NS11A-0154 – PASSIVE SEISMIC SIGNATURES OF A RELATIVELY FAST-FLOWING ALPINE GLACIER

Alex Brisbourne[1], Graham Stuart[2] and Bernd Kulessa[3]

1. SEIS-UK, Department of Geology, University of Leicester, Leicester, UK. Email: amb27@le.ac.uk

2. School of Earth and Environment, University of Leeds, UK. Email: g.stuart@see.leeds.ac.uk

3. School of the Environment and Society, Swansea University, UK. Email: B.Kulessa@swansea.ac.uk

1. INTRODUCTION

During the summer melt season of 2007 a multi-disciplinary geophysical experiment was carried out at a prominent break in surface slope of the Grubengletscher, Valais, Switzerland. As well as passive seismic recording, high-resolution reflection and refraction seismics, differential GPS, seismoelectric sounding, and GPR profiling were also undertaken. The flow velocity of the Grubengletscher can reach some 45 m / year, which is relatively fast for an Alpine glacier, although pronounced variability in flow velocity has previously been observed; thus, the glacier is anticipated to serve as a small-scale analogue for fast-flowing outlet glaciers from larger ice caps or ice sheets. It is intended that joint interpretation of the geophysical data sets will allow the sub-glacial mechanism sustaining the flow instability of the glacier to be isolated.

2. OUTLINE OF THE EXPERIMENT

The aim of the experiment is to The overall objectives of the experiment are to: (1) Identify whether sub-glacial sediment deformation or sliding sustains the relatively fast basal motion of the tongue of Grubengletscher; (2) Characterise the impact of spatiotemporal changes in basal mechanical processes on glacier flow speed.

An array of 6 high-frequency SAQS data loggers with 4.5Hz 3-component geophones was deployed for a period of 2 weeks. An inter-station distance of around 50m was used, comparable to the ice thickness. Data were recorded continuously at 3000sps with GPS timing. During the deployment a number of reflection of refraction seismic experiments were carried out, providing known surface sources for array calibration and the derivation of the velocity structure.

Figure 1 – Photograph of the field area (taken facing North)

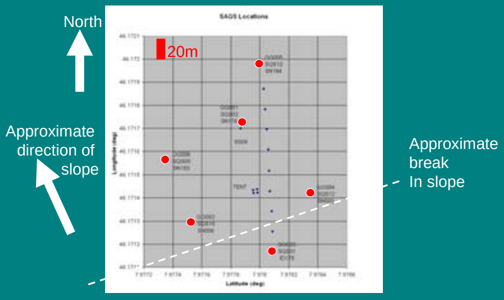


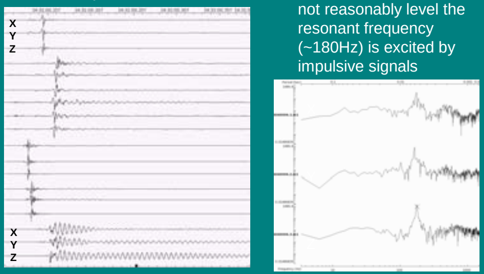
Figure 2 – Array geometry

3. FIELD EXPERIENCE AND METHODOLOGY

Three-component 4.5Hz geophones housed in a single case with 3 spikes were used. To ensure good coupling a recess was carved into the ice and holes drilled. This was then covered with ice and then rocks to protect from solar heating. Ensuring accurate levelling and orientation of the 3 spike geophone housing was extremely difficult. In future experiments we would recommend the use of 3 single-spike sets rather than one 3-spike unit.

Due to the high ablation rates, maintenance of the array required daily visits to each station to ensure good alignment and also coupling between the geophone and the ice, and also to prevent tipping over of the data logger box and battery. It would be impossible to run such an experiment without daily maintenance.

The most significant effect of the high ablation rate, other than the increasingly precarious tent plinth (photographs above), was the tilting of the geophones. When a geophone is deployed off-level there is a significant increase in the potential excitement of spurious / resonant frequencies as illustrated in the data presented below.



Scaled by trace

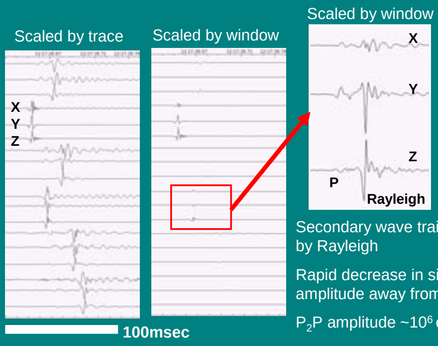
When the geophone is not reasonably level the resonant frequency (~180Hz) is excited by impulsive signals

Figure 3 - Hammer event recorded across the array. Spurious frequencies are clearly excited at the lower station due to tilt.

Swansea University

4. TYPICAL EVENTS

By way of calibrating the array and potentially allowing the discrimination of events by waveform a number of known events have been isolated.

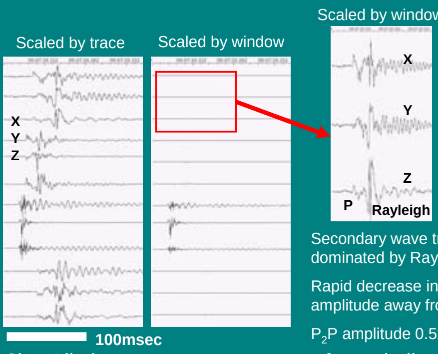


Secondary wave train dominated by Rayleigh

Rapid decrease in signal amplitude away from source

P_2P amplitude ~10^6 count

Figure 3a – Hammer source at glacier surface

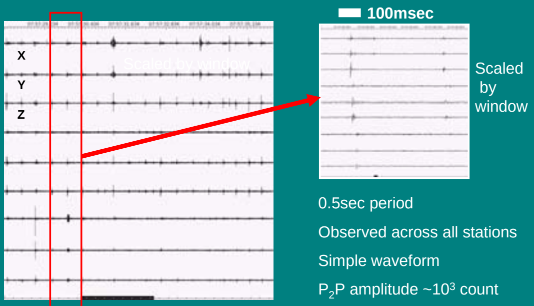


Secondary wave train dominated by Rayleigh

Rapid decrease in signal amplitude away from source

P_2P amplitude 0.5x10^6 count

Figure 3b – Likely crevasse event – waveform similar to hammer



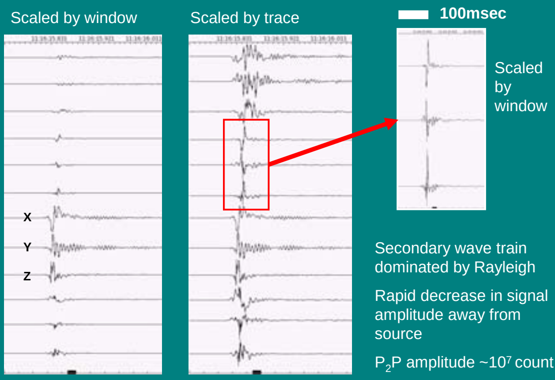
0.5sec period

Observed across all stations

Simple waveform

P_2P amplitude ~10^3 count

Figure 3c – Rock fall at side of the glacier recorded across array



Secondary wave train dominated by Rayleigh

Rapid decrease in signal amplitude away from source

P_2P amplitude ~10^7 count

Figure 3d – “Felt Event” – recorded whilst the field party was within the array.

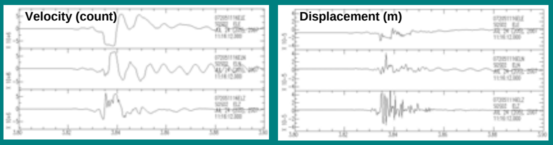
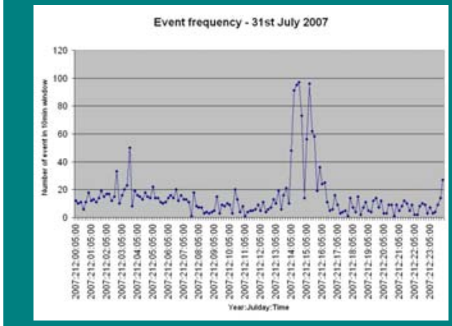


Figure 3e – “Felt Event” converted from velocity to displacement (gain of 30 on displacement scale).

The “felt event” occurred whilst the field party were on the glacier and gave the sense that the whole glacier “shuddered”. The displacement seismogram indicates a northward / down-dip kick of the station and vertical oscillation. The maximum displacement observed is around 3µm. However, it does not indicate a lateral or vertical shift as would be expected for a glacial movement event. The waveform implies a large crevassing event.

5. EVENT FREQUENCY AND STA/LTA TRIGGERING RESULTS

A simple STA/LTA triggering algorithm has been used to isolate events recorded concurrently by at least 4 stations of the array. By tuning the algorithm using the window length, STA/LTA ratio, filter frequency and slowness across the array, this relatively simple routine can be used to discriminate a large number of events. Initial results from the dataset indicate a dominance of crevasse type events. However, the huge volume of events presents a challenge in itself. For example, on 31st July 2007, 2162 events were recorded. This number includes around 700 hammer sources in the middle of the day. However, an event rate of over 100 per hour is not unreasonable. Examples below.



Event frequency – 31st July 2007

- 0.001 / 0.05sec windows respectively

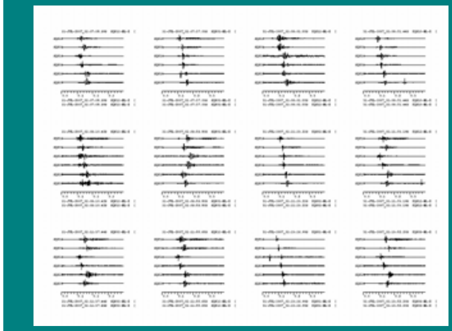
- 0.01sec sliding window

- Trigger ratio = 5

- Event correlation = 0.1sec

- Event observed on 4 stations to pass test

-2162 events observed including ~700 “hammer” events 14:00 to 16:00



Trigger results in a 7min window on 31st July

- 0.001 / 0.05sec STA/LTA windows

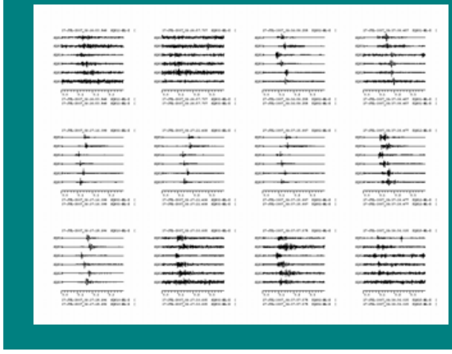
- 0.01sec sliding window

- Trigger ratio = 5

- Event correlation across array = 0.1sec

- Event observed on 4 stations to pass test

-2162 events observed



Trigger results in a 3min window on 31st July

- 0.05 / 0.1sec STA/LTA windows

- 0.01sec sliding window

- Trigger ratio = 5

- Event correlation across array = 0.2sec

- Event observed on 4 stations to pass test

-2837 event observed

5. CONCLUSIONS AND FURTHER WORK

- Passive seismic fieldwork on temperate glaciers during the melt season require daily maintenance due to high ablation rates. Solar shielding blankets over the geophone will help reduce maintenance requirements.
- Single-component geophone sets with a single spike should be used where ever possible.
- As a first pass, known events have been used to discriminate event types by waveform.
- An event frequency of >100/hr makes the identification of bed events difficult. The majority of event appear to be crevassing.
- The STA/LTA algorithm requires good a priori knowledge of the waveform of interest to make it a useful tool for identifying only a certain type of event.
- The next stage of data processing will involve the identification of any bed events, should they exist. At present the dominance of crevasse events in the trigger detection results precludes rapid identification of bed events.
- Joint interpretation with other geophysical results.