MMT-Cam: A new miniature multispectral thermal infrared camera system for field-based emissivity measurements

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Introduction
The field-portable miniature multispectral thermal infrared camera (MMT-Cam) was developed as part of the HyspIRI Preparatory project for the January 2017 airborne campaign. The MMT-Cam was built to acquire accurate emissivity data in situ with changing temperature on active lava surfaces. Constraining the relationship between the emissivity spectral change and radiance derived from TIR data will provide more accurate measurements of emissivity (1), Collection of accurate temperature and emissivity data during lava flow emplacement will greatly improve models designed to predict flow dynamics and down-flow hazard potential (2). Furthermore, through spatial degradation analysis, constraints can be improved for the identification of changes in temperature and emissivity during cooling at lower spatial resolutions.

Location
The first field campaign was conducted at Kīlauea volcano, Hawai‘i in January 2017 (Fig. 1a). Kīlauea volcano is a basaltic shield volcano (3) located on the eastern slope of Mauna Loa volcano on the island of Hawai‘i. During the campaign two volcanic processes were targeted:
1. Lava flows (primary) – the surface lava flow activity on the pali and coastal plains on the eastern slopes of Kīlauea volcano produced by the episode 61g flows from Pū‘u O‘O (4) (Fig. 1b).
2. Lava Lake (secondary) – the 250 m long and 190 m wide active lava lake within the Halema‘uma‘u crater (4) (Fig. 1c and 1d).

Airborne/Orbital Data
Multispectral TIR data were acquired on 7 occasions from January 19 to January 30 2017 in support of MASTER and ASTER overpasses, mostly at the Halema‘uma‘u crater lava lake.
- 4 MASTER overpasses – 2 day and 2 night
- 4 ASTER overpasses – 1 day and 3 night

Instrument

<table>
<thead>
<tr>
<th>Specification</th>
<th>MMT-Cam</th>
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<tbody>
<tr>
<td>Core</td>
<td>FLIR A65 (2nd generation)</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>640 x 512 pixels</td>
</tr>
<tr>
<td>Field of view (FOV)</td>
<td>45° x 37° with 13 mm lens</td>
</tr>
<tr>
<td>Gain settings</td>
<td>-25°C to 135°C / -40°C to 550°C</td>
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<tr>
<td>Detector</td>
<td>Uncooled VOX microbolometer</td>
</tr>
<tr>
<td>Spectral resolution</td>
<td>7.5 μm – 12 μm</td>
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<tr>
<td>Filter Wheel</td>
<td>7 port – 6 IR filter + 1 open port</td>
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</tbody>
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![Figure 2: a) Enclosure front showing the germanium window b) inside front of the filter wheel, c) interior side of the MMT-Cam. The red arrow indicates the location of the FLIR A65.](image)

Pre-processing: Data mining

![Figure 4: Standard deviation of raw data acquired by MMT-Cam.](image)

Calibration

The MMT-Cam system calibration was conducted at the Aerospace Corporation using environmentally controlled blackbodies at temperatures from 10 to 200 °C. The radiance measured by the detector at each pixel on the focal plane array (FPA) for each filter along with the broadband was compared to the blackbody radiance. Linear models were produced to correct for any attenuations and errors associated with the system design.

Results and Conclusions
The preliminary lava lake data show that the primary emissivity absorption feature (around 8.5 to 9.0 μm) transitions to longer wavelengths and shallows as a lava surface cools from 770 to 520 K, forming a progressively thicker crust. The spectra is a mixture of both the lava surface and SO2. The feature transition to longer wavelengths is partially due to the composition change as low silica components are preferentially solidified out of the melt. The shallowing of the feature as material transitions from a liquid to a solid is in part contributed to less degrees of freedom in its structural movement. This is the first time that accurate, unsaturated emissivity data with changing temperature has been measured in situ on active lava surfaces.

Future Work
Future work includes applying the current methodology to evaluate the spatiotemporal variability in temperature and emissivity during lava flow emplacement and cooling, with quantitative evaluation of SO2 on the emissivity spectra. Finally, these results and methodologies will be compared to proposed HyspIRI datasets for future capability.

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References