Can HyspIRI-like data constrain accurate temperature and emissivity measurements of active volcanic surfaces?

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Quantifying Active Volcanic Processes and Mitigating Their Hazards with HyspIRI Data

- proposed science questions:
  - how does the cooling and formation of a viscoelastic hot glassy surface affect the average emissivity of basaltic lava over time?
    - can these constituents be quantitatively extracted from future HyspIRI data of active flows to produce improved temperature and compositional estimates?
  - what are the ideal spatial resolution and band positions for the HyspIRI IR instrument to extract quantitative volcanological data?
  - can this approach in total be helpful for the prediction of lava flow advance over time through quantitative modeling of HyspIRI data?
## Science Goals

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- **Build, Test and Calibrate New Field Instrument**
  - in time for the field campaign
  - miniature multispectral TIR Camera (*MMT-Cam*)
    - calibrate and fully automate collection, processing and analysis
    - see James Thompson’s poster tomorrow (*MMT-Cam_\textsuperscript{v3.5} on display*)

- **Emissivity Change**
  - evaluate the change as lavas propagate and cool
  - evaluate the impact on extracted temperatures
  - compare field data to coincident MASTER and ASTER data

- **Modelling**
  - determine the affect of emissivity on rheological models used to forecast lava flow propagation and eruption rates
Field Campaign

overview | background | data | results | summary

- **Kilauea, Hawai‘i**
  - shield volcano
  - eastern slope of Mauna Loa
  - island of Hawai‘i

- **Lava Flow** (*primary target*)
  - Puʻu ʻŌʻō episode 61g flow

- **Lava Lake** (*secondary target*)
  - Halemaʻumaʻu Crater
  - continuous activity since 2010
  - 250 m long and 190 m wide
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2017 HyspIRI Science and Applications Workshop
Pasadena, CA (17-19 October 2017)
Field Campaign

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TIR Data

- 19 Jan to 31 Jan 2017
  - 8 acquisition opportunities
- 4 MASTER overpasses
  - 2 day and 2 night
- 4 ASTER overpasses
  - 1 day and 3 night

• critical for us: MASTER +ASTER
  - only ONE daytime collect
  - NO nighttime collects
Primary Airborne Instruments

- **MASTER**
  - 0.4-13 microns wavelength range
  - 50 channels
  - saturation
    - MIR band 26 (4.07µm) at 640 K (850 K at low gain)
    - TIR bands at ~420K

- **AVIRIS**
  - 0.4-2.5 microns wavelength range
  - 224 channels
Initial Data Analysis

overview  background  data  results  summary

- 10 meters
- 30 meters
- 60 meters
- 13 meters
- 30 meters
- 60 meters

Radiance (W.m\(^{-2}\).sr\(^{-1}\).μm\(^{-1}\))

Wavelength (μm)

Radiance  Planck Curve
**AVIRIS: 26 Jan 2017 at 05:57 UTC (19:57 HST on 25 Jan)**

- maximum Plank-derived temperatures:
  - **center:**
    - 13 m: \(\sim 1430 \text{ K} (\lambda_{\text{max}} = 1.49 \mu\text{m})\)
    - 30 m: \(\sim 1430 \text{ K} (\lambda_{\text{max}} = 1.49 \mu\text{m})\)
    - 60 m: \(\sim 1400 \text{ K} (\lambda_{\text{max}} = 1.49 \mu\text{m})\)
  - **edge:**
    - 13 m: \(\sim 1010 \text{ K} (\lambda_{\text{max}} = 2.26 \mu\text{m})\)
    - 30 m: \(\sim 950 \text{ K} (\lambda_{\text{max}} = 2.26 \mu\text{m})\)
    - 60 m: \(\sim 1050 \text{ K} (\lambda_{\text{max}} = 2.26 \mu\text{m})\)
MASTER: 26 Jan 2017 at 05:57 UTC \(19:57\) HST on 25 Jan

- maximum Plank-derived temperatures:
  - center:
    - 10 m: \(~860\) K \(\left(\lambda_{\text{max}} = 1.59\ \mu\text{m}\right)\)
    - 30 m: \(~860\) K \(\left(\lambda_{\text{max}} = 1.59\ \mu\text{m}\right)\)
    - 60 m: \(~690\) K \(\left(\lambda_{\text{max}} = 2.21\ \mu\text{m}\right)\)
  - edge:
    - 10 m: \(~550\) K \(\left(\lambda_{\text{max}} = 2.26\ \mu\text{m}\right)\)
    - 30 m: \(~570\) K \(\left(\lambda_{\text{max}} = 2.26\ \mu\text{m}\right)\)
    - 60 m: \(~570\) K \(\left(\lambda_{\text{max}} = 2.26\ \mu\text{m}\right)\)
Initial Data Analysis

W-E Transects of Lava Lake using MASTER

- Max. Radiance (W m⁻² sr⁻¹ μm⁻¹)
- λ_max (μm)
- Max temperature (K)
- Portion of molten surface in pixel

Pixel: W-E

10 m, 30 m, 60 m
Emissivity Extraction

- saturation over lava lake produces inaccurate spectra as one would expect
  - documented numerous times with ASTER TIR L2 data
- at crater-edge pixels, mixing with cooler/older basaltic lavas minimizes saturation
  - emissivity is resolved
  - loss of spectral depth with spatial resolution degradation
**MASTER: 26 Jan 2017 at 05:57 UTC (19:57 HST on 25 Jan)**

- maximum Plank-derived temperatures:
  - center:
    - 10 m: \( \lambda_{\text{max}} = 10.58 \, \mu m \) \( \sim 290 \, K \)
    - 30 m: \( \lambda_{\text{max}} = 10.11 \, \mu m \) \( \sim 290 \, K \)
    - 60 m: \( \lambda_{\text{max}} = 10.58 \, \mu m \) \( \sim 285 \, K \)
Preliminary Results

Saturation of all TIR/MIR MASTER Wavelengths
- max radiance between 1.5-4 microns at lava lake
- require high saturation temperature
  - ~1400 K in the MIR
  - ~900 K in the TIR

Thermal Mixing Within Pixels
- <2 – 40 % fraction of molten surface across lava lake

Emissivity Errors From Saturated Pixels (obviously)
- becomes less with lower spatial resolution and mixing at thermal boundaries (e.g., perimeter of lake)
- spectral features shallow with spatial resolution degradation
Did Not Achieve Our Primary Goal

- limited lava flow production and access during the time of the field campaign
  - would provide information on lower-temperature processes and smaller-scale mixing
  - much higher spatial resolution for the MMT-Cam data
  - direct connectivity to flow-scale modeling parameters

Real-Time Communication Was Frustrating

- critical considering access to (and challenging conditions of) the lava lake
  - limited knowledge of data acquisitions
    - cancelled flights to due HyTES issues
    - suggest direct MMS to field parties
Future Work

- **Redeploy to Hawaiʻi in 2018**
  - hopefully access active surface flows / acquire data
  - develop operational methodology for propagating lava flows

- **Evaluate Emissivity Changes**
  - spatiotemporal variability during active flow propagation
  - detailed study of emissivity change with cooling/thickening glassy crust

- **Integrate IR Measurement and FLOWGO Modeling**
  - determine influence on model results
Thanks To

- Matt Patrick and the rest of the USGS HVO staff
- Hawaii Volcanoes National Park
- NASA ground and flight crews
- HyspIRI Preparatory Campaign group
- our dedicated field-assistant and SPAM connoisseur
MASTER: 26 Jan 2017 at 05:57 UTC
- Night flight: 19:57 HST on 25 Jan

Maximum temperature:
Center:
- 10 m: ~415 K ($\lambda_{\text{max}} = 8.64 \, \mu\text{m}$)
- 30 m: ~400 K ($\lambda_{\text{max}} = 8.64 \, \mu\text{m}$)
- 60 m: ~380 K ($\lambda_{\text{max}} = 8.64 \, \mu\text{m}$)

Edge:
- 10 m: ~400 K ($\lambda_{\text{max}} = 8.64 \, \mu\text{m}$)
- 30 m: ~390 K ($\lambda_{\text{max}} = 8.64 \, \mu\text{m}$)
- 60 m: ~375 K ($\lambda_{\text{max}} = 8.64 \, \mu\text{m}$)
Lava Lake – Radiance Curves (Edge)

![Radiance Curves](image)

- **10 meters**
- **30 meters**
- **60 meters**

**MASTER**

- **13 meters**
- **30 meters**
- **60 meters**

**AVIRIS**

- **Radiance**
- **Planck Curve**

[Wavelength (μm)]
Lava Lake - Transects

W-E Transects of Lava Lake using AVIRIS

Max Radiance (W/m²sr/μm⁻¹)

λₘₐₓ (μm)

Max temperature (K)

Portion of molten surface in pixel

Pixel: W-E

Pixel size: 13 meters

10 m

30 m
Lava Lake - Transects

W-E Transects of Lava Lake using MASTER

- Pixel size: 10 meters
- Lambda max (µm)
- Max Radiance (W.m⁻².sr⁻¹.m⁻¹)
- Max temperature (K)
- Portion of molten surface in pixel

Pixel: W-E

10 m
30 m

Pixel size: 10 meters
Lava Flow - Transects

Transects across lava flow using MASTER

Max Radiance (W/m² sr/µm)

λ_{max} (µm)

Max temperature (K)

Portion of molten surface in pixel

Pixel: W-E

N

Pixel size: 10 meters

10 m  30 m
Lava Flow - Transects

Transects across lava flow using MASTER

Pixel: W-E

- Max. Radiance (W m⁻² sr⁻¹ μm⁻¹)
- λ_max (μm)
- Max. temperature (K)
- Portion of molten surface in pixel

10 m — 30 m — 60 m