TIME-LAPSE INFRARED IMAGING OF CRATERS ON MAUNAKEA

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ABSTRACT

On the summit of Maunakea, there are craters that have permafrost and they resemble the craters on Mars. The purpose of this research is to study the temperatures inside these craters. This project is divided into several subprojects. The first subproject is to improve a custom built camera system, which is used to take visible and infrared time-lapse images of the Maunakea craters. The second subproject is to analyze the infrared images collected with the camera system. The third subproject is to create an animation of the infrared-derived surface temperatures from the 24 hour image sequences. The last subproject is to analyze the images collected from a webcam installed on the edge of the crater to determine whether there is snow. By studying the temperature in craters on Maunakea, we will be able better predict where ice can be found in tropical craters on Mars. This project is directly relevant to NASA’s goal to expand scientific understanding of the Earth and of Mars.

INTRODUCTION

The summit of Maunakea is exceptionally dry and its climate is classified as an Alpine desert. In 1969, permafrost was discovered in two cinder cones near the summit (Woodcock et al. 1970). One of the locations extends from the north-facing inside wall to the floor of Pu‘wēkūi. Woodcock (1974) concluded that the survival of the ice is associated with shadowing by the crater rim and with nocturnal cold air lakes. The permafrost was below the melting point temperature by only a few tenths of a degree, and may have retreated since.

The environment on Maunakea may serve as analog to craters on Mars, where microclimates also play a major role (e.g., Schorghofer & Edgett 2006, Shean 2010). One of the methods used to study Mars is remote-sensing of surface temperatures with an infrared camera, called THEMIS, on board the Mars Odyssey spacecraft that orbits Mars. The Thermal Emission Spectrometer (TES) on board the Mars Global Surveyor also measured surface temperatures over many years.

A research project, by my mentor, is currently ongoing to study microclimates and permafrost inside the craters on Maunakea. Among the field methods that are being employed is infrared imaging with an autonomous infrared camera. A prototype camera system has recently been developed at the University of Hawai‘i by Dr. Brendan Hermalyn (Figure 1). The time-lapse infrared camera system maps the temperature distribution in the craters night and day.
The goal of this research project is to study surface temperatures inside craters on the summit of Maunakea. For this purpose, a custom-built camera system is used that consists of an infrared camera, a visible camera, a pyranometer that measures light intensity, a lithium-iron battery that provides power throughout the night, a solar panel that provides power at day and recharges the battery, and an electronic control box that is programmed to acquire a picture every five minutes. I have improved components of this camera system, employed it on Maunakea, and processed the data.

METHODS AND RESULTS

My research mostly centered around the camera system shown on figure 1, which was built by Dr. Brendan Hermalyn. My research was helped and advised by Dr. Norbert Schorghofer.

Before our research team deployed the camera system to the summit of Maunakea, we wanted to make sure that it will run for 24 hours and also make modifications for easier assembly. I tested the infrared camera system (IRCam) multiple times over different time periods including several 6 hour test runs and several 12–24 hour test runs. Voltage data from these test runs were gathered, and Figure 2 shows the voltage drop of the battery with time. From the graph, we are able to estimate the remaining battery capacity when we are in the field. I also measured the power consumption (~391mA), which is low enough for the 36Ah battery to last 92 hours without solar power. These measurements were made at room temperature and performance is potentially worse at lower temperature.
The pyranometer mount and solar panel mount of the system were modified. For the pyranometer, a few pieces of machined polycarbonate sheets were used as the base, and the 4m cable was shortened. For the solar panel, the original aluminum pieces were replaced with angled aluminum. These modifications allowed the mounting of the solar panel much faster by no longer requiring screws and nuts. With these two modifications, system assembly time was dramatically reduced.

After the modifications, my mentor and I flew to the Big Island to deploy the camera system in the field in October 2013. The system was set up in the environmentally sensitive summit area to take infrared images. The first run during this visit successfully collected infrared images of Lake Waʻiʻau for more than 24 hours. For the second run we pointed the camera to the south slope of the summit. This second run stopped at 1am after about 12 hours into the data gathering.

Next, I converted all the IR-derived temperatures into plain-text csv files. The FLIR E30 IR camera stores images in “radiometric jpeg” format that can only be read with proprietary software. At first, I tried to decrypt the format with my own custom Java program but we could not figure out the conversion factor between the binary value of the pixel and the temperature. Afterwards, I explored other possibilities, such as Windows scripting, but I ended up using the trial version of ResearchIR, a program by FLIR (the maker of the IR camera we are using), to convert all the data at once. Figure 3 shows the daily mean and the nighttime temperature of Puʻuʻwēkiu.

After converting all the IR images, I organized all the data that had been gathered so far (six time series from Maunakea). The problem with the data was that the clocks of the visible camera, the IR camera, and the pyranometer data were not synced, so we had to match them up using different strategies, including clouds and hikers that were in the field of view of the infrared as well as in the visible camera.
Afterwards, I started learning Matlab to calculate the daily (24hr) mean infrared-derived temperature of each pixel. Matlab was also used to create animations of our IR time series. We found out that occasionally a pixel is missing, and I cleared these ghost pixels from the data with a median filter.

During my first semester, I also wrote a UNIX script to download images from a webcam in front of one of the telescopes hourly from 7am to 5pm. Figure 4 shows one of these pictures. This webcam happens to point into Pu’wēkiu and can be used to determine the snow cover in the crater.
At the end of my second semester, I created a Java program that detects snow in the webcam images of the summit. The area with the red rectangle in Figure 4 is the area I check for the snow. To check if there is a snow cover on Maunakea, the image is converted into grayscale and then checked if the rectangular area is within the certain shade of grayness (pixel values from 171 to 255. Higher pixel value means whiter shade). If more than 62% of the pixels are within the grayness threshold, I consider it as a “snow suspected” image.

![Figure 4: A webcam image of Maunakea summit that we feed into the snow detection Java program. The red rectangle shows the area used for the snow detection of snow cover.](image)

I also wrote a UNIX script to run the Java program for all the pictures that were acquired so far. There were about 3500 pictures, and all of them were checked for snow coverage. On a typical sunny day, about 10% of the rectangle was within the grayness threshold for snow detection. On a typical rainy day, about 30% of the rectangle was within the grayness threshold for snow detection. On a typical heavily foggy or snowy day, about 80% of the rectangle was within the grayness threshold for snow detection. Therefore, heavily fogged days were also considered as “snow suspected” pictures, and these images have to be separated by visual inspection.

The snow cover time series can be compared with near surface temperature measurements from data loggers inside the crater. We find that periods of thick snow cover, as occurred in February 2014, correspond to small temperature variations. The cross-comparison of the webcam images with the near-surface temperatures at this one location enables us to validate the relation between small temperature amplitude and snow cover.

**SUMMARY, CONCLUSIONS, AND DISCUSSION**

From the research conducted over the course of a year, I am able to conclude the following.

First, from the testing we conducted in the laboratory and in the field, we know that our system battery will last longer than 24 hours. To test this, we ran the system for more than 24 hours in the lab, monitoring the voltage and current. After we finished the system modification, we deployed the system in the field.
Second, we can conclude that some spots in Pu’wēkiu and Pu’u Wai’au are colder than the surrounding areas. This can be seen from figure 3 (top), which shows the daily mean temperature of Pu’wēkiu. The coldest area indeed closely corresponds to the area where Woodcock (1974) had documented permafrost.

Lastly, we have maintained a record of webcam images and developed a program to analyze these images for snow cover. This provides specific information about snow in Pu’wēkiu, and is also used to compare with temperature sensors that continuously record near-surface temperature inside the crater. Snow cover corresponds to small daily temperature amplitude.

Studying the Maunakea craters and why they can have permafrost will help us understand Mars better. Both Maunakea’s craters and Mars tropical craters are in the same geographic location on each corresponding planet and both have icy floors. By studying the temperature in craters on Maunakea, we will be able to learn more about the temperature in Martian craters, and we will be able to better predict where ice can be found on Mars.

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REFERENCES


