Understanding basaltic volcanic processes by remotely measuring the links between vegetation health and extent, and volcanic gas and thermal emissions using HyspIRI-like VSWIR and TIR data

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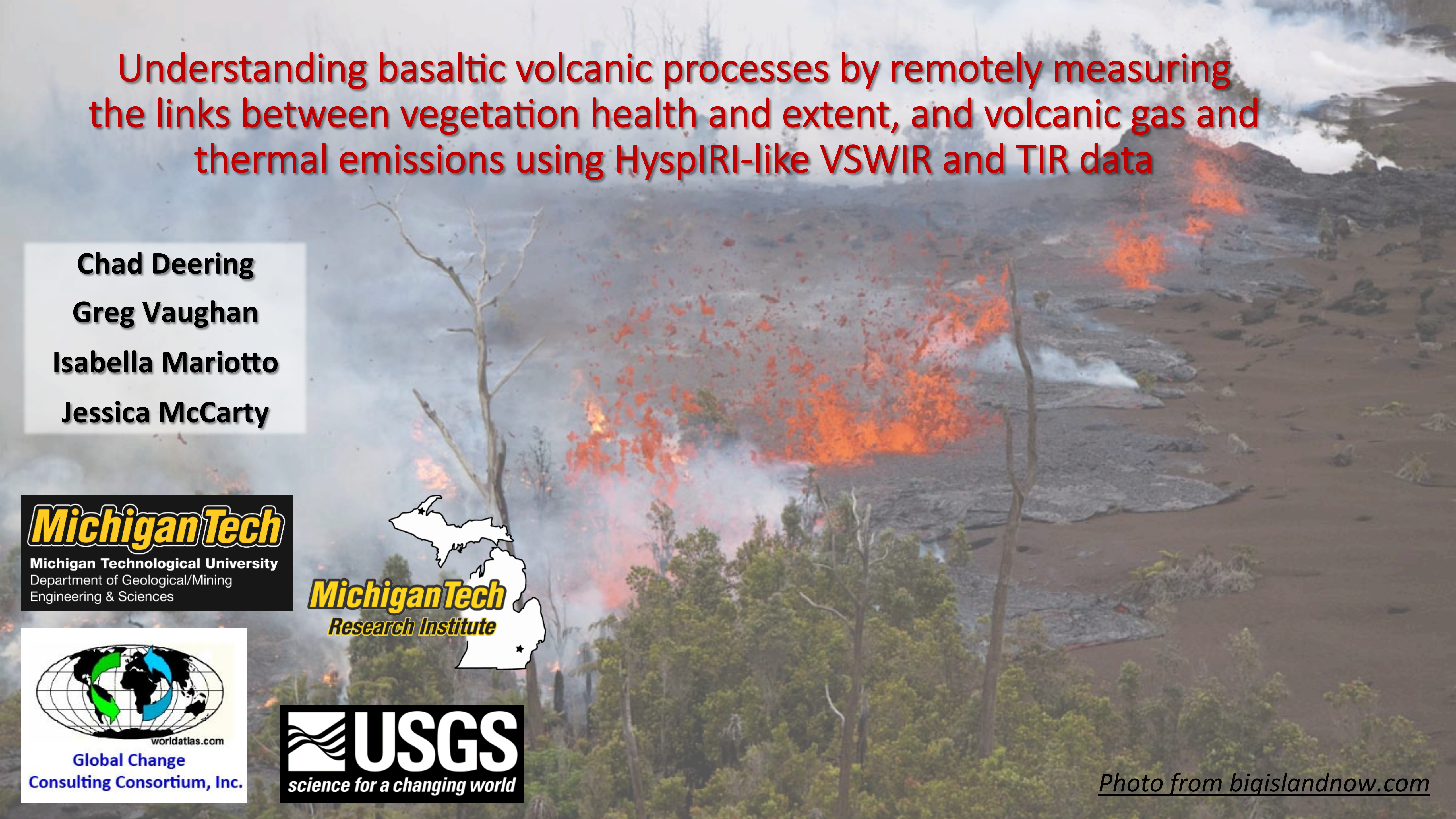


Photo from bigislandnow.com

Motivation

- **Parícutin scoria cone in Mexico ~320 km west of Mexico City**
- **Emerged in a local farmers cornfield in 1943**
- **By 1952 the volcano was 424 meters high and had damaged a large area**
- **Beginning five weeks before the eruption 21 earthquakes occurred**
- **Day of eruption Pulido family was working the farm when the ground nearby began to swell and form a fissure; smelled of rotten eggs**

Pulido reported:
At 4 p.m., I left my wife to set fire to a pile of branches when I noticed that a crack, which was situated on one of the knolls of my farm, had opened . . . and I saw that it was a kind of fissure that had a depth of only half a meter. I set about to ignite the branches again when I felt a thunder, the trees trembled, and I turned to speak to Paula; and it was then I saw how, in the hole, the ground swelled and raised itself 2 or 2.5 meters high, and a kind of smoke or fine dust -- grey, like ashes -- began to rise up in a portion of the crack that I had not previously seen . . . Immediately more smoke began to rise with a hiss or whistle, loud and continuous; and there was a smell of sulfur.

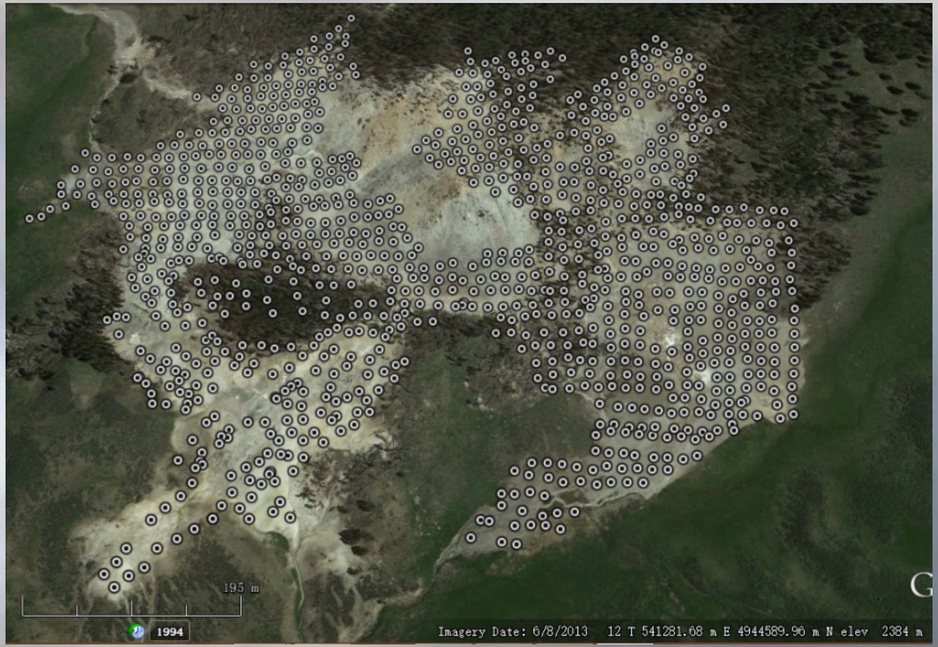
Motivation

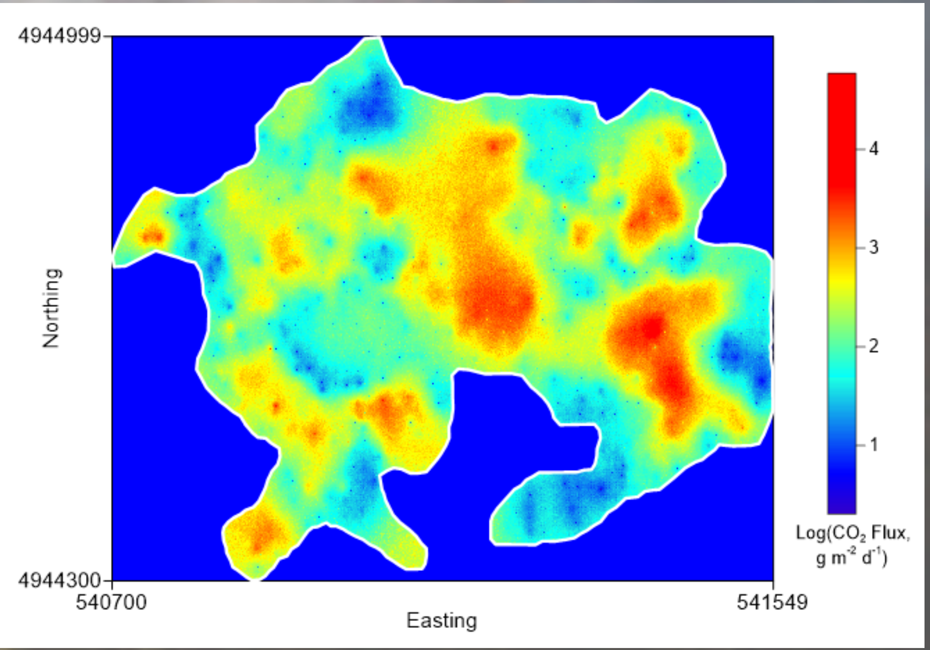
- **40 km down the east rift zone from the Kilauea summit earthquakes began in 1959**
- **By mid-January 1960 a crack opened up along the Kapoho fault within the Kapoho village**

Photos: USGS HVO

Motivation

- Typical field campaign
- *Example*: Crater Hills, Yellowstone (~1 km^2)
- 5-6 weeks, dawn to dusk…
- > 1500 measurements





Remote sensing offers a potential solution…

Early identification of vent shifts and migration (days to weeks)

- Inhospitable and/or inaccessible environments
- Avoid lengthy field campaigns
- **Significantly** improved spatial and temporal coverage

- CO_2 and SO_2 solubility leads to deep degassing, therefore, diffuse soil gas emissions are likely to precede eruption before shallow earthquakes

Note: InSAR already being used to detect inflation at volcanoes

The remote characterization of vegetation in volcanogenic environments stressed by anomalous increases in CO_2 and H_2S diffuse soil degassing has the potential to transform our ability to monitor volcanic activity on a global scale at unprecedented spatial and temporal resolution.

This project will answer the following scientific questions:

1. How can the effects that volcanic processes have on the surrounding landscape be quantified and regularly measured using HyspIRI remote sensing data?

2. What is the spatial / temporal relationship between surface temperature, gas emissions (SO_2, H_2S, CO_2), surface vegetation cover, and volcanic eruptions?

3. Do AVIRIS hyperspectral VSWIR data perform better in vegetation health and change monitoring compared to multispectral VSWIR data from MASTER?

HyspIRI science questions

- *CQ3: Do volcanoes signal impending eruptions through changes in the temperature of the ground, rates of gas and aerosol emission, temperature and composition of crater lakes, or health and extent of vegetation cover?*

- *TQ1: Can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?*

Objective 1: Diffuse H_2S and CO_2 measurements and mapping of local vegetation cover

- Conduct fieldwork to collect *in situ* measurements of diffuse soil H_2S and CO_2 flux and ground temperature as well as vegetation type and condition data along the planned flight paths, with a focus on the Kileaua, East Rift zone.
- Map the local vegetation cover type by identifying the HVIs and HNBs that best separate the major vegetation types/species, and compare them with the models and maps developed using broadbands (BBs) from MASTER and Landsat OLI.

Objective 2: Develop HVIs and HNBs

- Develop hyperspectral vegetation indices (HVIs) and optimized hyperspectral narrowbands (HNBs) that can characterize biophysical and biochemical properties of vegetation and consequent characterization of healthy and CO_2, H_2S, and SO_2 stressed vegetation located in non-active and active volcanic areas.

Objective 3: Hyperspectral Libraries

- Build a hyperspectral library of healthy and CO_2, H_2S, and SO_2 stressed vegetation for each vegetation type using AVIRIS data and field spectroradiometer data.

Objective 4: Plant stress gradient models

- Establish a plant stress gradient model from both the hyperspectral and multispectral data integrated into an open source visualization tool with GIS capable of mapping potential volcanic activity hazards.

Objective 5: Accuracy assessment

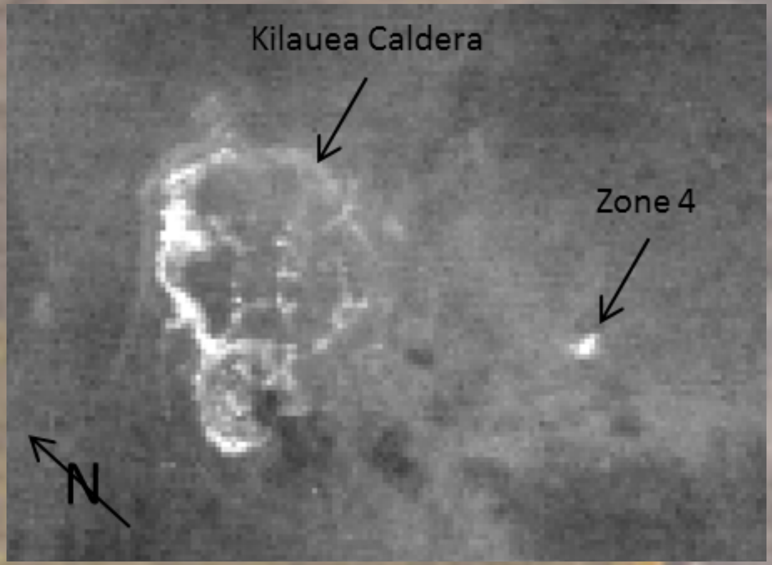
- Determine the accuracy of the plant stress gradient models derived independently from the hyperspectral and multispectral data from *in situ* vegetation type and condition data.

Objective 6: Automated change algorithms

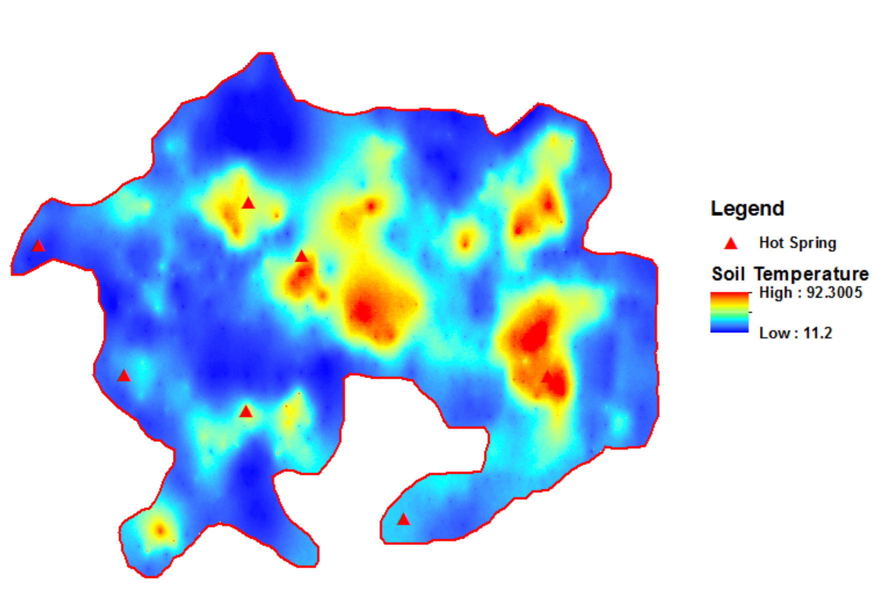
- Develop automated change detection algorithms that can detect rapid change in vegetation health and extent from hyperspectral data for the Hawaiian volcanoes. This will allow the identification of potentially pre-eruptive volcanoes conditions from future HyspIRI images.

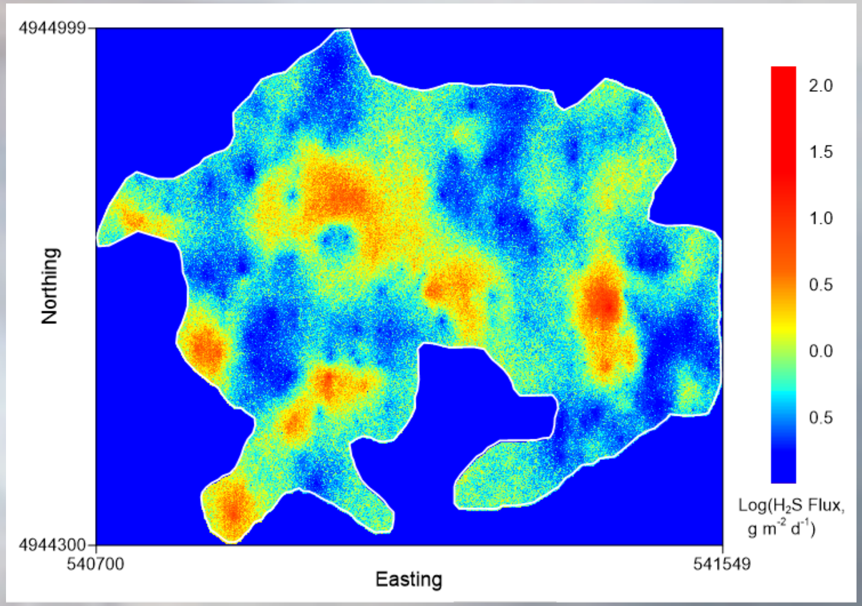
Objective 7: Surface temperature maps

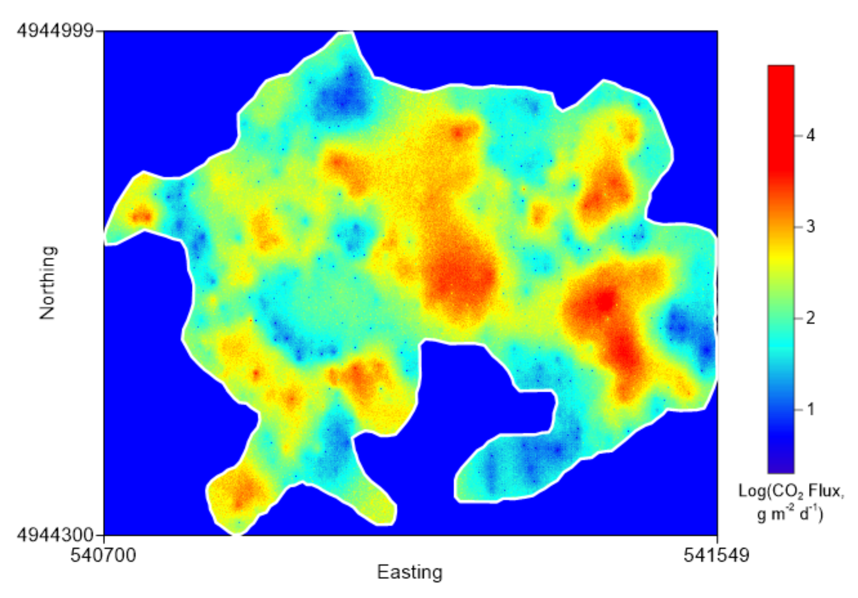
- Map the spatial and temporal relationship between surface temperature, gaseous emissions, and surface vegetation cover.



Thermal infrared radiance image from MASTER







Relevance of work to NASA

- Scientific advancement in assessing pre-eruptive behavior of volcanoes through targeted detection of **vegetation change within the time frame of future HyspIRI** scenes through novel development and application of hyperspectral and multispectral remote sensing data and methods.
- *Societal benefits* derived from this work include the potential to create a **non-invasive and remote (i.e., potentially safer) monitoring method of active volcanoes and volcanic activity**.
- Outside of Hawaii, these volcanic monitoring methods could be integrated into Early Warning Systems for natural hazards, implemented in agricultural and food security monitoring due to automated detection of vegetation stress, and used to improve emission inventories of CO_2, SO_2, and H_2S for both impacts on climate and secondary air quality (i.e., vog, O_3 production, acid rain).