Investigations into hydrology, sliding and ice flow at the Svartisen Subglacial Laboratory, Engabreen, Norway

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1. Project outline

- SVALI (Stability and Variation in Arctic Land Ice) is a 'Nordic Centre of Excellence' (http://noce-svali.org/).
- This project focuses on theme 2 of SVALI aimed at investigating glacier hydrology and ice dynamics.
- The aim is to investigate the interaction between glacial hydrology and ice dynamics, and in particular to further our process understanding between them.
- Here we present the plans for a range of investigations to be carried out at Engabreen over the next 2 years.
- We will be using the facilities at Engabreen (figure 1)and the Svartisen Subglacial Laboratory (SSL) (see below) to explore this interaction and develop a model that incorporates the observations we see at the SSL, particularly during short speed up events associated with large, sudden influxes of water.
- The two speed up events in particular are:
  - The spring speed up event
  - An artificial jökulhlaup experiment

2. Svartisen Subglacial Laboratory and Engabreen

- The SSL is a unique research facility(figure 2) run by The Norwegian Water Resources and Energy Directorate (NVE), and is located under 200m of ice under Engabreen (figure 1 and 3), an outlet glacier from the Svartisen ice cap in Arctic Norway.
- Here we will investigate pressure conditions, seismic events, subglacial discharge and sliding processes based around short-term speed up events.
- We will use existing and newly collected data from the lab to develop a data driven model of the interaction between meltwater and ice flow.

1

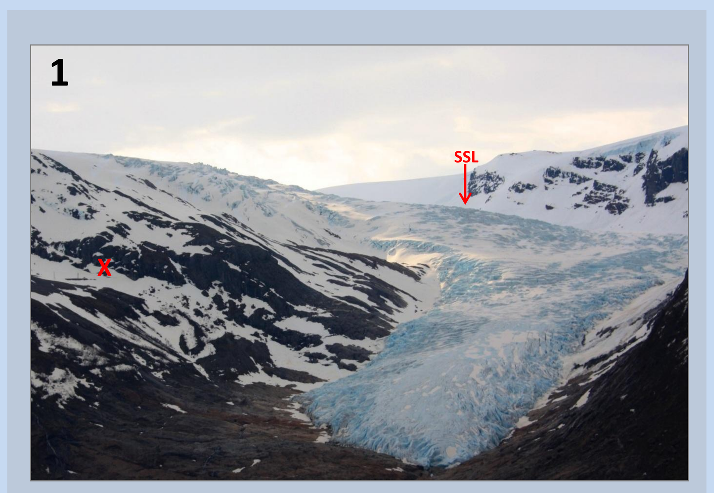

Figure 1. The lower section of Engabreen, an outlet glacier of the Svartisen ice cap. The red "X" marks the entrance of the tunnel system that leads to the research facility approximately 1.5km from the entrance at the bed of the glacier under the point labelled "SSL". Here there are two research shafts; a horizontal, and a vertical research shaft.

2

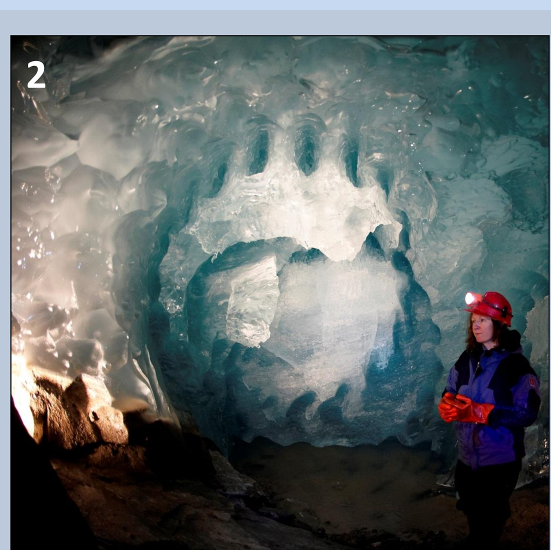

Image courtesy of M. Jackson

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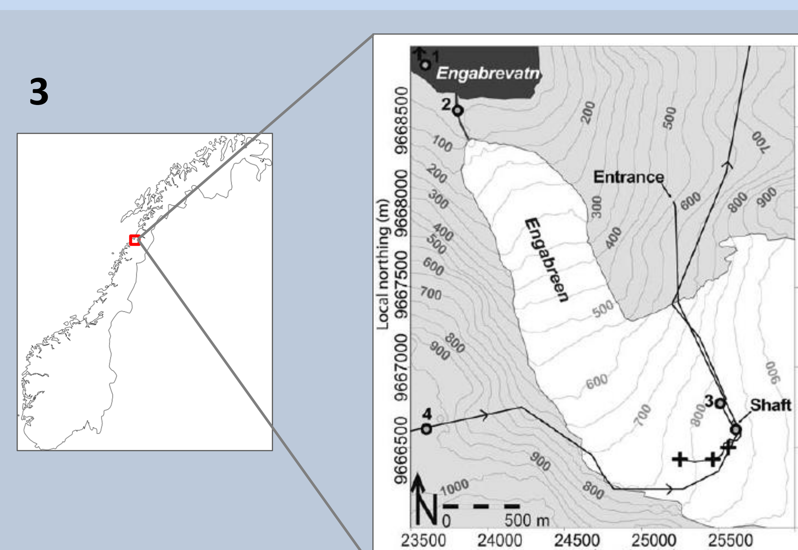

Image taken from Lappegard et al. 2006

Figure 2. An image showing a melted out ice cave at the bed of Engabreen under 200m of ice in the horizontal research shaft. The ice cave is melted out using a hot water drill.

Figure 3. A map of Engabreen and the Svartisen ice cap. The blown up section shows the tunnel system at Engabreen, the research shafts and water intakes. The water intakes(**+**) collect and deliver water to the hydropower plant through a series of tunnels.

4

Figure 4. Example of an exposed load cell drilled into the bedrock that sit under the glacier. The cells measure the overall pressure environment experienced at the bed. Note the distinct scours on the metal plate from the debris laden basal ice. Each load cell is approximately the size of a large dinner plate.

5

Figure 5. The vertical research shaft and the cabling leading to sensors that are currently placed in the vertical research shaft.

3. Sliding

- We plan to undertake a variety of sliding experiments at the subglacial lab with the aim of obtaining high resolution sliding information particularly around short-term speed up events, i.e. the spring speed up event in May.
- The measurement of sliding is anticipated to be carried out with a cable and anchor system. The anchor will be frozen into and incorporated in the basal ice and dragged along with the glacier as it slides over the bed, pulling the cable out of a spool.
- A spool with a time and distance stamp data logger will record the rate and variation experienced in the sliding at the glacier bed.

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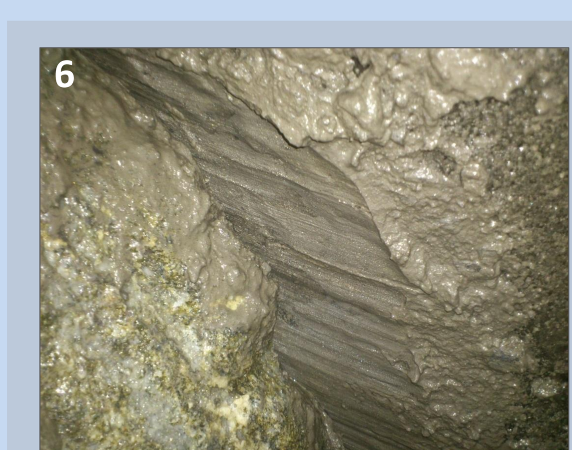

Figure 6. The bed of the glacier where the basal ice is sliding over the bedrock. The bedrock can be seen in the bottom left of the image and the glacier on the right of the image. Note the dirty, soft basal ice. We hope to measure the rate and variability of this sliding and compare it to our other datasets of seismic and pressure data. Additionally it will also be compared to the surface velocity data.

7

Figure 7. A nice example of basal processes caused by basal sliding. The rock to the right of the image is incorporated into the base of the glacier and has been scoured along the bedrock to create a small "striation". For scale the rock is approximately 15cm along the long axis from top to bottom.

4. Ice Flow

- This spring we will deploy 4 GPS' on the surface of Engabreen and hope to record the spring speed up event in the mid and lower sections of the glacier.
- We will attempt to place a GPS (GPS4) in the ice fall above the lab. This will provide some new results in which we can compare the GPS data with the pressure, seismic, discharge and sliding data collected simultaneously in the SSL.
- Time-lapse photography of the mid-Engabreen area. The field-of-view directly above the SSL (figure 9). We will obtain surface velocities through feature tracking of the repeat photography. This data will also be analysed with the GPS data in order to calibrate and compare the two methods to attain a greater spatial map of surface velocities.
- In addition to the GPS survey we also aim to map the velocity field of Engabreen during the spring speed up event using a terrestrial Laser scanner.

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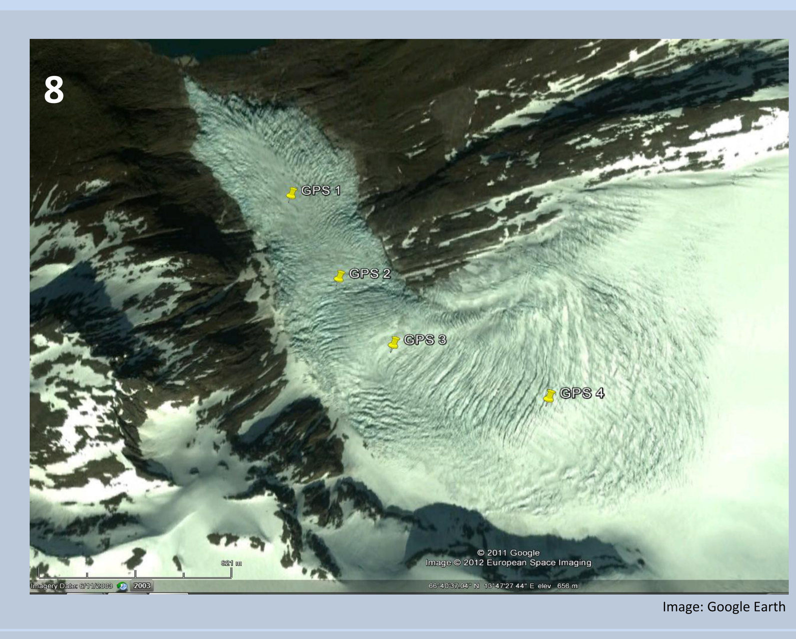

Image: Google Earth

Figure 8. The approximate location of the GPS's we will place at Engabreen this spring. They roughly follow the central flow line. GPS 4 is the GPS we are attempting to place above the subglacial laboratory.
Also note the asymmetric shape of the snout toward the left of the image where the over-deepening has occurred. The tip of the snout leads directly into the dominant proglacial channel.

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Figure 9. The approximate field-of-view we anticipate for the time-lapse camera system. It has identifiable landmarks and peaks to aid in the geo-referencing and scaling of the images. The subglacial lab is approximately in the middle of the glacier slightly to the right of the centre of the image. We hope that the GPS may be visible in the images, as this will further aid in the determination of the velocity.

5. Jökulhlaup Experiment

- We aim to repeat a novel experiment that was carrried out in 1997[5], by releasing an artificial Jökulhlaup under the lower section of Engabreen.
- We are able to release a controlled amount of water by flushing the sediment chamber of the water intake tunnels underneath the glacier.
- We will recreate the experiment and use the new advances in technology to monitor the experiment more closely and with a larger range of instruments.
- This will include multiple GPS on the surface, seismic monitoring, time-lapse photography and a terrestrial lidar survey before and after the experiments and dye tracing of the released water. The measurements of the dye tracing experiments will be collected at the gauging station shown in figure 10 below.

6. Hydrology

- We aim to reinstall the proglacial gauging station in order to achieve more accurate indication of the discharge through the glacier over the course of the year and in particular around the spring event, as well as during the jökulhlaup experiment.
- The proglacial gauging station will be placed at the main outlet shown in figure 10. There are very few other proglacial streams exiting the snout of Engabreen. This could be due to the asymmetric cross section of the valley carved by the glacier.
- Measurements at other small proglacial streams will be taken in order to estimate what percentage of the total flow is routed through the main channel.
- Proxy measurements from water intakes under the glacier and in the sediment chamber also give us a clearer indication of the volume of water flowing under Engabreen at given locations.

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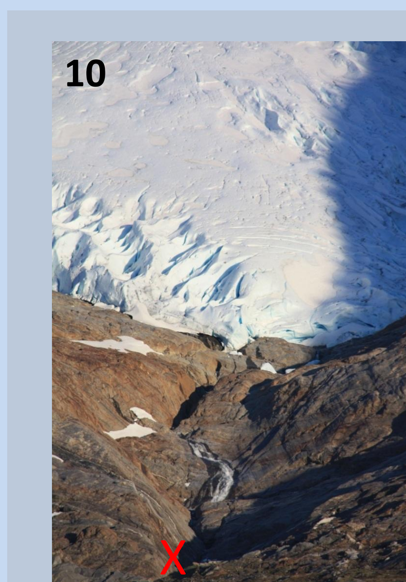

Figure 10. This shows the snout of Engabreen and the large meltwater channel cut into the solid bedrock. The gauging station will be installed at approximately where the red "X" indicates.

7. Summary

- Collect new data from the surface using a variety of novel and standard methods including; terrestrial LIDAR, time-lapse photography and GPS surveys, over two short-term speed up events: Artificial jökulhlaup and spring speed-up.
- Compare and analyse this data with simultaneous measurements collected at the SSL, which includes pressure, discharge, seismic and sliding data.
- Use this data to develop a model of the interaction between meltwater and ice flow in order to further our process understanding.

References:
[1]Seismic data courtesy of Pennsylvania State University (K. Christianson)
[2]Lappegard et al. 2006, Characteristics of subglacial drainage systems deduced from load-cell measurements, Journal of Glaciology, Vol. 52, No. 176, pp. 137-148
3Lappegard et al. 2005, Determination of basal hydraulic system based on subglacial high-pressure pump experiments, Annals of Glaciology, Vol. 40, pp. 37-42
[4]Jackson et al. 2005, Velocity measurements on Engabreen, Norway, Annals of Glaciology, Vol. 42, pp. 29-34
[5]Kohler et al. 1998, Effect of a controlled Discharge Pulse on the subglacial Drainage System and Ice Flow at Engabreen, Northern Norway. EOS. (Abstract) v.79(45), p274

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