2016 Heard Island Expedition Project Description

Definition

TITLE

MACROSCOPIC INCLUSIONS IN RETREATING GLACIERS ON HEARD ISLAND

Abstract

The termini, margins, and immediate vicinity of selected glaciers on Heard Island will be examined for macroscopic inclusions. Significant items exposed due to retreat of the glacier will be documented and collected for laboratory analysis.

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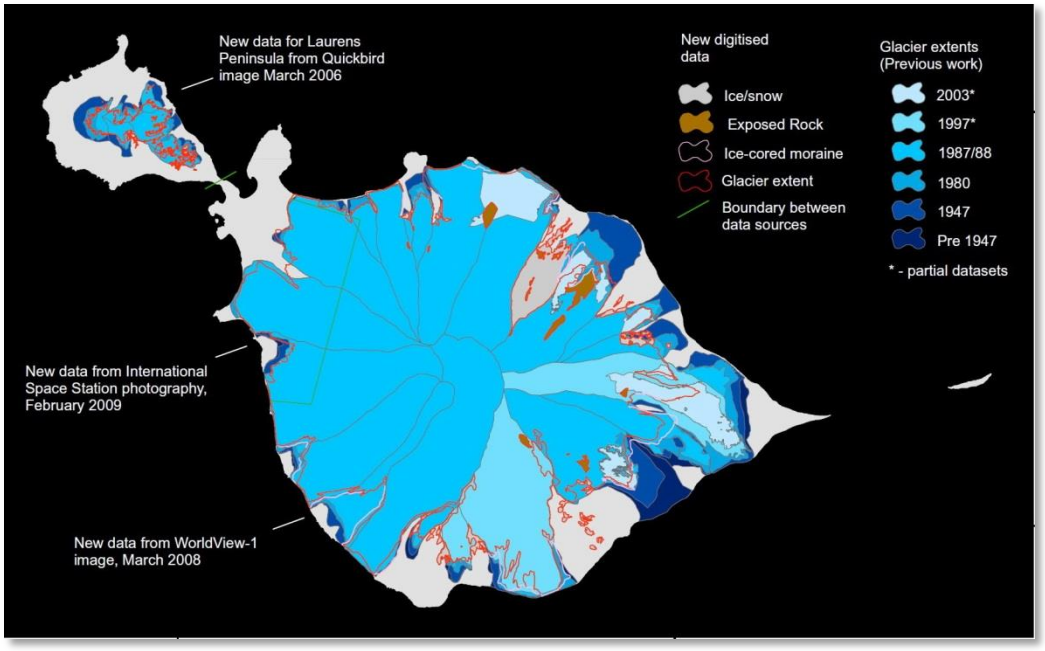
Context

Background

Besides the episodic volcanic activity of Big Ben, perhaps the most obvious dynamic process occurring on Heard Island is the retreat of the glaciers. The extraordinarily high rates of retreat, especially of the Stephenson Glacier (up to 100 m/y), are among the highest in the world. The following map shows historical changes between 1947 and 2009. There is, however, evidence that retreat since 2009 has continued, and even accelerated.



Source: Lucieer, et al. 2009.

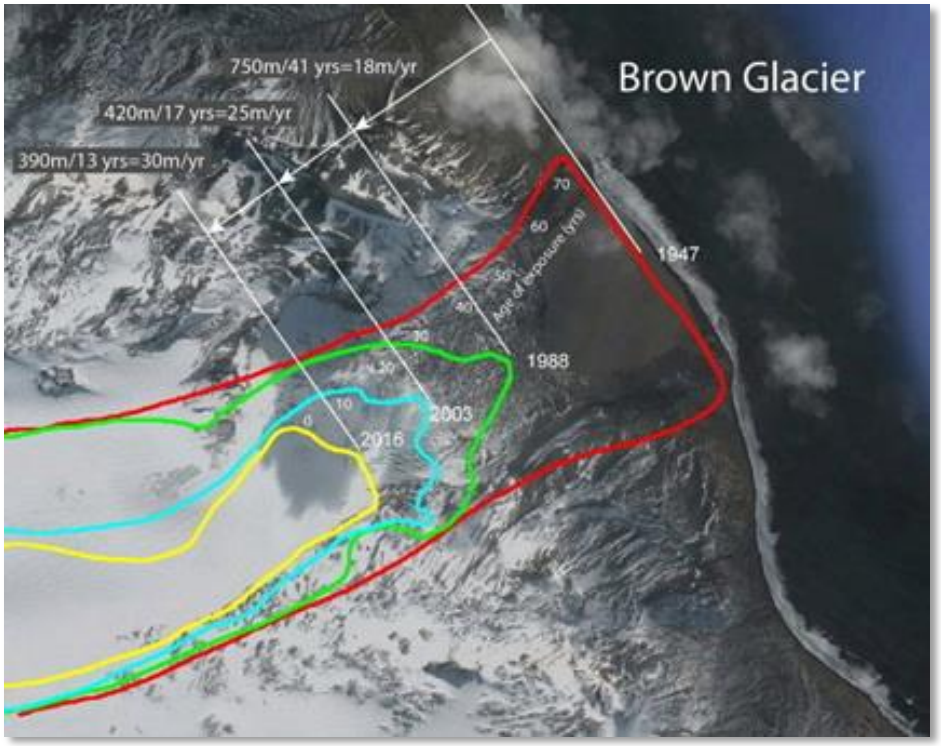
Kiernan and McConnell (2002) provide the following:

> Rates of both glacier retreat and melt-lake enlargement have increased by about one order

> of magnitude during the last two decades. Precise ice-volume loss cannot presently be calculated, but about 30% of the cross-sectional area of the terminal zone of Stephenson Glacier above sea level has vanished in the past three decades. That accelerated melting of older ice-cored moraines is contributing so significantly to melt-lake expansion rather than it being the product solely of glacier recession perhaps emphasizes the significance of temperature increases in causing environmental change on Heard Island. The resulting transformation of the landscape implies there have been some fundamental alterations to the nature, rates, and relative contributions of the various geomorphological processes that are shaping eastern Heard Island.

Thus, the dynamics of the glaciers on Heard Island are among the highest priority for any geophysical research effort. Unfortunately, the 2016 Cordell Expeditions visit to Heard Island does not have the capability to carry out glacial coring, or even to climb the high slopes to observe the formative parts of the glaciers. However, the retreat does serendipitously provide a good opportunity to access older contents of the glacier, namely by examining inclusions in the ice at the fresh termini and accessible flanks of the glaciers. This might be called the "road cut effect:" a new road cut, made for other purposes, provides an opportunity for the geologist to inspect and sample the exposed rocks.

One area that is of considerable interest is Brown Glacier. The following image shows how much this glacier has retreated since 1947.



Our central idea is that the volcano, together with the biological community, are sources of "foreign" materials, many of which were incorporated into the glacier many years ago and released when they reach the periphery. For marine and lacustrine termination, included material will be deposited in the ocean or lake, and lost.

However, because of the retreat, many of the Heard Island glaciers are newly accessible on foot. Hence, we can optimistically expect that the "raw" edges of such glaciers are releasing items of interest. Such items might include:

- Animal remains (bones, feathers, fish skeletons)
- Cryptobiota (e.g., tardigrades)
- Fumerole biota
- Human-origin debris
- Marine shells
- Meteorites
- Relictual plants
- Streambed pebbles
- Volcanic ash
- Volcanic cinders and bombs
- Windblown glacial sediment
- Wood fragments.

Not only might items of these kinds be discovered still locked in the ice, but it is virtually certain that such items have been released as the glacier retreated, and are lying on the newly exposed ground in front of the terminus. Statistically, the position of an item should correlate with its release date. Thus it will be important to document the location of discovery relative to the known retreat path of the glacier, especially if dateable items (plants, wood fragments, shells, etc.) are found.

Special attention should be paid to the observable layering of the glacial ice. The following satellite image, obtained in 2014, shows a remarkable colluvium slope piling up below an exposed glacier. This “gash” is about 700 ft. long and 80 ft. high (max). This would be a good target for the present investigation. Details about this feature are provided in Appx. 1.

Motivation and goals

Macroscopic inclusions provide the potential for investigating the very recent climate and volcanic processes on Heard Island. Assuming the dwell time of objects in the glaciers is less than 50 years, these objects provide probes of specific events within the past few decades. In this sense, the glaciers act like refrigerators, storing these items until they can be discovered.

The goal of this work is to explore the areas at and near recently deglaciated areas, and collect items that can reasonably be identified as relicts of incorporation in the glaciers. If a sufficient number of these objects can be found, a statistical understanding of their distribution in space will lead to an equivalent distribution in time.

Description

Onsite

Equipment	Camera, GPS, clean containers
Location(s)	Recently deglaciated areas, particularly the termini and exposed flanks of glaciers.
Procedure	The onsite work will consist mainly of walking to and through the areas to locate, document, and collect items that are likely remnant glacial inclusions.. Several members of the team will be trained to recognize, document, and collect such items, so that this project can be done simultaneously with other projects (e.g., stream water samples). Field personnel will avoid damage to vegetation at collection sites and avoid trampling vegetation when alternative routes exist on bare ground. Personal will avoid walking single file and avoid traversing vegetated hillsides when possible in order to minimize erosion. No wildlife will be approached or disturbed by specimen collecting activities. Historical artifacts will be left undisturbed.

Records

Photo-documentation	Each item will be documented by GPS location, photographs of the local environment, and a close-up image of the item as found.
Logging	Collected items will be conserved in Ziploc bags.
Nonliving specimens	We will collect almost exclusively nonliving items such as volcanic cinders, marine shells, and streambed pebbles.
Live specimens	We will collect two classes of live specimens: (1) Plants living within the ice; (2) Suspected relictual plants from the deglaciated area. This work overlaps with the project to collect soil samples to contribute to the known species diversity. (see “DIVERSITY”).

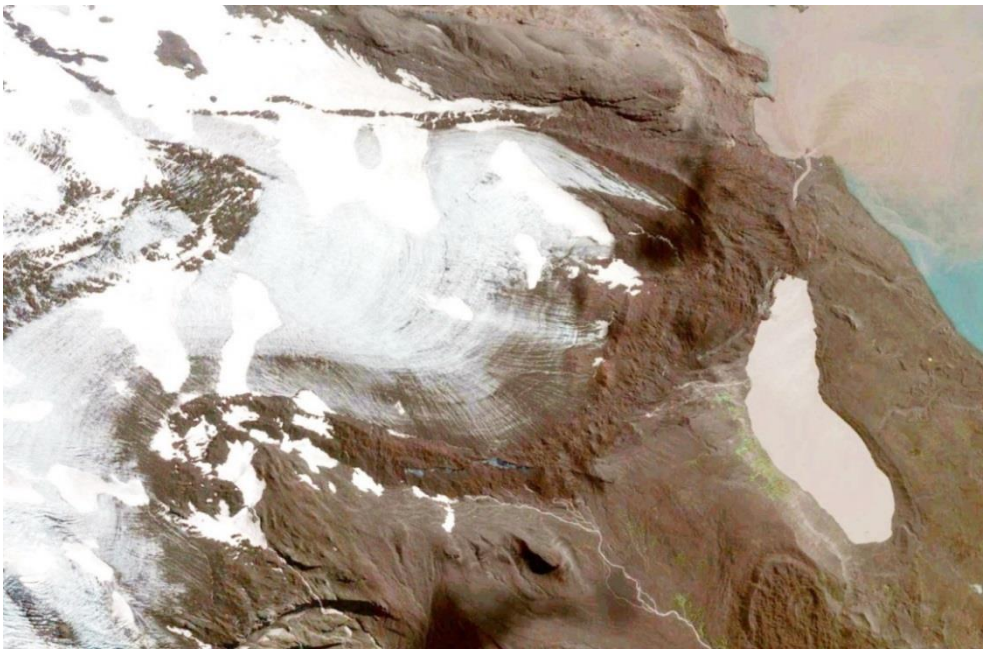
Post-expedition procedure

Destination(s) of records	Cordell Expeditions will retain custody of the collection. We have a variety of specialists capable of identifying these items.
Processing of records	The specimens will be documented together as a group, in order to facilitate statistical analysis of the collection
Publication(s) expected	Paper in the Heard Island monograph. Journal notes as appropriate.
Definition of success	A collection of specimens that are identifiable as glacial relicts, and (if possible) a statistically meaningful collection of items, and their identification.

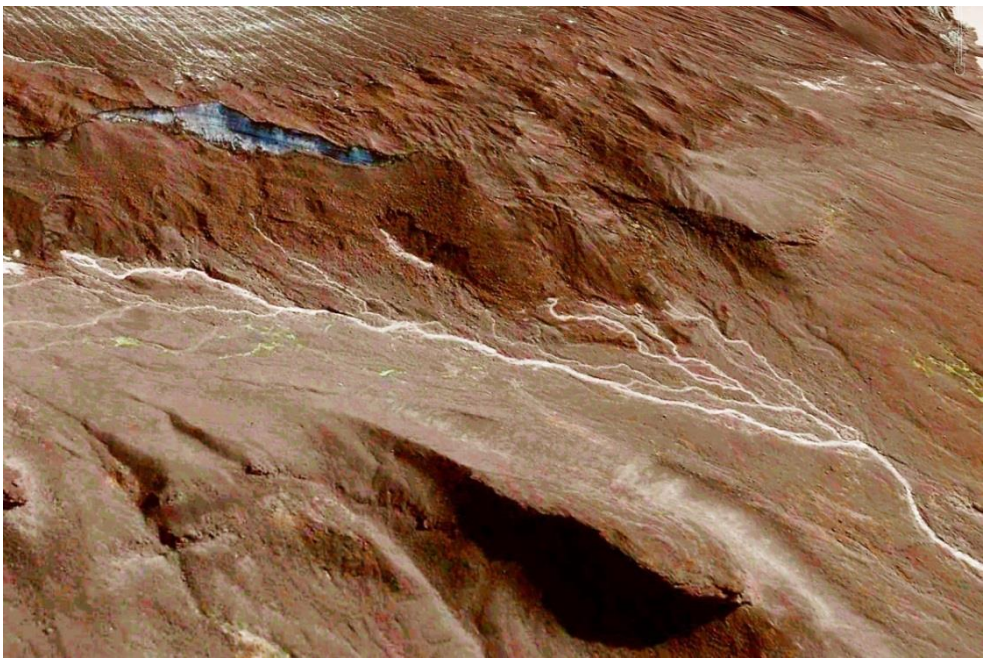
Appendices

Appx. 1 A remarkable colluviation event currently underway on Heard Island

The following image (2014) shows a remarkable feature to the immediate west of the tarn that provides the inlet to the Stephenson-Doppler Lagoon, namely a large (ca. 1 mi) plateau (apparently unnamed). The plateau is bounded to the north by the Graham Ridge (just to the west of the sediment outflow into the lagoon), on the south by Smith Bluff (just above the Winston Lagoon), and to the west by the upslope of the Big Ben massif.

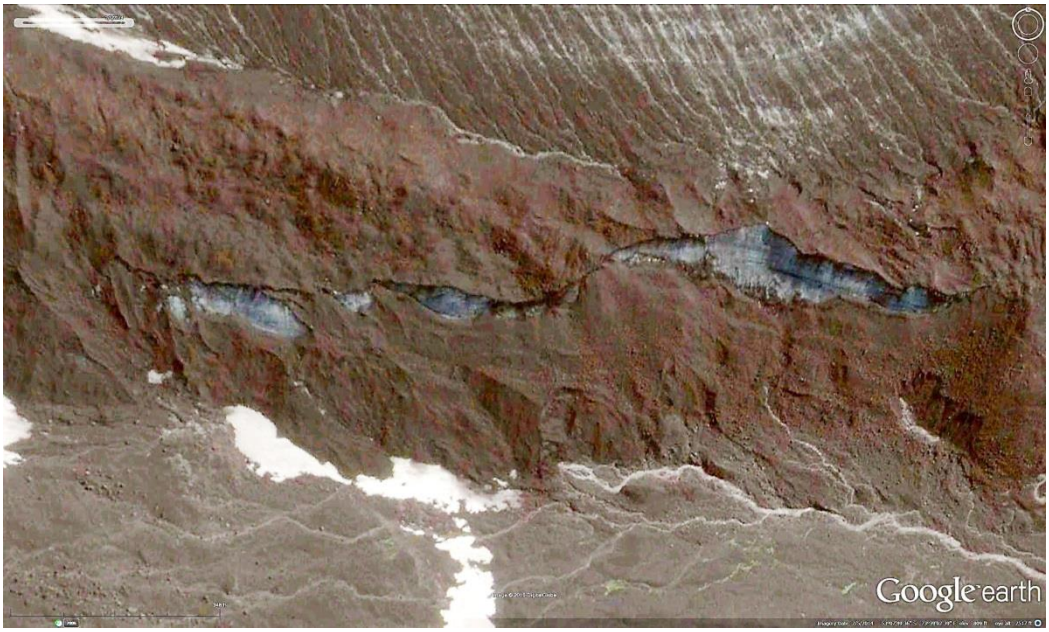


On the lower margin of the plateau is a drainage network, coalescing into the single major stream that moves 1.5 miles through the Paddick Valley to the ocean. Samples from the streams at their points of emergence will carry materials from the plateau.



The image above shows a remarkable feature: on the shoulder of the plateau appears to be a very large “gash,” revealing a bluish, bedded material, shown in here in 2009 and 2014. Two images taken from exactly the same viewpoint in the two years are shown below. These images have been processed slightly (increased brightness and contrast, sharpened, but no alteration of colors). The largest 2009 gash (rightmost) is about 700-800 ft. long and 100-130 ft. high.

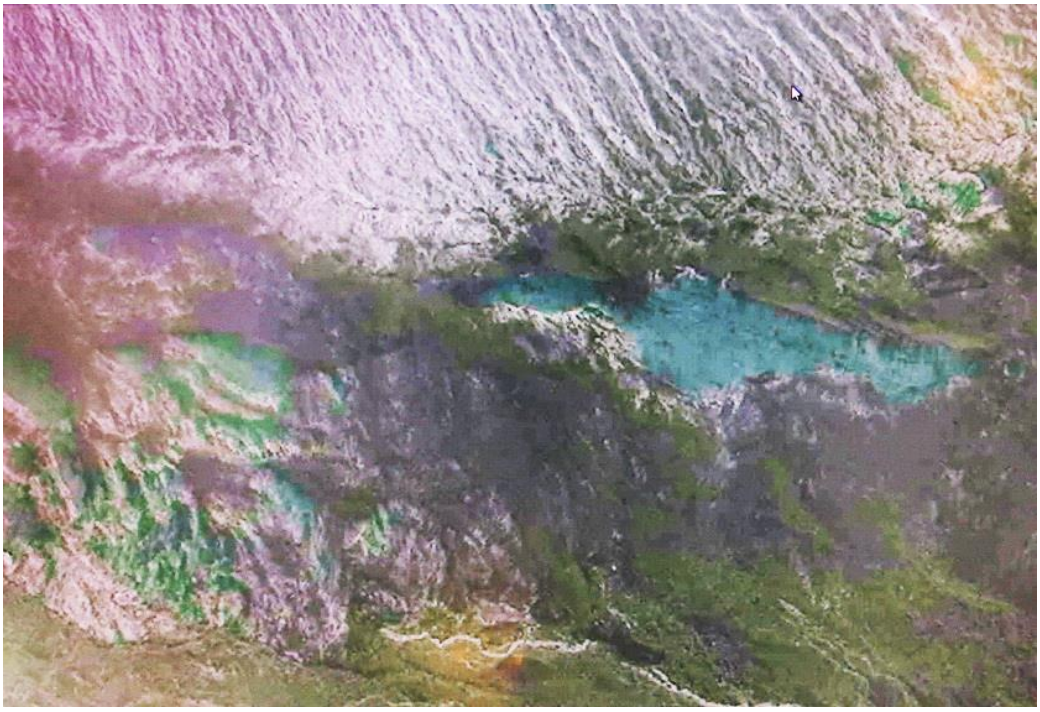
2009



2014

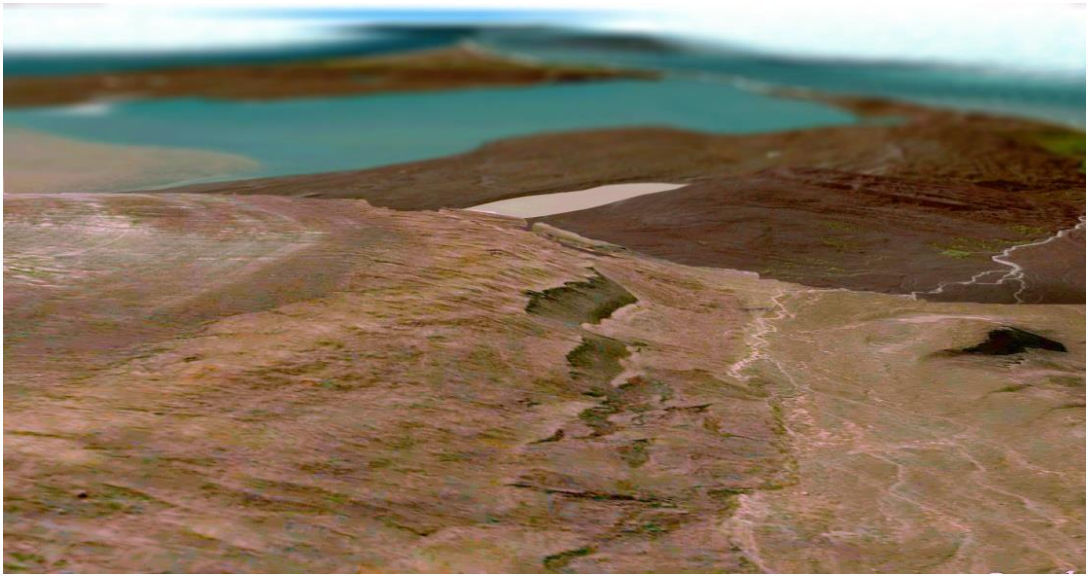
The color and layering of the gash suggests that it might be glacial ice. The images seem to show large-scale removal of a relatively thin overlay of reddish soil, revealing the underlying (and presumably older) bedding; probably we are looking at a sediment-covered glacier that is being actively eroded. However, a detailed comparison of these two images reveals a surprising fact: the 2007 gash appears *lower* than the 2014 gash. If the gash is exposed by large-scale removal of deposits, we might expect it to grow, but not “move.”

An indication of the rapidity of the changes is shown in the following image, obtained from DigitalGlobe. Although the colors are not properly balanced, this 2015 image clearly shows significant changes from the previous year. It is not unreasonable to expect that when we visit this site in 2016 there will be further significant changes.



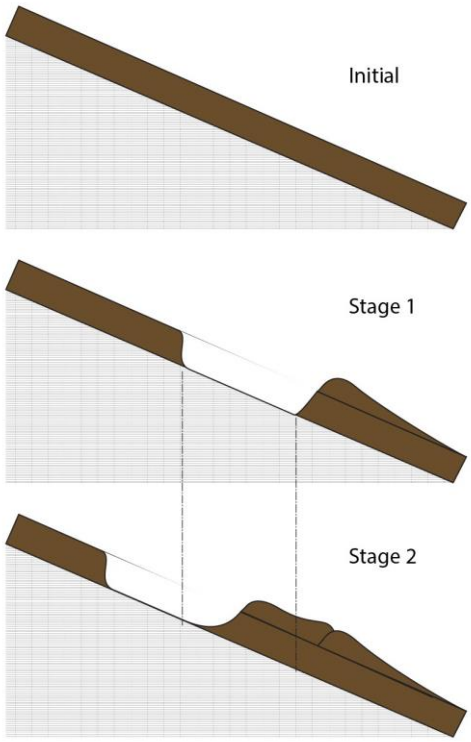
2015

A reasonable insight into the rapid (yearly!) changes is provided by the image below. This image is actually a composite of the 2009 and 2014 images with some enhancements to show more clearly the plateau and its apron. The view of this image is to the southeast.



This image above shows that the gash feature is likely produced by the washing of sediments from the upper edge of the plateau, down the apron, and depositing them at the foot of the slope. Material is removed from the upper edge of the gash and washed to the lower edge of the gash. The correct term for the deposits is “colluvium.”

The proposed mechanism is illustrated below (three time steps, latest in front). Starting with a smooth slope (rear trace), a short (ca 50-100 ft.) section of the overlying sediments is removed by a sudden slump. This exposes the bare glacier, seen as the blue "gashes," and the slump material (red) is deposited downslope. Some time later, another slump occurs, exposing more of the glacier. However, the material from this second slump is partially stopped by the lower bank, covering part of the glacier just previously exposed. That is, the sediment block just slides down and piles up. The net result of repeated slumping events is that the "window" (the "gash") moves upslope, as seen in the satellite images above. The average rate of advance of the gash is about 10 ft./yr., or about 1 ft./month, although it is highly likely that it is storm-driven rather than a uniform flow-transfer.



It is obvious that the open window exposes fresh ice, which might contain items that have been trapped for long times, just ready to be released. Thus, this would be a good candidate for inspection during the 2016 visit.

Appx. 2 Quantification of the glacial variation in the Heard Island using ground measurement in conjunction with satellite imagery

Prepared by Nezamoddin N. Kachouie

Historical variations in the extent of glaciers give insight into natural and forced changes of these indicators of the climate. Because of the limited number of ground observations relative to the number of glaciers, it is useful to develop techniques that permit for the monitoring of glacier systems using satellite imagery.

Trends in the glacial variation including terminus position and variation of individual glacier systems depend strongly on local geometry and local variations in temperature, precipitation, and other local and global factors. Since ground measurements are not available for many glacier systems, the geometry of individual glaciers can be estimated using remote sensing techniques. However, given that each glacier system is likely to be distinct both in the climate variations it

has experienced and in its response to these variations, augmenting ground-based observations with satellite-based estimates is vital.

In this project we model glacial variation of Heard Island glaciers using a combination of ground measurements and satellite imagery. The proposed method permits for collecting local parameters such as temperature and CO2, measuring the terminus position and/or the glacier boundary, modeling the dynamics of glacier system in the Heard Island, and estimating the glacier melt.

Because the collected local parameters will be used in the augmented model (based on ground observation in conjunction with satellite imagery), the proposed model can help us to better understand the glacial activity in response to variation of the local factors as well as global factors. In turn, we can potentially estimate the error associated with the glacial activities which are merely estimated based on remote sensing models. In this way, the proposed model can be used as a template to estimate the associated error with the estimated glacial variation for other glacial systems for which the ground observations are not available.

Ground Measurements:

- Temperature
- CO_2
- Glacier Terminus Location and/or boundary

List of Glaciers in the Heard Island and Their Historical Glacial Activity

- **Baudissin** 1955 -> Continuous marked recession
- **Vahsel** 1955 -> Continuous marked recession. Loss of at least 200 vertical feet of ice, with horizontal retreat as indicated by terminal moraines
- **Abbotsmith** 1947 -> Relatively little changes
- **Gotley** 1947 -> Relatively little changes
- **Winston** 1947–1963 Loss of about 300 feet in thickness as indicated by young moraines flanking the Winston Lagoon; Retreated 1 mile
- **Stephenson** 1947–1963 50 feet of coastal ice cliff disappeared and terminated 100 yards inland
- **Brown** 1947–1963; 2008 Similar to the Stephenson Glacier. 50 feet of coastal ice cliff disappeared and terminated 100 yards inland [2] 29% reduction in area
- **Compton** 1947–1986 Retreated 1600 metres
- **Jacka** 1955 -> Continuous marked recession

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Evaluation

HIMI Management Plan

The present project is sanctioned by Items **A5** and **A10** of **Table 2, Section 5.5** of the HIMI MP:

> **A5)** Long-term monitoring of climate, glaciers, and fauna and flora colonization of newly deglaciated areas.
>
> **A10)** Systematic geological mapping and monitoring of volcanic activity.

Section 5.5 of the HIMI Management Plan provides the following:

> Research within the Reserve is required for the integrated and ecologically sustainable management of the broader HIMI region. … Scientifically robust evidence is needed to make effective conservation management decisions. … Research and monitoring activities must be undertaken in accordance with the research and monitoring priorities identified in Table 2 and the Australian Antarctic Science Strategic Plan. … Research also facilitates the fulfilment of public reporting requirements.

In combination with the remarks about Table 2 (above), we interpret this statement to mean that the research described in this document is consistent with the AAD mission for management of the HIMI.

The HIMI Management Plan further provides

> … the policies … require … that: any biological resources taken are not intended to be used for commercial purposes; … that samples will not be given to other people … without permission … [Parts of this excerpt are omitted solely for space requirements in this document, and are not meant to be omitted in the agreement.]

We do affirm that this project has no commercial interest or activity, and that Cordell Expeditions guarantees conformance with the above statement, both in words and meaning.

Priority

This project is extremely high priority for the 2016 Cordell Expedition. It can be carried out simultaneously with other projects, particularly studies under the categories “DIVERSITY” and ”STREAMS”, which involve taking samples of the water and soil for documenting the environment and probing the volcano.

Specimens

This project centers on obtaining specimens that can reasonably be considered as having spent time in residence in a glacier. These artefacts cannot be reliably identified in the field, hence collection is essential.

Risks

There are no inherent risks in the work of this project, other than the risks associated with human access to the collection sites, which are covered in the Risk Management Plan for the visit to Heard Island. The team will take every reasonable precaution to avoid and minimize any impact on the environment.

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