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Environmental Geophysics

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This month I have been presented with an interesting problem sent in by a researcher from the University of the Sunshine Coast. Adrian McCallum is a researcher in geology and geomechanics (etc.) with a bent toward subjects having to do with ice and snow (based at the Sunshine Coast!?!). I am envious of the projects that he is working on and would love to be participating in them – have a look at his USC website: http://www.usc.edu.au/university/faculties-and-divisions/faculty-of-science-health-education-and-engineering/staff/adrian-mccallum

In this project his group has gone in hard on a project to measure ice thickness on a glacier in New Zealand. In hindsight, I think that we would all agree that a few mistakes were made. Nevertheless, Adrian is hoping that someone out there in the community of geophysicists that read *Preview* knows whether it is possible to retrieve the data that is buried in the early time response of the GPR system that his team built for the project. Here is Adrian's story:

Interpreting radar data from the Bonar Glacier, New Zealand – where to from here?

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The Bonar Glacier is a high-level valley glacier situated in the shadow of Mt Aspiring, in the New Zealand Southern Alps (Figure 1). Whilst glaciological studies have been undertaken on many New Zealand glaciers (Chinn, 2001) and mountaineers regularly access the area, no glaciological observations of the Bonar Glacier are known to have occurred (T. Chinn, pers comm., 18 June 2014).

A small glaciological expedition to the Bonar Glacier was conducted over the period 22 May to 1 June 2014 to carry out a preliminary glaciological assessment of the glacier. The intent of the research was to confirm logistical arrangements necessary to access the glacier and to obtain preliminary surface ice movement and ice thickness information.

Ongoing analysis of recorded radar data is proving challenging. This letter serves as a brief presentation of recorded data and analysis to date, the intention being to draw productive discussion and advice from the broader geophysical and glaciological community, to better allow for useful interpretation of gathered data.

Access to the Bonar Glacier was made on foot, via French Ridge from the road-head at Raspberry Flat. Testing occurred over the period 28–30 May 2014, based from Colin Todd Hut (Figure 1).

The original intent was to use commercially available Ground Penetrating Radar (GPR) equipment. However, personal communication (L. Mingo, 14 February 2014) suggested that other groups had experienced difficulty in imaging to depths of ~300 m in polythermal valley glaciers with the commercially available equipment, therefore it was decided to use a radar system that we would build in-house based upon the Narod impulse transmitter

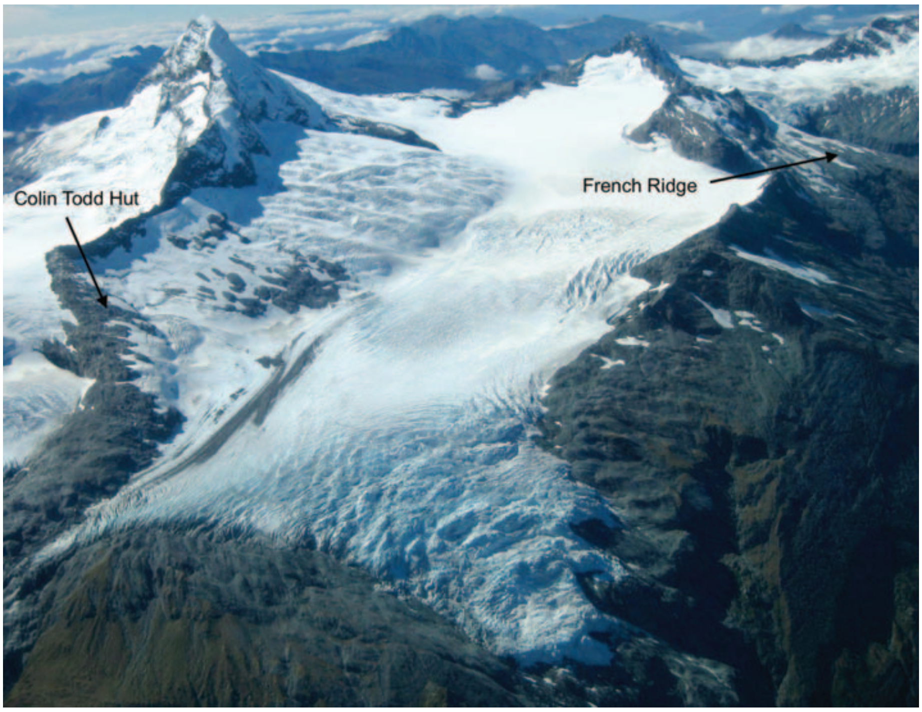

Figure 1. *The Bonar Glacier in the Mt Aspiring National Park, New Zealand. Mt Aspiring is in the top left of the image. Approximate position of Colin Todd Hut and the access ridge (French Ridge) are noted. (Image courtesy of New Zealand National Institute of Water and Atmospheric Research (NIWA).)*

(Narod and Clarke, 1994). The system used a centre frequency of ~8 MHz, utilising 5 m long resistively loaded dipole antennae. These antennae were constructed with guidance provided from Icefield Instruments Inc. (2000); each antennae dipole arm consists of five wire-linked resistors in series, giving a total resistance of 205 ohms per arm. The ice profiling system was comprised of:

1. Narod impulse transmitter;
2. 5 m resistively loaded transmitting antenna;
3. 5 m resistively loaded receiving antenna, with 50 ohm feed-through adapter to reduce noise; and
4. Picoscope 5243A, 2-channel, 100 MHz, USB oscilloscope, for identification of received radar pulse and data recording.

Use of Gecko data acquisition software (Pettersson, 2014) was envisaged. However, incompatibility with the 5243A Picoscope USB oscilloscope meant that continuous profiling was not possible and only discrete data were obtained; forty soundings were collected over a two-day period. Data were recorded by photographing the screen of the Panasonic Toughbook laptop. Selected individual digital photographs were later digitised using GraphClick software (Arizona Software, 2010) to enable data manipulation. Figure 2 shows an example of the radar data as photographically recorded and Figure 3 shows an example of digitised data, generated using GraphClick. Most recorded data were of this form or similar in nature.

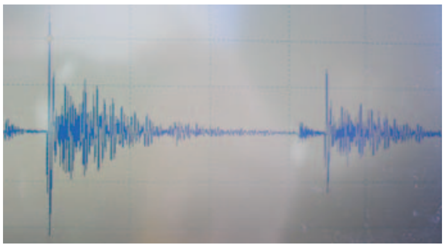

Figure 2. *Photograph of typical ice radar return. In this image, each vertical increment represents 40 mV and each horizontal increment 1.0 µs. The yellow diamond shows the value (+80 mV) at which the oscilloscope trigger was set to commence data capture.*

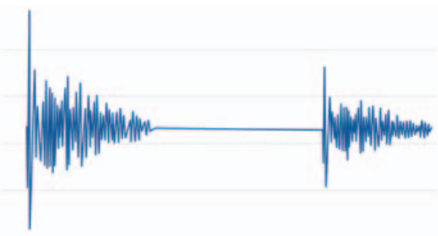

Figure 3. *Digitised version of data shown in Figure 2, created using GraphClick.*

Upon initial examination of data such as that represented in Figure 2 we naively assessed that the second pulse of radar data may be a bedrock return. However, discussion with colleagues suggested that such an assessment was most probably incorrect and that the observed second return was likely to be an air return from the walls of the mountains surrounding the valley glacier. Cursory calculation suggests that such a suggestion was plausible as a delay of ~6 to 7 µs (as evident from the timing in Figure 2) suggests a distance to reflective air boundaries of ~1000 m; this is consistent with the geometry of the location. Later in the data evaluation process we decided that it was possible that these returns may be an artefact or 'ghosting' caused by antennae or system architecture. We are still not sure what to make of this signal.

Continuing this line of investigation, further discussion with T. Chinn (pers. comm., 18 June 2014) and application of Equation 1 (Chinn, 2001)

$$D = 5.2 + 15.4\ A1/2 \quad (1)$$

where D is mean ice thickness (m) and A is total glacier area in km^2, suggested that for the Bonar Glacier, area ~20 km^2, the ice thickness was likely to be on the order of ~70 m.

If the speed of sound in ice is assumed to be ~1.67 × 108 m s^{-1} (Hubbard and Glasser, 2005) then a bedrock radar return may be expected ~0.4 µs after transmission. This is the zone highlighted by the rectangle in Figure 4. The implications of this observation is that any bedrock return (if it exists) is expected to lie within the time range obscured by the extended transmitted pulse, rendering immediate observation very difficult. We then tried to digitise the transmitted wave form, and remove that from the signal, hoping that we would be left with our bedrock reflection. However, this additional manipulation yielded no more conclusive results.

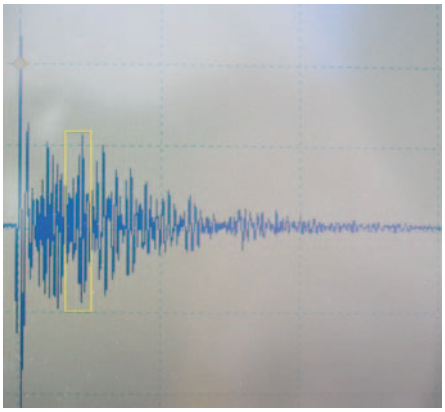

Figure 4. *Time zone (rectangle) in which a bedrock return may be expected if ice thickness was ~70 m. Data collected in this time range is 'smothered' by the transmitted radar pulse resulting in limited potential for bedrock return extraction, should it exist.*

Therefore, after a series of iterative data interpretation and analysis efforts, including discussion on both system design and post-acquisition analysis, it appears that no readily extractable bedrock data is available from the acquired data. As a result, advice is sought from the broader glaciological and geophysical communities on suggested methods by which ice thickness/depth to bedrock data may be extracted from the existing dataset. We are hoping that there may be methods to remove the air/ground wave that seems to be obscuring the bedrock contact data.

Acknowledgements

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