GPS survey of Svalbard glaciers, April 2002

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1 Introduction

A GPS survey of selected glaciers in Svalbard was carried out by The University of Wales, Swansea during April 2002, as part of an expedition run in conjunction with The University of Leeds. The expedition had two bases, Ny Ålesund in the North, giving access to Austre Brøggerbreen and Midre Lovénbreen and Svea in the South for Slakbreen, (fig1). The expedition was supported by a National Environmental Research Council(NERC) studentship(NER/S/A/2000/03651), NERC Geophysical Equipment Pool(GEP) equipment, NERC grant (712 L), The Royal Society and was approved by the Mount Everest Foundation(MEF).

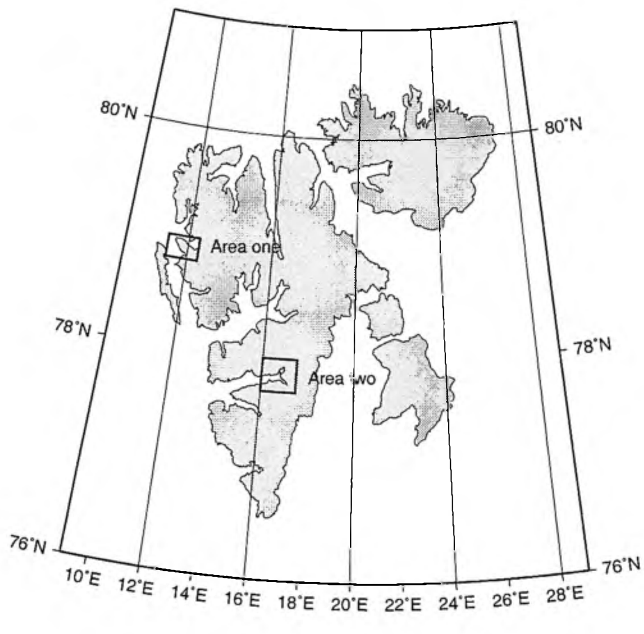


Figure 1: Location map showing the two fiedsites. Area 1: Austre Brøggerbreen and Midre Lovénbreen, Area 2: Slakbreen

2 Scientific Objectives

Sea level has risen by 10-15cm in the last 100 years and the Arctic has been identified as being an area likely to be particularly sensitive to future climatic change. We aim to quantify the volume change of a number of glaciers in the Svalbard archipelago using digital photogrammetry and compare the results with those produced through traditional methods.

The aims of the field trip was to install a network of high accuracy Global Positioning System

(GPS) points around a number of key glaciers. These surveyed points would then be used as ground control and ground truth data for the generation and assessment of Digital Elevation Models (DEMs). By repeating this process for a number of archived aerial photo surveys, it is possible to calculate the volume change of the glacier through time. The archived aerial photographs held by the Norsk Polar Insitute will allow volume changes to be calculated from 1960 to the present. The installation of an extensive network of Ground Control Points GCPs will address many of the criticisms levelled at previous studies, which have failed to adequately define the accuracy and reliability of the models.

3 Techniques

A critical part of any photogrammetric study is the acquisition and implementation of GCPs (Lane 1998). These are points of known planimetric and altitudinal position that are easily recognisable in the images. GCPs are required to stereo match the image pairs and to convert the image coordinates into a real world coordinate system and elevation values. The minimum number of GCPs required to perform such orientations and DEM collection is four points per image, however it is recommended to have more than this. Extra GCPs enable the operator to identify potential misplaced or incorrect points and improve the quality of the matching process.

Ideally, GCPs would be surveyed and marked in an appropriate manner prior to the photo survey being flown, making the task of identifying GCPs on the images much easier. This is not possible when working with archived photo sets. Instead, distinct points that are unlikely to have changed over the survey period may be identified and surveyed to give planimetric and altitudinal positions. Obvious features to use as ground control include mountain tops and the corners of buildings. Care must be exercised when using moraines and other pro-glacial features as they may be difficult to to locate to pixel accuracy and may also experience changes, either seasonal (internal ice formation) or year to year (denudation). Features such as rivers are avoided as they are too dynamic to be considered static for the periods being studied.

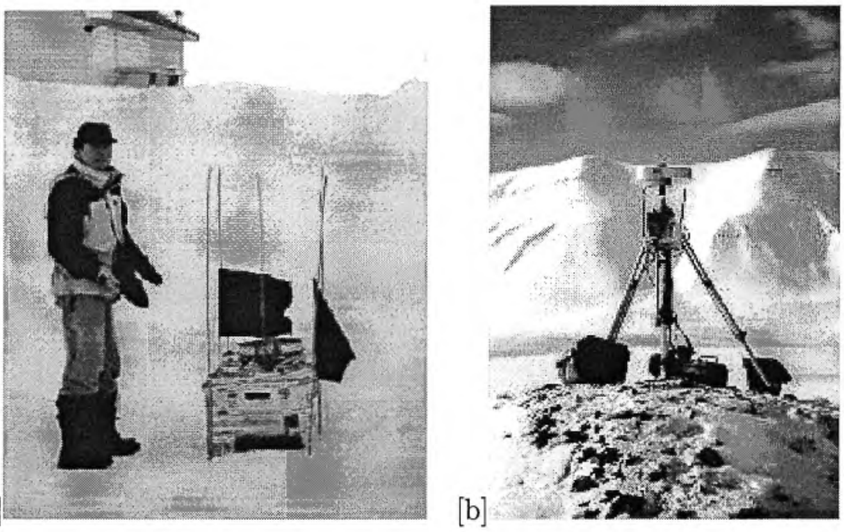
3.1 Base Station

The base station was set up close to our accommodation at both sites, as this offered several advantages such as:

- battery power could be easily monitored and changes at the end if each day

- data could be downloaded and backed up on a daily basis
- in the North, it was midway between the two study glaciers
- in the South, both teams could work independently
- the base station could then be left to record from the same position for over a week

The base station was programmed using the wake up session feature, it was set to switch on at 0900 hours each day and collect data at its maximum rate, *0.1s intervals*, until 2100 hours. This ensured that data was collected when we were in the field and allowed maintenance checks, data downloads and battery swaps to be conducted in the late evening. No radio modem was used on the base station since the survey was being conducted beyond the range of the radio, even with a repeater, this had the added advantage of prolonging the battery life. Car batteries were used to power the base station and this provided the roamer with a spare set of batteries, the car battery would comfortably last 2-3 days before swapping for recharging. The base station antenna was mounted on a tripod, which was weighted with boulders, the computer unit and battery were kept inside a metal Zargos box. This protected the fragile components such as the touch pad, and also prevented them freezing. Unfortunately, the tripod failed to arrive in Ny Ålesund and the base station antenna had to be strapped to a Zargos box with luggage straps, this was then dug into the ice to prevent it moving. Whilst not ideal, this proved to be stable and we did not experience any problems with the setup.



[a] [b]

Figure 2: [a] base station improvisation on metal box, and [b] preferred setup on tripod.

3.2 Rover Station

The roamer was used in two different modes during the field trip, static mode to acquire GCPs and kinematic mode to generate profiles.

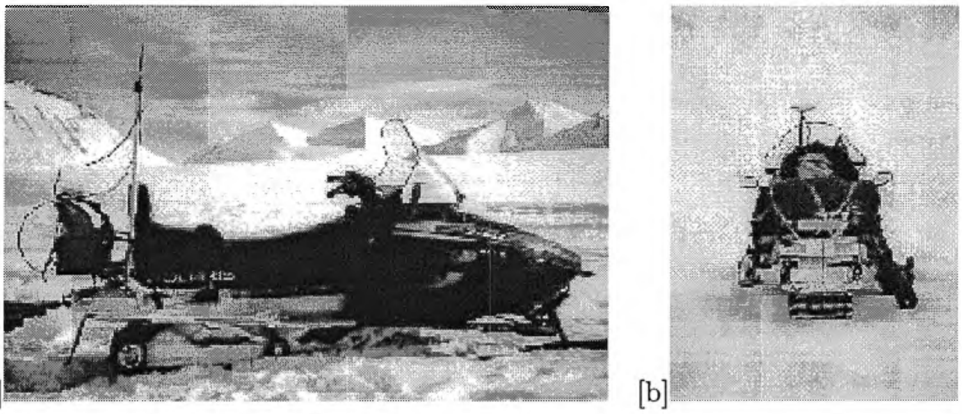
3.2.1 Static Mode

Most of the time was spent collecting GCPs with the roamer in static mode. The configuration file for this was relatively simple, data was logged at its maximum rate as this would make for easy comparisons with the base station. The antenna was attached to a pole and placed in the rucksack along with the terminal. This allowed the user to walk with both hands free, enabling them to climb to the selected points. The expendable pole was marked so the antenna could be set to 2m high, our chosen default antenna height. Positions were recorded for 3000 measurements, taking roughly five minutes. This duration was selected due to the length of the base line between the two receivers, up to 15km. To prolong battery life, the terminal was powered down between measurements as points were often far apart and took a while to get to. On average, we found that we were using three batteries a day, all spare batteries were stored in clothing pockets as this kept them slightly warmer. It was found that if the batteries were exceptionally cold then they would not work, however once they had started working they provided their own heating effect.

3.2.2 Kinematic Mode

This was used to profile the current ice surface, profiles were made up the centre line of glacier where possible. The receivers were set to record kinematic data with no initialisation. Data was recorded every second, to reassure the operator that everything was working correctly, the terminal emitted an audible alarm at each measurement. Again, no real time option was used owing to the distance to the base station was beyond the radio's capabilities, ??.

When operating in kinematic mode, the antenna was mounted on a pole, which was attached to the luggage rack of the snow scooter, this proved to be very secure. The vertical drop height of the antenna was measured and set as the default height in the config file. This arrangement allowed one person to drive the scooter while the other monitored the readings. In order to generate accurate profiles of the glacier it was necessary to determine the depth of the snow that had accumulated on the 2001 ice surface. This was achieved by digging snow pits down to the ice surface every 1.5km. We



[a] [b]

Figure 3: [a] side view of skidoo set up in kinematic mode, and [b] from the back.

had intended to probe the ice every kilometre but the effect of discontinuous ice lenses meant that this technique was unreliable. The pits were dug prior to driving the profile and this created a path in the fresh snow which could then be followed when taking measurements.

4 Data

As previously mentioned, the theoretical accuracy of the Leica GS50 is 0.01m but this requires ideal conditions to prevail for the duration of the survey. For this project there are a number of physical limitations that prevent such accuracies being achieved. To obtain the most accurate results, surveys should be performed at times when there as many satellites as possible visible above the horizon. Unfortunately, the High Arctic is not as well covered as lower latitudes, simply because the user market is not there with only a small percentage of the world population living in the Arctic Circle. By using the satellite coverage predictor contained within Leica SKIPRO it is possible to identify both periods of good coverage and times that should be avoided. The effects of this problem can be reduced slightly by setting the receivers to look for satellites as close to the horizon as possible, although measurements from at low angles are not ideal for producing accurate positions. Accuracy may be determined in the field if the real time facility is in operation but it may be estimated by monitoring the Geometric Dilution Of Position (GDOP). This represent s the geometric configuration of the being used to estimate the position of the receivers. A tight cluster of tends to return higher GDOP's than a dispersed network. In general it is accepted that results should be treated with caution or ignored if the GDOP is higher than 5 (Van Sickle 1996). Any measurements taken when the GDOP was greater than 5 have been highlighted in our notes and will be treated with appropriate caution, these are however very few in number.

Unsettled weather during the field season prevented us from collecting as much data as we would have liked to and meant that we were often forced to work during periods of low visibility. This raised a number of safety issues and we decided to concentrate on the areas of lower elevation in the glacier fore field to avoid exposing ourselves to any additional risk. This has resulted in the data collected being biased toward the front of the glaciers but this was unavoidable given the circumstances. Below is a map of the Brøgerhalvøya Peninsula with the ground control points marked with dots (fig ??. Prior to the trip it was decided to concentrate more time on Midre Lovénbreen as the GCPs around Austre Brøgerbreen were reasonably good. This explains the biased distribution of points around Midre Lovénbreen.

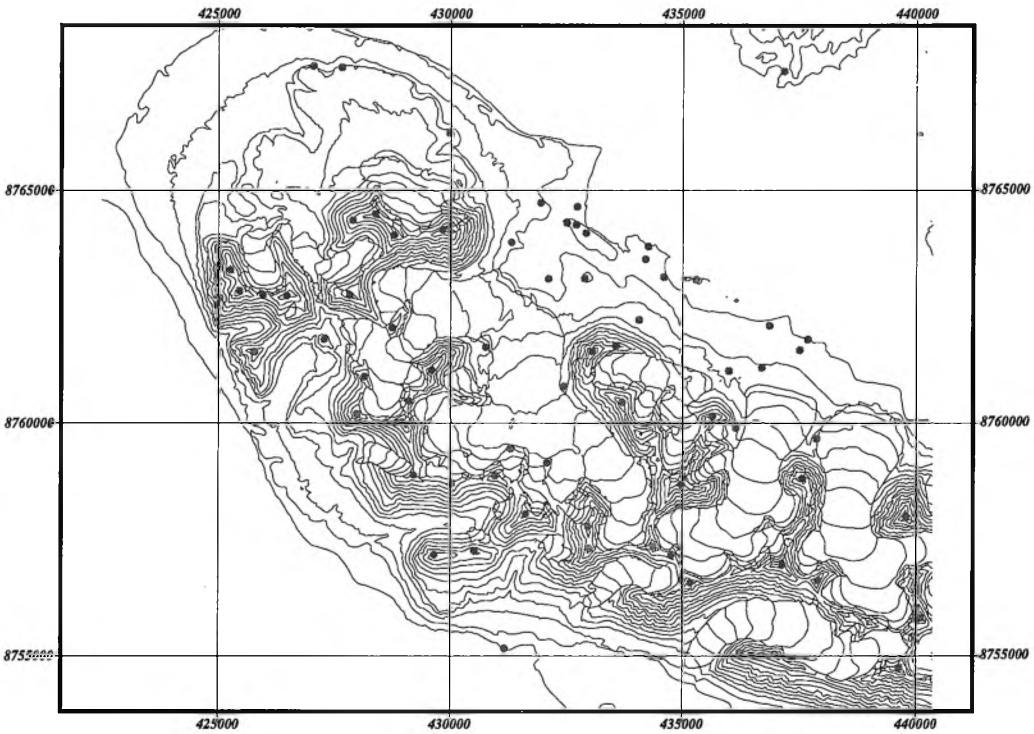


Figure 4: Map showing the location of GCPs Around Ny Ålesund. GCPs marked with dots.

Much of the data gathered has yet to be processed and the results shown here are the preliminary sets. Data will be corrected for atmospheric conditions and satellite wobble, this will improve the accuracy of the positional estimates further. It is important to analyse the data carefully and correct or remove any points that are erroneous as they will have an adverse effect on the quality of the DEMs produced.

5 Problems and limitations

Working in extreme environments always presents problems but it is usually possible to overcome them. The first setback was the delay of the scientific equipment probably due to customs, the base station tripod was delayed further and was not available for use in Ny Ålesund at all. As mentioned previously, this meant that the base station antenna had to be strapped to the top of a metal box by luggage straps. Site selection was now crucial as the antenna was less than 1m above the ground but the setup, while not ideal, was stable and reliable. Battery life was a serious concern, which is why a car battery was use for the base station. This had to record continuously for 10-12 hours a day and any failure would undermine the accuracy of the days work. By doing this we freed two batteries which were then used as a backup for the roamer. Even though the roamer was turned off between points, it still used on average three batteries a day. Spare batteries were kept in inner clothing pockets to keep them warm and this seemed to prolong their life slightly.

The extreme cold was responsible for a number of other problems such as intermittently freezing of the rubber keypads, freezing of the liquid crystal displays and various electrical problems. The terminal kept warning that the flash card bay was open, when checked it was not but data would not be logged until the terminal was happy that the port was closed. When powering down between points, the terminal repeatedly booted back up of its own accord.

The laptop provided by NERC did not seem to have the technical reference manual on it. Fortunately we had a number of laptops with us so were able to consult this guide. We do not feel that it was a case of not being able to find the manual, the file name was provided from the pother laptops and a thorough search was made. Unfortunately, the NERC laptop died during the field trip, possibly after a power surge which knocked other devices out temporarily.

5.1 Comments and Suggestions

The service provided by the GEP was excellent. The equipment helped us to fulfil all our objectives and its use was remarkably trouble free. Likewise, the training and technical support provided by the GEP staff could not be faulted and meant that we could use the equipment with confidence in the field.

As feedback is often very useful there are several things that may improve the service still further. An additional set of batteries, i.e. 6 per two receivers, would be extremely useful when working in cold climates. We were in a fortunate position as we had 8 batteries between two roamer receivers, being limited to two per would had severely reduced the amount of data we could collect each day. I light of the laptop problems we encountered, it could be an idea to suggest that users take, or you supply, a surge protector adaptor with each laptop as the user may not think to take one with them.

6 Looking forward

The data collected in the field is currently being processed and corrected as described earlier. DEMs will then be generated for the available photosets, differenced and the regression of the study glaciers can be calculated. This process will take between 3-4 months and will be conducted in parallel with a number of other research interests. The fieldwork was critical to the success of the project

References

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