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 temperatures as well [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 [1]. 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 Kilauea volcano, Hawai'i in January 2017 (Fig. 1a). Kilauea volcano is a basaltic shield volcano [2] 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 Kilauea volcano produced by the episode 61g flows from Pu'u 'Ō'ō [3] (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).

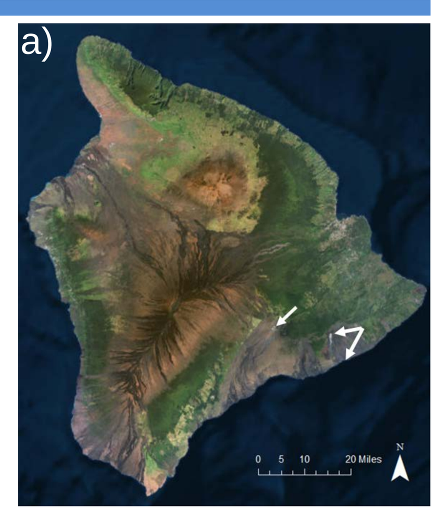


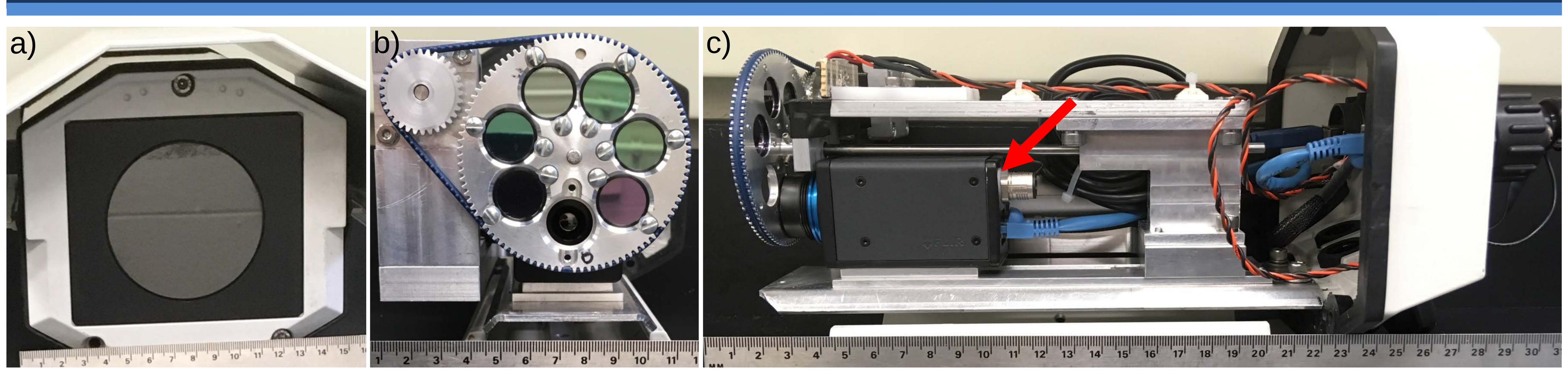
Figure 1: a) The island of Hawai'i, white arrows showing target areas (source: ESRI). MMT-Cam deployed at the **b)** lava flow ocean entry and **d)** lava lake. **c)** Image of lava lake from Overlook crater.

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

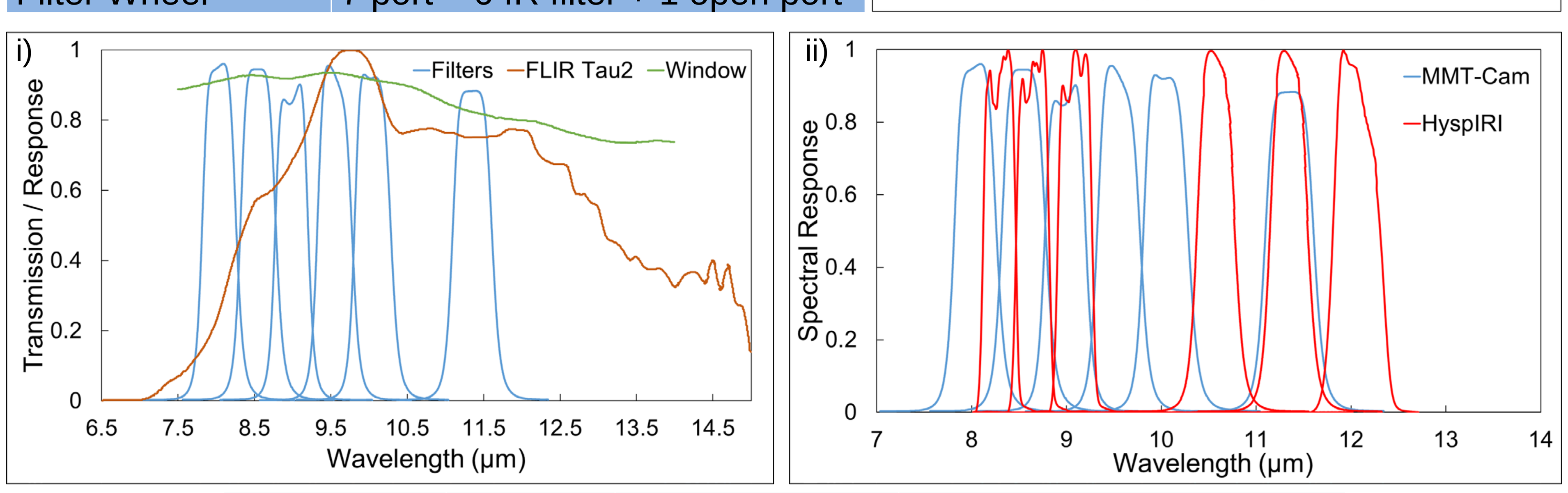
Instrument



Specification	MMT-Cam
Core	FLIR A65 (2nd generation)
Spatial resolution	640 x 512 pixels
Field of view (FOV)	45° x 37° with 13 mm lens
Image frequency	30 Hz
Gain settings	-25°C to 135°C / -40°C to 550°C
Detector	Uncooled VOX microbolometer
Spectral resolution	7.5 – 13 µm
Filter Wheel	7 port – 6 IR filter + 1 open port

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.

Figure 3: i) Spectral response of the six filters plotted with the FLIR Tau2 response and the transmissivity of the germanium window. **ii)** Comparison of TIR band locations between the MMT-Cam and proposed HyspIRI instrument.



Band Number	Band Center [µm]	Peak Transmission [%]	Spectral Range (FWHM) [µm]	
			Min	Max
Broadband	11.00	100.0	7.500	13.000
1	8.04	96.2	7.814	8.266
2	8.55	94.7	8.313	8.787
3	8.99	90.4	8.766	9.211
4	9.55	95.7	9.320	9.777
5	10.04	93.2	9.805	10.289
6	11.35	88.5	11.086	11.616

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Pre-processing: Data mining

The MMT-Cam acquires data continuously (Fig. 4) as the filters rotate in front of the camera lens. Data are extracted only where the camera and filters are aligned, with a data package being produced for each filter wheel cycle. This is achieved by convolving the raw data with a box-car filter, to exaggerate significant and smooth minor variability, so data are extracted at peaks (dy/dx=0) where the camera and filter are perfectly aligned (Fig. 4).

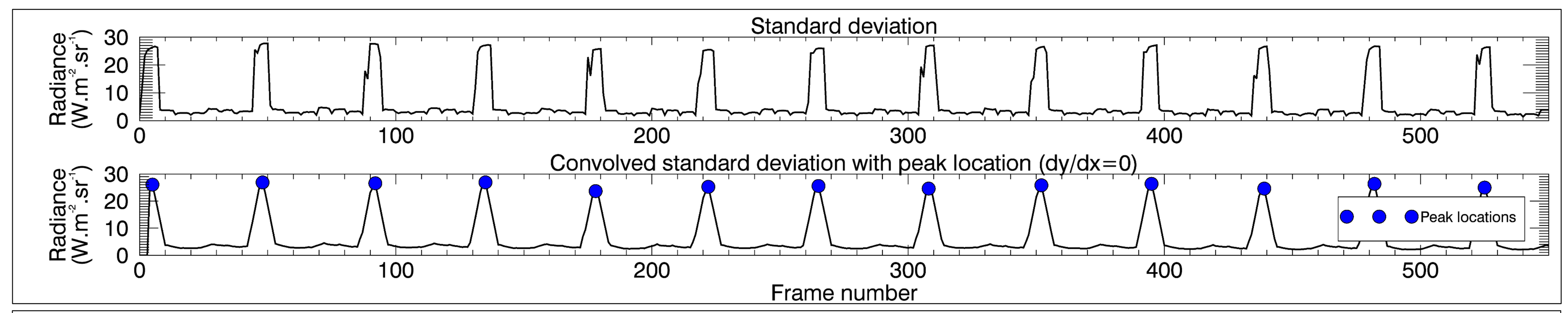
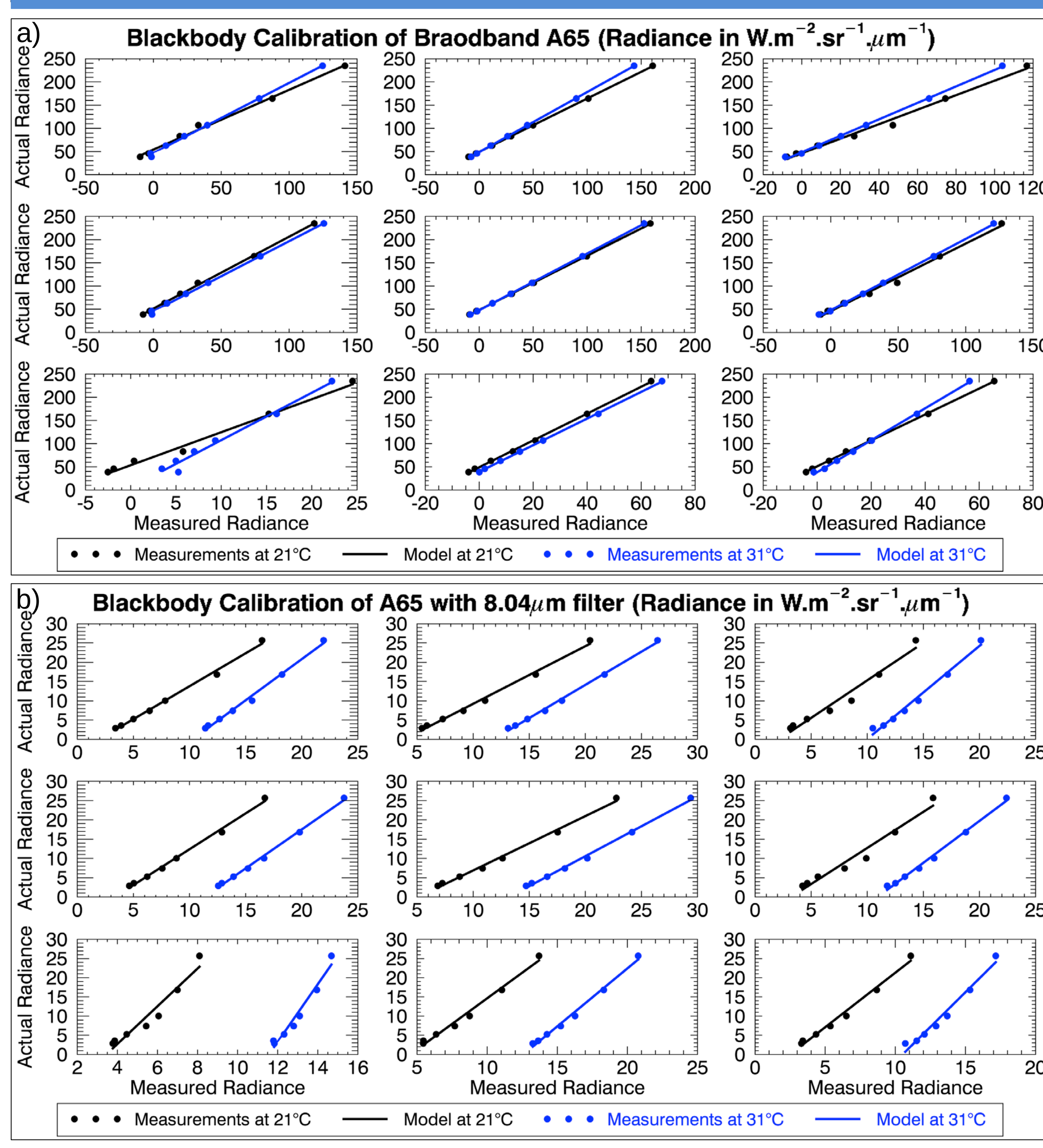


Figure 4: Standard deviation of raw data acquired by MMT-Cam (top). Convolution applied to data using a box-car filter with the location of camera and filter alignment in data determined where dy/dx = 0 (bottom).

Calibration



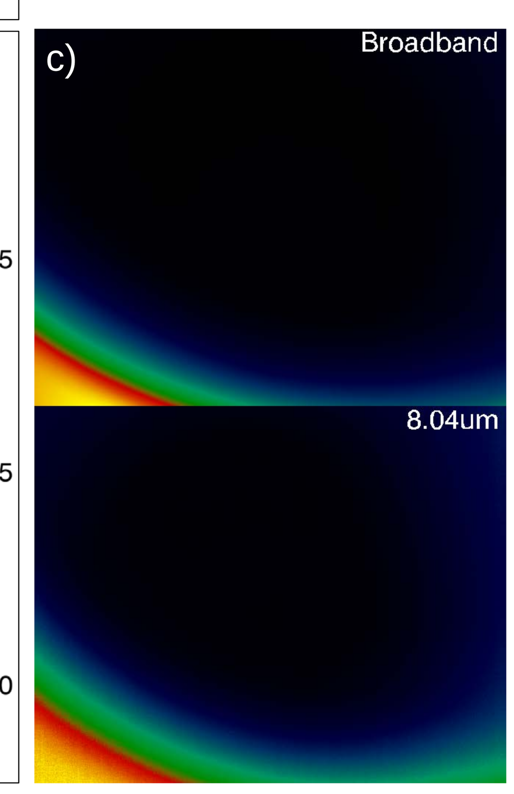


Figure 5: Comparison between the measured and actual blackbody radiance for pixels across the FPA for the **a)** broadband and **b)** 8.04 µm filter. The location of the plots corresponds to the location on the FPA. **c)** The linear gain correction maps for the broadband and 8.04 µm filter. Warmer colors represent higher values.

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 760 to 520 K, forming a progressively thicker crust. The spectra is a mixture of both the lava surface and SO_2. 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.

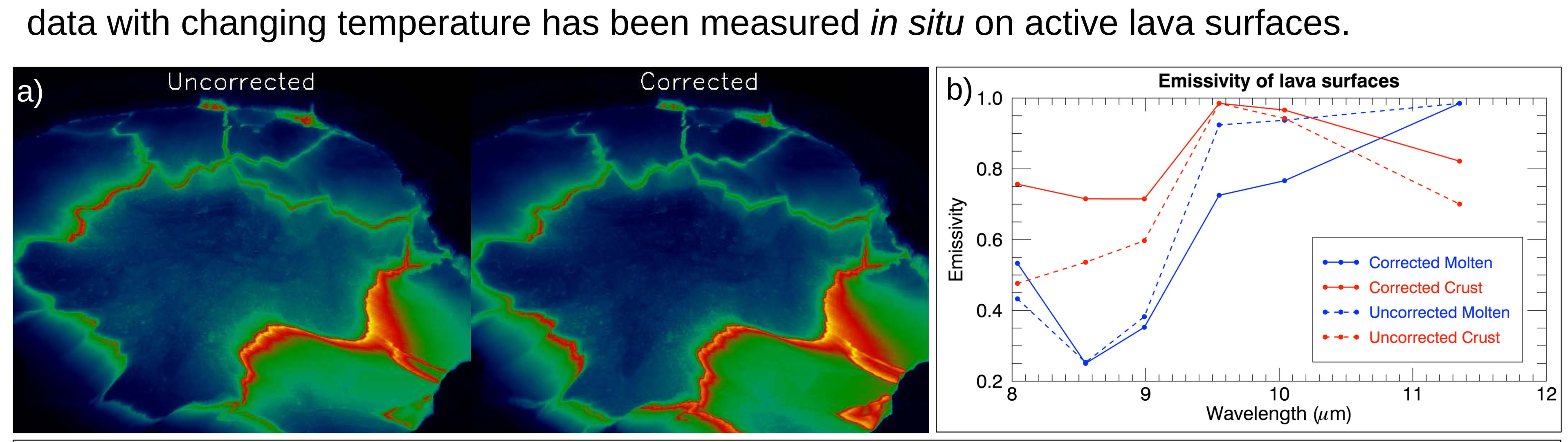


Figure 6: a) Before and after calibration TIR images of the Halema`uma`u crater lava lake acquired with the 8.04 µm filter. **b)** Emissivity spectra of molten and crustal lava surface, both before and after calibration.

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 SO_2 on the emissivity spectra. Finally, these results and methodologies will be compared to proposed HyspIRI datasets for future capability.

References

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