Identifying lava surface textures and flow relationships using multispectral thermal infrared data

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Introduction

Thermal infrared (TIR) remote sensing of silicic lava flows can detect and map distinct compositions and surface textures[1]. The identification and comparison of the degree and distribution of vesicular textures along flow's length and between successive flows are relevant to decipher changes in the flow's thermo-rheology and volatile content[5]. With recent orbital TIR data acquired during an active silicic eruption, surface textural changes are evident throughout the lava emplacement. The identification of, and changes to, these distributions during an ongoing flow emplacement can improve the understanding of the dynamics and potential hazards.

Location

The two study areas were chosen because of the silicic lava composition and the ample remote sensing coverage. Medicine Lake volcano is a large Quaternary shield volcano that formed a 12 x 7 km caldera[2]. Located in the extensional rear-arc basin of the main Cascade volcanic chain, this volcano has produced numerous high-Al basaltic to rhyolitic lava flows and domes[2] . Two flows were investigated at Medicine Lake volcano: Medicine Lake Dacite Flow (MLDF) and Big Glass Mountain Flow (BGMF). Chaitén is a Holocene volcano located along the southern Andean volcanic belt, with a 3 km caldera. The most recent eruption occurred in 2008-2009 and produced a rhyolitic lava dome[3].

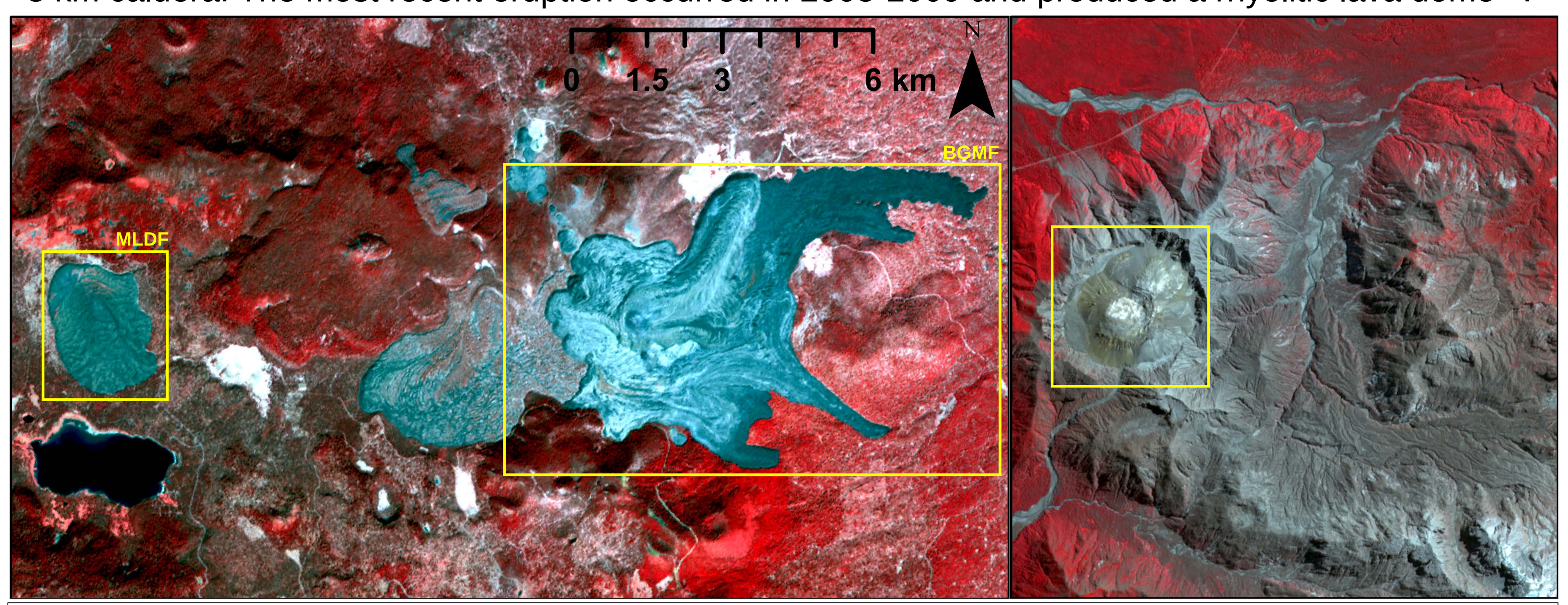


Figure 1: ASTER data of Medicine Lake (left) and Chaitén (right) Volcano. Visible/near infrared (VNIR) bands: 3 (0.807 µm), 2 (0.661 µm), and 1 (0.554 µm) in R,G,B, respectively. Study areas are highlighted in yellow.

Data

Dataset	MODIS/ASTER Airborne Simulator (MASTER)	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
Platform	Airborne	Orbital
Acquisition Date	September 14, 1999	2010-2012
Location	Medicine Lake Volcano, CA	Chaitén Volcano, Chile
Spectral Bands	9 TIR bands (8.16 – 12.87 µm)	5 TIR bands (8.30 – 11.32 µm)
Spatial Resolution	10 meters	90 meters

Methods

First, a decorrelation stretch (DCS) was applied to enhance spectral variations in three wavelengths and reveal regions that have significant spectral variability useful for subsequent spectral analysis. Bands 48, 44, 42 and bands 14, 12, 10 were used in the MASTER and ASTER data, respectively.

Secondly, a linear deconvolution model was utilized to detect textural variability[5,6], using laboratory TIR emissivity spectra of obsidian and blackbody (figure 2). These served as end-members for the model with the blackbody spectrum mimicking that of exposed vesicles (figure 4,5,7).

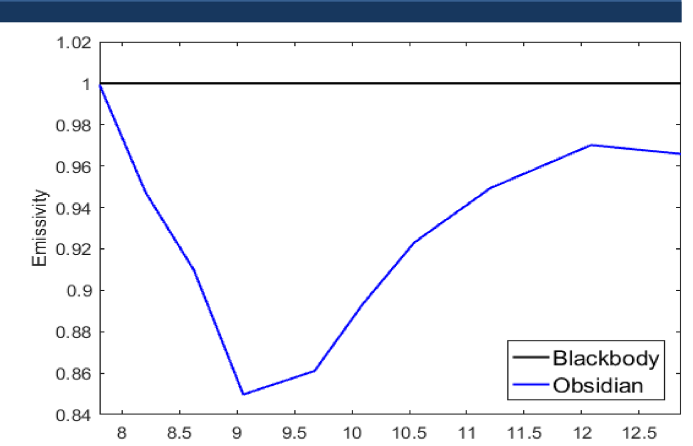


Figure 2: End-member emissivity spectra used in the linear deconvolution model.

Results

In DCS red surface regions have higher absorption at shorter wavelengths. The DCS result shows distinct contrast between more distal regions of BGMF (figure 3, black ROI) compared to the central regions. At BGMF (figure 4), lower surface vesicularity is observed on lava flows with lower silica content (black ROI).

The MLDF DCS shows spectral contrast between the central southern regions of the flow (black ROI) compared to the upper marginal regions (figure 5). At MLDF (figure 5), lower surface vesicularity is observed on the central and southern margins of the flow (black ROI) with radial channels of higher vesicularity (black arrows).

The DCS for the Chaitén Volcano highlights the lava dome, with some spectral contrast within its structure (figure 6). At Chaitén Volcano, surface vesicularity generally decreases with distance from the center of the dome with a small region of low surface vesicularity at the very center of the dome (figure 7). Figure 7a was acquired shortly after the 2009 eruption and shows highly variable surface vesicularity. Temporally, the overall dome vesicularity decreases during its continued growth until September 2011.

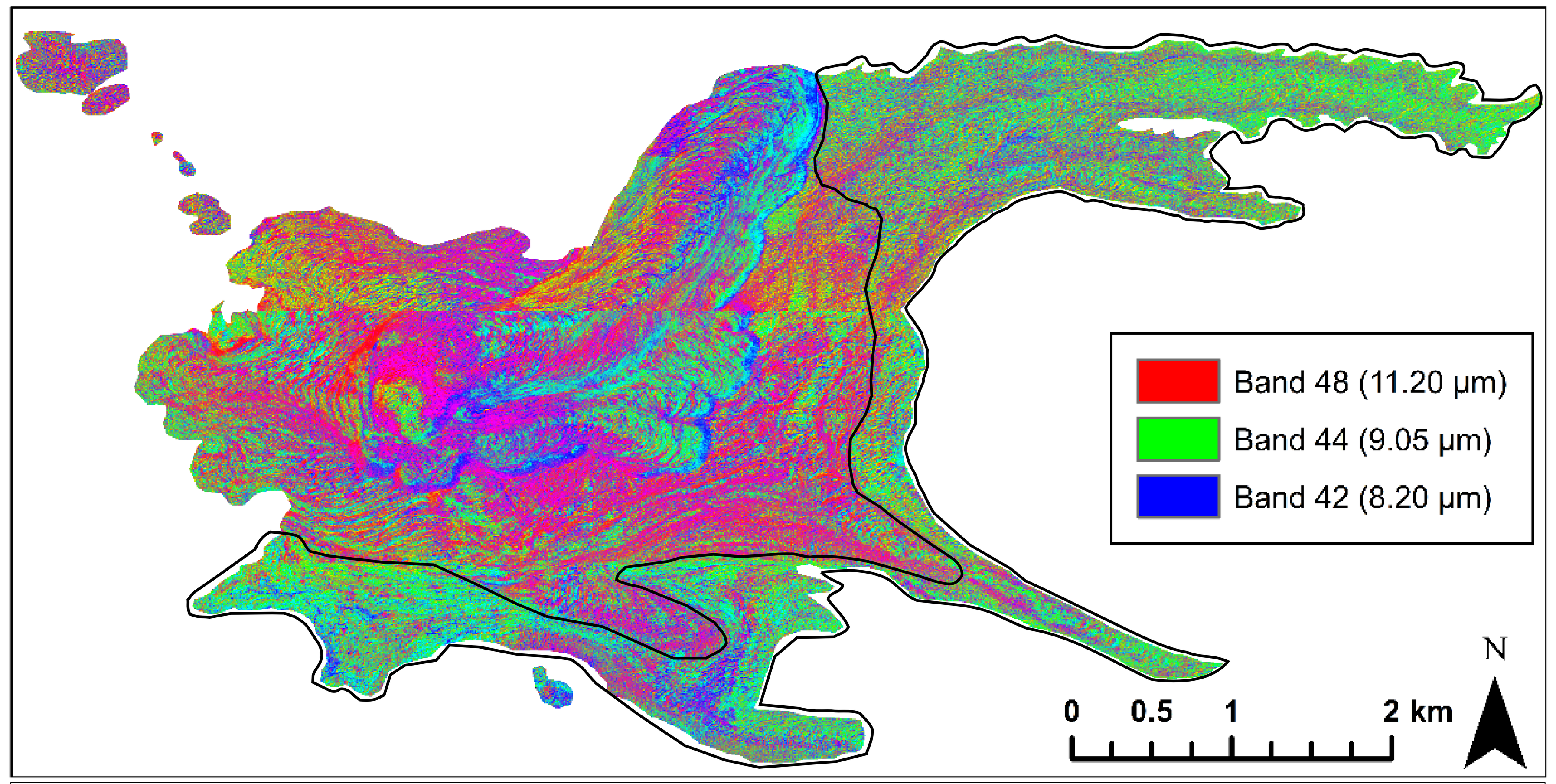


Figure 3: MASTER decorrelation stretch (DCS) result for the BGMF at Medicine Lake. The highlighted region indicates a spectrally contrasting region.

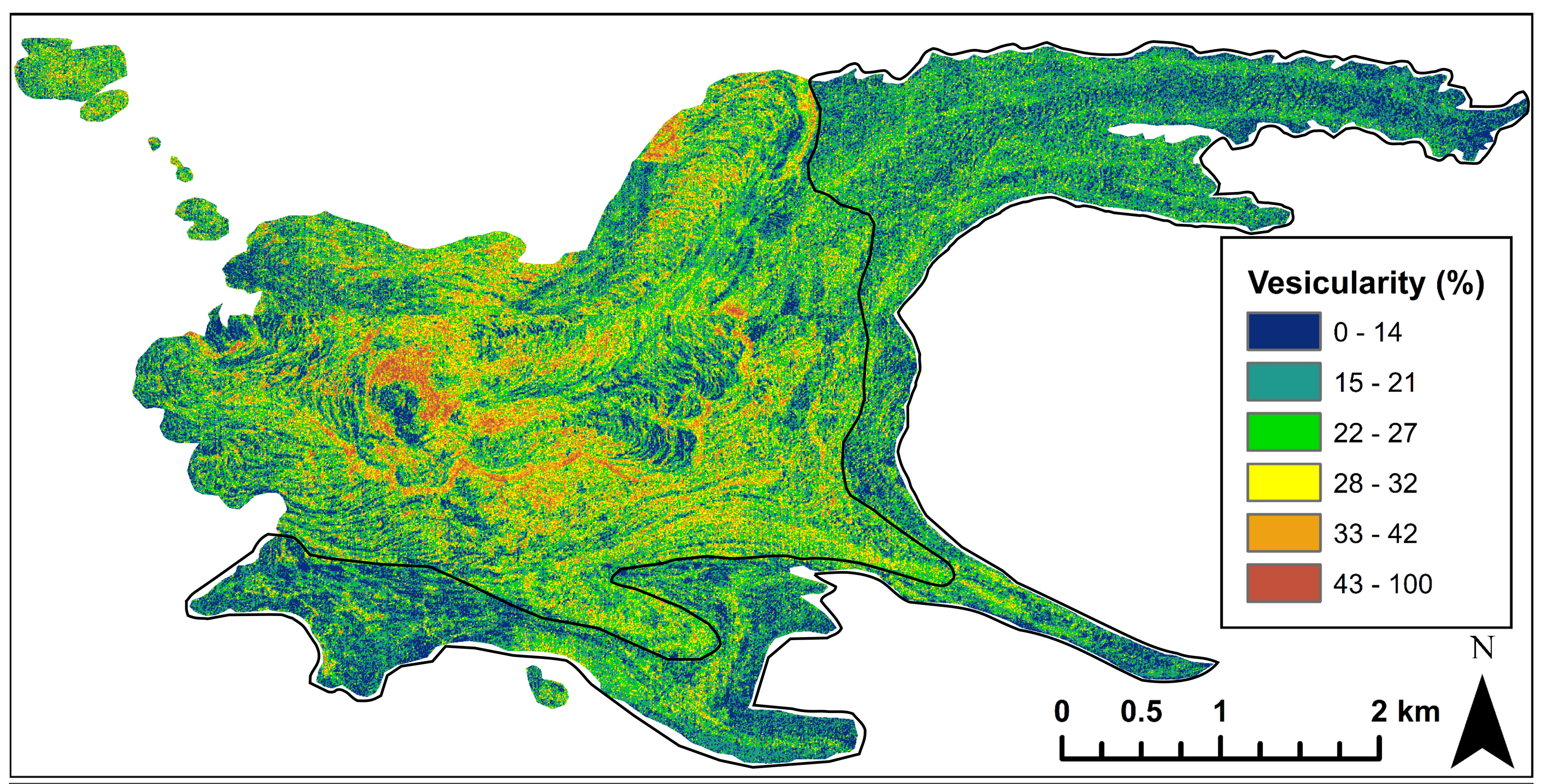


Figure 4: Vesicularity result for the BGMF, produced using a linear deconvolution model on the MASTER emissivity data and the two end-members (figure 2). The degree of vesicularity varies from 0 to 81%, with variation between individual flows and within a flow being up to 80% and 25%, respectively.

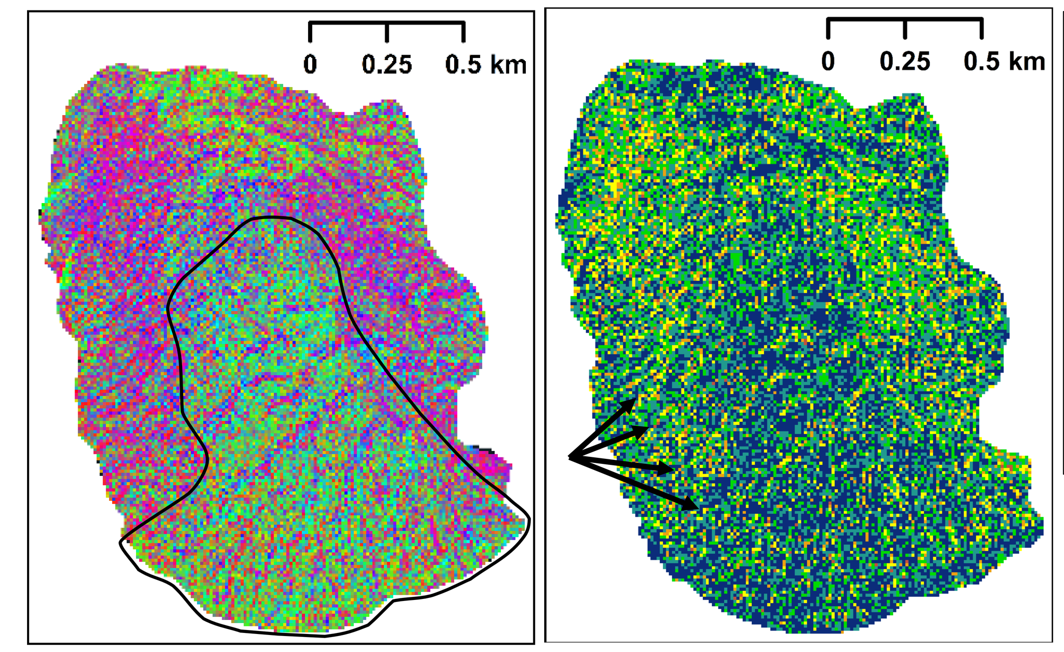


Figure 5: MASTER decorrelation stretch (left) of MLDF, using bands 48 (11.20 µm), 44 (9.05 µm), and 42 (8.20 µm) in R, G, B, respectively. The highlighted region indicates a spectrally contrasting region. Vesicularity image (right), produced using image deconvolution of the MASTER emissivity data with the same two spectral end-members (figure 2). The mostly compositionally homogeneous MLDF has lower surface vesicularity variability (0-28%) compared with BGMF (figure 4).

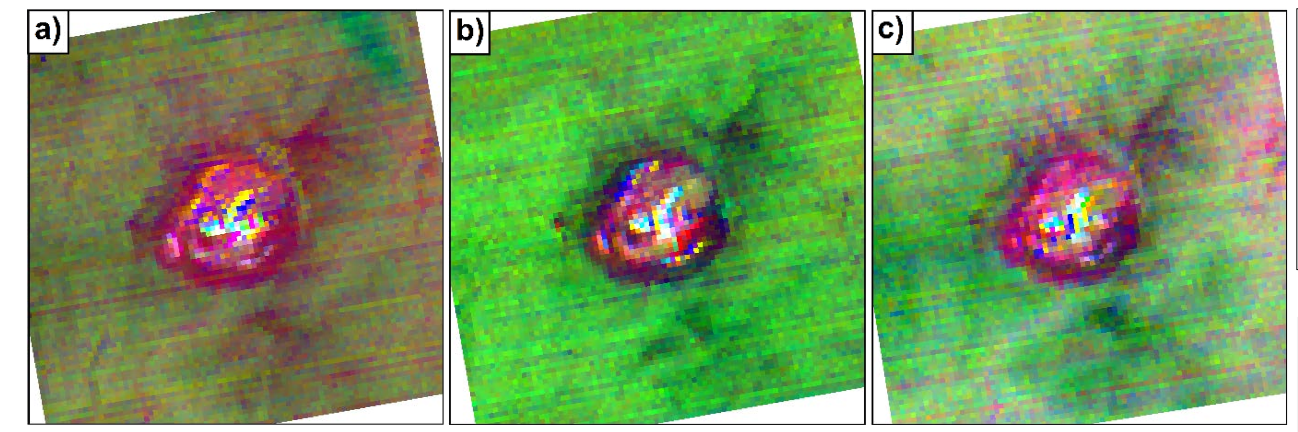
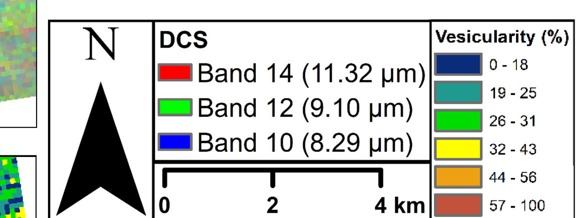


Figure 6: ASTER DCS of the Chaitén dome using bands 14 (11.32 µm), 12 (9.10 µm), and 10 (8.29 µm) in R, G, B, respectively. **a)** 12/31/10. **b)** 04/06/11. **c)** 02/13/12.



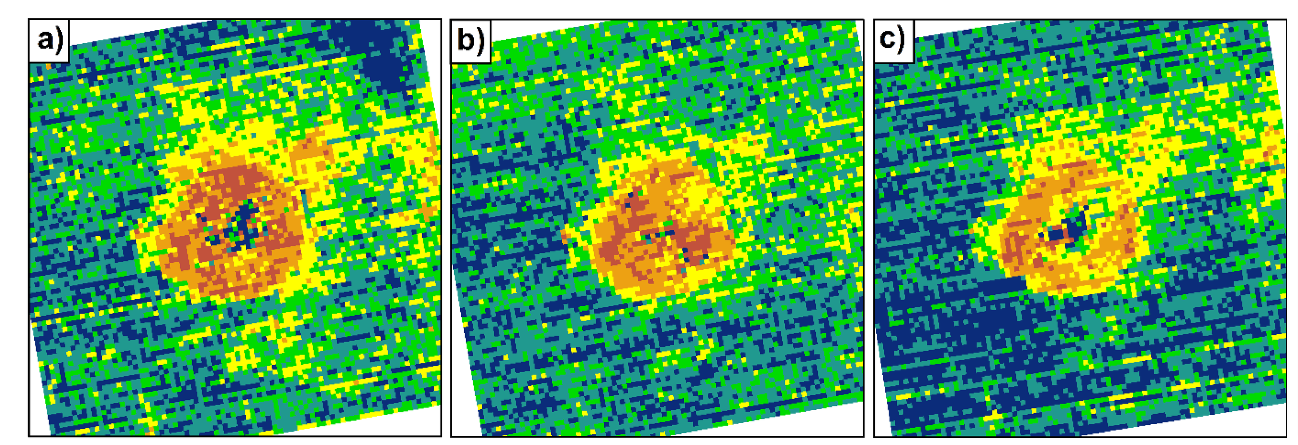


Figure 7: Vesicularity images of the Chaitén dome using image deconvolution of ASTER emissivity data and the two end-members (figure 2). Acquired at same time as figure 6.

Conclusions and Future Work

Multispectral TIR data is ideal for highlighting individual lava flows, and compositional and textural variability within those flows. Comparing the DCS and image deconvolution images implies there is a correlation between highly vesicular lava surfaces and more silicic compositions, especially as MLDF is nearly compositionally homogeneous and has low vesicularity variability (~28%). As more silicic lavas are generally more viscous and have a higher volatile content it can be inferred that the higher vesicularity lava flows at Medicine Lake had slower emplacement velocities and less volatile release. At Chaitén Volcano, we observe more vesicular surfaces at the center of the dome and decreasing vesicularity with time, which indicates progressive volatile release after emplacement. Initially, concentric rings of variable vesicularity around the dome could suggest progressive flows, similar to those seen at Medicine Lake[6]. In the 2011 data, we also observed a low vesicularity region on the eastern flank, which could infer a recent partial collapse of the dome.

To validate these interpretations, field samples from Medicine Lake Volcano will be analyzed through both hand sample observations and laboratory TIR spectroscopy. Also, published field observations of the Chaitén eruption will be compared with remote sensing results and interpretations.

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