: Science Projects on the Ronne-Filchner Ice Shelf, Antarctica. Update at the start of the 2015/16 Season. BAS Environment Office, September 2015.

British Antarctic Survey (2014). Sledge Tango, Ronne Deployment 13/14, Ronne Ice Front. James Wake, February 2014.

British Antarctic Survey (2015), FISS Project Operational Plan May 2015 – February 2017 (Version 1) September 2015.

Michelle LaRue, Gerald Kooyman, Heather J. Lynch and Peter Fretwell 2014. Emigration in emperor penguins: implications for interpretation of long-term studies. Ecography 37:001-007, 2014.

Morgan F, Barker G, Briggs C, Price R and Keys H. 2007. Environmental Domains of Antarctica Version 2.0 Final Report, Manaaki Whenua Landcare Research New Zealand Ltd, 89 pages.

Harris, C.M., Lorenz, K., Fishpool, L.D.C., Lascelles, B., Cooper, J., Coria, N.R., Croxall, J.P., Emmerson, L.M., Fijn, R.C., Fraser, W.L., Jouventin, P., LaRue, M.A., Le Maho, Y., Lynch, H.J., Naveen, R., Patterson-Fraser, D.L., Peter, H.-U., Poncet, S., Phillips, R.A., Southwell, C.J., van Franeker, J.A., Weimerskirch, H., Wienecke, B., & Woehler, E.J. 2015. *Important Bird Areas in Antarctica 2015 Summary*. BirdLife International and Environmental Research & Assessment Ltd., Cambridge.

AUTHORS OF THE IEE

This Initial Environmental Evaluation was prepared by Rachel Clarke, Hugh Corr and Keith Nicholls, British Antarctic Survey, and reviewed by Daniel Steinhage, Eberhard Kohlberg, Angelika Humbert and Stefan Hain, of the Alfred-Wegener-Institut, and Svein Østerhus from the Uni research, Bergen

Further information, or copies of this IEE can be obtained from:

Rachel Clarke
Head of Environment Office
British Antarctic Survey
High Cross, Madingley Rd
Cambridge, CB3 0ET
United Kingdom