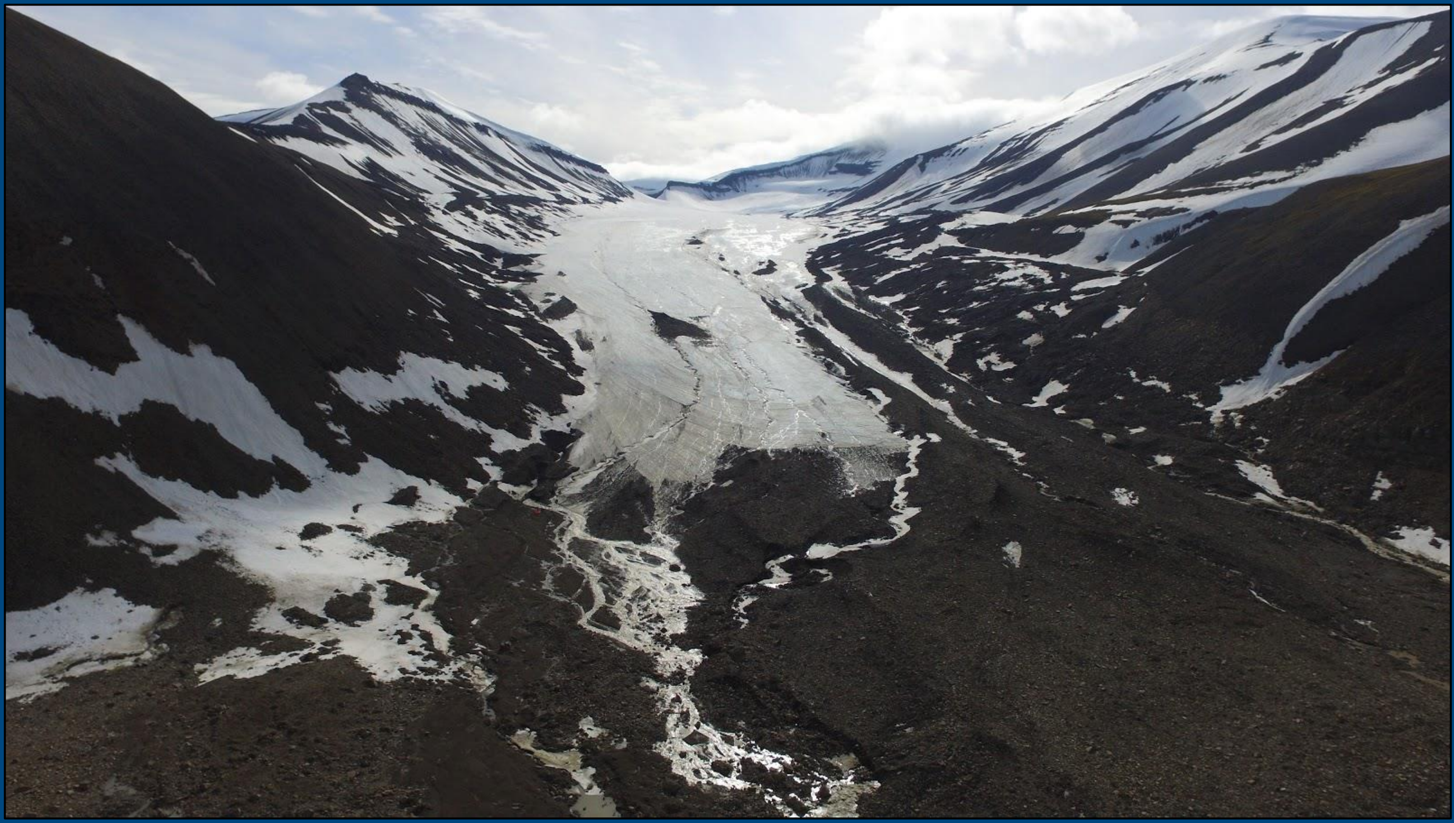
SVALBARD EXPEDITION 2017

POST-EXPEDITION REPORT



Expedition Dates: 28th June – 22nd July 2017

A team of 8 undergraduate Geography BSc students from Newcastle University ventured to Longyearbyen, Svalbard, to conduct dissertation research. The overarching focus of our research was to understand the geomorphological processes of a glaciated region, Svalbard.

Holly Chubb, Hayley Andrews, Emily Cave, Carl Giardina, James Dickinson, Connor Downes, William Ogden and Callum Cochrane.

Abstract:

Between the 28th June – 22nd July, our team of eight undergraduate geography students conducted our dissertation research in Svalbard, the high Arctic. Our field research combined to look at the geomorphology of land-terminating glaciers in Svalbard, with each team member conducting their own individual project. All projects had the main focus of studying how increasing air temperatures are affecting different aspects of Arctic glaciers. During our time in the field, we hiked daily to Longyearbreen glacier, which was approximately 45 minutes away from our accommodation, crossing various proglacial streams, negotiating scree slopes and icy areas. We employed a variety of field techniques, including mapping, water chemistry analysis and ablation stake measurements in order to answer our research questions. We were fortunate to be based at UNIS, the University Centre in Svalbard, which is the world's northernmost institution for higher education and research, located in Longyearbyen, Spitsbergen, Svalbard. They assisted us with both logistical and educational support for the duration of our expedition, and were essential to our research success. All eight team members enjoyed the expedition immensely, and have come away with a far clearer understanding of glacial processes that occur within the melt season.

Table of Contents:

Acknowledgements:

We would like to sincerely thank the following organisations for their financial and logistical support throughout the entire expedition process. We would have not gained such academic and exploration experience without their commitment to our projects.

Acknowledgements:

We would like to thank the following individuals for their essential advice and assistance throughout the entire expedition process:

Dr Rachel Carr	Dr Christopher Borstad (UNIS)
Dr Neil Ross	Mikko Syrjäsuo (UNIS)
Dr Andy Henderson	Dr Simon Drew
Dr Andy Large	Bunmi Eniola
Prof Andy Russell	Ana Contessa
Dr Stuart Dunning	Dr Matt Perks

We would also like to especially thank UNIS and Newcastle University for the opportunity to conduct our dissertation research in a fantastic Arctic Location. Without their guidance and support, this would not have been possible. Dr Borstad and Mikko Syrjäsuo alongside the logistical department at UNIS provided invaluable local knowledge and logistical support during the expedition, and Bunmi Eniola and Ana Contessa have helped greatly with post-expedition data analysis.

We also wish to thank Dr Rachel Carr for supporting our expedition in its earliest stages, and for helping us refine our individual projects back in January 2017. Her support was invaluable for us to successfully complete our many grant applications and gain the financial support for this expedition to progress.

All expedition supervisors, mentioned above, have also provided essential project support to individual team members, which ensured that data collection was efficient and accurate during the expedition.

Finally, we want to express our deepest thanks to every single one of the organisations who provided funds to support our expedition. We could not have completed the expedition without any one of them, and are extremely grateful for all providing the expedition of a lifetime. We are particularly grateful to the Gino Watkins Memorial Fund and the Arctic Club for bestowing the great honour of the 2017 Arctic Club Award.

Introduction:

The expedition to Svalbard was achieved through hard work and dedication from the 8 members of the team, with aim of collecting data for our individual dissertations. The overarching aim of the expedition was to assess the geomorphological changes on Longyearbreen glacier, with one sub-team studying the glaciological changes and the other measuring the hydrological variations. These fluctuations were measured as a response to climate change, with glaciers in Svalbard, among other Arctic locations, being very sensitive to global climatic changes. Many studies have been done on glaciers in Svalbard with regards to glacier surface elevation change and hydrological sediment and chemistry, with the archipelago containing 6% of all glaciers outside of Greenland and Antarctica (Moholdt et al., 2010). The research conducted on this expedition was important considering surface melt and runoff are the main causes of glacier mass loss in Svalbard and the Arctic (Dowdeswell et al., 2008). The objectives of the expedition were split into glaciological and hydrological sections. On the glaciological side, the objectives were to assess glacial retreat rates, the effect of supra-glacial debris on glacial thinning rates, and the efficiency of the glacial hydrological system. On the hydrological side, water chemistry and sediment concentrations were to be analysed, and pro-/supra-glacial stream discharges were to be measured. These objectives would allow for the expedition aim to be fulfilled and allow for each member to gather sufficient data for our final dissertations.

Project Background:

Longyearbreen glacier is on the island of Spitsbergen in the Svalbard archipelago, 78° 11’ N, 15° 30’ E (Etzelmüller et al, 2000). It has a total area of 2.7km2, an altitude range of 210-850m a.s.l., a length of 4.8km and an average thickness of 53m (YDE et al, 2008). The glacier, like many on Spitsbergen is cold based and does not experience basal sliding. Drainage of meltwater from the glacier is mostly supraglacial and is also aided by marginal streams which all lead into one proglacial stream. Englacial and subglacial meltwater activity is low due to its cold base however there are some englacial conduits which drain the glacier. The proglacial stream of Longyearbreen joins a second stream from a different glacier, Larsbreen, further down the valley towards the town of Longyearbyen.

Our expedition team spent 3.5 weeks in this region of the Arctic, with the aim of learning more about glacial landscapes, the processes that occur and how Longyearbreen glacier in particular is rapidly changing as a result of global warming. The team was based in UNIS accommodation in the town of Longyearbyen. Newcastle University has strong ties with UNIS through previous expeditions to Svalbard. Newcastle University students who have visited this region in 2016 kindly passed down their knowledge and shared their experiences with us aiding our expedition planning and preparations. Our expedition team hopes that fellow students will embark on Arctic expeditions, of which we will gladly guide and advise them allowing them to make the most of their adventures and research.

Project Relevance:

Svalbard is a scientifically important location to study as it is a particularly temperature-sensitive glaciated region and has a range of different glaciological and climatic environments. Previous research indicates that the area is rapidly responding to climate change and increasing air and water temperatures, which could have global ramifications including flooding and restricted access to freshwater resources.

Our research will make a significant contribution to geographical knowledge by improving understanding of Svalbard glaciers and their response to changes in global climate. We will be looking at the annual changes in the glacial system to understand how and why the glaciers of Svalbard are retreating.

This process-based knowledge is also applicable in other glaciated regions, which is useful as Svalbard is logistically easier to access than other glacial areas. This will further current knowledge in the scientific community about glacial retreat, imperative if we wish to protect communities from future glacial hazards as listed above.

We also hope this will develop our individual skills in data collection techniques, particularly in a foreign setting, and give us first-hand knowledge for postgraduate research and future careers.

The primary outputs of our research will be our individual dissertations, which will be submitted in March 2018. Our data may also be used for the benefit of UNIS (University Centre in Svalbard), who are also conducting research in the geographical area.

Aims and Objectives:

Group Aims:

Our overall aim is to evaluate glaciological, hydrological and geomorphological changes on Longyearbreen glacier, Svalbard. This will improve our understanding of the response of these glaciers to climatic change, and this knowledge can be applied to other glaciated regions. We aim to assess glacial retreat rates, the effect of debris on melt, and the efficiency of the glacial hydrological system by measuring water chemistry, assessing surface melt and capturing stream velocity measurements.

Individual Aims:

The group are studying a single glacier, Longyearbreen, investigating the following:

- Hayley - Direct measurements of suspended sediment concentration and discharge will be used to assess diurnal variations in the proglacial stream characteristics and their relationship to melt rates;
- Connor - Meltwater discharge will be measured daily to analyse the effect this has on glacier flow velocity during the ablation season;
- Emily - Chemical analysis of two proglacial streams to assess the efficiency of the glacial hydrology;
- Will - Finding how the supraglacial stream system of Longyearbreen changes through part of an ablation season, and over past years, but measuring stream cross-sectional profiles, locations, discharge and plan-form shape;
- Holly - The use of ablation stakes and hand-held meters, to quantify melt rates and their relationship to air temperatures;
- Carl - Investigating the effects of debris cover thickness and albedo on the glacier terminus thinning rates;
- James - The use of handheld GPS and DGPS readings along the glacier termini, in addition to secondary satellite imagery, to distinguish how and why the terminus positions of Longyearbreen have changed over time.
- Callum - To quantify the diurnal volume of meltwater storage on Longyearbreen Glacier for a period of summer melt.

Individual Objectives:

- Hayley - Use flow meters to measure proglacial stream velocities combined with channel cross-sections to determine stream discharge, as well as direct measurements of suspended sediment concentration (SSC) through the collection of 500ml water samples.
- Emily - To collect water and sediment samples Bi-daily from two locations for laboratory analysis to gather data on water chemistry (anion and cation concentrations) and oxygen isotopes of the proglacial

stream. This will all help to identify how variations in temperature and melt affect the water chemistry and oxygen isotopes of the proglacial stream.

- Holly - Utilise ablation stakes to measure mass balance on Longyearbreen, as well as thermos-hygrometers and anemometers to measure air temperature, wind speed and direction twice daily.
- Callum - To carry out discharge measurements on the proglacial stream of Longyearbreen glacier three times a day (morning, afternoon, and evening) to identify fluctuations in proglacial discharge, as well as measuring precipitation on Longyearbreen.
- James - To map the 2017 terminus positions, lateral extent and glacial tongues of both glaciers using a DGPS to calculate retreat rates and ice area loss for both glaciers with the aid of annual satellite imagery from 2000 to 2016 and 2017 infield measurements.
- Connor - Measure velocities and discharge of two supraglacial streams on Longyearbreen and two proglacial streams on Longyearbreen and Larsbreen using flow meters, impellers and transects.
- Carl - Build debris piles of different thicknesses with ablation stakes planted in the middle and measure the surface albedo, including exposed ice, to investigate the effects of debris cover on the ablation rates on Longyearbreen, as well as use a UAV to collate aerial imagery to compare the percentage of debris cover to a 2011 aerial image.
- William - Using GPS points, aerial photography and past satellite imagery to visualise how the supraglacial stream system plan-form has changed over the years, and over the time we were in Svalbard; and using flow-meters, depth poles and measuring tapes to ascertain how the supraglacial streams change in shape and discharge over part of an ablation season.

Maps and Figures:

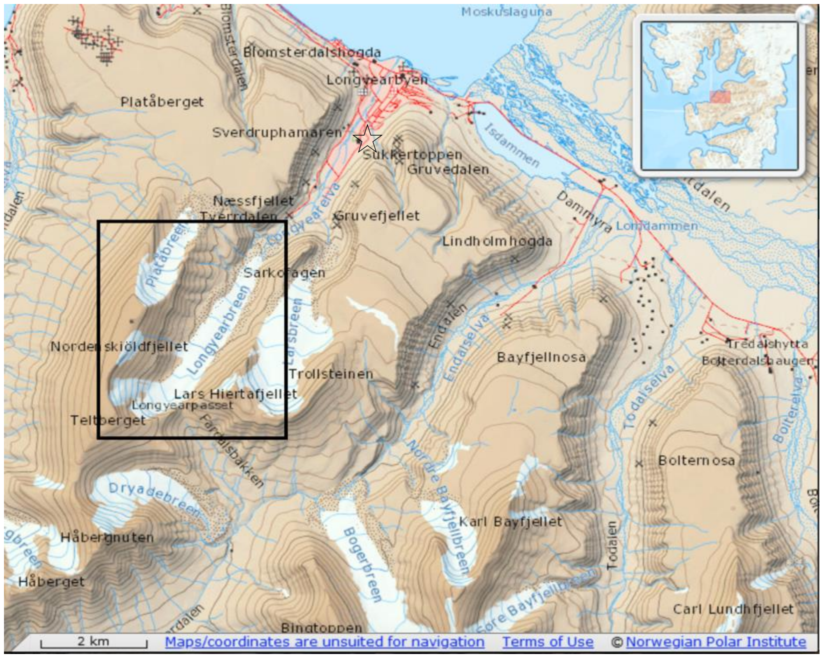


Figure 1.1: Topographic Map of Study Area; Longyearbreen is highlighted, with our Accommodation starred (Map courtesy of Norwegian Polar Institute, 2017)

Figure 1.2: Aerial Map of the studied glacier: Longyearbreen (highlighted). Map courtesy of Google Earth, 2016

Expedition Projects

Specifics of each individual expedition project are detailed below including; project methodology, results, discussion and conclusion.

Hayley: Controls on proglacial suspended sediment concentration, Longyearbreen, Svalbard

This study investigated the diurnal and seasonal variations in suspended sediment concentrations and the strength of discharge and air temperature as controls on these fluctuations in a proglacial stream at Longyearbreen, Svalbard. Through understanding diurnal and seasonal suspended sediment concentration (SSC) variation, we can build a bigger picture of the glacial system detailing erosion rates, landscape stability, and glacier movement. Research in the region of Svalbard is particularly important due to the sensitivity of Longyearbreen to climate change, which has shown to accelerate glacial retreat and thus increase glacial discharge. Discharge is the one of the main controls on SSC and is the focus of this study.

Two defining hypotheses regarding the relationship between SS and discharge have been highlighted in literature. Kostrzewski et al. (1989) notes that SS availability seasonally decreases thus resulting in lower SSC in both Arctic and temperate glacier basins. The opposing hypothesis, which is believed to be most applicable to Longyearbreen, is that of Repp (1988), Bogen (1991), Vatne et al. (1992) and Hodgkins (1996) who conclude that SSC increases in Arctic river basins throughout the ablation period. This study aims to determine which hypothesis can be attributed to Longyearbreen glacier. Initial research suggests that Longyearbreen will exhibit a seasonal increase in SSC based upon past regional studies. The occurrence of precipitation events should be considered when analyzing SSC fluctuations as high volume floods have been found to flush the subglacial system of sediment, depleting sediment stores (Bogen and Bønsnes, 2003). It can be said that with any substantial increase in discharge there will be direct implications on SSC due to the close relationship with discharge variation (Bezinge, 1987). These implications are in the form of SS release in a pulsing style.

Due to the complex nature and limited understanding of glacier hydrology, the true extent of all controls on SSC is not yet known. We know SSC controls are far more complex due to the lack of a complete linear relationship between SSC and discharge (Ferguson and Hodson, 1999). When discussing sediment sources the nature of such sediment and the underlying bedrock should also be noticed as this has an impact on erosion rates, and thus sediment production and availability (Bogen and Bønsnes, 2003). Knowledge into suspended sediment production and transport in the subglacial system provides insight into glacier movement and subglacial water pressure (Fowler, 1987; Harbor 1992).

Research questions:

1. Does proglacial suspended sediment concentration vary at a diurnal and seasonal scale?
    - How does these patterns develop and evolve throughout the ablation season?
2. To what extent do discharge and local temperature act as controls on suspended sediment?

Aim:

- Assess diurnal and seasonal variations in suspended sediment concentration in a proglacial stream at Longyearbreen, Svalbard.

Objectives:

- Proglacial stream velocities will be measured hourly for a 24 hour period (in addition to other sampling intervals), using a flow meter at depth integrated intervals, and combined with channel cross-sections to determine stream discharge. Both diurnal and weekly variations will be determined.
- Direct measurements of suspended sediment concertation (SSC) through the collection of 500ml water samples, and laboratory analysis will be used to assess the relationship between discharge variation and SSC to determine the extent to which discharge controls sediment transport.
- Melt data collected from other group members will be combined with air temperature and correlated with SSC to determine whether a relationship is present.

Field methods:

Data collection took place over 16 field days between 28th June and 19th July 2017. The collection site was located as close to the glacier snout as safely possible, to avoid sample contamination with Larsbreen glacial sediment. In order to determine both diurnal and seasonal variations in SSC and discharge, samples and measurements were taken daily in addition to two high-frequency sampling events. These high-frequency sampling events lasted 24 hours and took place at the start and end of the expedition. SSC samples and geomorphic measurements were taken on the hour every hour. In addition to this, 3 hours from each 24-hour period were subjected to sample and measurements occurring every 10 minutes.

Several discharge measurements are missing due to equipment failure. The absence of some SSC data can be attributed to the damage of sediment laden filtration disks that prohibited weighing and therefore SSC calculation.

Regular geomorphic measurements of the proglacial stream were taken at the same time as SSC samples. These were used to calculate proglacial meltwater discharge. Channel width was measured using a laser range finder. On 11/07/17 a supraglacial ice stream located near the glacier terminus rapidly expanded due to ice boundaries collapsing. This resulted in a large volume of supraglacial meltwater entering the proglacial stream and therefore increasing stream discharge. A sediment bar formed the following day. Therefore, channel width was measured to include the change in channel shape with measurements on the total stream width and divergent channels recorded. Stream velocity was measured using a handheld impeller; multiple measurements were taken, and averages calculated. Weather and channel development observations were taken daily to provide deeper insight into system development.

Bulk 500ml water samples (n=119 over 16 field days) were collected in wide neck polypropylene bottles, with bottles rinsed three times in proglacial meltwater at the sample site to eliminate quantities of sediment from previous sampling which would impact the data. To collect suspended sediment samples, each sample bottle was filled to contain as little air as possible ensuring constant standards across data collection. Samples were labelled with collection date and time to avoid confusion between samples. These were left in room temperature conditions (min. 1 hour, max. 1 week) to allow the suspended sediment within to settle, speeding up filtration time.

After allowing the suspended sediment to settle, each sample was filtered through Whatman glass-fibre filter papers (diameter 55mm). The first 3 collected samples were filtered using a vacuum hand pump. This unfortunately broke, resulting in the rest of the samples being filtered through an automatic vacuum pump of which was borrowed from UNIS. Small quantities of sediment lined the funnel of the vacuum pump. These were washed away with a small volume of sample water designed to flush them towards to filter papers without contaminating the sample with water from another source. In-between each filtration, the pump was rinsed and dried to remove fine sediment that may contaminate the following sample. Tweezers were used to remove sediment laden disks from the equipment to be air-dried.

Each sediment laden disk air-dried until visibly bone dry at room temperature. Once dry to the eye, samples were individually wrapped in cling film to keep the sample from breaking, and losing sediment mass. These were stored in individual sealed plastic bags labelled with the appropriate date and time of collection.

Laboratory methods:
All laboratory analysis was conducted at Newcastle University. Filter papers were all individually weighed to a high accuracy (mg), in order to calculate the different in weight after sediment filtration. All samples were air-dried, however to ensure each sample was bone dry they were oven dried at 105°C for 1 hour in a drying oven in a sediment laboratory. Each sediment laden disk was weighed for a second time to determine the difference in filter paper weight and therefore the weight of the sediment. This allows for the calculation of SSC using the following equation:

$$SSC = \Sigma \frac{M}{V}$$

Where:
SSC = Suspended Sediment Concentration (mg/L)
M = Mass of sediment retained by the filter paper (mg)
V = Volume of water in the SSC sample (L).

Results:
Figure 2.1 illustrates the primary discharge and SSC data collected during this study, highlighting both high-frequency sampling periods. Suspended sediment concentration increased throughout the study period substantially with the concentrations measured towards the end of the expedition being 4 times greater than those collected at the start of the 3.5 week period. Similarly, the average discharge of the Longyearbreen proglacial stream also increased over the study period. There is some correlation between discharge and SSC, with some peaks in measurements corresponding. Despite this, there are high fluctuations in obtained measurements.

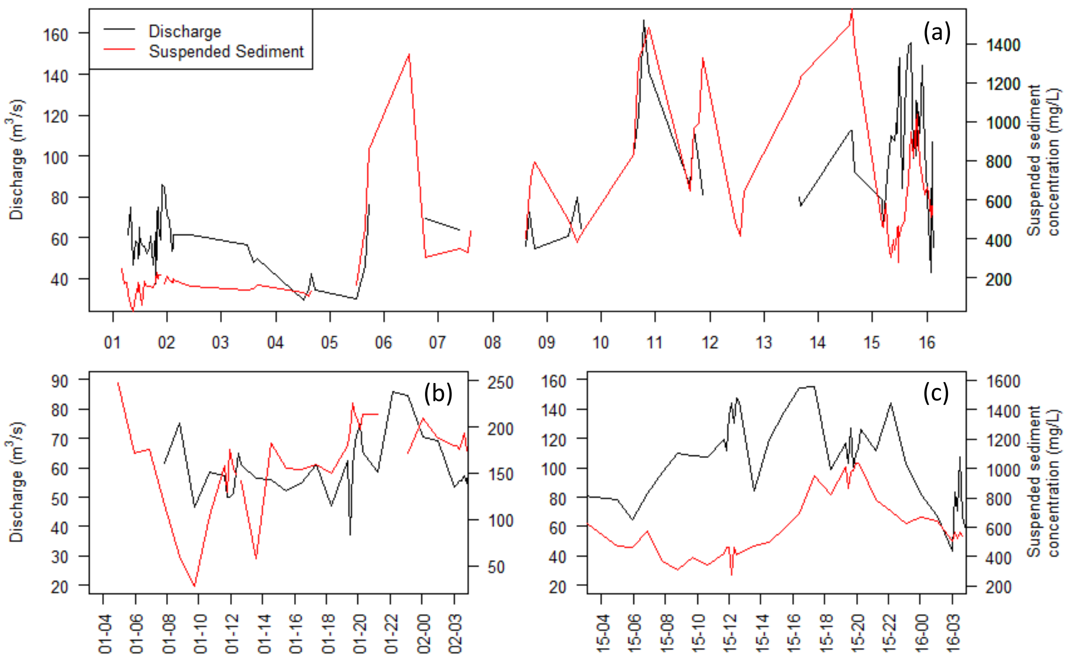


Figure 2.1: Discharge and SSC measurements of Longyearbreen proglacial stream from 1st July – 16th July. Figure 1(b) and (c) depict the high-frequency sampling events from 1st July and 15th July. The hour of the sample is displayed alongside the date on the x-axis.

Conclusion:

As expected, both the SSC and discharge of the Longyearbreen proglacial stream increased throughout the period and this observed relationship can be used to suggest the continuation of this trend throughout the development of the ablation period (Sollid et al*.,* 2000*)*. Due to the lack of total correlation between SSC and discharge, it can be suggested that SSC cannot only be explained by increased discharge over the ablation season; there is a more complex relationship. This relationship is currently being explored through statistical analysis of SSC, discharge, glacier melt and air temperature data sets. With the statistical analysis of additional data shared by members within this team, a better picture of the significance of each variable on SSC will be understood in more detail.

Connor: To assess properties of supraglacial and proglacial meltwater streams on Longyearbreen and Larsbreen, Svalbard, and how they vary within an ablation season

Svalbard's glaciers have experienced rapid changes since the end of the last ice age. Climate change has resulted in fundamental changes to glaciers and their thermal regimes in high arctic regions, including glacier flow mechanisms and how meltwater drains off the glacier. Supraglacial and proglacial meltwater streams transport most meltwater in Svalbard's now cold-based glaciers, therefore by understanding the relationship between these meltwater streams and changes in the environment, we can determine the processes controlling meltwater, and how climate change affects glaciers.

Aims:

Determine the velocity, discharge, plan flow and efficiency of supraglacial and proglacial meltwater streams on Longyearbreen and Larsbreen, Svalbard.

Assess how the differences in supraglacial meltwater properties on Longyearbreen and proglacial meltwater properties on Longyearbreen and Larsbreen vary within an ablation season.

Infer the properties of Larsbreen supraglacial streams based on the relationship between supraglacial and proglacial streams on Longyearbreen.

Objectives:

- Measure velocities of two supraglacial streams on Longyearbreen and one proglacial stream on Longyearbreen and Larsbreen using flow meters and impellers.
- Measure discharge of supraglacial streams and proglacial streams by using a transect to calculate channel cross-sectional area and multiplying it by stream velocity.
- Calculate stream efficiency (hydraulic radius) by finding the wetted perimeter of the streams, using a transect, and multiplying it by the cross-sectional area.
- Visually observe the course of the proglacial and supraglacial streams and record their location with handheld GPS to determine their planform/channel system.

Methods:

Measurements of velocity, discharge and efficiency was taken at two sites along two supraglacial streams at Longyearbreen and one site at one proglacial stream each at Longyearbreen and Larsbreen. This was measured twice daily. Velocity was measured using flow meters at the left bank, the middle and the right, held in place for 30 seconds to even out short term fluctuations.

At the proglacial stream sites, channel cross-sectional area was calculated using a laser range finder to measure the width of the stream. For the supraglacial streams, the width of the streams was small enough to be measured with a tape measure. The stream was then divided up into sections across the width and a depth pole used to measure the depth of each section to determine the cross-sectional area of each stream section, which were then added together to find the total cross-sectional area.

Stream discharge was calculated by multiplying stream velocity and channel cross-sectional area together.

A dGPS and photographs were used to record the location of the supraglacial streams and proglacial streams, thus measuring the channel avulsion patterns.

Efficiency of the streams was calculated by using a heavy chain laid across the stream to work out the wetted perimeter, and multiplied by the cross-sectional area, giving hydraulic radius.

Results:

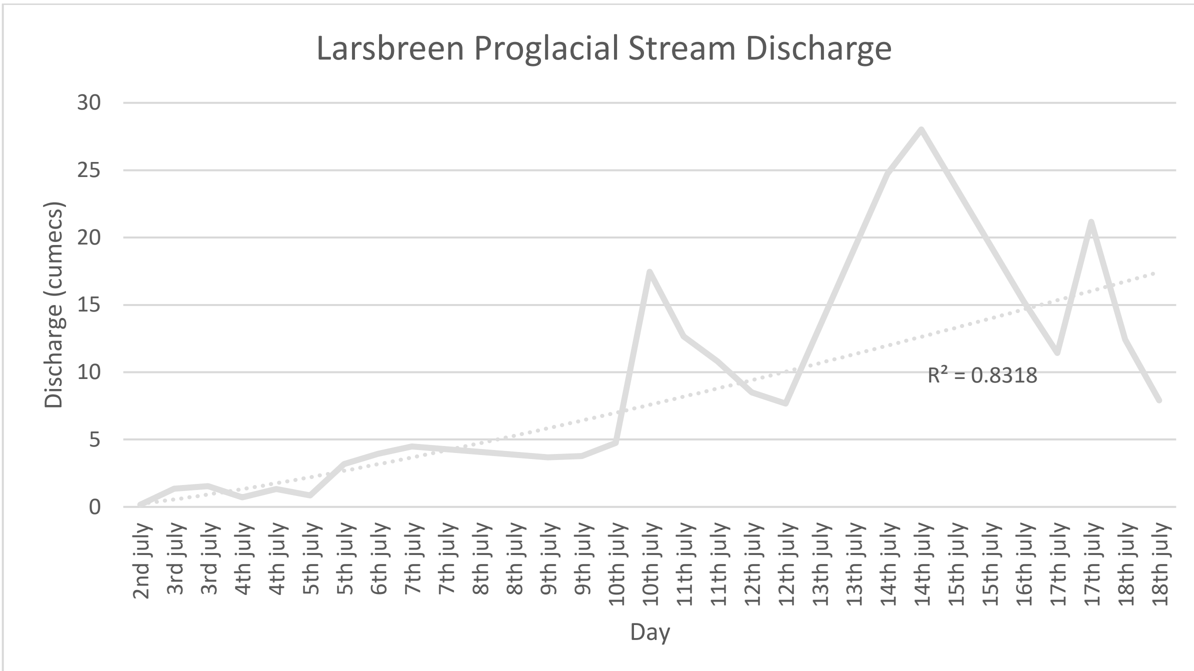


Figure 3.1: Larsbreen proglacial stream discharge

Larsbreen proglacial stream had a highly variable discharge over the 16-day period of data collection (Figure 3.1). Stream discharge started off very small on the 2nd July, at 0.163 cumecs, and began to gradually increase over the course of 8 days. On the 10th July, discharge at 1:40pm was 4.74 cumecs, while later that day increased to 17.452 cumecs, over 3 times as much. After the 10th July, larger fluctuations were recorded, the largest increase being from 7.668 cumecs on the 12th July to 24.725 cumecs on the 14th July. Three large peaks were found on the 10th July, 14th July and 17th July; the highest discharge was 28.028 cumecs at 7:35pm on the 14th July. The trend line is a power function with an R^2 value of 0.83183.

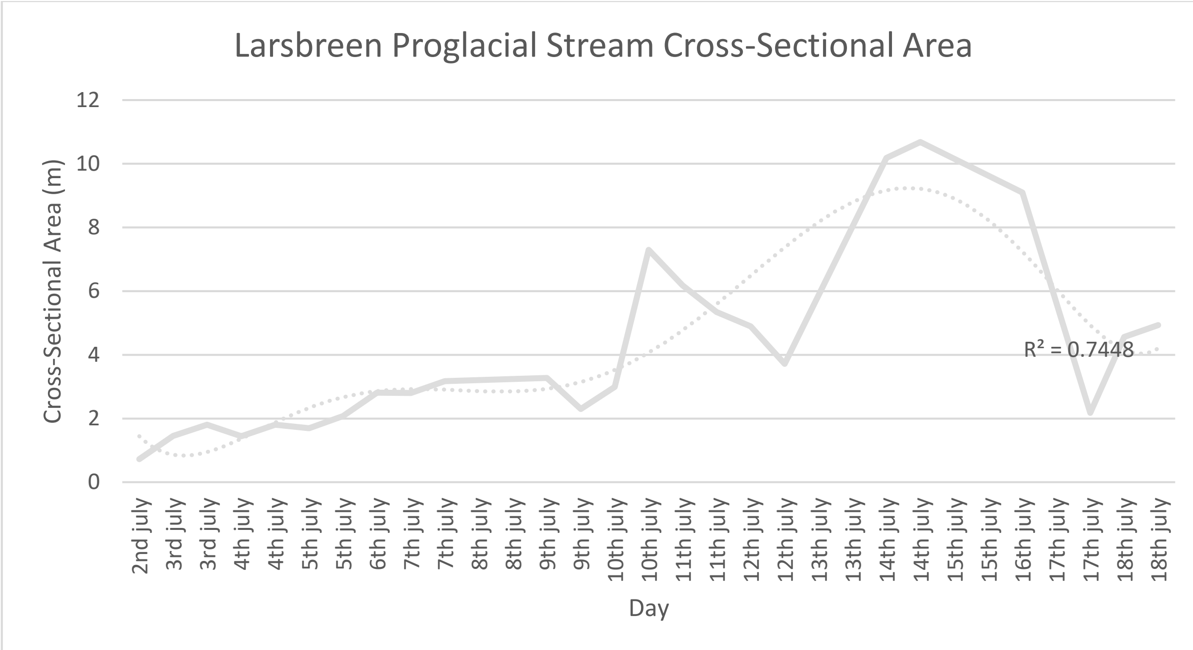


Figure 3.2: Larsbreen proglacial stream cross-sectional area

Figure 3.2 shows that Larsbreen proglacial stream cross-sectional area had a generally positive trend throughout most of the data, apart from decreases on the 11th July, 12th July and the 16th July when cross sectional area dramatically decreased. The stream's cross-sectional area started at 0.723m on the 2nd July and by the 14th July had increased by 9.96m to 10.683m, the largest cross-sectional area found between all streams. This increase was predominantly gradual, with most days recording an increase of up to 1m. However, high variation was seen even within a day, as seen on the 10th July, when measurements of 2.992m and 7.299m were found at 1:40pm and 9:51pm respectively. The order 6 polynomial trend line shows the positive increase and then decrease in cross-sectional area. The R^2 value is 0.74479.

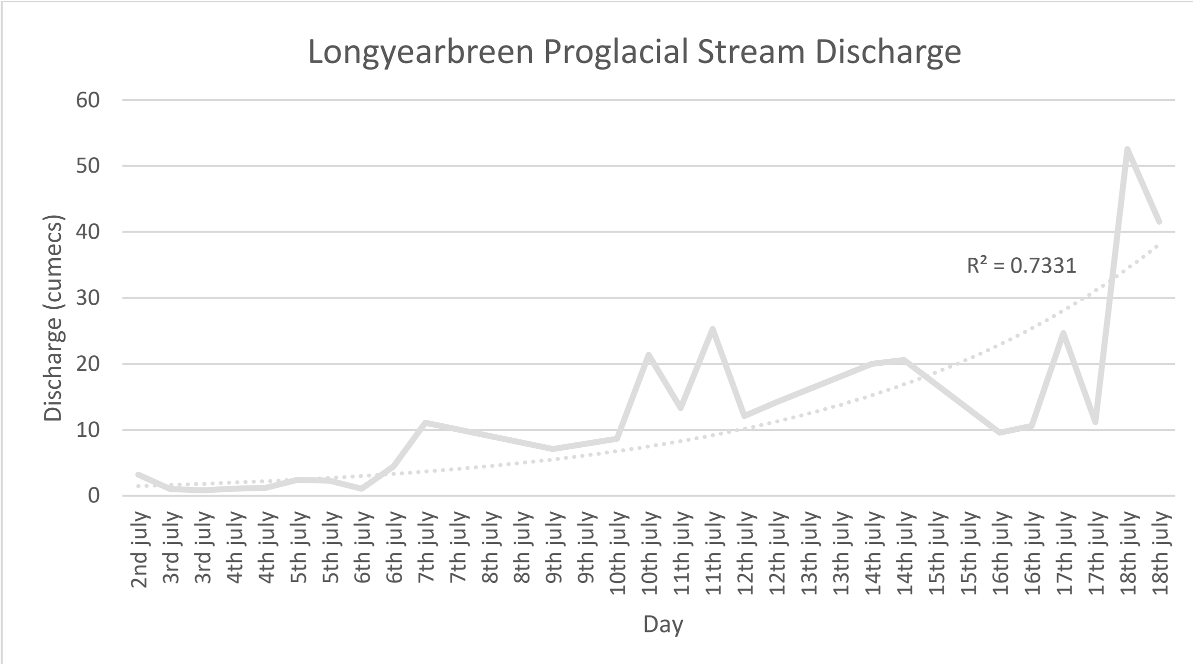


Figure 3.3: Longyearbreen proglacial stream discharge

Longyearbreen proglacial stream discharge had a significant increase throughout (Figure 3.3). On the 2nd July, discharge was recorded at 3.194 cumecs and by the 18th July had risen by 38.389 cumecs to 41.582 cumecs. Changes in discharge were small from the 2nd July to the 6th July, however, on the 6th July discharge reached 4.447 cumecs, a difference of 3.37 cumecs from 1.077 cumecs recorded at 10:30am earlier that day.

Larger variations in discharge were recorded from the 6th July to the 18th July, the most dramatic of these being an increase of 41.392 cumecs in just over 16 hours, from 11.177 cumecs at 7:16pm on the 17th July, to 52.569 cumecs at 11:50am on the 18th July, which was also the highest discharge found. The trend line is an exponential function with an R^2 value of 0.73312.

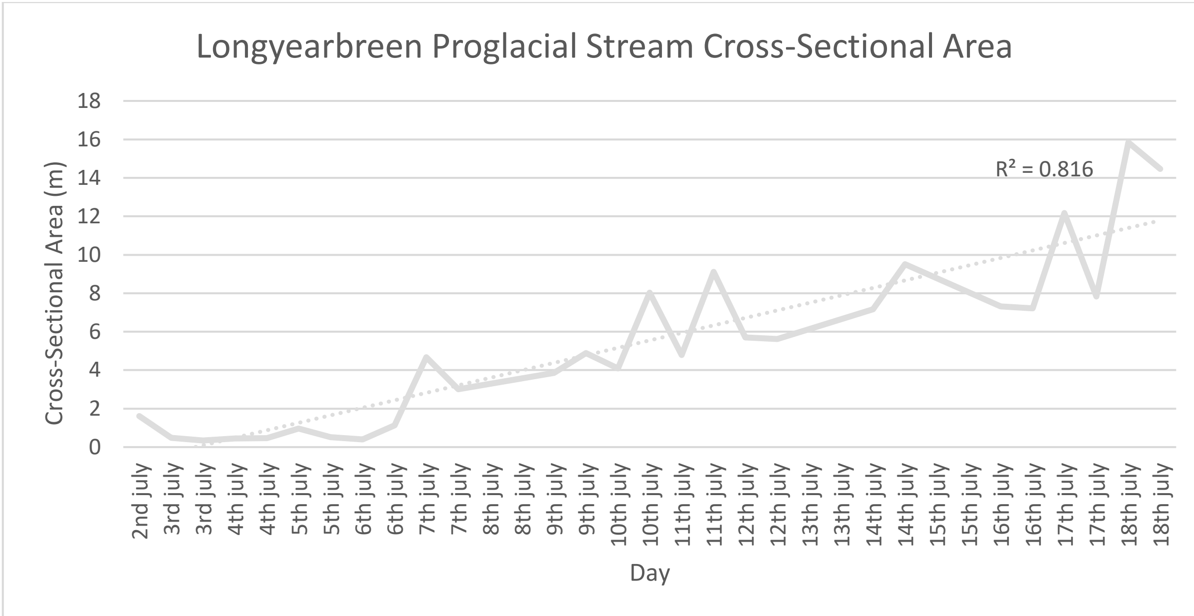


Figure 3.4: Longyearbreen proglacial stream cross-sectional area

Longyearbreen proglacial stream's cross-sectional area has a very clear positively increasing trend from the 2nd July to the 18th July, shown in Figure 3.4. Throughout the 16-day period, gradual as well dramatic increases were recorded, with few decreases. Cross-sectional area is first found to be 1.619m on the 2nd July and by the 18th July had increased to 14.466m, a difference of 12.847m. The largest increase was found between the 17th July and the 18th July, when the stream's cross-sectional area rose by 8.009m from 7.823m to 15.841m, which was also the highest cross-sectional area in the data set.

Another notable point is the variation in cross-sectional area on the same day and the fact that some days record large changes while others are mostly unvarying. This is evident on the 11th July, as an increase of 4.317m over the course of 7 hours and 11 minutes was recorded, compared to a day later on the 12th July when a difference of only 0.086m was recorded over 5 hours and 55 minutes.

The trend line is linear, with an R^2 value of 0.81599.

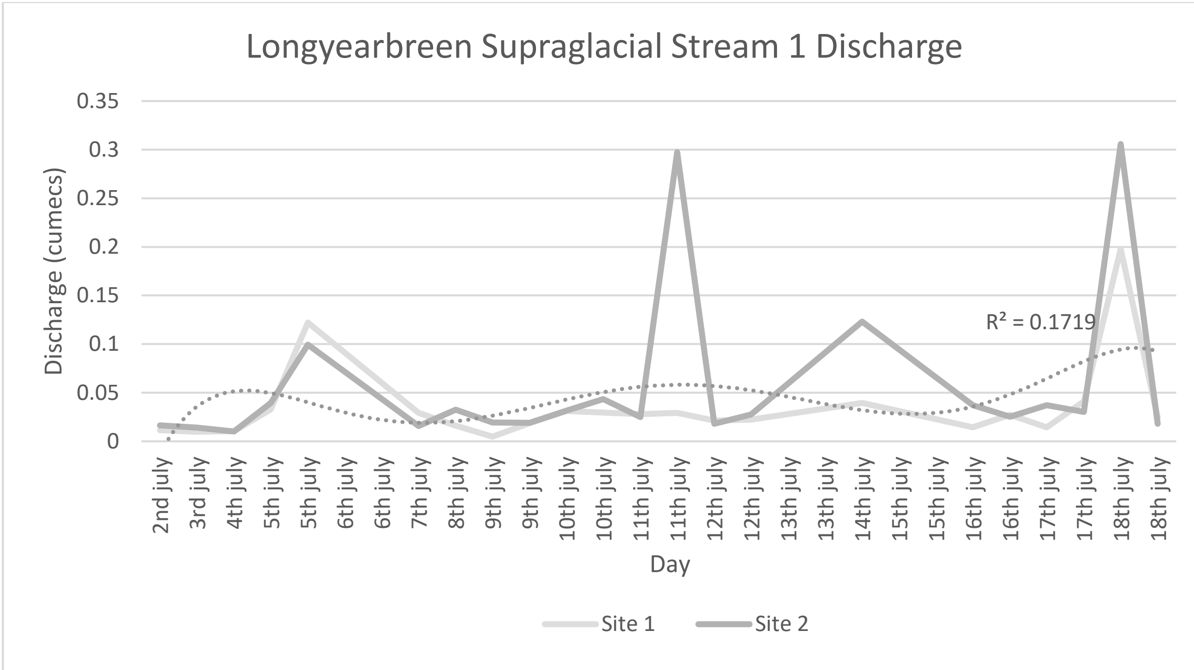


Figure 3.5: Longyearbreen supraglacial stream 1 discharge

Longyearbreen supraglacial stream 1 discharge stayed fairly similar, at very small values, throughout the data, with occasional dramatic increases on a short temporal scale (Figure 3.5). On the 2nd July, the stream had a discharge of 0.012 and 0.016 cumecs in Site 1 and Site 2 respectively, while on the 18th July, discharge was found to be at comparable values of 0.025 and 0.018 cumecs in Site 1 and Site 2 respectively.

Site 1 and Site 2 follow the same trend of small discharge values, with both even increasing considerably on the same two days, except for two large increases found in Site 2 that are not found in Site 1. Site 1 therefore had two large increases recorded while Site 2 had twice the amount at four.

Both sites increased notably on the 5th July between 1:37pm and 4:24pm; site 1 increases from 0.033 to 0.122 cumecs and site 2 increases from 0.040 to 0.099 cumecs. Additionally, both sites increased significantly on the 18th July; it was found that site 1 had the highest discharge for that site, at 0.198 cumecs, while site 2 reached the highest recorded discharge for the whole stream at 0.306 cumecs. Site 2's extra increases were found on the 11th July, at 0.297 cumecs, and on the 14th July, at 0.123 cumecs.

The order 6 polynomial trend line shows the average discharge of the stream over the two sites, showing the slight fluctuations in discharge. The line has an R^2 value of 0.17192.

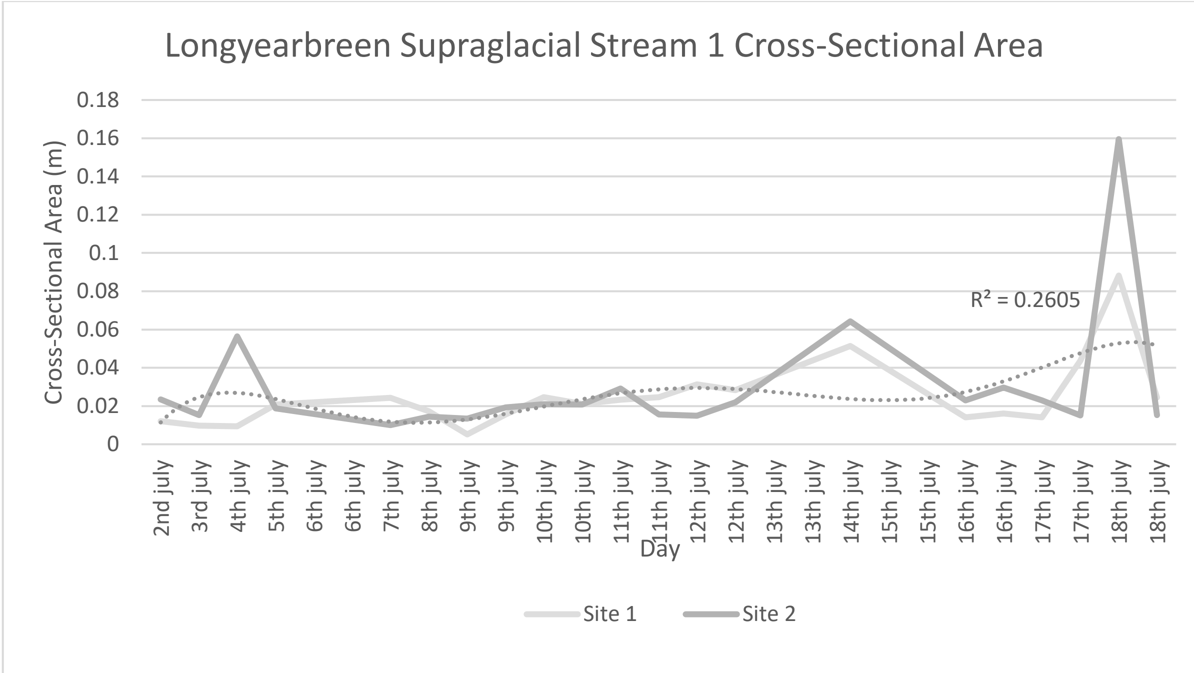


Figure 3.7: Longyearbreen supraglacial stream 1 cross-sectional area

Figure 3.7 illustrates changes in Longyearbreen supraglacial stream 1 cross-sectional area, showing that stayed almost entirely the same at very small values, the exception being at the end of the data set when high increases were recorded. Cross-sectional area started off at 0.012m and 0.023m for Site 1 and Site 2 respectively. Despite a notable increase in Site 2 up to 0.056m on the 4th July, until the 12th July each site had very small variations, with the largest variation in Site 1 being only 0.023m on the 12th July.

From the 12th July onwards, both sites were found to have bigger changes in their cross-sectional areas, as seen in Site 2's 0.036m increase from 0.022m to 0.058m. Even with these changes, Site 1 and Site 2 still follow the same trend, clearly seen as both sites decrease by similar amounts between the 14th July and 16th July.

Between the 17th and 18th July, Site 1's cross-sectional area increased from 0.019m on the 17th July to over four times larger at 0.088m on the 18th July. Site 2 increased by over ten times as much in the same, short temporal scale, from 0.015m to 0.160m. Both increases recorded the highest cross-sectional areas throughout the data set.

The order 6 polynomial trend line shows the average cross-sectional area of both sites, with an R^2 value of 0.26049.

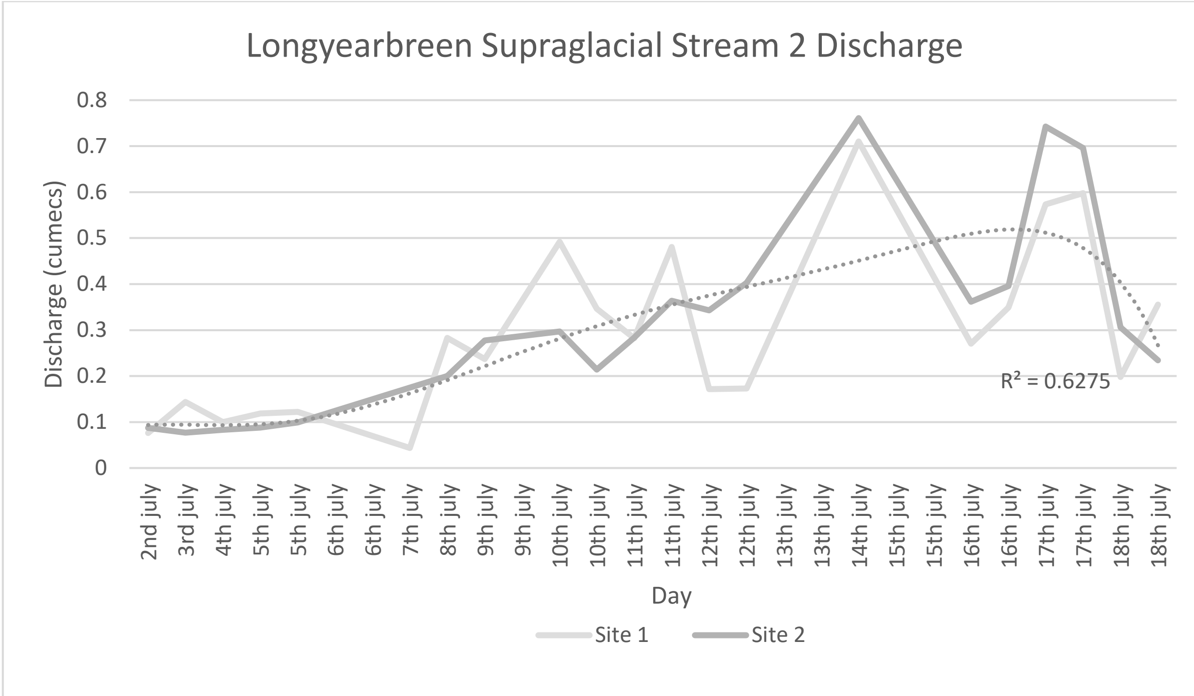


Figure 3.8: Longyearbreen supraglacial stream 2 discharge

Longyearbreen supraglacial stream 2 had a positively increasing discharge trend from the 2nd July to the 18th July (Figure 3.8). Site 1 and Site 2 discharge vary in the first half of the data set, however have similar data sets in the second half of the data set, in which they follow the same general patterns of discharge increase and decrease. The stream began with very low discharge on the 2nd July, at 0.076 and 0.087 cumecs for Site 1 and Site 2 respectively. From the 6th July onwards, Site 2 increases daily with few decreases, whilst Site 1 has more fluctuations throughout. Between the 8th July and 11th July, site 1 decreases three times, notably from 0.492 to 0.345, then further to 0.282 cumecs. Site 2 only decreases once, from 0.297 to 0.214 cumecs, which is a lot smaller than site 1's decrease. After the 12th July, Site 1 and Site 2 follow a much similar trend, with both sites having their highest peaks on the 14th July around 3:44pm, at 0.710 and 0.736 for Site 1 and Site 2 respectively.

The order 6 polynomial trend line constitutes the average of both sites, showing increasing discharge until the 17th July, when average discharge quickly decreases through to the 18th July.

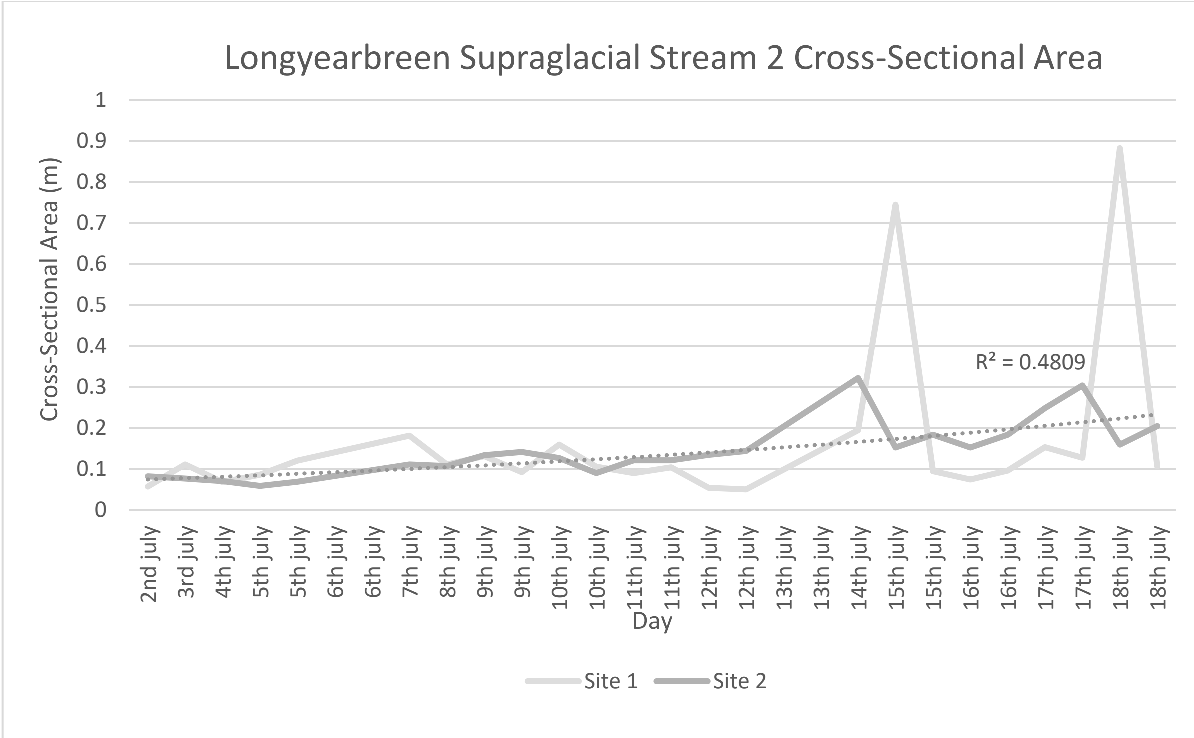


Figure 3.9: Longyearbreen supraglacial stream 2 cross-sectional area

Figure 3.9 shows the cross-sectional area of Longyearbreen supraglacial stream 2, In which it was found to be small and had a very slight positive increasing trend throughout, with two areas of dramatic increase in the second half of the data set. Site 1 and Site 2's cross-sectional area were first measured at 0.057m and 0.082m respectively, and stayed around these values until the 12th July, after which the values began to increase more significantly. Between the 12th July and 14th July, Site 1 increased by 0.143m from 0.051m to 0.194m, while Site 2 increased by 0.178m from 0.144m to 0.322m.

Up until the 15th July, Site 1 and Site 2 had similar patterns of slight increase and decrease in cross-sectional area, however on the 15th July, Site 1 dramatically increased whilst Site 2 decreased. Site 1 increased by 0.550m from 0.194m to 0.744m, which is the first time Site 1 had recorded a measurement of over 0.2m. Site 1 on the other hand dropped from 0.322m to 0.153m, a reduction of 0.169m. This pattern, of a large increase at Site 1 paired with a smaller decrease in Site 2 was seen again on the 18th July at 1:15pm, when Site 1 recorded the highest cross-sectional area in the data set, at 0.882m. However, by 2:30pm on the 18th July, a cross-sectional area of 0.107m was found at Site 1, thus the cross-sectional area was at comparable values to the start of the data set again. The exponential trend line shows the average cross-sectional area of both sites, with an R^2 value of 0.48093.

The exponential trend line shows the average cross-sectional area of both sites, with an R^2 value of 0.48093.

Discussion:

The changes in meltwater stream dynamics seen on Longyearbreen and Larsbreen can partly be attributed to the evolution of the drainage system over an ablation season (Gulley, 2009), as rising summer temperatures cause the snowpack on the glacier to melt, producing highly variable water discharge (Pälli, 2003), especially later in the ablation season. Sharp increases and decreases in discharge and cross-sectional area are only seen towards the end of the dataset, which would be expected as the dataset was taken at the start of the ablation season, before most of the snow has melted.

Additionally, it makes sense that Longyearbreen proglacial streams mirror the patterns of supraglacial streams (Swift et al, 2005) as they are fed by water on and flowing off the glacier. Variations in these patterns however, can be a result of englacial channels routing water to different outlets (Hodgkins, 1997; Riger-Kusk, 2006). This relationship between supraglacial and proglacial streams has the potential to give an insight to the supraglacial streams on Larsbreen, since Larsbreen proglacial stream trends are similar to that of Longyearbreen, which could prove important in studying glaciers where certain areas of interest cannot be reached. However, to fully understand the relationship between supraglacial and proglacial streams, data must be collected over a full ablation season.

James: Understanding the recent surface elevation change and glacier retreat of Longyearbreen glacier, Svalbard, since 2010

This study investigates how the surface elevation of Longyearbreen glacier, Svalbard has changed over time in response to fluctuations in temperature and precipitation. The study site, Longyearbreen, Svalbard, was chosen as it has displayed significant changes in SE and lateral ice extent in recent years.

Research question:

How and why has the terminus positions, lateral ice extent and surface elevation of Longyearbreen glacier changed since 2010, because of recent climatic variations in temperature and precipitation?

Objectives:

- Record the surface elevation of the ablation surfaces of Longyearbreen using a using a Differential Global Positioning System (DGPS), and generate a Digital Elevation Model (DEM) for the lower ablation zones of both glaciers.
- Compare the elevation data to previous studies and DEMs, as well as temporal changes in climate data from Longyearbyen Meteorological Station in Longyearbyen, Svalbard.
- Map the 2017 terminus positions, lateral ice extent and debris cover areas of Longyearbreen.
- Calculate the retreat rates and ice area loss of the lower ablation surfaces of both glaciers using two computer-based Geographical Information System (GIS) mapping programs, Arcmap 10.3.1 and QGIS 2.10.1, with the aid annual satellite imagery from 2000 to 2017 as well as 2017 DGPS measurements.
- Compare the retreat rates of both glaciers to temporal changes in temperature and precipitation from Longyearbyen Meteorological Station in Longyearbyen, Svalbard.

Methods:

A Trimble R4 differential Global Navigational Satellite System (GNSS) was used to precisely record the elevation of the ice service at different areas of the glacier surface using systematic sampling. The DGPS was made up of three components including the receiver, controller and carbon pole (Figure 4.1). The DGPS has a high level of accuracy at +/- 5mm + 0.5ppm RMS and +/- 5mm + 1ppm RMS for horizontal and vertical positioning respectively.

An attempt to record the glacier terminus was made. However, it was difficult to accurately distinguish its location due to the presence of large terminal moraine deposits. Instead, the points where the ice surface is no longer visible was used as the terminus and compared to satellite imagery of previous years. Finally, areas of debris cover were also recorded to see if their position on the glacier may have changed over time.

Figure 4.1: Trimble R4 Rover DGPS setup

The DGPS uses radio signals from several satellites to pinpoint exact locations on the earth's surface. It also calculates land height above average sea level by inferring the distance between the satellite and the land surface using the time taken for the signal to be received. The high accuracy of the DGPS reduced the average level of error to just 3.436mm.

ArcMap 10.4 was used to calculate the change in surface elevation, by subtracting the height above sea level of both a 2011 DEM from DGPS points.

QGIS 2.18.9 was used to visualise changes in lateral glacier extent and terminus positions using satellite imagery from 2014, 2015, 2016 and 2017.

Results:

Error in the datums for the 2011 DEM and the DGPS points has resulted in a surface elevation gain of 24.86m or 4.14m elevation gain per year between 2011 and 2017, across the glacier.

The lowest elevation change seen was 5.54m or 0.92m per year. Whereas the greatest surface elevation change being 33.97m or 5.66m per year.

Average June and July temperatures have increased slightly since 2000 by 2.9^{o}C and 3^{o}C respectively (Figure 4.2).

Precipitation data has not yet been analysed.

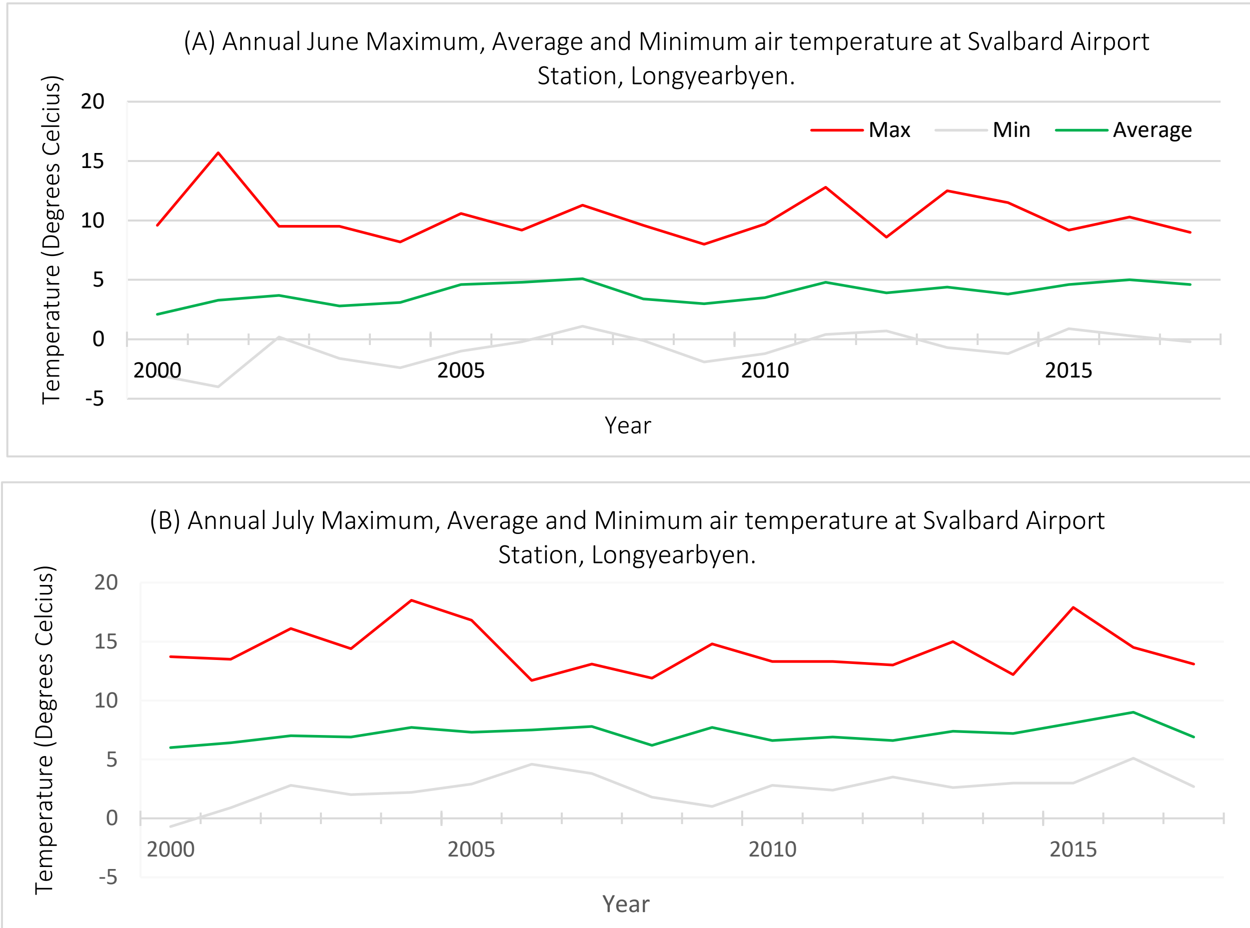


Figure 4.2: Annual Maximum, Average and Minimum air temperatures for Svalbard Airport Station, Longyearbyen since 2000.

Discussion:

Previous studies by Hodgkins et al., (1999) suggest that glaciers in this area of Spitsbergen have indicated thinning prior 2000. However, the results from this study do not support previous findings for glacier surface elevation change. Although climate change could potentially be enhancing precipitation in this area of Svalbard, it is unlikely that this would explain net gain of 24.86m across the glacier. Furthermore, more than half of the top 15 highest average temperatures for June occurred between 2000 and 2017. This suggests that the gain in elevation is likely a result of errors in the GIS datums.

Conclusion:

Overall, the datum error has made it impossible to draw accurate conclusions from the data present. Temperature data since 2000 would suggest a constant climate with a slight increase in air temperature. However, this is not represented by high net gain in surface elevation seen all across the glacier surface. Therefore, further research into the Datum conversion is needed to improve the accuracy of these results and make them representative.

Carl: Investigating the effects of debris cover and surface albedo on the ablation rates of the glacier tongue on Longyearbreen, Svalbard

The project aim is to investigate the direct effects of debris thickness and albedo on surface elevation change in the ablation zone of Longyearbreen Glacier. It aims to build on Östrem's (1959) study on the altered ablation rates of ice under different thicknesses of moraines on a Swedish glacier, producing the renowned Östrem curve (figure 5.1). Many studies correlate thick debris-coverage with suppressed melt rates and thin coverage with accelerated melt rates; however, the critical thickness is still a grey area. Regarding albedo effects, it is understood that a lowered albedo induces greater absorption of solar radiation, without necessarily resulting in increased ablation rates on glaciers, depending on debris thicknesses.

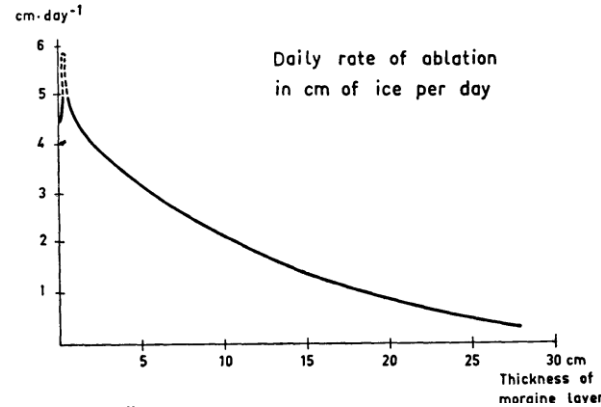


Figure 5.1: Östrem curve showing an increase to a maximum melt rate under specific debris thicknesses (Östrem, 1959).

Östrem (1959) was one of the first to study the effects of different debris thicknesses on ablation rates, summing it up very well in a graph showing a maximum melt thickness as well as a critical thickness where melt rates are the same as they are on exposed ice. However, Reid et al. (2012) added that the position on the glacier alters the critical thickness, as it changes with altitude and geographic location. Debris decreases the albedo of the ice, hence making it absorb more solar radiation, therefore inducing melt; however, the thicker the debris, the more insulation it provides the ice with to prevent it from melting (Azzoni, 2016). Little research has been conducted on the effects of debris cover on ablation rates in Svalbard, whilst extensive research has been undertaken on the same topic in other parts of the world; therefore, it seems appropriate to study such a topic on two glaciers in southwest Svalbard. Svalbard's glaciers represent 6% of the world's glaciers outside of Greenland and Antarctica, most of which have a negative mass balance (Moholdt et al., 2010). The climatic sensitivity of the rapidly shrinking glaciers in Svalbard, makes it an important location to study the accelerating/suppressing effect of debris cover on melt. However, uncertainty remains over the critical debris thickness and a full understanding of the relationship between debris thickness and melt rates.

Methods:

Two sets of 6 debris piles of debris of thicknesses of 1-6cm were set up just above the debris covered glacier tongue; with one set being dark-coloured clasts, and the other being light-coloured clasts. 1m long ablation stakes and a tape measure were used to measure daily melt rates and debris thickness when the stakes were initially planted; daily melt measurements were taken on the glacier. A lux-meter was used to measure the incoming and reflected solar luminescence in order to calculate the albedo of the ice and debris covered ice, with lux-meter readings being taken once at the start of the trip and once at the end on fully overcast days without precipitation. A thermoanemometer was used to measure air temperature every day to monitor the micro-climates and then compare it with the data from the Longyearbyen weather station. A handheld GPS was used in conjunction with a UAV drone to map the debris depth and collect aerial imagery of the extent of the large natural debris covered areas of the glacier, in order to calculate the percentage of debris cover. Later, Agisoft PhotoScan was used to produce a DEM and an orthophoto of the glacier tongue, used to compare it to a 2011 image with the use of ArcMap. Additionally, the raw data was processed using Excel and RStudio to relate the data to each other.

Results:

Ablation data:

Figure 5.2 shows the unmodified curve created from the correlation between debris thickness and sub-debris glacial thinning rates. The curve has resemblances with the Östrem curve (figure 5.1), however, has a much shallower gradient to the maximum thinning rate at 1-2cm of debris thickness. This maximum coincides with that of Östrem's, but the slight increase in thinning rates with debris thickness on site 1 is unique to this graph. There is a large spread of data, especially at a thickness of 4cm, with thinning rates varying between ~1.5cm/day and ~11cm/day. Figure 5.3 shows the daily temperatures measured with a thermoanemometer on the glacier and from the weather station located above Longyearbyen. There is a much greater variation in temperatures with measurements from the thermoanemometer than the weather station, however, both trends show an increasing temperature with time.

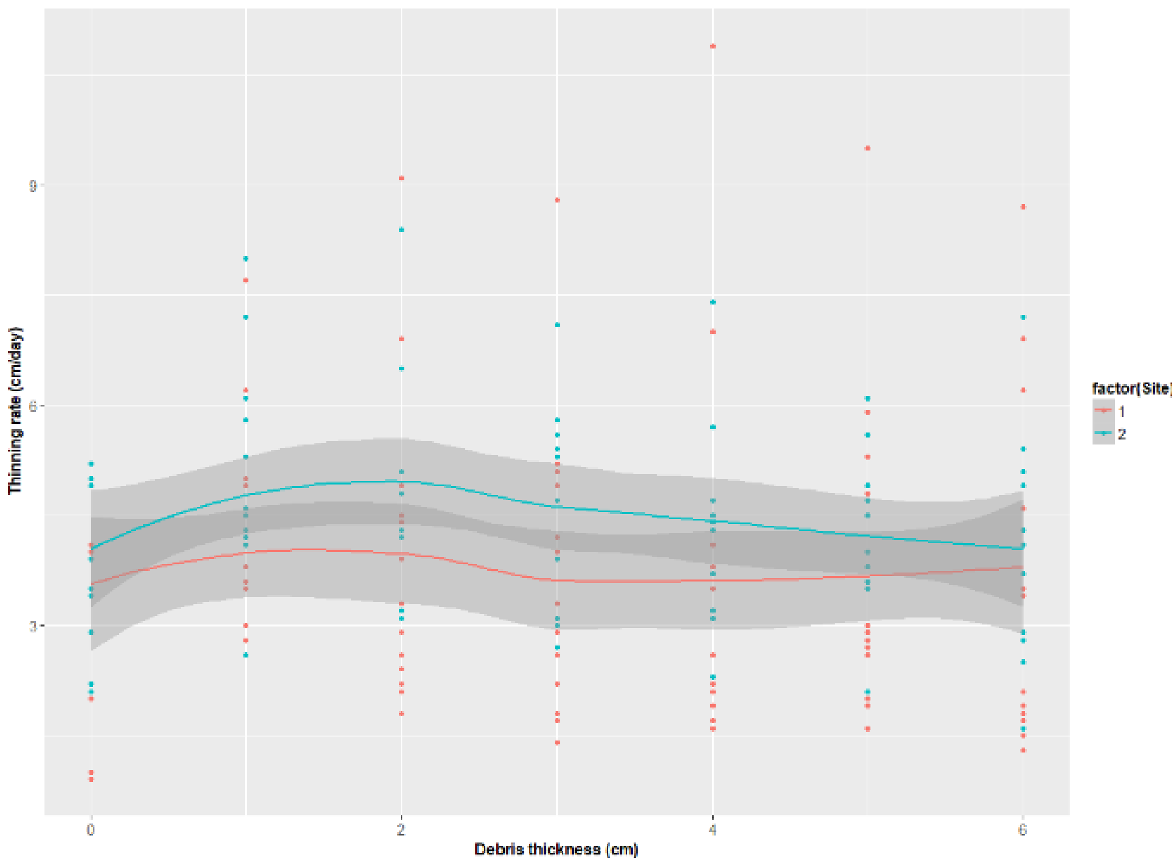


Figure 5.2: Graph showing the thinning rates of the ice under different debris thicknesses. Site 1 refers to the debris piles with a mean albedo of 0.32 and site 2 with a mean albedo of 0.42.

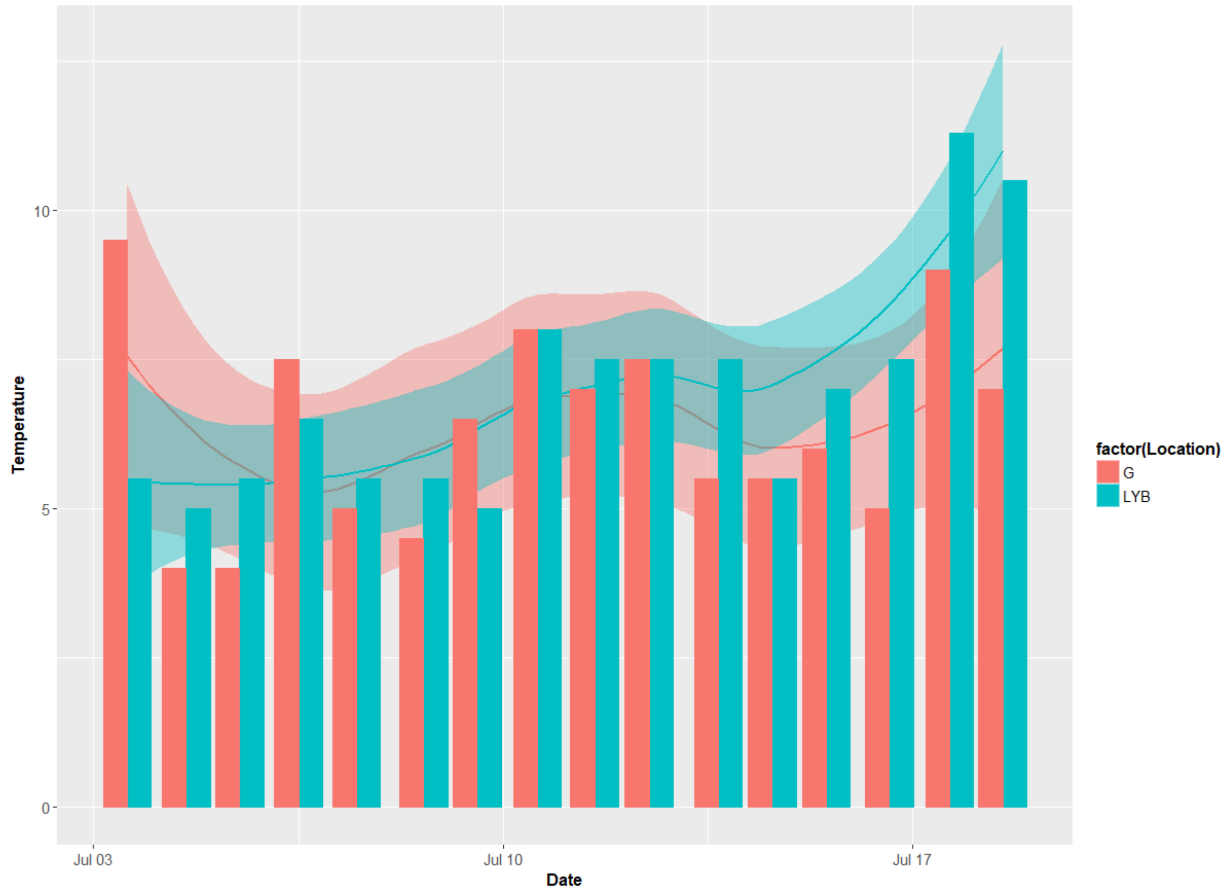


Figure 5.3: Graph showing the measured temperatures at Longyearbreen over the time of data collection. Location G is the temperature measurements taken with a thermoanemometer on the Glacier and LYB represents the Longyearbyen weather station temperature measurements

Aerial images:

Figure 5.4 shows the DEM produced from the aerial imagery of the UAV flown over the glacier tongue to show the debris cover. There is a large amount of debris covering the glacier terminus, including a larger terminal moraine. Supraglacial debris features such as dirt cones are also visible slightly further up glacier. Figure 5.5 shows the 2017 aerial image with the visual terminus of the 2011 aerial image traced in red. There appears to be an increased debris cover with time.

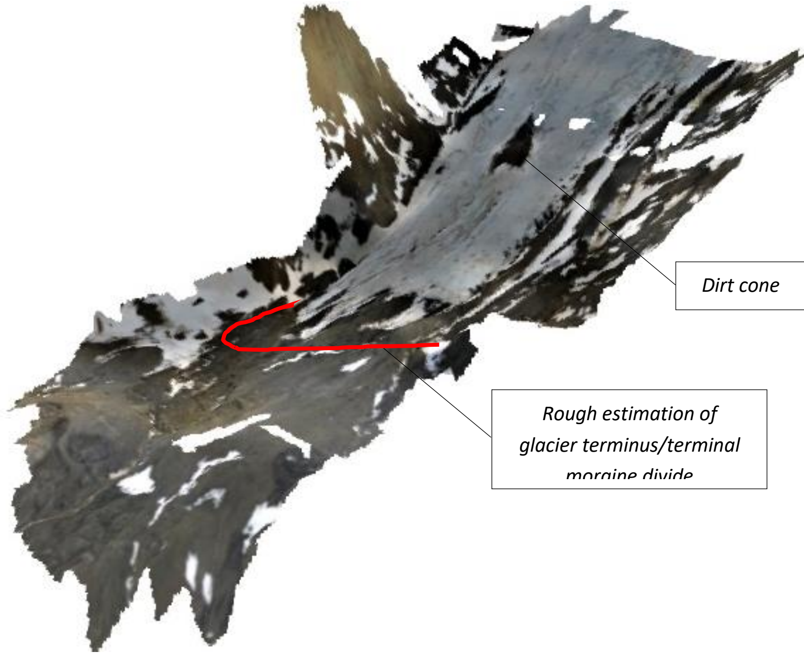


Figure 5.4: DEM produced on ArcScene showing the Longyearbreen debris-covered glacier terminus.

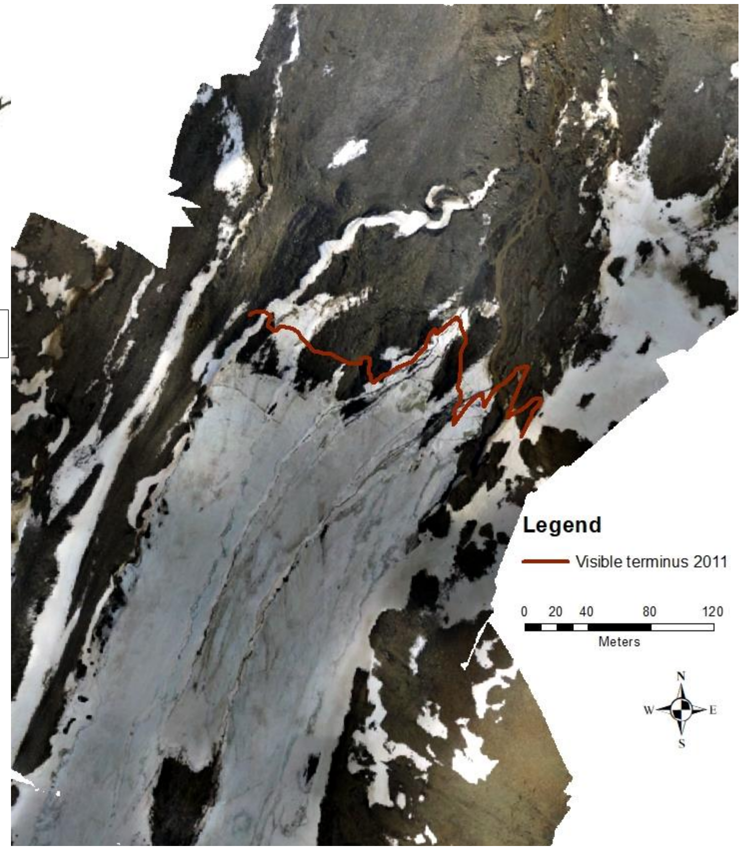


Figure 5.5: Aerial image produced on ArcMap showing the Longyearbreen glacier terminus and the visible terminus of the glacier in 2011.

Conclusion

As shown by many studies, a thin layer of debris enhances melt, whilst a thick layer inhibits melt, something visible in the trends found in this data. (Fujii, 1977; Reid et al., 2012; Yao et al., 2014). However, Östrem's (1959) curve showed a very steep gradient either side of the maximum melt rates unlike the graph in figure 5.2; this may be due to the variation and overall increase in temperature over time (figure 3) which is yet to be taken into account in this study. Reid et al. (2012) states that the lower albedo of thin debris layers on the ice can significantly enhance melting, as can also be seen in figure 5.1. Conversely, the data shows that the debris of higher albedo enhances melt rates further than the debris of lower albedo; however, this may be due to the difference in rock type and their individual thermal properties. Further data analysis and reading is needed to fully understand the data collected.

Callum: An investigation into the spatial and temporal variations of meltwater storage on Longyearbreen Glacier, Svalbard

Introduction:

Storage meltwater is the delayed runoff of meltwater from a glacier due to supraglacial, englacial or subglacial interception (Jansson et al, 2003; Singh et al, 2011). The storage of meltwater has implications for global sea level rise as well as for towns and cities with water supplied by glacierized catchments (Hagen et al, 2003). Thermal regime of a glacier has been identified to play a key role in the spatial and temporal scales of meltwater storage (Hodgkins, 2001; Hodgkins, 1997). Studies on temperate glaciers have shown storage of meltwater to be dominated by englacial and subglacial features (Östling and Leb, 1986; Iken et al, 1983). Ice in a non-temperate glacier acts as an aquiclude which prevents the formation of englacial and subglacial storage features; and are therefore dominated by supraglacial storage. Svalbard, in the Norwegian high arctic, consists of cold based glaciers such as Scott Turnerbreen and polythermal glaciers found at lower altitudes (Hodgkins, 1997). Meltwater storage can be identified on three different timescales: long term, intermediate and short-term. The project will focus on the short-term. Short-term storage is the diurnal cycles of runoff and storage of meltwater (Jansson, 2003).

Aims:

1. To measure how the storage of meltwater varies during an arctic melt period, both temporally and spatially.
2. To develop an understanding of the efficiency of the hydrological system of Longyearbreen glacier.
3. To identify the location of meltwater storage on Longyeabreen glacier.

Objectives:

1. To carry out discharge measurements on the proglacial stream of Longyearbreen glacier twice a day (morning and afternoon) to identify fluctuations in proglacial discharge.
2. To calculate a degree day factor for Longyearbreen glacier using daily ablation and 24-hour temperature monitoring.
3. To measure the precipitation for the study period so that storage volume calculated is representative of solely glacier melt.

Methodology:

Six stations collecting data on precipitation, ablation, temperature and humidity were established on Longyearbreen glacier. Ablation stakes were 1 metre long plastic tubing and a measurement from the ice surface to the top of the stake was taken daily to measure ablation.

ETI precipitation gauges were fixed to the top of each of the ablation stakes. These were assessed for precipitation content daily and emptied when necessary to ensure weight of precipitation did not cause the stakes to lean.

OM-EL-USB-2 temperature loggers were fixed to each of the ablation stakes using cable ties. Each logger took a reading every 15 minutes for this period. The gauges were in weather proof bags and placed 20cm above the glacier surface so that data represented the ice/air interface. The error for temperature and relative humidity recorded to be, +/- 0.55°C and +/-2.25%, respectively.

Discharge of the proglacial stream flowing from Longyearbreen glacier was measured daily. Measurements were taken at 0900 and 1800. The method Discharge is equal to cross-sectional area multiplied by velocity was used (D = AV). The stream was split into nine subsections and for each the depth and flow rate was measured using a measuring staff and flow metre respectively. The full width of the stream was measured using a laser range finder.

Snow/ice cover estimations were made for the Longyearbreen catchment which had the potential to contribute to discharge at the point where discharge was measured. This was done using sentinel data accessed from the Sentinel Hub playground and areas of snowcover were extracted using ArcGIS.

The density of three types of material, firn, slush and glacier ice, was calculated. The densities of the material was then used to calculate melt water equivalent at each of the ablation sites.

Results:

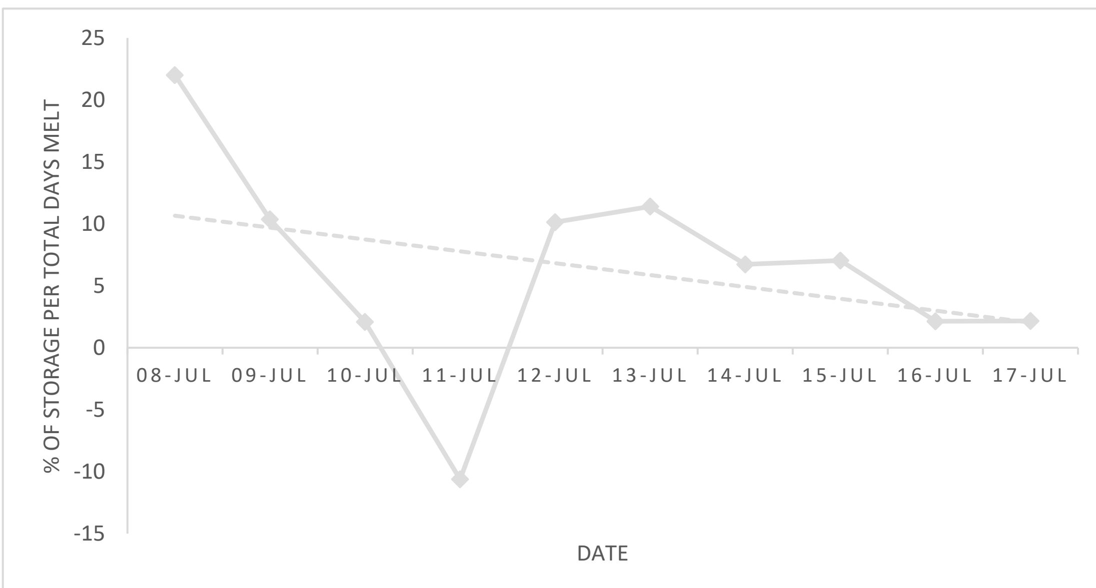


Figure 6.1: The percentage of storage per volume of daily melt (blue solid) for period 08 July to 17 July. The trend in percentage storage for the same period is also shown (dashed blue line).

Preliminary Conclusions:

- Daily meltwater storage as a percentage of total daily melt decreased as the quantity firn/snow available for supraglacial storage decreased.
- The majority of meltwater stored on Longyearbreen was stored supraglacial in the snowpack.
- Stream discharge, glacier melt, and temperature all had an increasing trend for the study period.
- The melt/°C above 0°C decreased as the slope of the glacier decreased. It is suggested this is due to katabatic winds on steeper glacier sections enhancing melt.

Emily: Ionic and Isotopic variability of Longyearbreen's proglacial stream during the 2017 ablation season

The area of glacial research into the understanding of the internal drainage system of a glacier and its effects on the ice loss through melt over the ablation season, has been of great interest in Svalbard (Hodson et al, 2000; Rutter et al, 2011). The water chemistry and oxygen isotope concentrations of a proglacial stream can give insight into the efficiency of the internal drainage system and how it changes over time (Hodson et al, 2002; Tranter et al, 1996; Rutter et al, 2011; Threakstone and Knudsen, 1993). Research in Svalbard can then be applied to other areas, such as Greenland, which experience similar temperature changes which could be the reason for greater ice loss in these regions.

This fieldwork follows a hydro-chemical study conducted over 10 years ago on the same glacier in Svalbard (Yde et al, 2008), with an aim to compare results in order to understand the glacial processes and how they may have changed over time.

Aim:
To identify variations in the ionic and isotopic characteristics of Longyearbyen's proglacial stream to determine the englacial stream efficiency.

Objectives:

1. To collect water samples Bi-daily from two locations for laboratory analysis to gather data on water chemistry (anion and cation concentrations) and oxygen isotopes of the proglacial stream.
2. Identify how variations temperatures and melt effect the water chemistry and oxygen isotopes of the proglacial stream.

Methods:
Field Methods for water chemistry and oxygen isotope data

- Two sampling locations will be identified (Figure 2), where samples will be taken twice daily from each location. One location will be close to the terminus of the glacier and the other will be further downstream where another proglacial stream joins.
- 30ml samples for water chemistry and 30ml samples for oxygen isotope will be taken and immediately pressure filtered through 0.45μm cellulose nitrate filters, the samples will then be sealed and taken for laboratory analysis.

Laboratory Analysis for Water chemistry data

- Concentrations of cations (Calcium, Magnesium, Sodium and Potassium) and anions (Sulphate and Chloride) will be determined:
    - Cations: ion chromatograph metrhm compact C4-150/4.0 column with Tartaric Acid/Dipicolinic Acid eluent
    - Anions: ion chromatograph metrhm compact IC 761 with metrosep C4-150/4.0 column and suppressor mode with a sodium carbonate/ sodium bicarbonate eluent.

Laboratory Analysis for Oxygen Isotopes

- Laboratory analysis will be done by an external laboratory.
    - Oxygen isotopes will be measured in the NERC isotope geosciences laboratory, British Geological Survey.

Results:

As laboratory results have been delayed, analysis of all results has not been fully completed, therefore the water chemistry data is not available. However, oxygen isotope values have been analysed (figure 7.1).

Yde et al (2008) identified three periods within the ablation season: the early melt season, peak flow period and a late melt season. The results suggest the period of time in which this study was conducted was in the transition between the early melt season and peak flow, however most of the results are within the peak flow period.

As the ablation season begins to develop a rise in $\delta^{18}O$ values is expected (figure 7.1) due to the rise in air temperatures and increasing melt rates. The analysis of the $\delta^{18}O$ in Longyearbreens proglacial stream shows the switch between a snowmelt dominated system to one that is driven by summer rainfall. The increase of $\delta^{18}O$ values is ~2% which is similar to that of Yde et al (2008) which comparatively had a rise of ~3%.

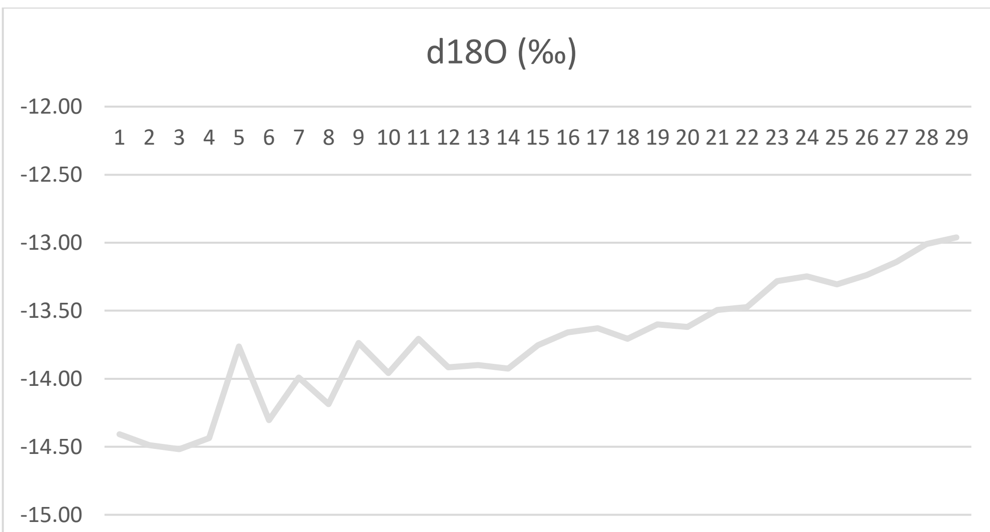


Figure 7.1. $\delta^{18}O$ values from Longyearbreens proglacial stream 2017

Conclusion:

The region of Svalbard and the warmer temperature it experiences can be used to evaluate melt in other Arctic regions, such as Greenland, therefore understanding en-glacial and subglacial systems is of great importance for future ice loss. The short and long-term hydrochemistry of sub-glacial waters are controlled by a complex mix of factors, including climate, lithology and englacial and sub-glacial processes. The results show to the development of a more efficient sub-glacial drainage system with the increase of oxygen isotope values. During the ablation season temperature increases leading to the higher melt rates causing more water to be flushed out the system. The water which could have been stored within the glacier with a less efficient system is lost during the melt season, therefore the efficient system within a glacier increases the total ice loss of the glacier.

Will: Evolution of a Supraglacial Stream System

With climate change causing air temperatures to rise at an increasing rate all around the world, this effect is most prevalent in the Arctic Circle, where air temperature change is exacerbated by phenomenon known as the Polar Amplification effect (Holland, M., 2003; Masson-Delmotte, V., 2005). This has the effect of reducing precipitation onto glaciers and ice sheets, as well as increasing their melt rates, serving only to increase the rate at which ice retreat occurs. This increase in melt means that there will be a larger volume of meltwater flowing over, through and around large volumes of ice, and due to the slightly higher temperature of the flowing water, will only serve to increase the melt that the glaciers and ice sheets undergo.

Aims:

1. Measure and assess the changes in supraglacial stream velocity and discharge on multiple streams over the course of the three week study period.
2. Assess how the supraglacial stream system changes in both plan-form and cross-sectional profiles over a three week period in the ablation season.
3. To find how the supraglacial stream system has changed in plan-form profile over the course of several years.

Objectives:

1. Take multiple velocity readings of supraglacial streams at ten different sites on three streams, spread across the glacier.
2. At each site, measure the width of the stream and the depth at three points to build a cross-stream profile of the stream bed.
3. Document changes in supraglacial stream plan-form using aerial images and sketches, to determine how the streams change in sinuosity and shape.
4. Utilise velocity, width and depth data to estimate changes in supraglacial stream discharge over the expedition period.

Methods:

Following the guide set out by JC Lambie in 1978, I employed a valeport flow-meter to measure stream velocity at three equidistant points across the supraglacial stream, at each of the ten sites I had chosen. At each of those three points, I also took a depth measurement using a metric rod, inserted into the stream at a right angle to a stadia rod (Gleason et al., 2016). The width of the stream at each site was measured using a measuring tape. The velocity, depth and width at each site was recorded by day and by time, in order to gain an temporal understanding of change, and were used to produce graphs showing discharge, using the area-velocity method that Lambie also describes. The depth readings taken at each site were used to produce cross-stream profiles of the stream bed, showing changes in stream bed shape over time, and in different streams with higher/lower discharges.

Changes in supraglacial stream plan-form were documented at each site alongside the velocity readings, with sketches helping to identify areas of change. Aerial photography was also used, with pictures taken from a Phantom 4 drone (Giardina, 2017), to obtain information on the plan-form of the supraglacial streams as a whole.

Results:

The first supraglacial stream that was studied, on the South side of the glacier, stayed relatively the same throughout the three-week study, with its discharge only increasing from 0.0012 m/s^3 at the start of the expedition, to 0.0304 m/s^3. While it did get slightly wider and deeper as the melt season progressed, it did not do so on anywhere near the scale that the second and third supraglacial streams that I studied did. However, whilst the first stream didn't show much change in cross-sectional shape or discharge, it had the largest changes in plan-form. Due to the slow stream and the relatively flat surface of the glacier at that point, the stream had multiple meanders and so was very sinuous. These meanders changed in number and sinuosity over a relatively short period of time (a few days or so). In contrast, the third stream that I took measurements from was much larger and faster flowing. While the third stream changed very little in its plan-form shape, it changed dramatically in cross-sectional shape and discharge. For example, its width increased from 0.238 meters to a maximum of 1.349 meters, with a minimum discharge of 0.0164 m/s^3, and a maximum recorded discharge of 0.421 m/s^3 (just over 0.4 tons of water passing every second).

Conclusion:

As expected, there was an increase in meltwater discharge through all of the measured supraglacial streams on Longyearbreen Glacier as the ablation season progressed. This increase in meltwater flow, caused in part by the increasing air temperatures, leads to the opinion that, as global air temperatures rise even further from global warming, there will be larger volumes of meltwater running over glaciers and ice sheets around the world, especially in the polar regions, due to the polar amplification effect. As meltwater causes a slight increase in melt rates of the ice around it, larger volumes of warmer meltwater flow around ice masses would therefore cause even more melting to occur than before. This positive feedback loop is already in progress, albeit at a very slow rate, yet with increasing global air temperatures, will soon begin to pick up the pace, causing glaciers and ice caps to retreat at an even faster rate.

Holly: To assess the spatial and temporal variations in summer ablation across Longyearbreen, Svalbard

Aims:

1. To assess the controls of summer surface melt of clean ice on Longyearbreen in Svalbard.

2. To analyse the spatial variations in melt across clean ice of Longyearbreen glacier.

Objectives:

1. Utilise ablation stakes to gather primary measurements of summer melt on Longyearbreen between the 2nd – 18th July 2017.

2. Employ hygrometer-thermos to measure primary air temperature and wind speed at each ablation stake.

3. Use a compass clinometer to gather data on the prevailing wind direction at each ablation stake.

4. Apply secondary data from Hagen and Leistøl (1990) to establish a pattern of melt and air temperature on Longyearbreen glacier since 1977.

Project Background:

Climate conditions are also spatially variable in Svalbard with central regions "receiving 40% less precipitation than the east and south" (Nuth et al., 2010). Recent changes in atmospheric circulation patterns over Svalbard (Lang et al., 2015) has also seen south-westerly flows bringing warmer air over the glaciated region, increasing summer temperatures which could have a knock-on effect on glacial melt. Due to its high latitude location, there is a general consensus between scholars (Førland and Hanssen-Bauer, 2003; Nuth et al., 2010) that Svalbard could be particularly sensitive to a rise in air temperature (IPCC AR5, 2013). These combined factors make Svalbard is an essential area to study the impact of temperature on summer ablation.

Further climate conditions that are not directly associate with temperature are also known to have an impact on summer ablation, specifically wind speed and direction (Ångström 1933). The location of Longyearbreen, my study glacier (figure 8.1) is within a valley, which causes wind to be channelled over the glacier increasing in force (Humlum 2002), potentially scouring snow and ice off the glacier as a result. This research will investigate whether this channelling of wind has resulted in increased ablation on clean ice on Longyearbreen glacier during the summer season.

In addition to climatic impacts on melt rates, my research also studies the spatial disparities in clean ice melt on a land terminating glacier in the Arctic – specifically the impact of elevation on melt. There is a general agreement amongst Arctic scholars such as retreat (Hagen et al., 2003; Nuth et al., 2010), that glaciers at lower elevations are experiencing more rapid thinning and retreat. Part of Longyearbreen glacier lies at 250MASL and ranges up to 850MASL, however my research only covers up to 531 MASL due to health and safety concerns. This elevation allows me to assess the variability in ablation across Longyearbreen glacier and assess whether this matches the wider Arctic pattern.

Method:

The glaciological method (Kaser et al., 2003) was implemented to measure the surface melt due to its accurate and most detailed methodology. One-meter white plastic stakes were inserted using an ice drill an average of 23m in elevation apart, as distance in elevation rather than meters apart is judged to be a better method of measuring mass balance, according to Fountain and Vecchia, 1999. White plastic stakes were chosen due to their lightweight and transportable nature (Kaser et al., 2003), their colour reducing solar absorption and radiation into the ice. Each stake was marked with a DGPS point (Kaser et al., 2003), allowing the mapping of each site (figure 8.1), as well as ensuring each stake could be found during poor weather conditions. In total, 13 stakes were inserted along the glacier, a sufficient amount as per Fountain and Vecchia, 1999. To measure melt, each stake was drilled using an ice drill to a known depth (Kaser et al., 2003) which was then recorded. Each day, the stake was measured from the top of the stake to the snowline (or ice line when all the surface snow had melted), which provided an accuracy to the centimetre (Hagg et al., 2004) of the surface melt.

Daily air temperature readings were taken at each stake with a hygrometer-thermo to assess the sensible heat flux from and to the glacier surface (Kaser et al., 2003), with data supported by an air temperature logger which took 24-hour measurements of air temperature during the expedition. Wind speed and direction was measured 1m above the ground using the hygrometer thermo and a compass clinometer.

Secondary Data Collection:

Secondary data from the Svalbard Airport has been used to supplement both my temperature and wind speed data. The airport is located approximately 6.3km away from the study site, and is 28 MASL. These factors have been taken into consideration when using Airport data to supplement my primary data, as temperatures are known to be greater at lower elevations as a result of higher air pressure.

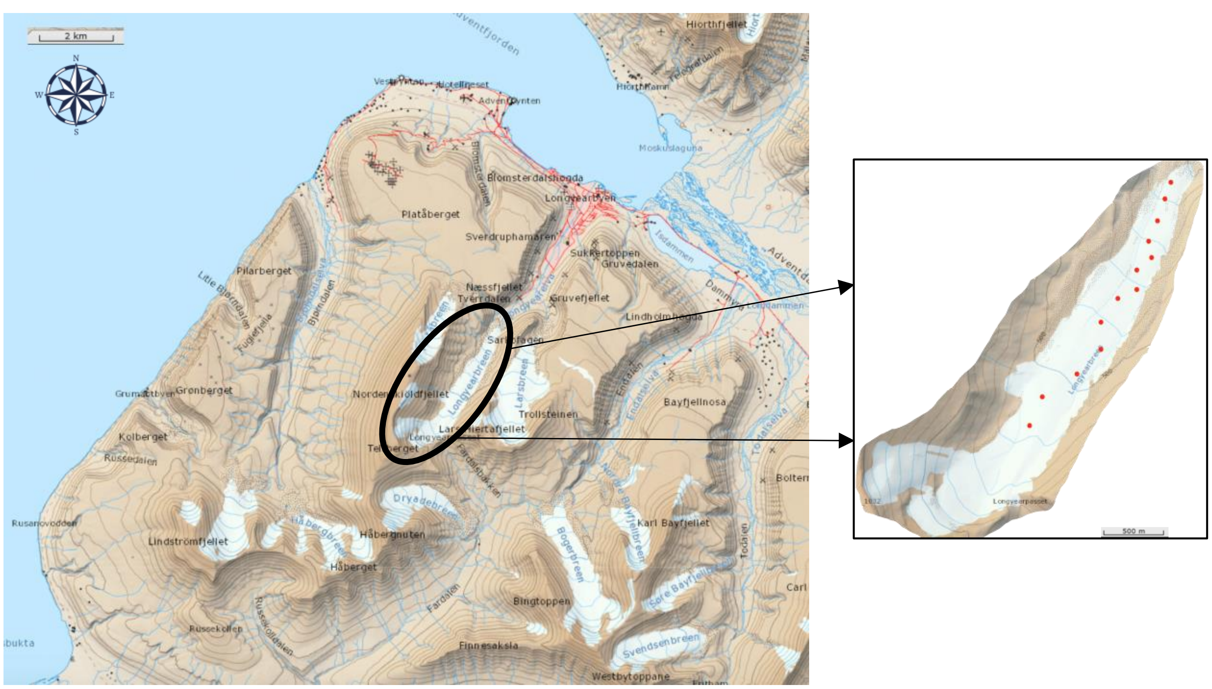


Figure 8.1: Location of study area from TopoSvalbard

Conclusions:

Preliminary analysis of data presents a weak correlation between air temperature increase and melt rates, and while this correlation does not necessarily indicate causation, scholars including Hagen et al., 2003 have observed a similar trend on other land-terminating Arctic glaciers. Stakes at lower elevations appear to match this consensus, showing a rapid melt response (either on the same or next day) to air temperature increase. However, stakes at higher elevations show localised contrasts to this theory, where melt and temperature do not appear to be strongly related. However, this may be due to external factors such as wind exposure and overnight freezing playing a more significant role in stakes over 400 MASL.

The effects of wind speed on mass balance is a relatively understudied area of glacial research in the Arctic, however my data shows that particularly strong wind events (during this expedition, more than 3m/s-1), one of which occurred on the 14th July, have an increased effect in the accumulation zone. This event saw an increased firn loss of 32.9cmd-1 between stakes 10 – 13 inclusive, with an average of 6.4m/s-1. I hypothesise that this extreme wind event scoured the surface of the glacier of all unstable snow (Singh et al., 2011) and caused mass glacial loss.

I further hypothesise that this wind event was exacerbated by the direction of the prevailing wind; the glacier flows in a north-east direction towards Adventfjorden bay, and so the north-easterly winds observed on Longyearbreen on the 14th July were funnelled down glacier, allowing them to magnify and increase in force (Humlum 2002; Holden 2012) and therefore their ability to remove the less stable upper areas of snow and firn.

Expedition Conclusion and Recommendations:

During the three and a half weeks, we saw first-hand the evolution of a glacial landscape which was fascinating to all members of the team. Our time in the Arctic was only a short experience of a glacial ablation season, but allowed the team to gain valuable fieldwork and team-work experience. Each member successfully collected 16 days of data whilst in Svalbard which could not have been done without team-work. Our days were mentally and physically challenging but with planning and preparation, our time was spent efficiently in order to gain the most experience in glacial conditions. The expedition as a whole was an extremely rewarding experience and each member feels a great achievement having completed their data collection. The results and conclusions drawn from the data show the progress of individuals dissertation analysis thus far.

The fieldwork we undertook follows the techniques used for decades by academics, therefore the team felt confident with the reliability of their results. Most of the data have comparative studies, therefore we are able to make more accurate conclusions and predictions about our individual results. However, a limitation to all of our results was the length of time spent in the Arctic. Conducting research over a full ablation season would be a suggestion for future data collection.

References:

Azzoni, R., Senese, A., Zerboni, A., Maugeri, M., Smiraglia, C. and Diolaiuti, G. (2016). Estimating ice albedo from fine debris cover quantified by a semi-automatic method: the case study of Forni Glacier, Italian Alps. The Cryosphere, 10(1), pp.665-679.

Bezinge, A. (1987) 'Glacial meltwater streams, hydrology and sediment transport: the case of the Grande Dixence hydroelectricity scheme' in Gurnell, A. M. and Clarke, M. J. (Eds), Glacio-fluvial Sediment Transfer: an Alpine Perspective. Wiley, Chichester. pp. 473-498.

Bogen, J. (1991) `Erosion and sediment transport in Svalbard', in Gjessing, Y., Hagen, J. O., Hassel, K. A., Sand, K., and Wold, B. (Eds), Arctic Hydrology. Present and Future Tasks. Norwegian National Committee for Hydrology Report No. 23, Oslo. pp. 147-158

Bogen, J. and Bønsnes, T. (2003). Erosion and sediment transport in High Arctic rivers, Svalbard. Polar Research, 22(2), pp.175-189.

Dowdeswell, J., Benham, T., Strozzi, T. and Hagen, J. (2008). Iceberg calving flux and mass balance of the Austfonna ice cap on Nordaustlandet, Svalbard. Journal of Geophysical Research, 113(1), pp.1-12.
Ferguson, R. and Hodson, A. (1999). Fluvial suspended sediment transport from cold and warm-based glaciers in Svalbard. Earth Surface Processes and Landforms, 24(11), pp.957-974.

Fowler, A. C. (1987). Sliding with cavity formation. Journal of Glaciology, 33, pp.255-267

Fujii, Y. (1977). Field Experiment on Glacier Ablation under a Layer of Debris Cover. Journal of the Japanese Society of Snow and Ice, 39(1), pp.20-21.

Giardina, C. (2017). [Photograph].

Gleason, C. et al., (2016). Characterizing supraglacial meltwater channel hydraulics on the Greenland Ice Sheet from in situ observations. Earth Surface Processes and Landforms, 41(14), pp.2111-2122.

Hagen, J.O., Kohler, J., Melvold, K. and Winther, J.G., 2003. Glaciers in Svalbard: mass balance, runoff and freshwater flux. Polar Research, 22(2), pp.145-159.

Harbor, J. M. (1992) 'Application of a general sliding law to simulating flow in a glacier cross-section', Journal of Glaciology, 38, 182-190.

Hodgkins R. (1996) Seasonal trend in suspended-sediment transport from an Arctic glacier, and implications for drainage-system structure. Annals of Glaciology, 22: 147– 151.

Hodgkins, R., 1997. Glacier hydrology in Svalbard, Norwegian high arctic. Quaternary Science Reviews, 16(9), pp.957-973.

Hodgkins, , R., (2001), 'Seasonal Evolution of Meltwater Generation, Storage and Discharge at a Non-Temperate Glacier in Svalbard', Hydrological Processes, 15, pp. 441-460

Hodgkins, R., Hagen, J. and Hamran, S. (1999). 20th century mass balance and thermal regime change at Scott Turnerbreen, Svalbard. Annals of Glaciology, 28(1), pp.216-220.

Hodson, A., Tranter, M., Curnell, A., Clark, M., Hagen, J. (2002) 'The hydrochemistry of Bayelva, a high Arctic proglacial stream in Svalbard' Journal of Hydrology, pp 91-114.

Hodson, A., Tranter, N., Vatne, G. (2000) 'Contemporary rates of chemical denudation and atmospheric CO2 sequestration in glacier basins: an Arctic perspective' Earth Surface Processes and Landforms, pp 1447-1471.

Holland, M. (2003). The North Atlantic Oscillation–Arctic Oscillation in the CCSM2 and Its Influence on Arctic Climate Variability. Journal of Climate, 16(16), pp.2767-2781.Lambie, J.C, 1978

Jansson, P., Hock, R. and Schneider, T., 2003. The concept of glacier storage: a review. Journal of Hydrology, 282(1), pp.116-129.

Kostrzewski, A., Kaniecki, A., Kapuscinski, J., Klimczak, R., Stach, A., and Zwolinski, Z. (1989) `The dynamics and rate of denudation of glaciated and non-glaciated catchments in central Spitsbergen', Polish Pol. Res., 10, 317-367

Masson-Delmotte, V., Kageyama, M., Braconnot, P., Charbit, S., Krinner, G., Ritz, C., Guilyardi, E., Jouzel, J., Abe-Ouchi, A., Crucifix, M., Gladstone, R., Hewitt, C., Kitoh, A., LeGrande, A., Marti, O., Merkel, U., Motoi, T., Ohgaito, R., Otto-Bliesner, B., Peltier, W., Ross, I., Valdes, P., Vettoretti, G., Weber, S., Wolk, F. and YU, Y. (2005). Past and future polar amplification of climate change: climate model intercomparisons and ice-core constraints. Climate Dynamics, 26(5), pp.513-529.

Mette Riger-Kusk, (2006), 'Hydrology and hydrochemistry of a High Arctic glacier: Longyearbreen, Svalbard', (Master Thesis), [Online], Available at: https://brage.bibsys.no/xmlui/bitstream/handle/11250/277221/Riger_Kusk_Hydrology%20and%20hydrochemistry%20of%20a%20high%20arctic%20glacier.pdf?sequence=1 , (Accessed 27th December 2017)

Moholdt, G., Nuth, C., Hagen, J. and Kohler, J. (2010). Recent elevation changes of Svalbard glaciers derived from ICESat laser altimetry. Remote Sensing of Environment, 114(11), pp.2756-2767.

Nuth, C., Moholdt, G., Kohler, J., Hagen, J. and Kääb, A. (2010). Svalbard glacier elevation changes and contribution to sea level rise. Journal of Geophysical Research, 115(F1).

Östrem, G. (1959). Ice Melting under a Thin Layer of Moraine, and the Existence of Ice Cores in Moraine Ridges. Geografiska Annaler, 41(4), pp.228-230.

Reid, T., Carenzo, M., Pellicciotti, F. and Brock, B. (2012). Including debris cover effects in a distributed model of glacier ablation. Journal of Geophysical Research, 117(1), pp.1-15.

Repp, K. (1988) `The hydrology of Bayelva, Spitsbergen', Nord. Hydrol., 19, 259-268.

Rutter, N., Hodson, A., Irvine-Fynn, T., Solas, M. (2011) 'Hydrology and hydrochemistry of a deglaciating high-Arctic catchment, Svalbard' Journal of Hydrology, pp 39-50

Singh, P., Kumar, A. and Kishore, N., 2011. Meltwater storage and delaying characteristics of Gangotri Glacier (Indian Himalayas) during ablation season. Hydrological Processes, 25(2), pp.159-166.

Sollid, J., Tonning, T., Mysterud, R., Vatne, G., Ødegård, R. and Etzelmüller, B. (2000). Glacier characteristics and sediment transfer system of Longyearbreen and Larsbreen, western Spitsbergen. Norsk Geografisk Tidsskrift - Norwegian Journal of Geography, 54(4), pp.157-168.

ST. Germain, S. and Moorman, B. (2016). The development of a pulsating supraglacial stream. Annals of Glaciology, 57(72), pp.31-38.

Swift, D.A., Nienow, P.W., Hoey, T.B., Mair, D.W.F., (2005), 'Seasonal Evolution of Runoff from Haut Glacier d'Arolla, Switzerland and Implications for Glacial Geomorphic Processes', Journal of Hydrology, Vol. 309, pp. 133-148

Theakstone, W., Tvis Knudsen, N. (1993) 'Isotopic and Ionic Variations in Glacier River Water During Three Contrasting Ablation Seasons' Hydrological Processes, 10, pp 523-539.

Tranter, M., Brown, G., Hodson, A., Gurnell, A. (1996) 'Hydrochemistry as an indicator of subglacial system structure: a comparison of alpine and sub-polar environments' Hydrological Processes, pp 541-556.

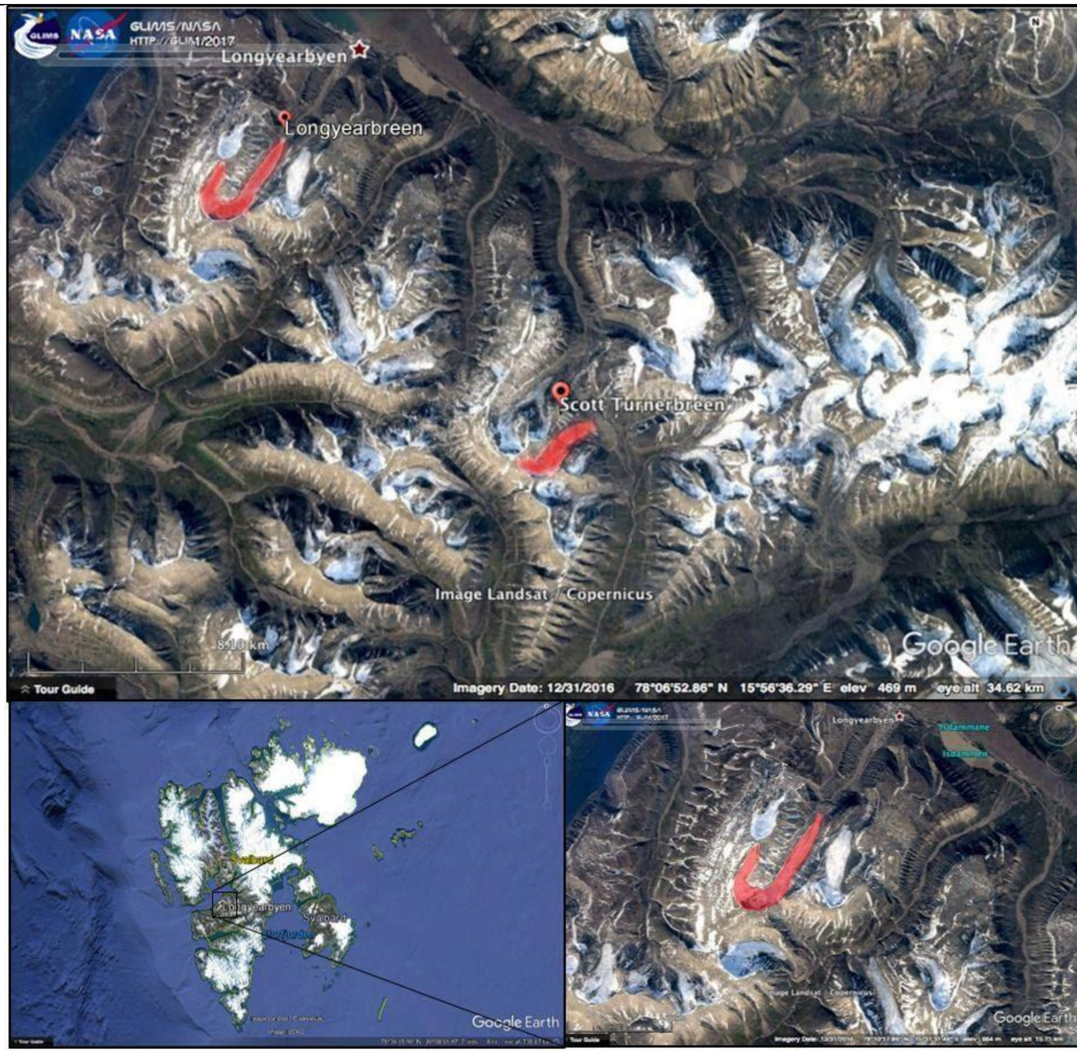
Vatne, G., Etzelmuller, B., Odégard, R-S., and Sollid, J. L. (1992) 'Glaciofuvial sediment transfer of a sub-polar glacier, Erikbreen, Svalbard', Stuttgarter Geograph. Stud., 117, 253-266.

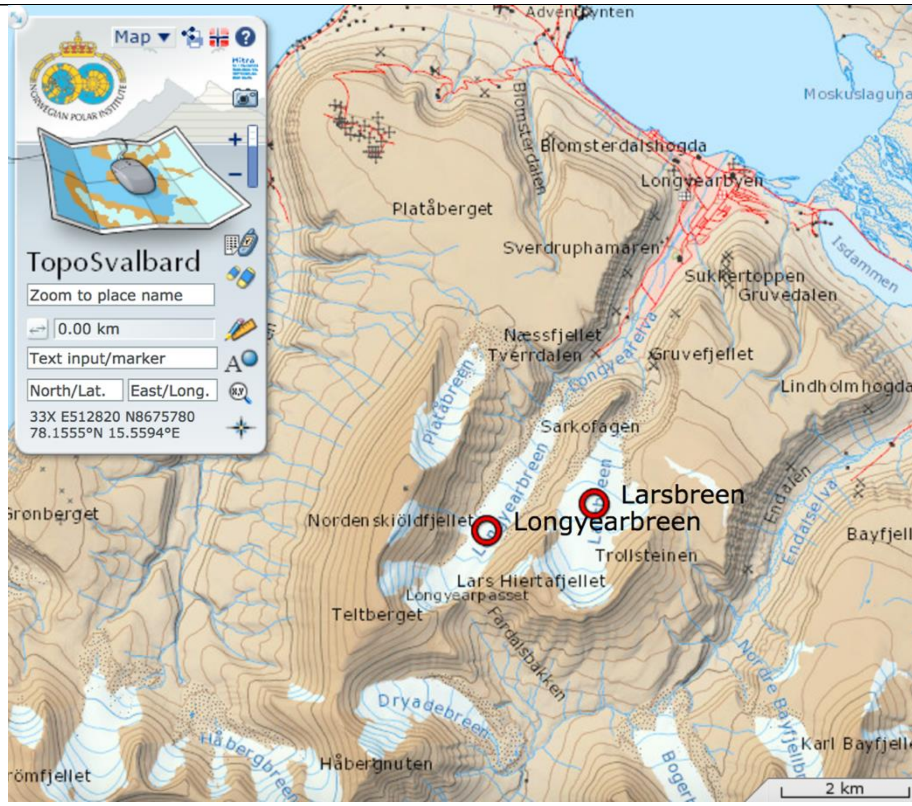
Yao, J., Gu, L., Han, H., Wang, Y. and Liu, S. (2014). The surface energy budget on the debris-covered Koxkar Glacier in China. Environmental Earth Sciences, 72(11), pp.4503-4510.

Yde JC, Riger-Kusk M, Christiansen HH, Knudsen NT, and Humlum O (2008) Hydrochemical characteristics of bulk meltwater from an entire ablation season, Longyearbyen, Svalbard. Journal of Glaciolog y, 54: 259-272.

Geography Dissertation Fieldwork & Travel Risk Assessment Form

Note	***Travelling without appropriate risk assessment may prejudice subsequent insurance claims.***		
Project title & fieldwork activities	*To understand the geomorphological/glaciological processes of an active glacial system*		
Expedition Leader	*Holly Chubb*	***Other participants***	*Hayley Andrews* *Emily Cave* *Connor Downes* *James Dickinson* *Callum Cochrane* *Carl Giardina* *William Ogden*
School	*Geography, Politics and Sociology*	***Unit***	*Geography*
Travel dates	*28/06/17 – 20/07/17*	***Date of assessment***	*20/06/17*

Fieldwork Location (attach map)	 *Longyearbreen Glacier, Svalbard.*

	 *Field site location of Longyearbreen and Larsbreen, Svalbard.*  *Field site location of Scott Turnerbreen, Svalbard.*

Emergency contacts ** = required for overseas travel only*	
Contact overseas*	*Chris Borstad, Associate Professor, Snow and Ice Physics, The University Centre in Svalbard (UNIS)* *+47 79 02 64 14* *chris.borstad@unis.no*
Accommodation	*The University Centre in Svalbard (UNIS)* *P.O. BOX 156* *N-9171 Longyearbyen* *Norway* *+47 79 02 33 00*
Emergency services	*Telephone: 112* *The emergency telephone number for the Governor of Svalbard is 0047 79 02 12 22. Need to dial the 0047 prefix first when calling from a satellite phone.*
British Embassy*	*Sysselmannen pa Svalbard* *Postboks 633* *NO-9171 Longyearbyen* *Norway* *+47 79 02 43 00*
Insurance*	Emergency claims are dealt with by Chubb Assistance: Tel: +44 (0) 207 895 3364 Our policy number is: 64811698 Also contact Newcastle University immediately regarding all claims: Email: insurance@ncl.ac.uk or Telephone: +44 (0) 191 222 6520. Also inform your tutor.
Newcastle University contact	*GPS Office telephone number: +44 (0)191 208 3923* *Nicola Kelly, School Manager: +44 (0)191 208 6477* *Security contacts are the security office who are available 24/7 on tel: +44 (0) 191 208 6817 (Security Control 24 hrs a day)*
Travel & fieldwork itinerary	• *Travel from Newcastle to London. Stay at the houses of William Ogden prior to flight from London Heathrow to Longyearbyen.*

	• *Travel from London Heathrow to Longyearbyen Airport, Svalbard, with stops in Stavanger Oslo, on 28/06/2017.* • *Once landed in Longyearbyen, we will travel to UNIS accommodation. Only taxi services recommended by UNIS will be used.* • *Data collection will take place over the following 22 days, with most travelling taking place on foot. Travel during the fieldtrip will be to the town (for food supplies), Longyearbreen, Scott Turnerbreen and potentially Larsbreen, should they be safe enough to travel to.* • *Travel to Scott Turnerbreen will involve taking a taxi along the road to reach the glacier.* • *Travel from Longyearbyen Airport to London Heathrow on 28/07/2017.* • *Team members will make their own way home once landed in London.*
Does this travel and activity present a significant risk to safety? Yes / No	

Hazards and risks

In the space provided below, you must outline ALL of the hazards and risks associated with your project

Hazard 1	*Travel & transport* *(consider vehicles, roads, public transport)*
Risks	• Bad road conditions (ice and black ice) • Collision with another vehicle • People at risk - Students, members of the public.
Control Measures	• No student will be driving a vehicle. • Minimal vehicle use will occur as the majority of travelling will be on foot, using maps and GPS systems to ensure the team doesn't get lost. • Take care when crossing roads in Longyearbyen town. Make sure to walk on designated food paths. • When using taxi services, use reliable and trustworthy companies. • Always wear a seat belt when in a vehicle.
Hazard 2	*Accommodation* *(consider security and fire safety standards)*
Risks	• Theft of belongings • Risk of fire • People at risk - Students, members of the public.
Control Measures	• Keep digital and paper copies of passport and all other important documents (e.g. insurance papers, flight tickets) • Follow fire safety procedures from UNIS in the event of a fire. • Always lock accommodation doors when out in the field, and at night. • We will attend relevant safety briefings and make ourselves aware of the safety procedures for each building.
Hazard 3	*Dealing with people and cultural differences* *(consider safety in public and private places, culture, political issues, landowners, authorities)*

Risks	● Upsetting local inhabitants with cultural differences ● Team disagreements ● People at risk - Students, members of the public.
Control Measures	● Abide to cultural customs, habits and etiquettes. ● Be open about discussing research when locals ask. ● Research Svalbard culture e.g. Polar Bears and other native animals are protected; do not harm or disrupt unless there is risk of fatality/injury. ● Everyone will respect each-others research, as we are at a research institution. ● Should team disagreements occur, these will be resolved in a polite manner through discussion. A resolution that is fair and suits all will be achieved. No grudges will be held. ● English is widely spoken, and therefore there will be no language barrier.
Hazard 4	*Infections and health conditions* *(consider food, clean water, pests, immunizations, allergies.)*
Risks	● Illness/infection ● Minor injuries: cuts and grazes from handling equipment/minor falls ● Personal injury as a result of a lack of physical fitness ● People at risk - Students
Control *Measures*	● Ensure every team member has an up to date medical form that is to be carried on them at all times in case of emergency. ● If necessary, all personal medication is to be documented and carried on the team member at all times. ● All team members are to be aware of where medication is kept for emergency conditions e.g. inhalers for asthma. ● Remember to wash hands upon return from field, and before eating. Anti-bacterial hand gel is to be used in the field. ● Each sub-group (min. 3 people) is to carry a first aid kit at all times when out in the field containing medication for minor ailments (e.g. Paracetamol) and bandaging supplies. All cuts should be treated immediately using antiseptic equipment from the first aid kit. ● Ensure team members have improved stamina levels prior to fieldtrip through individual training. ● Sub-teams to carry mobile phones, and walkie-talkies. There will be 2 satellite phones between the 8-student team at all times, with 1 sat-phone for each sub-group at all times during the expedition. ● Sub-teams to carry walkie-talkies to contact other teams in case of any issues that arise and to keep them updated as to their location. ● Do not touch wild animals as they can carry rabies and tapeworms. ● In the case of a health condition arising: Contact project/field leader. Carry out appropriate emergency measures by seeking medical attention at Longyearbyen hospital (Doctor: +79 02 42 00, Emergency; 113), if symptoms worsen. If medication is required, use pharmacy facilities (+79 02 12 12) in the town of Longyearbyen.
Hazard 5	*Extreme weather conditions* *(consider hot/cold/wet climates, hurricane season, etc)*
Risks	● Prolonged exposure to cold conditions may results in hypothermia and/or frostbite ● Working outdoors in sunlight may increase the changes of sunburn ● Rapid change of weather conditions which could leave us caught in a blizzard/fog/snow storm ● People at risk - Students, members of the public.
Control Measures	● Knowledge of the symptoms for the onset of hypothermia and frostbite so that in the event of a team member experiencing these medical issues, help can be called immediately to limit the physical damage to their body. ○ Frostbite: Initial symptoms include white spots on skin affected, numbness, stabbing cold feeling in skin. Once the individual can no longer feel these symptoms, frostbite has set in.

	○ Hypothermia: Initial symptoms include shivering, tiredness, fast breathing and cold or pale skin. Shivering may become more violent as the hypothermia gets worse, with the individual being at risk of falling unconscious. ○ When these symptoms are noticed, the whole team is to be notified and they will aid the individual in warming up. To warm the individual in the field, any damp or wet clothing will be removed and replaced by dry layers clothes and a foil blanket(s) to reduce further heat loss. Warmth will be shared from other members of the group and the patient will be encouraged to shiver to promote heating. They will be given warm drinks and high energy foods such as chocolate if they can swallow normally. ○ Once the patient has warmed sufficiently that it is safe to move, they will be escorted to a warmer location as quickly as possible. If symptoms are severe, the emergency services will be called. ● The weather forecast will be monitored daily and each time before entering the field using forecast websites online. We will seek advice from UNIS as to what stations provide the best forecast information. ● Appropriate clothing is to be worn; thermals, waterproofs, many thin layers, and walking boots. In the climate of Svalbard, a feather down coat is necessary in addition to gloves and hat. ● In case of severe/risky weather conditions, we will not enter the field site until the bad weather has passed and it is safe to do so. ● Be aware of the potential of sudden changes in weather conditions and be prepared for them e.g. carry extra layers in case temperatures drop. ● Always carry sufficient fluids to avoid dehydration, including hot drinks to help keep warm. ● Always carry food, first aid kit, spare clothing and sun cream. ● Two emergency shelters will be carried at all times in the field, easily accessible to all team members. ● Adapt plans if the forecast is too poor and would endanger the health of team members. ● Have a pre-planned escape route off the glacier marked by handheld GPS waypoints in the case of sudden bad weather. ● Sufficient food, plus stores, will be carried when in the field. ● Sufficient emergency shelters will be carried at all times in the field to ensure all team members are safe and prepared in case of an emergency. ● Mark waypoint on every member's' GPS when arriving on glacier to create a trackable meeting spot.
Hazard 6	*Fieldwork Activities: Slipping/falling/handling equipment*
Risks	● *Falling into crevasses, moulins and meltwater channels (both supraglacial and proglacial) whilst working on the glacier. Possible fatality, broken limbs, hypothermia or frostbite.* ● *Slipping on glacial ice and tripping on debris/moraines/uneven surfaces. Possible injuries can include sprained ankles or broken limbs.* ● Getting lost and disorientated. ● *Obtaining an injury whilst carrying fieldwork equipment to and from the research site. Possible injuries include pulled/strained muscles.* ● Injury to misuse of potentially dangerous equipment (e.g. ice drill). ● Infection from contact with microbes in water samples. ● *Injury when walking with crampons* ● *Injury associated with the improper handling or storage of the Rifle* ● People at risk – Students.
Control Measures	● *Use maps to locate any risk areas, and research the location of recent incidents. Talk to UNIS staff who may have knowledge of dangerous areas. Avoid entering and collecting data in hazardous areas which pose a risk to safety. Route knowledge will be obtained from the group of students who visited last year.* ● *A visual assessment of the terrain will be carried out on arrival and any areas insecurity will be avoided.* ● *All team members to know basic navigation. Everyone is to carry a map, handheld GPS and compass.* ● Take special care when around water bodies of all sizes. Do not work near water deeper than knee height.

	• *Each sub-team is to have one member who is officially first aid trained. All team members to have undergone health and safety training through UNIS, and every team member to have basic lifesaving knowledge (e.g. how to perform CPR, how to handle broken bones etc).* • *Research routes to take, as well as backup plans in case the original route is too hazardous.* • *Be aware of surroundings, especially when in upland areas which may have steep valley walls with loose material. Research hazard maps showing possible danger zones. An initial visual assessment of areas around the glacier, which may possess unstable moraine deposits, will be carried out prior to venture on these deposits.* • Adhere to guidance/warnings issued by UNIS and the Governor of Svalbard regarding hazardous areas. • Spread the weight of the equipment around amongst team members so not to cause unnecessary injuries. • Only bring heavy equipment when it is needed. • Always bend at the knees when lifting heavy equipment, and keep your back straight. • Before using the ice drill students will conduct independent online research regarding the safe handling and usage of the drill. The ice drill will be carried in protected boxes whilst travelling in the field. It will only be assembled at project sites. • Always wear gloves when taking water samples. Ensure to wash hands before eating. Do not wash open wounds with channel water. • Use walking poles to negotiate difficult terrain and provide additional stabilising support • *Make sure the crampons are always facing downwards, and walk with a wide enough stance to minimise the risk of stepping in yourself.* • *The rifle will never be aimed at someone.* • *Always ensure that the rifle is empty when receiving or giving the rifle to someone by looking inside the magazine and looking and feeling inside the chamber.* • *The rifle will never be transported or carried fully loaded.* • *The rifle will never be left or stored when half loaded or loaded.* • *The rifle will never be carried with ammunition in the magazine when in Longyearbyen town and the firearms will not be carried inside public buildings.* • *The Rifle will be half-loaded at a specified location as we leave Longyearbyen and subsequently emptied at the same location when re-entering the town.* • *The rifle will be stored by removing the bolt from the rifle which will be locked up with the ammunition in a separate cabinet from the rifle itself.* • Loading and emptying of the rifle will be carried out under supervision of another group member and will be done well away from the rest of the group. The rest of the group will be informed that the rifle is being loaded/emptied.
Hazard 7	Handling and use of Drone
Risks	• UAV-drone injuring people below • Risks related to retrieving a fallen drone • People at risk – students, members of the public.
Control Measures	• *All team members have read and will abide by the Norwegian 'Regulations concerning aircraft without a pilot on board etc' (http://www.luftfartstilsynet.no/caa_no/Regulations_concerning_aircraft_without_a_pilot_on_board_etc* • *Make sure to fly UAV no closer than 150m from people and have consent from others around before flying.* • *Make sure the drone is always within sight and is at a height of no more than 120m, and truncate flight time to reduce risk of unexpected falling.* • *A log of the drone flight times will be kept, with the drone type, name of flight conductor, time and flight area.* • *Name and telephone number shall be written on the drone.* • *Read and understand the paper by Cunliffe et al. (2017) regarding the UK Civil Aviation Authority laws of lightweight drone flights for research (http://dx.doi.org/10.1080/01431161.2017.1286059)*

	• *Make it obvious when the drone is being flown by wearing a high-vis jacket and warning those around.* • *Make sure to practice and familiarise myself with the drone for at least 2 hours before using on a large-scale for data collection. I have discussed the logistics of drone flights and the safety aspect with Dr Matt Perks, who uses drones for parts of his data collection.* • *Identify potential hazardous areas where drone should not be flown over in case of a crash.* • *In the case of a crash in a potentially inaccessible area, one must be very careful of the dangers of rockfalls or especially crevasses, and in no case, can the drone be retrieved if it has fallen inside a crevasse.* • *The drone shall be transported in a hard case to minimise the damage to the drone and the lithium-ion batteries (https://www.premiumbeat.com/blog/how-to-take-a-drone-on-a-plane/).* • *Lithium-ion batteries will be removed and transported in hand-luggage rather than checked in with the drone.*
Hazard 8	Fieldwork Activities: Remote working area
Risks	• Disorientation whilst collecting research in the field. • Exhaustion and the accessibility of seeking medical attention. • People at risk – Students.
Control Measures	• Background information on the field area has been obtained from Dr Chris Borstad (UNIS), Dr Rachel Carr (Newcastle University) and students from 2016 expedition team all who have knowledge of fieldwork in glaciated regions. Some have visited and undertaken field work in this field area. • Enter the field as one group, the team will only break up into smaller groups of a minimum of 3 team members. Each sub-group will always carry two forms of communication; a satellite phone and a radio, in order to remain in contact with other expedition members and be able to access emergency services should they be required. • *There will be 2 satellite phones between the 8-student team at all times, with 1 sat-phone for each sub-group at all times during the expedition.* • A hand-held GPS device, map, compass and whistle will be carried by all expedition members when in the field. • If fatigued, local transport may be used to avoid excessive walking and strain on individuals, in order to avoid exhaustion. • Sufficient food and water will be carried in the field to sustain each team member for the field day, with emergency supplies carried as a precaution. • Students will sign in and out of UNIS each day when picking up and returning field equipment. • If the group is split into two sub groups regular checks will be made via radio. • Checks will be carried out prior to entering the field and throughout the day with UNIS regarding changing weather conditions.
Hazard 9	Fieldwork Activities: Unstable surfaces and geohazards
Risks	• Avalanche, rock fall and landslides. • Proglacial and supraglacial meltwater streams. • Icy banks of meltwater streams. • Falling into water. • People at risk - Students, members of the public.
Control Measures	• Use maps to locate any risk areas, and research the location of recent incidents. Avoid entering and collecting data in hazardous areas which pose a risk to safety. • Follow any guidance and/or warnings provided by UNIS relating to the terrain. • Be aware of surroundings, especially when in upland areas which may have steep valley walls with loose material. • Take care when walking on slippery surfaces; walk slowly and watch footing. • Avoiding deep and turbulent flows of water and taking care around all water bodies. • Take care when collecting data from supraglacial and proglacial streams. Wellies should be worn near water bodies while collecting data and crampons will be worn where necessary on hazardous surfaces

	(near supraglacial streams on the glacier). Students will not enter streams or channels if the water velocity (ms^{-1}) x water depth ≥ 1. ● Water samples will be collected from the bank where possible. ● All sub-team members will watch river levels to keep an eye on sudden rises in discharge that may occur due to precipitation. The river level will be marked using a pole or stake, allowing easy comparison of river levels over time. Should the river level rise, students are to stop working and move away from the bank edge. Data collection will only be resumed once the river is at a safe level again. ● We will study the local diurnal meltwater pulse to establish when river levels may be at their peak. This will allow safe and pre-planned crossing times for when the river is at its lowest levels during the day. ● Only cross streams when necessary taking extreme caution. Streams will not be crossed if turbulent, or above ankle height. ● We will not study streams deeper than 25cm deep or wider than 1.5m. Nor will streams with banks of an incline greater than 35° be studied. ● If crossing is necessary, find area of narrow and shallow water ● Never stand in a supraglacial stream; collect data from the bank. ● Only cross streams at straight sections, not meanders, because water flow will be less turbulent and the distance of which to be crossed will be less. We will use walking poles and walk into the flow to stabilise ourselves. ● Carry a metal tipped walking stick for extra balance when working near supraglacial streams or walking long distances. ● Loose moraine deposits both at the snout of the glacier and around the lateral margins will be avoided to minimise the risk of an induced landslide.
Hazard 10	Specific FCO advice relating to this location (*overseas travel only*) Svalbard is not listed on the FCO website but a link to advice from the governor of Svalbard is available at: http://www.sysselmannen.no/ (Last checked on 03.05.17)
Risks	● Petty theft (particularly at Oslo Airport) ● Assaults and muggings ● People at risk – Students.
Control Measures	● Keep all luggage close by at all times, in particular passports, money and credit cards. ● Stay in a group; minimum group size of 4 at any one time. ● Always remain alert in quiet hours or locations. Stay to main roads and well-lit areas, avoiding areas with no other pedestrians. ● When using taxi services, use reliable and trustworthy companies. ● If the attacker or aggressor requires items of equipment, money etc, the student will give them up immediately and not enter an aggressive confrontation.
Hazard 11	Mental Health
Risks	● Due to the extensive period spent in the field in isolation from others, members of the team may feel under pressure, lonely and mildly depressed ● Conflicts between group members causing negative feelings ● People at risk – Students.
Control Measures	● In order to mitigate these negative feelings, the group will strive to identify those who may be struggling and support them, through conversation, motivation and guidance ● Pre-existing conditions will be identified to the relevant members of the team, such as team leader, second-in command and health officer ● All information pertaining to mental health will be kept in strict confidence, and no team member will divulge any information on the subject to outside members of the group ● There will not be a pressure to speak about issues, but an open door policy will be employed by both the team leader and the health and safety officer for people to freely speak about their feelings, should they want to

	• Should any conflicts within the group occur, these will be solved as soon as possible either between the members involved, or if needed, by the team leader through group discussions of negative feelings • By acknowledging these risks prior to departure, the risks are mitigated as all team members will understand that it is natural for these feelings and conflicts to occur, but that it is important to reduce them to ensure the best quality of data collection. This will be achieved by understanding others' emotions and being empathetic towards them
Hazard 12	Polar Bears and Arctic Foxes
Risks	• Polar Bear attack. • Arctic Fox attack. • Becoming infected with a disease from wildlife; Arctic Foxes are known to carry rabies and tapeworms. • People at risk - Students, members of the public.
Control Measures	• Every member of the expedition team will complete the UNIS Arctic Survival and Safety course, involving rifle training. Details can be found here: http://www.unis.no/course/as-101-arctic-survival-and-safety-course/ . Safety procedures can be found in the UNIS safety instructions for fieldwork and excursions form: http://www.unis.no/wp-content/uploads/2014/08/Version8English_Safety_field_excursions.pdfhttp://www.unis.no/wp-content/uploads/2014/08/Version8English_Safety_field_excursions.pdf • One member of each sub-team (min. 3 people) will have a rifle and will be on look out at all times. • Research into recent Polar Bear sightings and attacks, and common locations through UNIS and http://www.sysselmannen.no/ . If we see any Polar Bears we will notify UNIS for the safety of other people. • Continuously make noise while in areas of high risk, to let the wildlife know you are present. • *If a close encounter with a polar bear might be expected the rifle will be carried half loaded.* • Do not litter or leave food, and store both food and waste properly, which may attract Polar Bears and Arctic Foxes. • If a sighting occurs during fieldwork activities, radios will be used to immediately notify the other research group, with regular updates on the situation. • To ensure radios are in range, when sub-groups are walking at a distance from each other and changing site locations regular checks as to whether the radios are still in range will be executed. • Sub-groups will be labelled 1 and 2. If walkie-talkies are to fallout of range, the sub-group 1 will come into closer range and walk towards sub-group 2 which who will remain stationary. This will eliminate issues of confusion as to the location of the other sub-group. • Team members will not approach the Polar Bear or Arctic Fox in any circumstances. • In instances where a polar bear is encountered, the group will do the following (please see crisis management plan for a more detailed explanation of this): • The group is to stay together and make as much noise as possible, using intimidation techniques from a distance of at least 200 metres. • Place flares in front of the bear that is heading towards us. • Quickly decide at which line/point in the terrain the student with the rifle will shoot at the bear. A warning shot will be fired aimed just in front of the Polar Bear. Prepare to kill should the situation escalate. • In the case of an attack, all members will endeavour to keep all team members safe which may result in the use of the rifle on the Polar Bear. Shoot to kill. If serious injury occurs, the emergency services will be called immediately using the Sat-phone when safe to do so. As field sites may not be accessible by vehicle, an air ambulance is the most likely option. In this case, another team member will accompany the injured team member to the hospital and provide the necessary health information should the student not be able to do so themselves. • Arctic foxes are considered by UNIS to be harmless and curious, and so there is little risk of attack, however we have been advised than in the incident of observing an arctic fox, to not approach and stay back, and report any particularly rabid foxes to UNIS.

Emergency Procedures

Despite all preparations and no matter how careful you are, accidents can happen. In the space below outline the procedures you will follow in an emergency (who will you contact? here will you go? could an ambulance reach you at the field site? who will know where you are? how often will you send them updates? what should they do if they don't hear from you when expected?) You need an Emergency Plan even if you are undertaking UK based fieldwork.

For situation-specific emergency protocols, please see the crisis management plan. Should an emergency accident occur the follow procedure will be followed:

1. *The injured person is to call for help to alert their sub-team member who will always be working in the same group in close proximity to the other sub-team members. No team member is to work alone or at a distance from the rest of the group.*
2. *Team members within this sub-team (min. 3 people) will attend the injured person being careful not to injury themselves also (e.g. falling while running).*
3. *Basic first aid is to be applied to the injured team member by the student who has first aid training. Meanwhile, one student is contacting the other team via walkie-talkie, and the final student is identifying their location through the use of a map and GPS coordinates, ensuring to tell the emergency services which coordinate system is in use (this is for the use of the emergency services so they can find the location of the team as quickly as possible,).*
4. *Should the injured student not be able to move, in order to prevent on the onset of hypothermia the following emergency survival gear:*
    - Stove
    - Sleeping bag
    - Water supply
    - Food
5. *The emergency services are to be phoned stating the following information:*
    - *Who we are*
    - *Where we are (GPS coordinates)*
    - *Closest known location*
    - *Number of people in the group*
    - *How many people are injured*
    - *Current weather conditions*
6. *The likelihood of an ambulance of other motor vehicle reaching our location is small, so we will need the assistance of an air ambulance.*
7. *Should the injured student need to travel to hospital via the air ambulance, another team member will accompany them to provide important insurance and health information. Every team member will be carrying a copy of their medical form which should be taken to the hospital.*
8. *Should the emergency services not arrive within a reasonable time, further calls will be made to the emergency services, as well as to our UNIS contact.*
9. *Once the immediate threat of danger is no longer present, the other sub-team can be notified as to the situation.*
10. *The remaining two members of the fragmented team are to leave the field site and return to UNIS, where they will inform our contact of the situation.*
11. *If there is no other assistance that is required, the sub-team may continue their research but ensure they return within a reasonable timeframe.*

The team member assisting the injured student is to make regular contact with both UNIS, the other team members, and our Newcastle University contact giving updates on the situation.

Approval

Assessor

Name:	**Signature:**	**Date:**
Holly Chubb (Expedition leader)		**20/06/17**
Emily Cave (sub-group 1 leader)		**20/06/17**
James Dickinson (sub-group 2 leader)		**20/06/17**

PI / Module Leader / Line Manager / Supervisor

Name:	**Signature:**	**Date:**
PROF. ANDY RUSSELL		22/06/17

Head of Geography (signature required only for data collection taking place outside of EU)

Name: Professor Anoop Nayak	**Signature:**	**Date:** 22/06/17