ICE Fimbulisen – Top to Bottom

Season 2 Expedition 2010-2011

Field Report

Version 1.1

July 2, 2011

Compiled by Stein Tronstad

Contributions by

Kirsty Langley, Tore Hattermann, Kjetil Bakkland, Johan Hustadnes, Elvar Ørn Kjartansson

This report outlines the fieldwork and scientific activities at Fimbulisen (ice shelf) during the austral summer 2010-2011, and presents some useful experiences we had during the season.

Table of Contents

Purpose

- Revisiting all radar stations and radar transects from ICE Fimbulisen 2009/2010
- Repeat GPS positioning of all stakes and stake nets
- Data retrieval and maintenance of the oceanographic stations at M1, M2, and M3
- Maintenance of the automatic weather station at S53
- Sea ice measurements at the Troll ship unloading site

For further details see the ICE Fimbulisen project plan and Appendix 1.

Summary of events

The planning and preparations for the 2010-2011 field season at Fimbulisen started after Easter 2010 and was a continuous process until the expedition left for Antarctica in early November 2010. From late August onwards the PIs and four of the expedition members had weekly meetings in Tromsø, and regular consultations with the Antarctic Operations Manager, and the Station Manager and crew at Troll Station.

The expedition team travelled by air to Troll Station in early November, and started its work in Antarctica on November 11. After 10 days of preparations, the expedition left the station on November 22 with two TL-6 tracked vehicles ("Sembla" and "Jack"), one heavy sledge carrying the IPY living module and another for fuel and equipment, and four snowmobiles piggybacking for lightweight side trips en route. We commenced our scientific work at Fimbulisen two days later.

Initially the work conditions were excellent with calm weather and good visibility, and we were able to travel across Eastern Fimbulisen and the difficult shear zone to Jutulstraumen (ice stream) perhaps a little too easily. On November 29, just over a week after leaving Troll Station, the oceanography team was able to complete the maintenance work at the third and last oceanographic station. The two team members returned to Troll Station with two snowmobiles and small sledges, via the ship unloading site for sea ice measurements and S53 for weather station maintenance, and completed their season by December 3.

Meanwhile, the glaciology team continued their work of stake measurements and radar profiling on Jutulstraumen. Deteriorating conditions later in the season led to a total of 10 working days being lost to poor weather. Nevertheless, the full scientific programme for Jutulstraumen was completed by December 23. The following day the glaciology team of four moved across the shear zone to Eastern Fimbulisen. The science programme there had to be reduced from a double to a single series of measurements due to lack of time. A substantial loss of stakes entailed some problems in this region, but nevertheless we were able to complete one full series of repeat measurements.

The entire science programme was completed by January 2, and the expedition returned to Troll Station by way of the ship unloading site, arriving on January 5. Some six days of concluding work and two days of waiting for favourable flying conditions ensued, and the three expedition members not involved in other work at the station returned to Cape Town on January 13.

Participants

Glaciology team:
Stein Tronstad, expedition leader
Kirsty Langley, glaciologist
Elvar Ørn Kjartanson, photographer and field support
Kjetil Bakkland, mechanic and paramedic

Oceanography team:
Tore Hattermann, oceanographer
Johan Hustadnes, electrician and field support

Scientific work, glaciology

Planned activities

Set-up radar and GPS equipment at S53 on ice shelf. Cross eastern Fimbulisen measuring GPS/radar stations on the way. Drive Jutulstraumen south and north loops twice to measure the GPS/radar stations and stake nets. Set-up a new 6 stake strain net close to M2. Drive a closely spaced 14 km long radar grid close to M2, plus an additional 2 new cross sections over southern Jutulstraumen. Return to eastern Fimbulisen; drive two rounds of eastern Fimbulisen measuring the GPS/radar stations and stake nets. Finish by driving out to S53 and down to the shelf edge remeasuring GPS/radar stations en route. Priorities were stake nets and radar stations.

Completed activities

All stakes set out in the 2009/10 season were revisited at least once. Jutulstraumen sites were all visited twice. An overview is given in Appendix 1. Some stakes were broken and were either protruding above the

surface, or were completely buried. Where the stakes were found, the position was measured by placing an extension in the remaining section of stake. More stakes were missing in coastal compared to inland areas. It is thought that more extreme weather conditions, icing combined with winds, together with the length of the stakes (ratio of stake above and below surface) led to the stakes breaking. Not all bamboos marking the radar stops were found. Weather and burial by snow were thought to be the causes for the loss.
All stake nets were measured at least once. Broken stakes in a stake net were replaced with new stakes and both the original and new nets measured. A new 6 stake net was installed just north of S14. Radar was driven around all stake net areas to investigate basal structure that may affect the strain rate estimates.

Scientific work, oceanography and weather station

Planned activities

1. Data retrieval from the current meters and thermistor strings at the oceanographic drill sites M1, M2, and M3; replacement of their data loggers and batteries, and preparation of the drill sites for the next visit.
2. Maintenance of the automatic weather station at S53.
3. Thickness measurements of land fast sea ice in the embayment near the Troll landing site ("losseplassen"), and retrieval of an ice-core for salinity measurements in Tromsø.
4. Priorities 2 and 3 were scheduled as an optional activity, depending on the success of priority 1.

Completed activities

Priority 1: All the oceanographic stations were successfully revisited. All the data could be retrieved, and the stations were prepared for another visit next season.

Priority 2: The automatic weather station (AWS) was deployed at site S53 in January 2010. However, due to poor weather the station was mounted without solar panels and thus stopped transmitting data in April 2010 when the batteries were depleted. We found the station to be in good condition, mounted a solar panel on the mast and replaced the battery.

Priority 3: Only the sea ice thickness measurements were taken, because the oceanographic team did not carry along the core drill when returning to Troll from the base camp at M2.

Science equipment and data collection

General remarks

Most scientific equipment has been custom made and may be available only as a unique prototype. This entails a high level of vulnerability. In worst case an entire season's measurements can fail if spare parts are unavailable and repairs cannot be improvised. One example from this season: A sudden failure to the USB card of the Hubra radar during tests at Troll resulted in a new one having to be couriered to Cape Town and flown in to Troll. Once installed the radar worked, and the delay was limited to 0,5 day for additional testing. The consequences would have been quite different if this had happened later in the season.

<u>For next time</u>

~ It is important to have the highest practicable level of equipment redundancy in order to reduce the considerable risks of critical equipment failure.
~ The requirements regarding technical equipment quality, durability etc. should if anything be higher than for comparable work at home.
~ These might be good reasons for more coordinated acquisition procedures for scientific equipment at the NPI

Radars

200-500 MHz FMCW radar

Hubra radar set-up is shown in Fig. 1. The radar was mounted on a Nansen sled. All large metal supports were removed from the sled and wooden struts lashed on to strengthen it. The radar antennas were mounted with a quick release system so that they could be easily removed and placed on the ground for the stationary measurements. T blocks were made to support the radar antennas when placed on the snow surface. A pole for a Trimble GPS, with pin system to lock the antenna in place was installed at the front of the Nansen sled. A pole with a prong on the end was welded to allow the GPS antenna to be lifted onto the stakes whilst continually measuring. Having the GPS running continuously allowed for PPP processing.

The Hubra radar was measuring continuously as we drove. At the stakes the antenna was placed between the bamboos to give an exact repeat of the 2009/2010 measurement. In addition, a measurement was made 2 m either side of the bamboos and finally the antennas were placed back on the sled and dragged slowly between these end points. A calibration measurement was made with a 100 m coaxial cable before and after each stationary site.

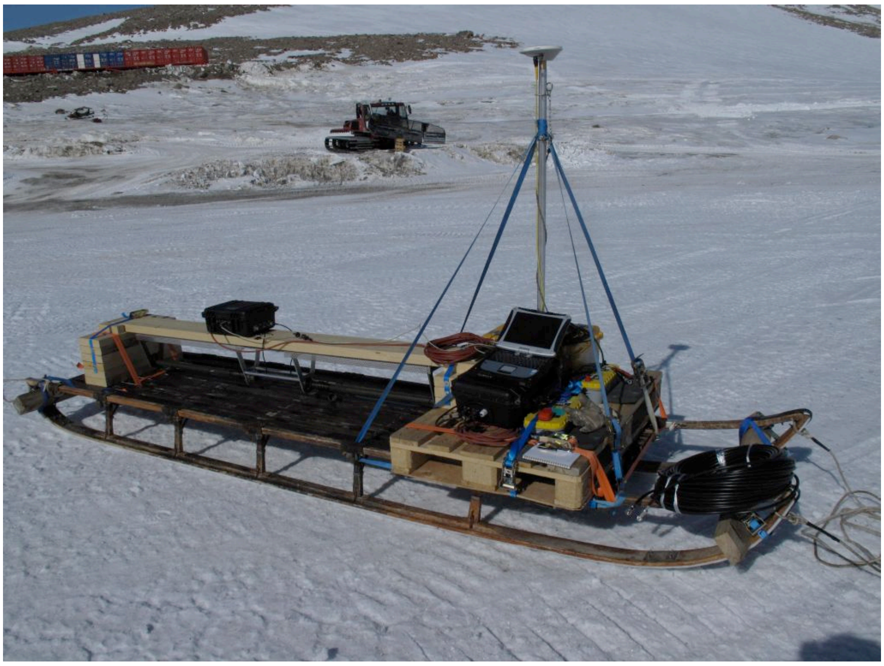


Figure 1. Nansen sled with Hubra radar and Trimble GPS.

Impulse, dipole radar

A dipole impulse radar was also operated continuously. 10 MHz data was retrieved for all profiles, with additional sections being collected at 5 MHz and 2 MHz.

Other equipment

Oceanographic stations

The oceanographic instrumentation appeared to be very reliable. All the 5 metre bamboo site markers were still standing and visible from about 2 km away. Refrozen surface melt water had accumulated around the instrument boxes, approximately one metre below the surface. The ice had to be removed with a pinch bar, with great caution to avoid any damage to cables or instruments. Downloading and deleting the data from the Aanderaa data storage units (DSUs) took more time than expected and was the most time consuming part of the data retrieval (slow pc to DSU communication, careful backup routines before erasing data from the DSUs). Future maintenance should rely on DSU exchange rather than data downloads in the field.

Downloading the data from the ITAS data loggers (thermistor strings & AWS) worked fine. A pc with 9 pin serial port is required. The instruments were cleaned from ice, lifted up and put back approximately 0,5 m below the surface. We had an extension cable for the Aanderaa data logger in case there was not enough free cable to lift the data loggers. This year we managed without the extension, but it should be taken along for the next visit. We added improvised radar reflectors (2x2m foam mattresses covered with aluminium foil), and two new, redundant bamboo stakes to all three stations.

Automatic weather station

The AWS battery failure was at least partly due to moisture, as the battery was buried unprotected in the snow. The battery was replaced and protected by plastic bags inside a waxed cardboard box. As of June 2011 the station is still operative. Nevertheless the improvised battery protection should be replaced by a proper battery case. After about 60 cm of snow accumulation last winter we had to lift the entire station back on to the surface, while preserving the wind sensor orientation. However, due to poor weather the initial calibration the previous season was not very accurate. The sensor should be properly calibrated during the next visit.

GPS receivers

~ The Trimble receivers have a poorly designed, confusing and vulnerable cable system, increasing the likelihood of equipment failure.

Equipment sledges

☺ The sledge solutions for the radars (modified Nansen and "torpedo") worked very well: simple, sturdy, flexible and versatile in use, reliable and easy to fix.

Stake drills

~ Bent sections in stake drill resulted in wonky and large stake holes.

Other remarks

~ All battery-driven equipment should be connected through a fuse
~ Cables, strips and plastic parts becoming brittle and breaking in the cold is an eternal problem
~ Adequate wind and water proofing is essential to protect electrical circuitry and other vital parts against wind-blown snow and (on the ice shelf) humidity.

Logistics, vehicles

General remarks

All the tracked expedition vehicles (TL-6) were in poor condition after the previous season, and it was not until late in the Antarctic winter that it became clear that we would have more than one tracked vehicle available. For this reason, the initial logistics plan was to have a lightweight expedition travelling by snowmobiles and accommodated in tent camps. As it became clear that we could employ both Sembla and Jack, the plan was incrementally modified. Eventually we were able to drive the tracked vehicles and pull the IPY living module most of the time. Without this raise in travelling standard we would not have been able to complete the season's work programme efficiently and safely, for a number of reasons:

☺ The living module provides a much safer and more efficient working environment than tents.
☺ Camp management takes considerably less time.
☺ Blizzard time can be spent doing computer work instead of shovelling snow and barely staying dry.

- The snow mobiles could not drive at the slow speeds required for radar work (15 km/h) without overheating.
- During long distance driving, even with relatively lightweight sledges, the snowmobile travel speed is mostly limited to 20 – 30 km/h by rough surfaces, thus reducing their speed advantage.
- The downside is a much larger need for equipment and much higher fuel consumption.

Snowmobile travelling would have meant camping in tents throughout the season. The blizzards at Fimbulisen are sufficiently frequent and powerful that this could have compromised the crew safety.

Generally TL-6 vehicles with sledges and GPR also provides a safer mode of travel in crevasse areas and in poor weather. However, our snowmobiles added welcome flexibility and redundancy, allowing a split-up of the two field parties, and a quick return To Troll Station for the oceanography group without affecting the mobility of the remaining group.

Tracked vehicles

The TL-6 vehicles are ideal for this kind of expeditions, and the fleet should be maintained. However, there have been consistent reliability issues. We believe that most of these can be solved by a more thorough and consistent maintenance programme. The winter season maintenance is key; the vehicles should be fully serviced and shipshape at the beginning of the summer season and certainly before leaving on expeditions.

The second Fimbulisen season saw much more careful vehicle routines, compared to the previous season. We believe this to have extended the driving distance by a decisive margin. This suggests a need for written guidelines for vehicle field maintenance, believing that consistent operation procedures, independent of personal taste, is what it takes to keep these vehicles operating reliably.

<u>Breakdowns</u>

The vehicles suffered a number of mishaps en route:

- An oil pressure problem appeared on Sembla a few days prior to departure, and was deemed serious enough to warrant an engine replacement.
- Jack stopped just 10 km out of Troll, because several essential actuators were missing. Spares were brought out from Troll immediately.
- Sembla lost a sprocket wheel near M2 when the centre bolt broke. We had no spares, but the mechanic was able to improvise a repair using scavenged parts from the blade mount on Jack.
- Sembla suffered persistent engine performance problems at Jutulstraumen. After several consultations with Berco and Cummins a disengaged air intake heater was identified as the source of the problem, and fixed.
- Immediately before arrival at Troll Station on January 5 it became clear that the forward differential gear on Jack was about to break down.

Several other unauthorised and undocumented modifications to the vehicles also led to minor difficulties:

- Due to cracks and drilled holes in the battery casings, essential electrical circuitry and components became packed with snow during blizzards
- Long fuel hoses had been shortened, making refuelling less convenient
- The power supply for the living module and Webasto batteries had been removed
- The vehicle toolkits were depleted

Figure 2: The improvised sprocket wheel repair.

Other comments

- ☺ The 220 V power supply in the TL-6 vehicles seems adequate, but be aware that one of the two converters on each vehicle has been disengaged.

For next time

- ~ Written maintenance procedures for all vehicles & modules (folder on board)
- ~ A maintenance record in each vehicle, with all modifications, repairs and maintenance work continuously recorded
- ~ Equipment lists in each vehicle (customisations have been made for specific reasons that summer mechanics may be unaware of)

Spare part planning will be a challenge for any future expedition with these vehicles. Given the weaknesses of the vehicles it will take some consideration to determine what contingencies to plan for. A systematic maintenance record will ease the task.

Fuel consumption

Pulling fairly lightweight sledges at very low altitudes we expected the fuel consumption to come down to about 2 litres per km (compared with approximately 4 litres during the IPY traverse, pulling up to 3 times heavier loads at high altitude). The overall consumption during the expedition turned out to be somewhat higher, approximately 2,3 litres per km (conservative calculation based on 200 litres per fuel drum).

Snowmobiles

The four-stroke snowmobiles seemed reliable enough and must be considered essential equipment, if only for safety reasons. However, for radar driving they proved to be inadequate.

Most of the distance we let Sembla pull the radars, but after a vehicle breakdown we had to employ the snowmobiles for this on one of the Jutulstraumen loops (160 km). Radar driving requires a maximum driving speed of 15 km/h for extended periods of time, which had the snowmobiles overheating very quickly due to insufficient cooling. The two snowmobiles had to swap tasks regularly to allow the radar pulling vehicle to cool down.

On the way back to Troll Station, while crossing areas of hard snow or blue ice, the snowmobiles suffered repeated overheating and partial melting of the "belt-gliders". The "scratchers" seemed not to throw up enough ice/snow for adequate cooling, even at speeds of 40-50 km/h. One machine even lost both scratchers near MPT.

Fuel consumption

At the slow driving speeds the fuel consumption increased considerably, nearly doubling the estimate of 2 l per 10 km. During low speed radar driving with Nansen sledges, the actual consumption approached 4 liters per 10 km. During long distance driving at normal speeds, the consumption was approximately 2,3 liters per 10 km. We had sufficient fuel for this, but the margin for contingencies was lower than desired.

For next time

- ~ Snowmobiles must undergo an equally consistent maintenance programme during the winter seasons.
- ~ Maintenance and checks must include accessory equipment and spare parts.

Field equipment

Camping

Living module

The IPY living module makes life a lot easier and safer as compared to spending the entire season in tents. Less time is spent on camp management, the fieldwork itself becomes more efficient, and time weather-bound can be spent doing computer work instead of shovelling snow and managing dampness.

Although cleaned and tidied after the previous Fimbulisen season, the module evidently had been messed up again quite thoroughly later in that season. As a result we had to spend valuable Troll time on cleaning and repairs (balcony welding, heating system leakage).

A few problems with the module should be amended. Depleted and damaged batteries are common, so a main circuit breaker should be added to the electrical system (also on 'Richard' and 'Rønne'). However, the main switch should not disengage any solar panels or charging inputs, nor the gas alarms. For the same reason the electric refrigerator could be replaced with a gas powered one (without external power the electric fridge would drain the batteries within a couple of days). The kitchen cupboards are beginning to show wear from meltwater intrusions through the roof. Finally, the rubber hinges on the door to the Webasto cabinet tend to become brittle in cold weather.

For next time

- ☺ A 220 V converter would allow battery charging and operating 220 V equipment by vehicle power during transport.
- ☺ Solar panels on the roof.
- ~ A main circuit breaker on the electrical power system.
- ~ A circuit diagram should be available in the module.
- ~ Replace halogen light bulbs with LED lamps to eliminate fire hazard.
- ~ Smoke alarms for safe sleeping; extinguisher maintenance.
- ~ Maintenance of Webasto heater and heating system, electric power system, batteries, snow melter, water pipes, hatches
- ~ Replace the rubber hinges on the Webasto cabinet.
- ~ Always remove snow and ice from the roof after summer storms, as this will melt and seep in through the ventilation system.
- ~ The module must be solidly strapped to the sledge rig, and the straps checked daily as they tend to work loose.
- ☺ Nice to have: weather station, binoculars, white board, couch cushions.

Tents

We camped in tents during several loops and side trips. Both the Hilleberg Base Camp tent and the North Face VE-25 sleeping tents worked very well, but were only used and tested in favourable weather conditions. The Hilleberg is big enough for camping chairs and tables and for standing upright, thus providing good working conditions in a base camp setup. However, we are uncertain of the storm performance of this large and not very rigid tent.

- ☺ 1 x 2 m insulation mats from last season's hot water drilling were great as a tent floor. These also support camping chairs and tables.
- ☺ In small tents (or outdoors!) two foam mattresses and a blanket works equally well.
- ~ Untried weather performance.

Cooking

For cooking we found only one serviceable camping gas stove at Troll, in poor condition. More of these should be available, as two or three burner gas stoves are safer, cleaner and more efficient than the MSR type liquid fuel stoves currently available, and hence more convenient for snowmobile-based field parties. More compact, single-burner stoves could also be considered.

Hygiene

The little hand-pumped field shower proved to be invaluable. With 10 litres of hot water from the snow melters, it is possible and reasonably comfortable to have a shower even in -20, as long as there is sunshine and no wind. Taking the shower cabinet is pointless; just use a plywood sheet or a pallet to stand on. A toilet shelter is essential, and the little outhouse piggybacking on the living module serves the purpose well. Biodegradable bags were used, and taken back to Troll in emptied fuel drums.

- ☺ Take abundant hand sanitizer.

Communications

For internal communications we had both UHF and VHF handsets and VHF vehicle radios. For external communications we were equipped with 4 Iridium terminals (main and backup for two field groups) with data kits, plus one Inmarsat BGAN terminal and an air band radio for the living module. Each vehicle also carried an Emergency Locator Beacon.

The Inmarsat BGAN system is vastly better than Iridium for phone calls and data communication down at Fimbulisen and served us extremely well while operating from the living module, although the reception was somewhat variable during the evenings. At Hellehallet however, below 71 S, we had poor to no reception on this Inmarsat system.

For emailing we relied on a Uuplus account and software, which works extremely well given the constraints of the Iridium connection. The software was installed on the expedition leader's pc only, leading to some usage conflicts and waiting time.

- ~ An independent server with WiFi is recommended to other teams using the living module as their base.
- ~ Printed and programmed copies of the communication plan should always follow every Inmarsat and Iridium terminal.
- ~ The UHF handsets for internal communication proved to be virtually useless. Take VHF handsets!
- ~ Take an abundant supply of spare cables.

Navigation

The navigation GPS receivers in the vehicles need replacement:

- ~ poor screens and user interfaces
- ~ very limited waypoint capacity
- ~ complicated data transfer

Power supply

Generally the Honda generators provided enough power while in camp, although with a slight margin. Fewer Hondas than expected were available, and one failed. More abundant power supply would have smoothened the daily routine of charging batteries for the radars and other instruments.

- ☺ Overnight charging by Honda generators worked well. Charging during evenings and mornings (not at night while "lights out") is sufficient.
- ~ Solar panels and 24 V chargers for 2 batteries each would give more efficient charging procedures.
- ~ The stock of 12 V batteries at Troll Station is of variable quality and reliability. The inventory and status should be updated after each season.
- ~ Equipment to gauge battery capacity should be available

Some solar panels were used on a somewhat experimental level. Generally these work well. Solar panels could easily be mounted on the module roof with a cable extending down for battery charging. This would reduce generator use.

A small, wooden generator house with a custom exhaust outlet was improvised to protect the Honda generators from the elements during storms. This worked well, and kept the generators running continuously in weather conditions that would have made the generator choke almost immediately if left unprotected.

Miscellaneous equipment

- ☺ Great sunglasses (Adidas) need extra lenses.
- ☺ Outer clothing and sleeping bags from NPI worked well.
- ~ Video tripod from NPI is not sturdy enough for rough fieldwork.

Provisions

The core element of the field menus was fish/meat rations precooked and prepacked at Troll, supplemented by rice, pasta, potatoes and/or veges cooked in the field, and initially some fresh produce (see Appendix 3). A set of two week dinner menus were planned in advance by the Troll Station cook, which was a great help. Thus we had good food with minimal kitchen efforts throughout the season. All other food provisions were planned, collected and packed by the expedition, keeping one person busy for three days while at Troll.

Due to the mild summer weather at Fimbulisen we had to pay some attention to cold storage: storing some food in snow pits, packing food with snow in white, waxed cardboard boxes etc.

- ☺ The pre-cooked and pre-packed dinner rations worked very well.
- ☺ Pre-packed rations for 2 persons rather than 4 or 6 gave welcome flexibility.
- ☺ An early list of potential shortages at Troll allowed us to order resupplies from Cape Town.
- ☺ The supplies of dry and hermetic food kept us happy during the entire season, save for a minor coffee crisis.
- ☺ Fun to have a range of raw ingredients that allowed some baking on storm days, as the kitchen is perfectly equipped for this.

- ~ Food calculations is specialist work, and to any small-scale expedition a pre-planned (standard) list of provisions would be extremely helpful and save valuable time during pre-season preparations at Troll.

For next time

- ☺ Set up a complete list of provisions well in advance.
- ☺ A potentially recyclable list of essentials is in Appendix 3.

Safety and preparedness

Daily check-in

As a standard procedure we gave a daily situation report to Troll Station at 9 pm. Eventually emails turned out to be the most efficient means of reporting.

Storms and weather forecasts

Weather pattern: The summer weather at Fimbulisen seemed to follow a fairly regular pattern of 2-5 day storm cycles interspersed with week-long periods of calm and pleasant conditions. We were hit by four storm systems during the season; three of them strong enough to interrupt the work. A total of 10 working days were lost to weather, 6 of them just to wait out strong winds and 4 more to extricate vehicles and sledges, clean out engine compartments etc. as the storms abated. The stronger storm offered a day of estimated force 10 wind (full storm), but generally winds down to force 8 or even 7 (sterk kuling, stiv kuling) prevented work beyond the camp area due to drifting snow and low visibility.

Parking: Initially we parked the vehicles and sledges to take the wind from the side; spaced to allow snow drifts to form between the vehicles without impeding forward movement (using the camp plan from the IPY traverse). This worked reasonably well, but eventually prompted the question of how much wind the large catchment of the living module can take across. We decided not to investigate the matter, and took to parking the vehicles against the wind. This worked well and gave some peace of mind, although we once made the mistake of parking the sledge trains too close. To be certain to avoid excessive post-storm digging they should be parked some 50 meters distant from each other. This parking pattern may introduce a risk of high snow banks building up in front of the vehicles in the exit direction – but to us this posed no problem.

Weather service: We found the weather forecasts from Neumayer Station to be very reliable and immensely valuable, as they allowed us to plan and prepare for poor weather 2-3 days in advance.

For next time

- ☺ Subscribe to the Neumayer weather service
- ~ Check the module strapping regularly
- ~ Have a long safety rope accessible and tethered by the module exit in case high winds and low visibility compromises safety
- ~ Tailored tarps for vehicle protection could possibly save work after the storms
- ~ TL-6 battery casings have to be airtight!

Hazardous terrain

Crevasses, route planning: The itineraries to and around Fimbulisen were planned in advance with travel safety as a key concern. Route planning before season 1 was based on satellite images, field checked during the season and re-checked before season 2. High resolution TerraSAR-X images proved to be an extremely valuable tool in this respect, allowing quite reliable identification of potentially hazardous terrain. While the 25 meter resolution RAMP data forms a good basis for route planning at higher elevations, the crevasse regions at Fimbulisen generally do not show in this mosaic (due to summer melting?). High resolution SAR data is required.

Other obstacles: Generally the Eastern Fimbulisen and lower part of Jutulstraumen are safe to travel outside of the identified crevasse zones, but dangerous ice pits and other obstacles occur. Travel in very low visibility is not advised.

Emerging danger zone: On the route segment between waypoints F14 and F15 we found an area of nascent crevasses. This was rather interesting, as the crevasse radar showed the area to be generally clear of obstacles. While driving westwards on November 28 we found a solitary crevasse across our track, extending indefinitely towards the north and south. The crevasse was about 1 meter wide, clearly visible on the surface and the radar signature equally clear, so the obstacle offered no difficulty or safety problem. However, on the return journey on December 24 another little crevasse had cracked open about 1,5 km further west – clearly visible on the radar and on the surface, but only 10 cm wide. At the same time the original crevasse had widened to over 2 meters. Later parties should remain observant while passing this area.

Route marking: The obstacled section of the route through the main shear zone turned out to be only a few hundred meters wide, and thanks to the crevasse radar and favourable light conditions we were able to find a safe passage in just 2-3 hours. Somewhat frivolously we prioritised an early arrival at M2 to going back for flag marking. As a later contingency might compel a crossing in poor visibility and without radar, flagging should be a general procedure. Bamboo markers should be put in at bridge crossings and corner points after the optimal way through has been found. If time expenditure is a concern this can be done by having a second vehicle following some 200-300 meters behind the scouting vehicle, putting in the flags only when the best way forward has been found. With careful flag marking the route can be travelled whenever the visibility is good enough to see the flags at a moderate distance.

<u>For next time</u>

~ Do not travel unscouted routes in poor visibility.
~ Keep an eye open for widening crevasses east of F15
~ Ideally crevasse zones should only be negotiated in excellent visibility
~ Flag marking of difficult exit/supply routes is recommended.
~ Save the GPS track log of the last vehicle to cross difficult ground (can be emailed to relief parties), while bearing in mind that the Jutulstraumen flows dozens of metres seaward during a season.

<u>Crevasse radar</u>

Two areas of known crevasses and some potentially difficult areas could not be avoided, and for this reason a 400 MHz GSSI SIR3000 ground penetrating radar was pushed by the lead vehicle all the way, except when driving previously scouted routes. The radar has proved to be a perfectly reliable crevasse detector, in the limited sense of indicating present crevasses and separating crevasse free areas from disturbed ground. However, substantial challenges remain. Reliable detection requires optimal radar settings, and interpretation of the radar image is far from trivial. Judging the actual width, depth and snow bridge strength on a detected crevasse can be quite difficult, mainly due to "noise" sources such as convoluted crevasse patterns, varying internal shapes, snow mushrooms, collapsed snow bridges and other filling material.

When returning from Jutulstraumen on Christmas Eve, we approached the mentioned crevasse "breeding ground" carefully. The radar images appeared very similar to those seen in November, and believing the wider crevasse still to be narrow enough for safe crossing, we proceeded. Somewhat surprisingly the trailing runners of the living module sledge penetrated the snow bridge and revealed an abyss about twice as wide as observed in November. Careful post-examination made it clear that the radar image did indeed point to a wider crevasse, but the information was difficult to interpret due to a pattern of parallel and much narrower cracks.

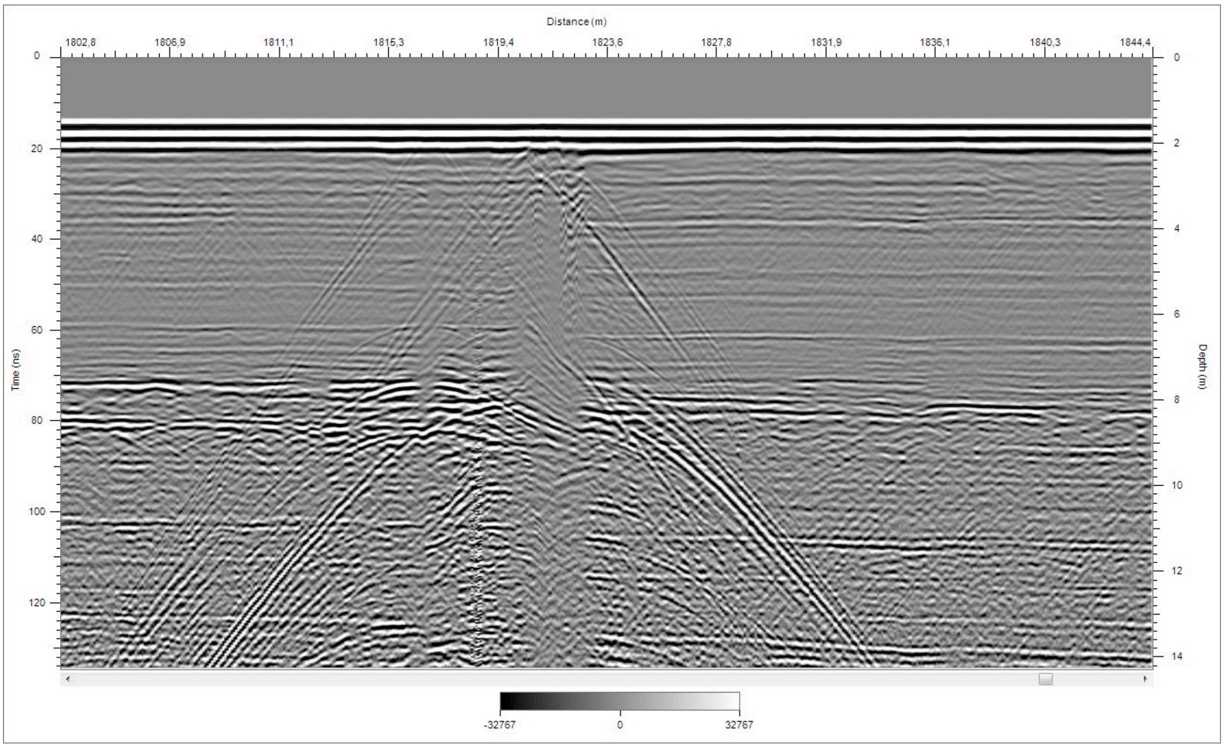


Figure 3: Radar image of the offending crevasse, 2-2,5 m wide.

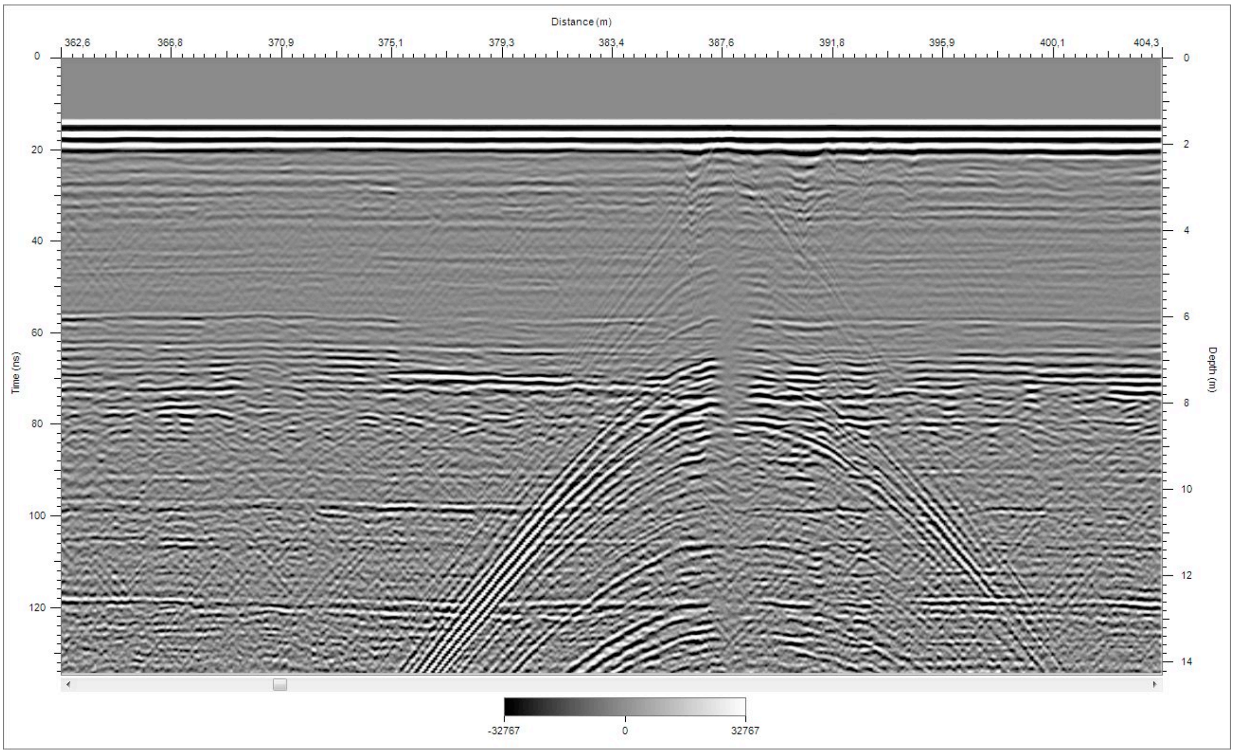


Figure 4: Radar image of the newly formed crack, 10-20 cm wide.

The 400 MHz antenna suffers from old age and hard usage, and indeed failed in the middle of the crevasse zone close to S7/F9 due to a connector problem. The problem was solved on the spot, but eventually the antenna failed completely and must be repaired.

- ~ Crevasse radar operation requires extensive training and ground truthing.
- ~ Always take redundant equipment.
- ~ Negotiating crevassed terrain without some ground inspection is not recommended.

Radar mount

After more than 7000 km the crevasse radar boom has reached the end of its life span. It is severely broken and needs extensive repairs and some minor modifications. However, the rig as such works extremely well, and the general design should be kept as it is. The individual sections of the boom could be modified to allow easier substitution (for redundancy).

Rescue equipment and drill

For personal safety and crevasse rescue we took one standard personal equipment bag per person (Troll blue bag kit) and miscellaneous extra equipment (100 m rope, pulleys, litter, equipment for difficult access). All expedition members having previous experience and training, we established that a three hour rescue drill executed in the Hinge Zone was enough to sharpen everybody's skills.

Equipment failure and redundancy

After Sembla's drive wheel failure and before the improvised repair we were left with one operational tracked vehicle, possibly not too trustworthy, and two snowmobiles. The need for spare parts led to some delicate considerations regarding supply chain and safety margins. An air drop was considered, but would have required a dedicated and thus expensive Basler flight. Eventually the spare parts were sent from Troll station with the ordinary transport to the ship landing site, and put in a depot at site S53, some 260 km from our camp at M2. At the time we were still weather-bound at M2 and could not rendezvous with the transport from Troll at S53. Given that we would have no more than 3-5 days left at Jutulstraumen when the storm abated we had to consider some thorny options. To make the most of our time we eventually decided that Kjetil and Stein would drive Jack alone from M2 to S53 to pick up the parts, while Kirsty and Elvar would finalize the science programme at Fimbulisen by driving the last 160 km loop with the two snowmobiles. In the not too unlikely event of Jack breaking down somewhere between M2 and S53, this could have put us in a difficult position. Kirsty and Elvar might have had to cross the unmarked shear zone on snowmobiles to assist, without a crevasse radar, or a support team might have been compelled to do the same thing with snow groomers. Fortunately the contingency dissipated when Sembla was repaired on site.

Medical preparedness

We were fortunate enough to have along a mechanic who is also a trained paramedic, and equally fortunate not to need his skills en route. Our medical defence line thus consisted of the medical doctor at Troll Station (in charge at all times), the paramedic on the field team, and prearranged back end support at UNN in Tromsø. The first aid and medical field kits were prepared to allow interventions such as manual defibrillation, intubation, thorax drainage, sutures and minor surgical interventions, provisional dental care, eye treatment, infection treatment, advanced pain relief etc. The field kit consisted of, i.a.:

- 12-lead ECG
- 2 complete oxygen kits and spare cylinders for several hours' use
- Manual suction pump
- Scoop stretcher
- Assorted vacuum splints
- Sager splint
- Immobilisation collars (3 sizes)
- Creams for sunburns and frostbites
- Complete military type body heater, charcoal fuelled

- Twin sleeping bag, blankets

Each vehicle carried additional first aid kits with dressings and bandages, pain relievers, eyewash kit etc. A library of medical reference books was also taken along.

A first aid training session for the entire team was held at Troll Station prior to departure, including equipment drills. Such training is essential, but also serves to draw most team members' attention to the limitations of their abilities. Proper medical preparedness on an expedition of this nature thus requires one or more team members with a medical background or special training.

Planning and execution

Planning

The weekly planning meetings during the last couple of months gave us sufficient overview of the situation, but it would have been advantageous to enter this phase earlier. Some of the expedition members were not nominated until September and thus were excluded from the planning; the overall planning would have benefited considerably from having them involved in the earlier phases. This particularly concerns the field mechanic, who should have been given time to look more deeply into the technical planning (vehicle preparation, spares, fuel needs, sledge capacity etc.). Contact with Troll Station was well established at an early stage, but even here deeper involvement at an earlier stage would have been beneficial, preferably with quick weekly or bi-weekly video meetings with a nominated contact person.

The information we had from Troll during the planning phases was always timely and reliable. However, it did emerge that even more thorough equipment inventories would have been of great assistance to the station crew and expedition members alike; detailing availability and technical state of equipment, tools, spare parts, field gear etc.

The details of the actual fieldwork could have been laid out in more detail during the planning phase; this would have improved the time estimates considerably, and also ensured an optimal distribution of tasks and even more efficient routines in the field.

<u>On a positive note</u>

☺ Weekly meetings in Tromsø
☺ Daily morning meetings at Troll

<u>On a negative note</u>

~ The GPS data from the previous season was not processed until after we arrived at Troll Station, and this gave a certain amount of unnecessary last minute stress.
~ The time estimates for the fieldwork were not quality checked before departure, and turned out to be rather optimistic.

<u>For next time</u>

~ More closely coordinated acquisition of equipment; eliminate the somewhat counterproductive separation of science acquisitions and logistics acquisitions (e.g. generators, tents, communications equipment).
~ Set up a maintenance plan for field equipment at Troll by the close of each summer season; adjust during the winter season according to developing plans for field activities the following season.
~ Have a contact person at Troll plus field mechanic and field support staff directly involved in the pre-season planning from an early stage.

~ The more pre-season preparations that can be done by the wintering crew, the more fieldwork can be done during the short summer.

Working

During the preparatory phase at Troll station we organised our work around a relatively detailed ”to do” list and daily morning meetings to keep each other updated, and otherwise working independently on individual tasks. This seemed to work well with respect to keeping the overview and managing both known and unknown tasks, continuously adjusting the plans as required. The Troll staff was very supportive and prioritized our needs, thus enabling us to get started as soon as possible. The systems and level of organisation at Troll Station are continuously improving, but nevertheless we spent a lot of time just looking and searching for equipment while preparing for departure. We hope the wintering crews will keep up the good work.

The daily routines in the field also worked fairly well, and usually gave all the expedition members a good overview of the situation. Nevertheless, a daily information exchange procedure would have been beneficial even when working as a small team in the field, by opening up an arena for even more flexible adjustments according to changing circumstances. But altogether we seemed to have a very pleasant and productive atmosphere, both inside our field party as well as together with the station personnel. Independent operations of glaciology and oceanography already at early stage added efficiency and flexibility and reduced stress for both teams.

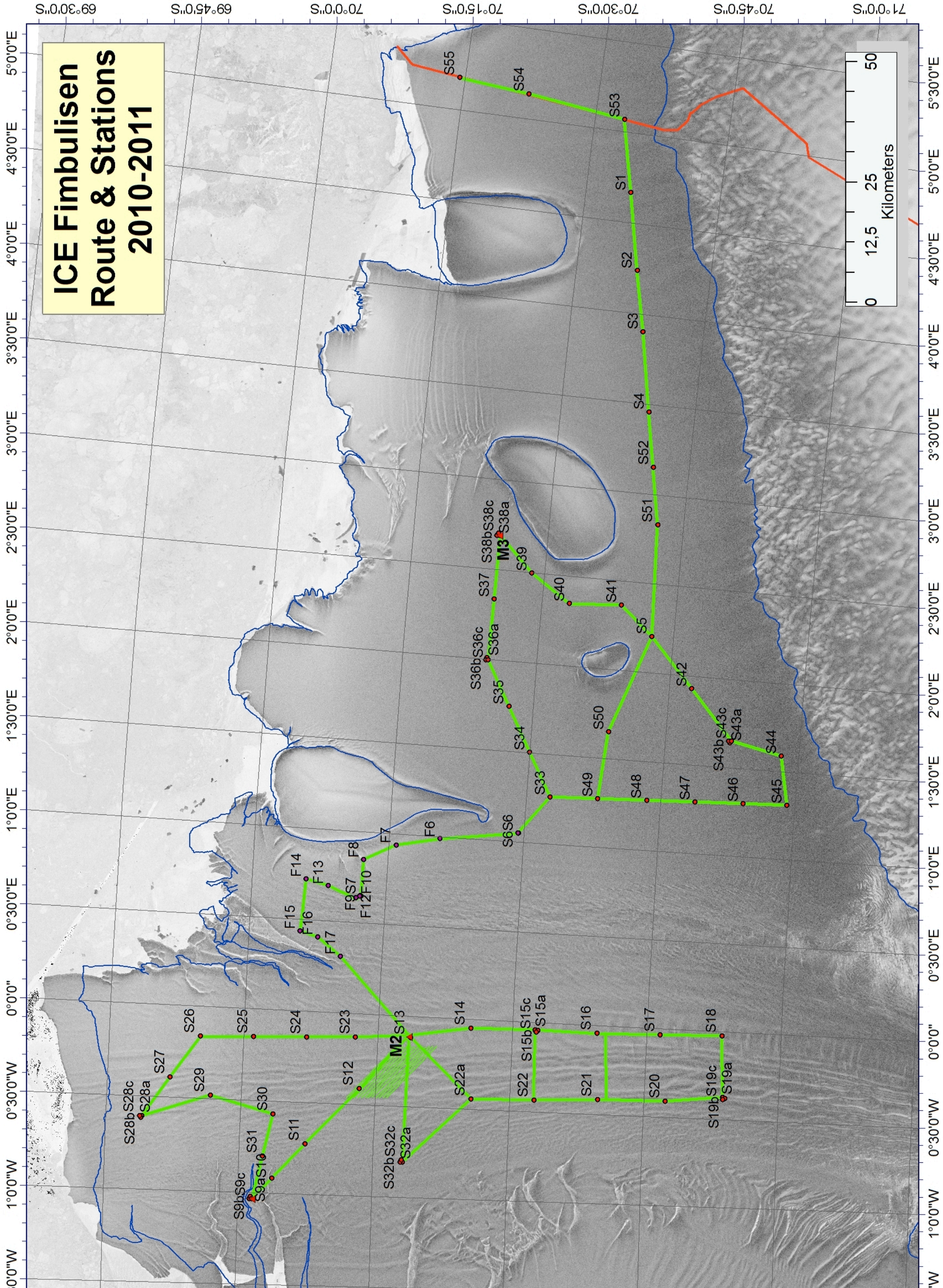
A well-organised and well-drilled routine for the science stations (all the repeat measurements) with fixed tasks for all involved persons greatly assisted efficiency of work and data consistency, and could have been developed further at an earlier stage. One of the team members also concluded, on a reflexive note, that the best way to ensure proper work is to have along someone personally interested in the collected data.

Appendix 1: Schedule

Dato	Dag	Gruppe	Sted	Distanse	BV-km	Skuter-km	Staker	Stake-nett	Annet arbeid
11.11.	-11	Alle ex. JH	Ankomst Troll						11 dager forberedelser
22.11.	1	Alle 6	Troll - MPT	47	94				Transport
23.11.	2	Alle 6	MPT-85	149	297				Transport
24.11.	3	Alle 6	85 - S53	30	60		1		Bresikkerhet
25.11.	4	Jack 3	S53-S3	45	45		3		
		Sembla 3	S53-S51+	96	96				Transport
26.11.	5	Jack 3	S3-S50	85	85		5		
		Sembla 3	S51+-M3-S50	89	89				Vedlikehold M3
27.11.	6	Alle 6	S50(-S49)-nær F7	61	122		3		
28.11.	7	Alle 6	Nær F7-M2	68	136		1		Kryssing skjærsonen
29.11.	8	Glasiologi	M2	22		50		1	Nytt 5-stakers nett, leirarbeid
		Oseanografi	M2-M1-M2	94		188			Vedlikehold M2 og M1
30.11.	9	Glasiologi	M2			10		1	Radar M2, leirarbeid
		Oseanografi	M2-S5(-M2)	114 + 88	228	175			Transport (eskorte t/r skjærsonen)
1.12.	10	Glasiologi, Sembla	M2-S15	30	30		1		Leirarbeid, start sørtur
		Oseanografi	S6-Losseplass	160		320			Transport, vedl.hold værstasjon
2.12.	11	Glasiologi, Sembla	S15-S19	51	51		3	1	
		Oseanografi	Losseplass-85	80		160			Sjøismålinger
3.12.	12	Glasiologi, Sembla	S19-S32	72	72		4	1,5	
		Oseanografi	85-Troll	200		400			Transport, avslutning
4.12.	13	Glasiologi, Sembla	S32-M2	26	26			0,5	Klargjøring for storm
5.12.	14	Glasiologi (alle 4)	M2						Værfast
6.12.	15	Alle 4	M2						Værfast
7.12.	16	Alle 4, Sembla	M2-S24	21	21		2		Utgraving etter snøstorm
8.12.	17	Alle 4, Sembla	S24-S28	43	43		3		Reparasjon Sembla
9.12.	18	Alle 4, Sembla	S28-S9 (M1)	47	47		3	1,5	
10.12.	19	Alle 4, Sembla	S9-M2	47	47		3	0,5	
11.12.	20	Alle 4, Sembla	M2-S18	66	66		4	1	
12.12.	21	Alle 4, Sembla	S19(-S16/S15)-S22	67	67		4		
13.12.	22	Alle 4, Sembla	S22-M2	45	115		1		Radargrid ved M2 (4 snitt)
14.12.	23	Alle 4, Sembla	M2		130				Radargrid ved M2 (6 snitt), havari
15.12.	24	Alle 4	M2						Værfast
16.12.	25	Alle 4	M2						Værfast
17.12.	26	Alle 4	M2						Værfast
18.12.	27	Alle 4	M2						Utgraving etter snøstorm
19.12.	28	Alle 4	M2						Utgraving etter snøstorm
20.12.	29	Alle 4	M2	22		50		2	Stakenett ved M2 og 5-stakenett
21.12.	30	Glasiologi	M2-S28	64		128	5		
		Støtte	M2	20	30				Innhenting og rep. Sembla
22.12.	31	Glasiologi	S28-S9 (M1)	47		94	3	2	
		Støtte	M2						Leirarbeid
23.12.	32	Glasiologi	S9-M2	47		94	3		
		Støtte	M2						Leirarbeid
24.12.	33	Alle 4	M2-forbiF9	58	116				Transport, kryssing skjærsonen
25.12.	34	Alle 4	Ca F9-S34	58	116		3		
26.12.	35	Alle 4	S34-S38	48	96		2	1	Flere brukne staker

27.12.	36	Alle 4	S38-S40	21	84		2	1	Stakenett S38 målt 2 ganger
28.12.	37	Alle 4	S40						Værfast
29.12.	38	Alle 4	S40						Værfast, utgraving
30.12.	39	Alle 4	S40-S45	68	136		5	1	
31.12.	40	Alle 4	S45-S49-S5	75	150		6		
1.1.	41	Alle 4	S5-S2	76	152		4	1	
2.1.	42	Alle 4	S2-Losseplassen	83	166		4		
3.1.	43	Alle 4	Losseplassen-S53	51	102				Fotodag
4.1.	44	Alle 4	S53-91	154	308				Transport
5.1.	45	Alle 4	91-Troll	73	146				Transport
			Sum		3569	1669			

Appendix 2: Map



Appendix 3: Provisions list

MIDDAGSMAT

Hovedrett: Meny fra Einar, porsjoner for 2p.

	Ris	1 dl/p	Ketsjup	4 fl.
	Pasta	100 g/p	Sennep	2 fl.
	Potet, hermetisk	18 *2	Salt, pepper, krydder, kanel	
	Potetmos		Tabasco, HP, Worc.	
	Grøtris		Soyasaus	
			Olje	4 fl.
	Grønnsaker, frosne	150 gram / p	Smøremargarin	6 pk
	Grønnsaker, hermetiske		Stekemargarin	3 kg
	Grønnsaker, tørka		Sauser, pasta	
	Frosne bær		Sukker	Mye
	Puddingpulver		Tørrmelk	
	Moussepulver		UHT-melk	
	Kakemiks		Fløte	
	Müsli, alpen	20 pk	Kaffe, espresso (KL)	
	Havregryn		Kaffe, koke	5 kg
	Tørka frukt, rosiner		Kaffe, pulver	10 gl.
	Hermetisk frukt		Solbærtoddy	
			Rett i koppen	
	Egg, kanne, utporsjonert	2		
	Brød, halvstekt	60-70		
	Knekkebrød			
	Flatbrød			
			Målebeger	
35 kg pålegg totalt	Syltetøy/marmelade			
	Leverpostei			
	Sardiner			
	Tubeost/-makrell			
	Nøtte			
	Peanøttsmør			
	Brunost			
	Kvitost, skiver			
	Kjøttpålegg, servelat			
	Kjøttpålegg, reinhjerte			