MOUNT EVEREST FOUNDATION

Patron: HRH The Duke of Edinburgh KG KT

BRITISH MOUNTAINEERING COUNCIL

F I N A L R E P O R T

from an MEF and/or BMC SUPPORTED EXPEDITION

1 - Name of Expedition: The first UAV-based glaciological analysis of two adjacent freshwater-calving glaciers in south-east Iceland.

2 - Expedition Leader/Organiser: Mr Nathaniel Ross Baurley
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3 - MEF reference: 19-15. BMC reference: N/A.

4 - Country/Region:

Iceland, South East region of Vatnajökull.

5 - Names of all expedition members, indicating leader, climbing members, and support:

1) Mr Nathaniel R. Baurley – Expedition Leader.

2) Mr Chris Tomsett – Expedition support/research assistant.

6 - Original objective(s) of expedition – mountaineering / scientific / medical, include location of objective (or study area) with indication of special points of interest (e.g. 'first ascent of NW Ridge') and heights of peaks:

Scientific fieldwork on two poorly-studied and explored adjacent glaciers in the region.

Due to time and logistical constraints, we were unable to undertake any research on Breiðamerkurjökull during this research trip, and so our research focused entirely on Fjallsjökull. Even then, however, due to the make of UAV we had available to us, we were still unable to survey the entire frontal region of the glacier as hoped. Nevertheless, we chose to survey as large an area as possible while we were there with the UAV and batteries available to us. This way we could survey the same area repeatedly and at high resolution. As such, we were able to undertake several surveys this way and we believe the data obtained from these surveys will still be highly relevant and of interest. It is hoped that future trips in 2020 will involve the use of a better model of UAV (i.e. longer fight time and survey range) and the trip itself will be longer, allowing for both glaciers to be surveyed to the full extent.
See below for revised study area image for this research trip.

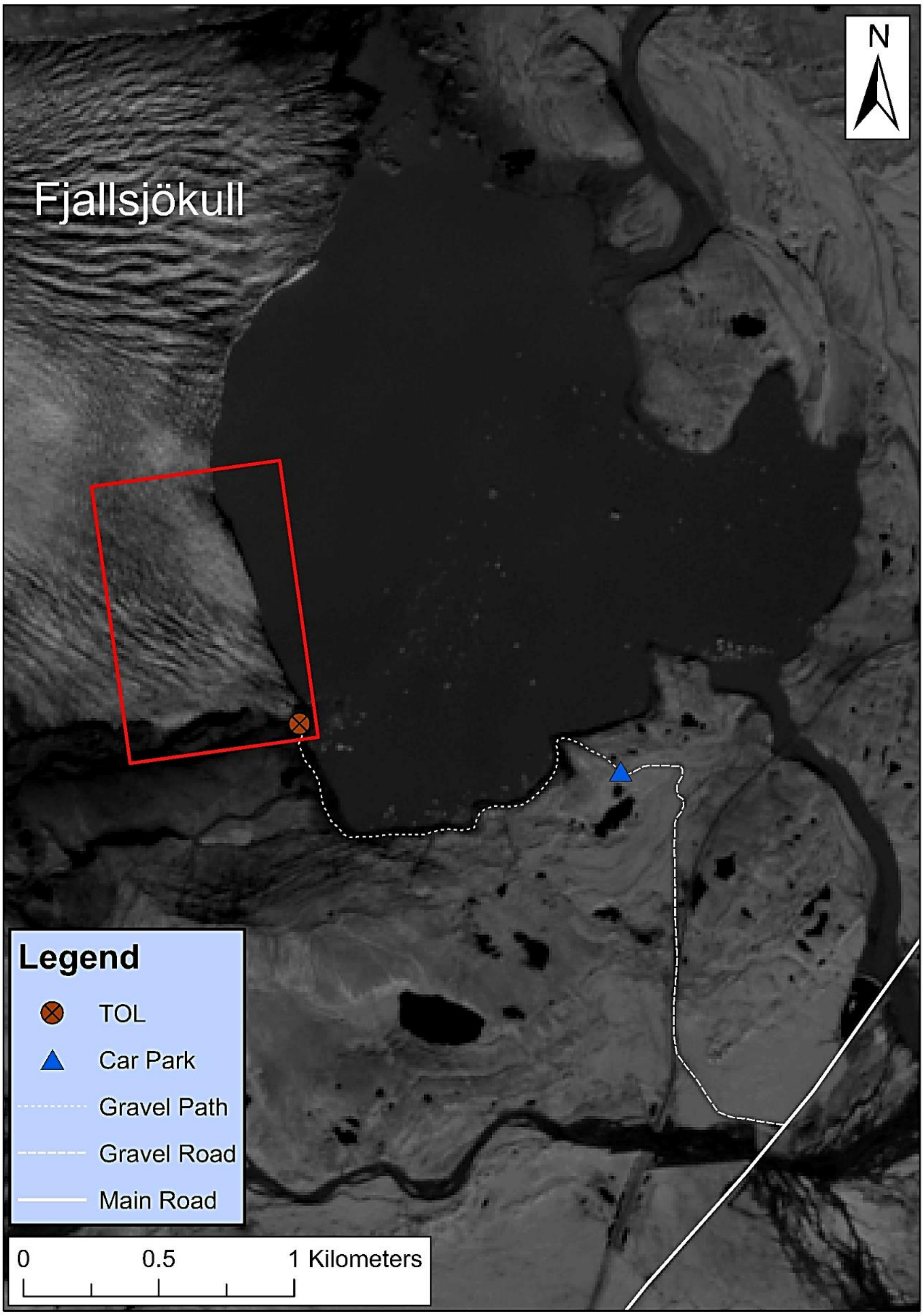

Figure 1: Revised study area image for the fieldwork undertaken in September 2019. Note the route used to access the glacier (white lines), our UAV take-off and landing site (TOL) and the area surveyed (red solid rectangle).

7 - Overall dates of expedition (e.g. 'March-June 2015'), showing time spent on approach, climbing, and return:

18th – 25th September 2019.

18th – Arrived in Iceland late afternoon, drove straight to accommodation in SE Iceland (4 and a half hours away).

19th – Visited field site which was a 20 minute journey to a 'car park' followed by a 30-45 minute hike to the glacier. Set up ground control point network, marked locations with dGPS and undertook a set of UAV surveys (in the field for 5 hours).
20th – Headed to field site to undertake surveys. However, this was stopped prematurely due to adverse weather conditions (in the field for 3 hours).
21st – Headed to field site to undertake surveys. Weather stayed good and so we managed a full set of UAV surveys (in the field for 6 hours).
22nd – Adverse weather conditions and so stayed in the accommodation.
23rd – Headed to the field site to collect the ground control network. Weather was damp and drizzly so no flying could be undertaken (in the field for 2 hours).
24th – Returned to Reykjavik from SE Iceland ready for early morning flight.
25th – Early flight out of Keflavik airport to LHR.

8 - Give the following details for each route climbed or attempted:
Name of mountain/crag, altitude, estimated route length, dates, grade, style (eg alpine, fixed rope), whether first ascent, successful or not, high point reached, reason for retreat (if applicable), weather conditions, and names of climbers:

N/A. No routes climbed.

9 - Any other relevant comments (permits, liaison officer, etc):

We had our research permit from the Icelandic Centre for Research on us at all times when in the field in case we were stopped by park rangers. However, this never occurred.

10 - Details of any injury or illness to expedition members/porters:

There were no injuries or illnesses suffered during the fieldwork.

11 - Details of waste disposal:

All food waste eaten and food packaging opened while out in the field was always placed back in our bags and then disposed of properly in the bins back in the accommodation. We were extremely careful with all other forms of rubbish (especially plastic) and made sure we did not leave any behind at the field site at the end of each day. All waste related to sanitation was disposed of correctly in the toilets in the accommodation.

12 - Notes on access, porters, or other issues of interest to future visitors:

Generally, the route to the glacier is quite simple. The path is relatively well marked, and even with scientific kit it only took us ~30-45 minutes to walk it. The route follows the edge of the lake quite closely, particularly on the second half of the hike. After this the path drops down to a large, flat relict outwash plain which takes you right to the glacier front. Walking further west from here (along the lateral margin of the glacier) would bring you to a location where you can access the glacier directly. However, we saw no need to do this during this trip. It is important to note that after a prolonged period of heavy, persistent rain the lake level rises by a considerable amount – up to 50 cm in our experience. Although this may not sound much, when we returned to the field site on the 23rd September we found that our access was affected slightly. The rising water levels had inundated part of the path where it closely followed the lake edge, forcing us to take a slight detour. Furthermore, the outwash plain was largely inundated, with ponds appearing in old depressions on the surface. This forced us to take a further extended detour to reach the glacier as the normal route we'd take was underwater.

It is also worth noting that this glacier is actively calving, and such events can occur at any time, although these are more likely during the summer months. When these blocks of ice calve off, they cause tsunami-like waves to propagate outwards from where the ice calved into the water, with the size of the waves depending on the size of the ice lost. We observed several of these calving events occurring during our research, and although they often occurred over 1 km away from us, the waves that reached the shoreline near us were still a good size, and could quite easily knock someone more unaware off their feet into the freezing lake water. Therefore, it is advisable that if someone hears a calving event occurring (signalled by a very loud cracking sound as the ice fractures) that they immediately head for higher ground or away from the lake edge until the waves have dissipated.

13 - Summary of exhibition accounts, including income and expenditure:

Income:
Grants awarded: 1) MEF - £600
2) Quaternary Research Association - £1500.

Personal Contributions: ~£50.

Total Income: £2150.00.

Expenditure:
Return flights (including 3x pieces of extra hold luggage): 375.08 (+225.60): £600.10
Travel to/from Heathrow airport (fuel costs): £42.50.
Hire car for research period (includes full insurance and extra driver): £625.20
Fuel costs: ~£130.83
Accommodation for 7 nights: £656.86.
Subsistence: ~£85

Total Expenditure: ~£2141.07.

14 - Photographs of glaciers for comparison with past/present images:

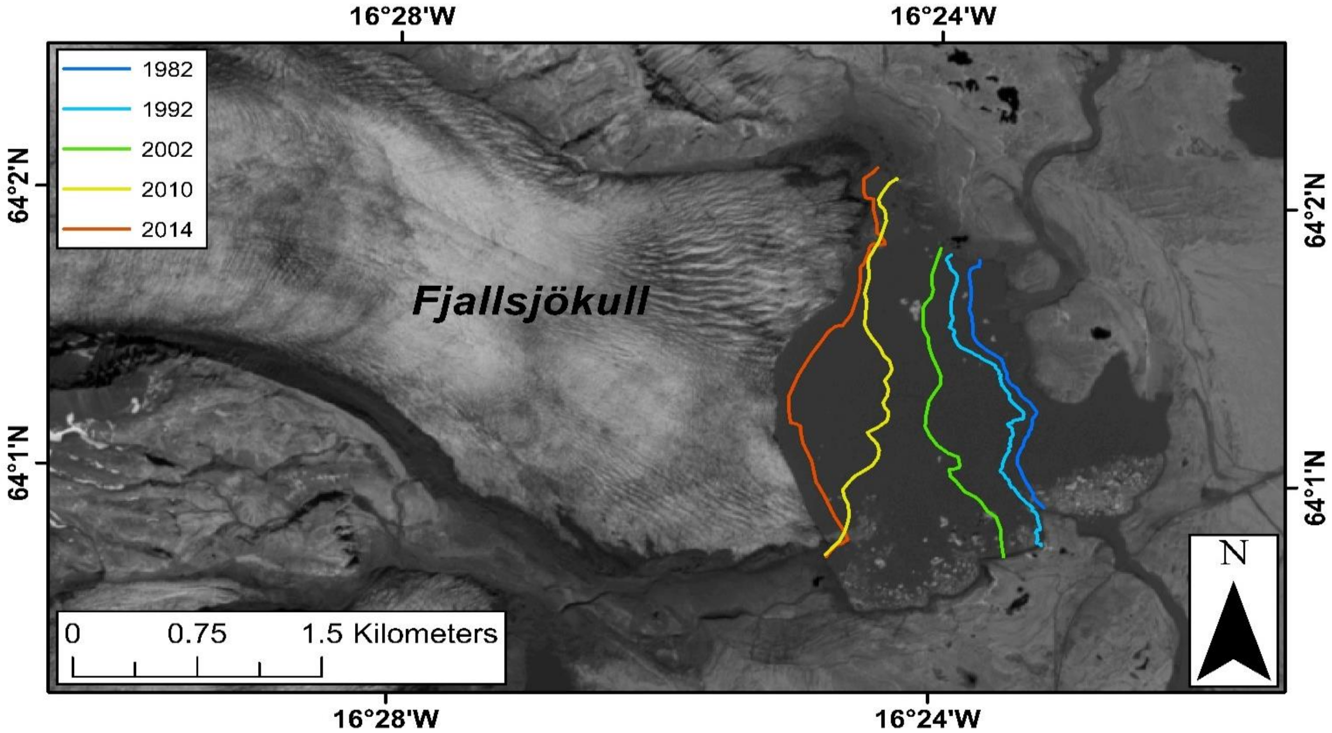

Figure 2: Change in terminus position of Fjallsjökull since 1982. Note the clear pattern of retreat occurring over recent years, particularly since 2002. Also note how as the glacier has retreated the area of the lake has also increased. Background image is from September 2019.

Fjallsjökull, like many outlet glaciers in Iceland, has undergone significant change over recent decades. Figure 2 above illustrates the frontal retreat of the glacier since 1982, with each coloured line representing the glacier front at a previous time. To show this slightly differently, Figure 3 below shows an image of the lower portion of Fjallsjökull from 6 different dates since 1982. Like Figure 2, it clearly shows that rapid retreat began after 2001, and again clearly shows the corresponding increase in lake area as the glacier retreats. Since the mid-1970s the glacier has retreated by ~1.21 km, resulting in an increase in lake area of 2.72 km² and a 40% increase in the portion of the terminus that is lake-terminating. This is important as it is the process of calving (where icebergs calve from the glacier front) which is the primary mechanism behind the recent retreat at Fjallsjökull. Due to the majority of the terminus now being in contact with the lake which has led to an increase in calving activity, it is likely that this rapid retreat will continue until the glacier retreats out of the lake and stabilises. It is, therefore, important to continue our research into this glacier to help better predict its future response.

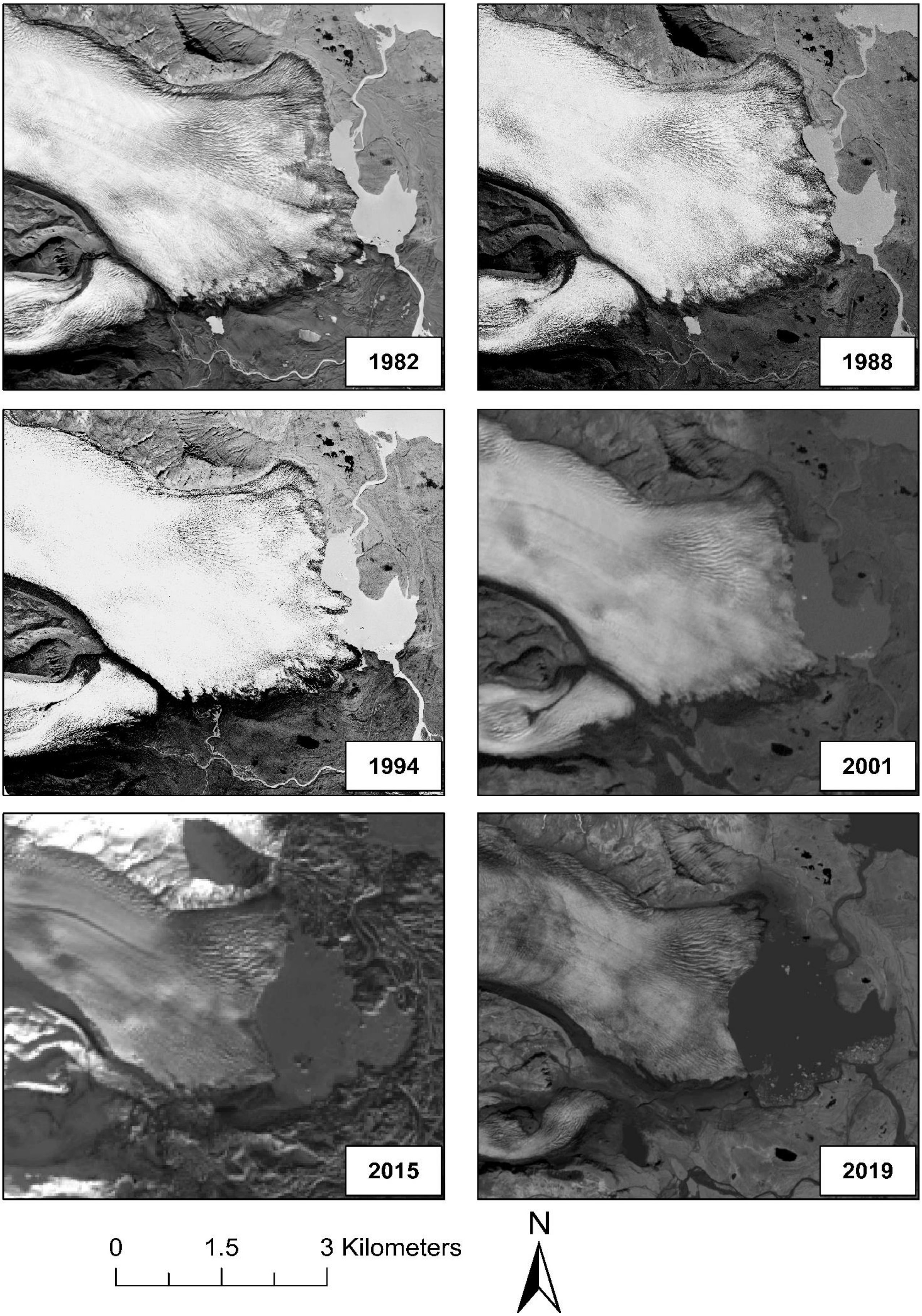

Figure 3: Change in Fjallsjökull glacier for selected dates since 1982. Extensive retreat (laterally as well as frontal) can be seen to have occurred over this period. It is also clear that the area of the adjacent proglacial lake has also increased considerably over this period. The images from 1982, 1988 and 1994 are black and white aerial photos, while the images from 2001, 2015 and 2019 are satellite images shown in greyscale.

15 - Observations/accuracy of Google Earth imagery:

Google Earth is an extremely useful tool in scientific research. It is free, simple to use and allows you to undertake some basic analyses. The resolution of the imagery is particularly good for planning trips and exhibitions as well as analysing landscape change and evolution using the historical images tool. Such imagery can then be exported resulting in high quality maps of landforms, features and landscapes.

However, for more in-depth analyses, such as those undertaken in this study, it is beneficial to use commercially-available satellite imagery, such as those acquired by the Sentinel satellites. These images are acquired every 12 days over the entirety of the Earths' surface at a resolution of 10 m. Such imagery cannot be obtained from Google Earth. Data acquired this way can also be imported into GIS software, such as ArcGIS, which allows the user to undertake a wide variety of additional processing and analyses on their data.

Therefore, Google Earth certainly has its merits in exhibition and route planning, however, if thorough analyses are required, as is often the case in scientific research, then it is more beneficial to utilise different imagery and GIS software to undertake this analysis.

16 - Suggestions for new routes or new subjects for study in the area:

As previously discussed, the process of calving resulting from the increase in lake area, combined with rising air temperatures in the region is causing increasingly rapid glacier retreat at Fjallsjökull. This is also true for several other lake-terminating outlet glaciers in Iceland which have seen an increase in their retreat rate over a similar period. This is particularly the case for the neighbouring glacier to Fjallsjökull, Breiðamerkurjökull, which has seen over 3.5 km of retreat since 1982, with the majority of this occurring since the early 2000s. However, there is much we still do not understand about glacier calving, particularly how the process varies between glaciers and regions. There is, therefore, a need to further our understanding of these processes and how this will impact upon the future response of calving glaciers. Iceland is the perfect place to do this as access to its calving glaciers is relatively straightforward, meaning a large amount of research can be undertaken on these 'natural laboratories', the data of which can then be applied to other calving glaciers worldwide, such as those from the two ice sheets. Such research would involve UAV surveys, satellite imagery, laser scanning and monitoring/recording equipment set up on the ice surface to obtain a full picture of the calving activity occurring at these glaciers.

A further potential subject of study would be to investigate the structures and features present on the surface of calving glaciers. During two research trips to Fjallsjökull in 2019, UAV surveys revealed an interesting array of structures and features on the ice surface, such as lakes, streams and water-filled crevasses within 30–50 m of the calving front. Such features, although widely reported on the large outlet glaciers in Greenland, have, to the best of our knowledge, yet to be observed this close to an actively calving glacier front. This is certainly the case for those glaciers in Iceland, and potentially for other glaciers further afield. Such features play an important role in the magnitude and frequency of calving events, and consequently the stability and dynamics of calving glaciers as a whole. An in-depth analysis of these features would allow us to better understand their role in controlling the future dynamics of calving glaciers. Furthermore, the results could be combined with the research outlined in the paragraph above to greatly improve our understanding of the calving process.

Finally, as detailed earlier in this report, I was not able to fully survey the entire calving front of Fjallsjökull, nor was I able to undertake any flights on Breiðamerkurjökull. This was due to logistical and time constraints, and as such the project that I originally outlined in my proposal to MEF - investigating glacier dynamics and hydrology - has yet to be fulfilled. I hope to address this fact this year, however. I have already planned a research trip to the same region in Iceland for July 2020 for a longer duration than was had previously. July is the driest month and, therefore, it is my hope that I should get a large amount of data based off of my experience in July 2019 when the weather was excellent every day. Furthermore, I am currently in the process of acquiring a more efficient model of UAV which will allow me to survey the entire frontal region of both glaciers. From this, I could acquire incredibly detailed information on the velocity, hydrology and calving activity in the near-terminus region of both glaciers. This could then be combined with glacier-wide velocities acquired using satellite imagery over the same period to enable me to better understand the linkages between glacier hydrology and dynamics and how this will impact upon the future response of glaciers in Iceland and worldwide.