Permit Request:
Long-Term Monitoring and Sampling of Permafrost on Maunakea

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Summary

The summit plateau of Maunakea is a stone desert, yet ice-rich permafrost has been found in two cinder cones near the summit in the 1970’s. Our studies from 2012–2016 revealed that these ice-rich bodies are still present, but one has dramatically shrunk in volume, and both are expected to ultimately disappear due to climate warming. We propose to establish long-term monitoring boreholes for permafrost health and sample material for scientific analyses.

Previously we investigated the permafrost from the surface; in the proposed research the ice bodies would be studied in-situ. Specifically, the proposed research activities in the Maunakea Science Reserve (MKSR) and the Maunakea Ice Age Natural Area Reserve (NAR) are:

1. Continue limited ground temperature data collection in two cinder cones (Pu‘uwēkiu and Pu‘uhaukea)
2. Drill one up to 8 m deep 1”-diameter borehole at each of the two permafrost bodies, and fit them with temperature sensors for long-term permafrost monitoring
3. Sample the material extracted from these boreholes for scientific analysis

1. Background

Permafrost is ground that is continuously frozen over two or more years. Two small ice-rich permafrost bodies were documented in the early 1970’s (Woodcock et al. 1970, Woodcock 1974). From 2012–2016 we investigated the state of the permafrost with methods that involve minimal disturbance to the environment: shallow temperature data loggers, electrical resistivity tomography (ERT), and ground penetrating radar (GPR), supplemented with satellite observations and computer modeling. The study resulted in the characterization of four bodies of perennial water or ice in the Maunakea summit region: permafrost bodies in Pu‘uwēkiu and Pu‘uhaukea, the vicinity of Lake Waiau, and Pu‘upōhaku Pond.

Nearly half a century after their discovery, two ice-rich bodies are still present, but the one in Pu‘uwēkiu has retreated all around; its volume has shrunk by an order of magnitude and the remaining ice body is expected to disappear soon. The other, in Pu‘uhaukea (Figure 1), is still at least 50 m wide and about 10 m thick, and no previous documentation is available to judge its
change over time. We also prospected the summit region for additional permafrost bodies, based on modeling of solar irradiance, additional ERT surveys, temperature probing, and geomorphological indicators, but no other ice-rich bodies were found.

The results of this research are published in three journal articles (Leopold et al. 2016; Schorghofer et al. 2017; Schorghofer et al. 2018) and a report (Schorghofer 2018). As was stipulated in the permits, air and shallow ground temperature sensors that were deployed during the 2012–2016 study period have been removed, and no further geophysical surveys are proposed. As an interim solution, a few temperature sensors have been left in place at two cinder cones, while awaiting a long-term plan for permafrost monitoring.

![Figure 1: Hawaii’s largest known perenniially frozen ice body hides below the interior south slope (facing the camera) of the cinder cone Pu‘u‘haukea. The arrows point at two field team members at locations of shallow temperature sensors.](image)

2. Permit Request

2.1 Surficial Monitoring

At Pu‘u‘haukea (NAR jurisdiction) two ~1 m deep temperature sensors are in place above the permafrost body. We propose to leave one in place over the next decade or longer.
At Pu‘uwēkīu (MKSR jurisdiction) several of Woodcock’s vertical pipes are still in place and we re-instrumented (with considerable effort) two of them with temperature sensors up to 4 m and 6 m depth, respectively. These two boreholes were once immersed in the ice. In the same area, several sensors have been placed at shallow depths above the permafrost body. Based on these sensor measurements, we currently investigate the relation between snow cover and ground temperature, and we propose to continue this study to capture a range of winter snow conditions. The five current monitoring locations are aligned roughly along a north-south transect.

These sensors record temperatures above and next to the permafrost bodies. This investigation requires no new instrumentation, but field visits to read the data loggers approximately every two years.

2.2 Long-Term In-Situ Permafrost Monitoring

The most direct way to assess permafrost health is through long-term temperature measurements within the ice body (Osterkamp & Jorgenson 2009). These temperature sensors have to be inserted into the interior of the permafrost bodies by means of a borehole. The geophysical surveys have revealed that the smaller of the two bodies extends 2–6 m below the surface, and the larger about 1–11 m. Ideally, we would drill through the entire bodies, but, at a minimum, the sensors need to be well within the current ice bodies. We ask for permission to establish such permafrost temperature monitoring stations at Pu‘uwēkīu and Pu‘upōhaku with a maximum depth of 8 m. (In the 1970’s Woodcock managed to drive pipes 10 m deep into the ground.) Practically, the depth will be determined by the ease or difficulty at which the drilling proceeds, and realistically we expect to reach ~4 m depth within a few days of field work. The locations are marked on the map in Figure 2.

The temperature sensors will be emplaced with a 1" diameter dry coring system, with the help of a scientist with extensive experience with permafrost monitoring (Figure 3). The drill is operated electrically using a portable Honda 4-stroke 2 kW generator. The rationale behind choosing a 1" diameter is that it can be accomplished with portable equipment. Once the borehole is established, it will be cased with a 0.5" diameter PVC pipe that will form a conduit for up to 8 temperature sensors. The drill diameter is only 1", and the heat generated during drilling poses no risk to the permafrost body as a whole. A dry drilling technique is chosen to avoid any contamination risk.

After the temperature monitoring stations have been established, the data will need to be read periodically. This could be accomplished with satellite communication and solar panels, but antenna and panels would protrude from the surface, and satellite communication would potentially interfere with the nearby radio telescopes. Instead, we propose to use battery-powered data loggers that are maintained by visits every 1–3 years. These can be easily hidden below boulders, so no component will be visible from afar. Figure 4 shows the type of data logger we plan to use, which has been successfully deployed on Maunakea in the past.
Figure 2. Study sites (red) and planned access routes (blue) on Maunakea. Pu‘uwēkiu lies within the Maunakea Science Reserve (MKSR) and Pu‘uhaukea within the Maunakea Ice Age Natural Area Reserve (NAR).

Figure 3. The coring equipment we plan to use on Maunakea for drilling and sampling consists of 1" diameter pipe segments.
We propose to keep these monitoring boreholes and sensors in place for at least a decade to monitor the retreat of the permafrost. The data loggers and sensors could ultimately be removed, if desired, but the 0.5" diameter vertical PVC pipes might not be removable. Vertical pipes with sensors, also known as “frost tubes”, are extensively deployed for permafrost monitoring worldwide, and pose no risk to the ice, even in the long-term.

A temporary weather station (1 m high) will be placed above the permafrost monitoring location to collect context information. This is only proposed for Pu‘uhaukea, where it will not be visible from any road or trail. After one year, this weather station will be removed and no part of the underground monitoring station will be visible from the surface. The temporary weather station is an optional component of the study, which would aid in characterizing the physical environment in ways not available from existing data.

2.3 Sampling

With the drilling, a small amount of material will be brought up to the surface, and we propose to use this material for scientific analysis. As the ice retreats to greater depth over coming years, sampling will become increasingly difficult, and ultimately the opportunity to study this unique natural historical record will be lost entirely.

The age of the ice on Maunakea has never been determined. The ice may be a leftover from the last Ice Age or of more recent origin. Either way, formation of the permafrost marks a major climatic event that affected the summit region, and probably all of Hawaii. The emplacement age of the ice could be determined by carbon-14 dating of organic inclusions in the ice (in the form of insect fragments or other particulate organic carbon). C-14 dating has been unsuccessfully attempted by Woodcock (1974) with insects he found in the ice, but with modern technology, specifically Accelerator Mass Spectroscopy (AMS), the detection limit for C-14 is considerably lower, so dating of the permafrost is feasible, as long as we can find fragments of organic matter. Variations in isotope and ion concentrations with depth will allow inferences on whether the ice is made up of layers of varying age.
We also propose microbial analysis to characterize the diversity and function of microbial communities in this extreme environment. Since the corer is not sterile, we propose to sample this material (<5x100g) from the pristine surface layer in the immediate vicinity of the borehole that will subsequently be disturbed in any case.

To maximize the science return, samples will be sent to several laboratories for a variety of analyses. Specifically, the planned sample analyses are:

a) Carbon-14 dating of insect fragments immersed in ice, which will constrain the age of the ice

b) Stable isotopes (2H/1H, 18O/16O) every ~0.3 m along the permafrost core

c) Ion concentrations every ~0.3 m along the permafrost core

d) Microbial analysis: methane oxidizing bacteria, 5x100g at each site

We will photographically document the core on-site, seal aseptically collected samples for microbiological analysis, and transport the core segments to lower elevation. Some of the ice within the thin core may already melt during the drilling. Samples will then be promptly delivered to laboratories at the University of Hawaii at Hilo and at Manoa, and mailed to laboratories in Japan, UC Berkeley, and Princeton University. The remaining soil core and melt water will be stored at the University of Hawaii (at room temperature), and registered with SESAR (System for Earth Sample Registration), so scientists worldwide will be aware of the core’s existence and can request samples. (Ice core repositories do not accept permafrost cores.)

3. Schedule and Field Participants

The majority of the field work—probe emplacement and sampling—, will take place during a single field trip of about 5 days, tentatively scheduled for summer 2019. The portable equipment will be carried in and out of the cinder cone craters by a team of 3–4 people.

Thereafter, we plan to visit the data loggers every 1–3 years to read the stored data and replace batteries in the data loggers. This can be accomplished by one person, but for safety, it will involve two people.

As we have done for previous field work, we will notify OMKM and DLNR in advance of the date for each field trip.

- Norbert Schorghofer, Ph.D. (Planetary Science Institute & University of Hawaii at Manoa) will be responsible for overall project coordination, for assuring successful project completion, submission of progress reports, and scientific publications.

- Kenji Yoshikawa, Ph.D. (University of Alaska at Fairbanks) has extensive experience in permafrost monitoring. He will provide the coring equipment and lead the drilling effort.

- Jesse Eiben, Ph.D. (University of Hawaii at Hilo) is an entomologist with extensive field experience on Maunakea. He will study insect samples found in the ice.

- OMKM staff or interns might participate in the field work.

- Students (from the University of Hawaii or Hawaii-based internship programs) might participate in the fieldwork and/or help with data analysis.
4. Summary of Proposed Activities

*Maunakea Science Reserve, Pu‘uwēkiu interior south slope (MKSR)*

- a) Keep existing temperature sensors in place at five locations for a decade or longer
- b) Establish one up to 8 m deep 1" borehole, insert ½" plastic pipe, and instrument with sensors
- c) Sample material from the permafrost core and up to 500g from its immediate vicinity
- d) Thereafter visit every 1–3 years to read data loggers over a decade or longer

*Maunakea Ice Age Natural Area Reserve, Puʻuhaukea interior south slope (NAR)*

- a) Keep existing sensors in place at 1 location for a decade or longer
- b) Establish one up to 8 m deep 1" borehole, insert ½" plastic pipe, and instrument with sensors
- c) Sample material from the permafrost core and up to 500g from its immediate vicinity
- d) Thereafter visit every 1–3 years to read data loggers over a decade or longer
- e) Place temporary weather station (1m high) for one year

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<tr>
<th>Investigation</th>
<th>Number of Locations (Current / Proposed)</th>
<th>Proposed Duration</th>
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<tbody>
<tr>
<td><strong>Maunakea Science Reserve (Pu‘uwēkiu interior south slope)</strong></td>
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<tr>
<td>existing temperature sensors</td>
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<tr>
<td>sampling</td>
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<td>sampling</td>
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<td>n/a (one time)</td>
</tr>
<tr>
<td>weather station (1m high)</td>
<td>0 / 1</td>
<td>1 year (visible from within crater, not from outside)</td>
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5. Further Programmatic Aspects

**Potential Cultural, Environmental, and Natural Resource Considerations:** The field study requires access to two cinder cones. Mitigation actions include:

- Advance mapping of access routes and consultation with OMKM rangers to avoid cultural sites and prime Wekiu bug habitats; we use existing trails where possible, walk on large cinders to avoid leaving footprints, and ascend Puʻuhaukea cinder cone on the west side out of view from the main road
- Hiding of data loggers left in the field
- Thorough cleaning and following invasive species protocols

**Information, Data, & Sample Management:** Manuscripts for academic journals will first be submitted to OMKM and DLNR for review. Raw and derived data will be placed in a public data archive. Samples will be catalogued and made available to other scientists for further analysis.

**Funding:** The Office of Maunakea Management is considering to provide funding for this project. Some of the sample analysis will be carried out by external institutions at their own expense.

**References**


