Remote Sensing of Pyroclastic Flow Deposits: Investigating Eruption Style on Shiveluch, Kamchatka

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Introduction

Shiveluch is one of the largest and most active volcanoes of the Kuril- Kamchatka arc, producing pyroclastic and block-and-ash flows during vulcanian and dome-collapse eruptions[1] (active dome in Fig. 1C).

Remote sensing techniques allow data collection on volcanic deposits on a range of scales and wavelengths. Here ASTER 90 m pixel TIR and 15 m VNIR, and ca. 0.5 m pixel FLIR (TIR) data is used to investigate two pyroclastic flows deposited on 27-28 February, 2005 and 27 July, 2012 on Shiveluch volcano. This research aims to interpret eruption and depositional processes on pyroclastic density currents (PDC) where the causative eruption was not observed. This is proposed through investigating deposit temperature, morphology, surface roughness and block size distribution to remotely interpret surficial grain size deposition and vesicularity distributions throughout the flow, and their changes through time.

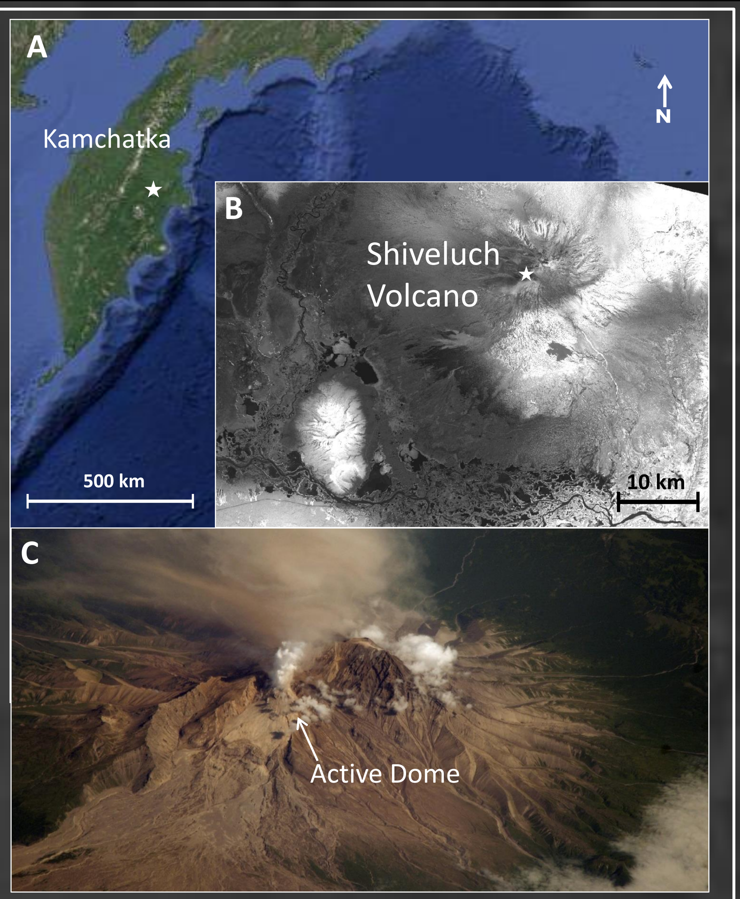


Fig. 1 A) Shiveluch location in Kamchatka, Russia[2]; B) Shiveluch in Landsat 8 image acquired 13 May, '13; C) S view of Shiveluch [3].

Eruptions

27-28 February, 2005

KVERT reported a large eruption producing a pyroclastic flow and 45 km ash plume. The 19 km long, 24.09 km^2 pyroclastic flow (Fig. 2) was deposited on the SW flank of Shiveluch, diverting towards the west 12 km from the dome.

27 July 2012

KVERT reported explosive activity from 26 July to 6 August and a pyroclastic flow was deposited on July 27. Ramsey M.S. collected aerial FLIR data the following day.

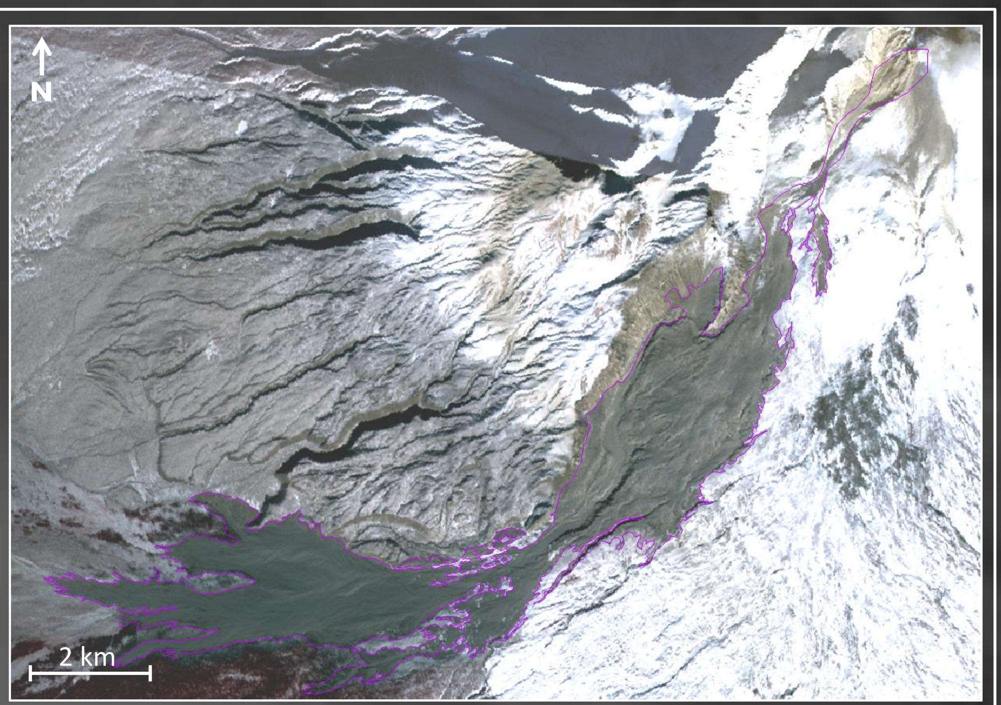
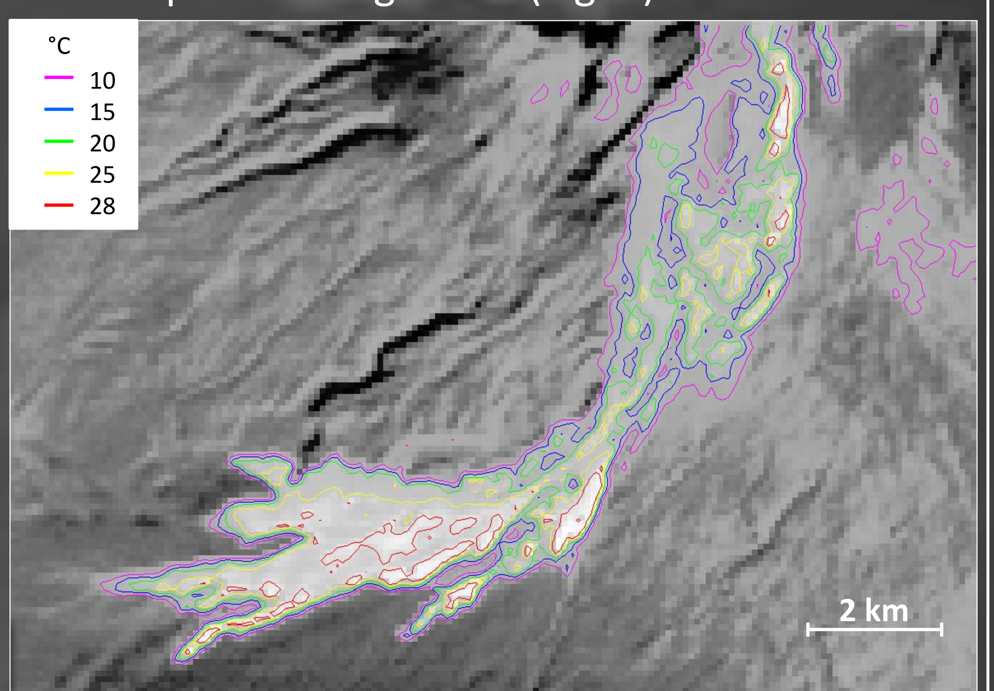


Fig. 2 27 February 2005 pyroclastic flow on the SW flank of Shiveluch volcano. ASTER VNIR image acquire 12 March '05, 13 days post -deposition.

Thermal Analysis

Temperature (Fig. 3) and emissivity are derived from atmospherically derived ASTER thermal infrared (TIR) radiance images of the 27 February, 2005 pyroclastic flow using the ENVI emissivity normalization function. Micron-scale roughness can be determined using TIR emissivity data through changes in the spectral absorption features produced by the Si-O bonds in silicate materials. A two-component (glass plus blackbody) spectral deconvolution model is applied and the percentage of blackbody serves as a proxy for surface vesicularity[4,5,6]. An increase in roughness (and hence the volatile content of the predecessor magma) produces a reduction in the depth of the emissivity absorption band which is mapped to investigate relative vesicularity of the deposit through time (Fig. 4).

Fig. 3 Temperature distribution of the '05 pyroclastic flow. Elevated temperatures occur along the SW edge of the flow, interpreted as higher block deposition[7]. ASTER daytime TIR radiance image acquired 13 days after deposition. Temperatures accurate to 2 °C[8].



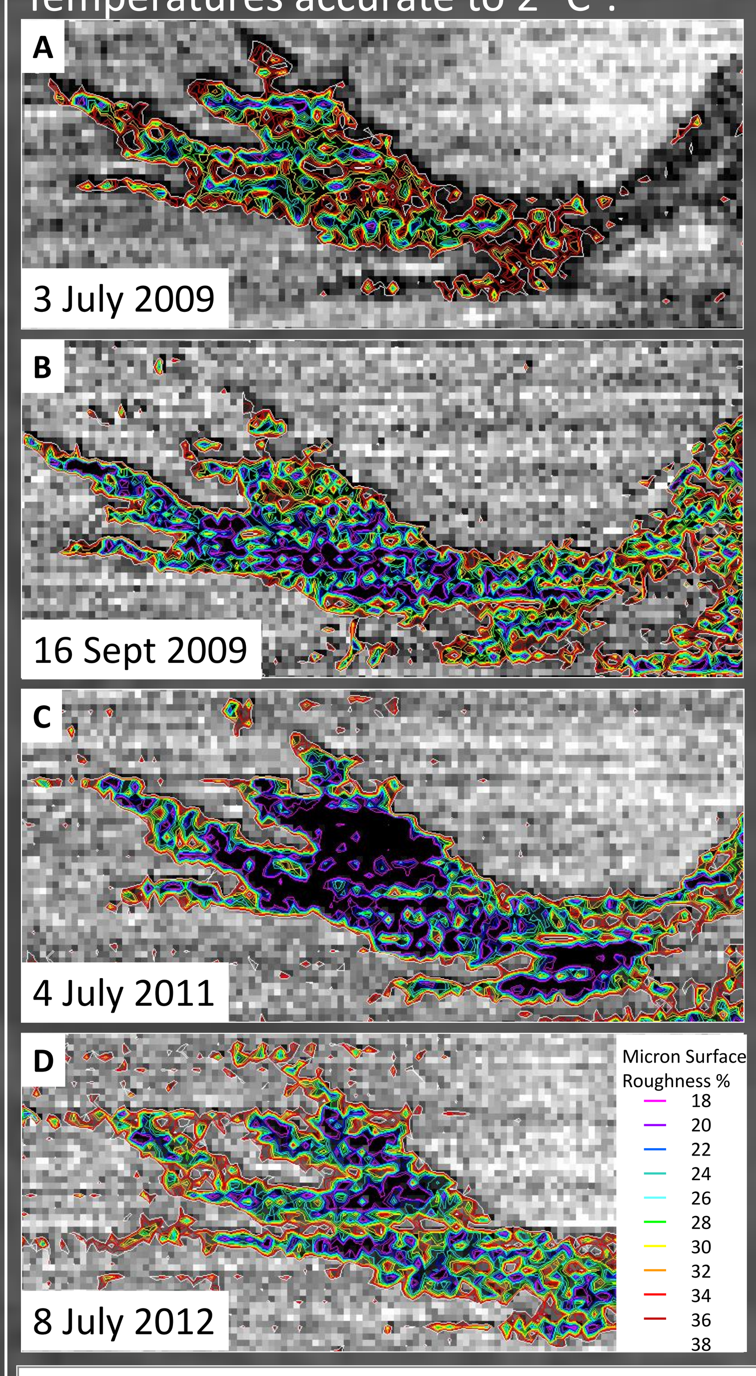
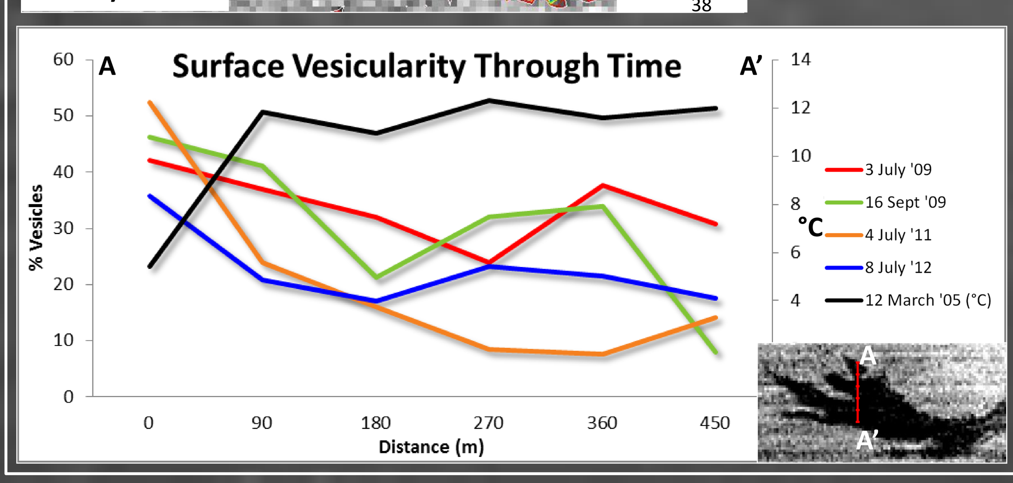


Fig. 4 Preliminary relative micron-scale surface roughness maps of the main body of the 2005 flow, used as a proxy for surface vesicularity % (SV). The flow edges contain higher vesicularity values. This could be due to higher ash contents, and effect that will be investigated in the field and laboratory. There is an increase in the area of lower vesicularity values from A through C. D displays a slight SV increase that could be due to physical flow properties (e.g. surface moisture) and/or horizontal striping, a sensor miscalibration effect[9]. There is a weak correlation between near-emplacement temperature and SV at this scale, more apparent in A. Field and lab vesicularity investigations will be carried out to improve this method. Data derived from ASTER night time TIR radiance images, pixel size 90 x 90 m.

Fig. 5 SV through time across the flow width versus post-emplacement flow temperature (black series).



Minimum temperature at the flow edge correlates with highest SV, possibly due to higher ash content deposition. There is a weak negative correlation between SV and time, more data will be incorporated to further investigate this trend. Block and ash distribution and vesicularity will be validated through field work.

FLIR Image analysis

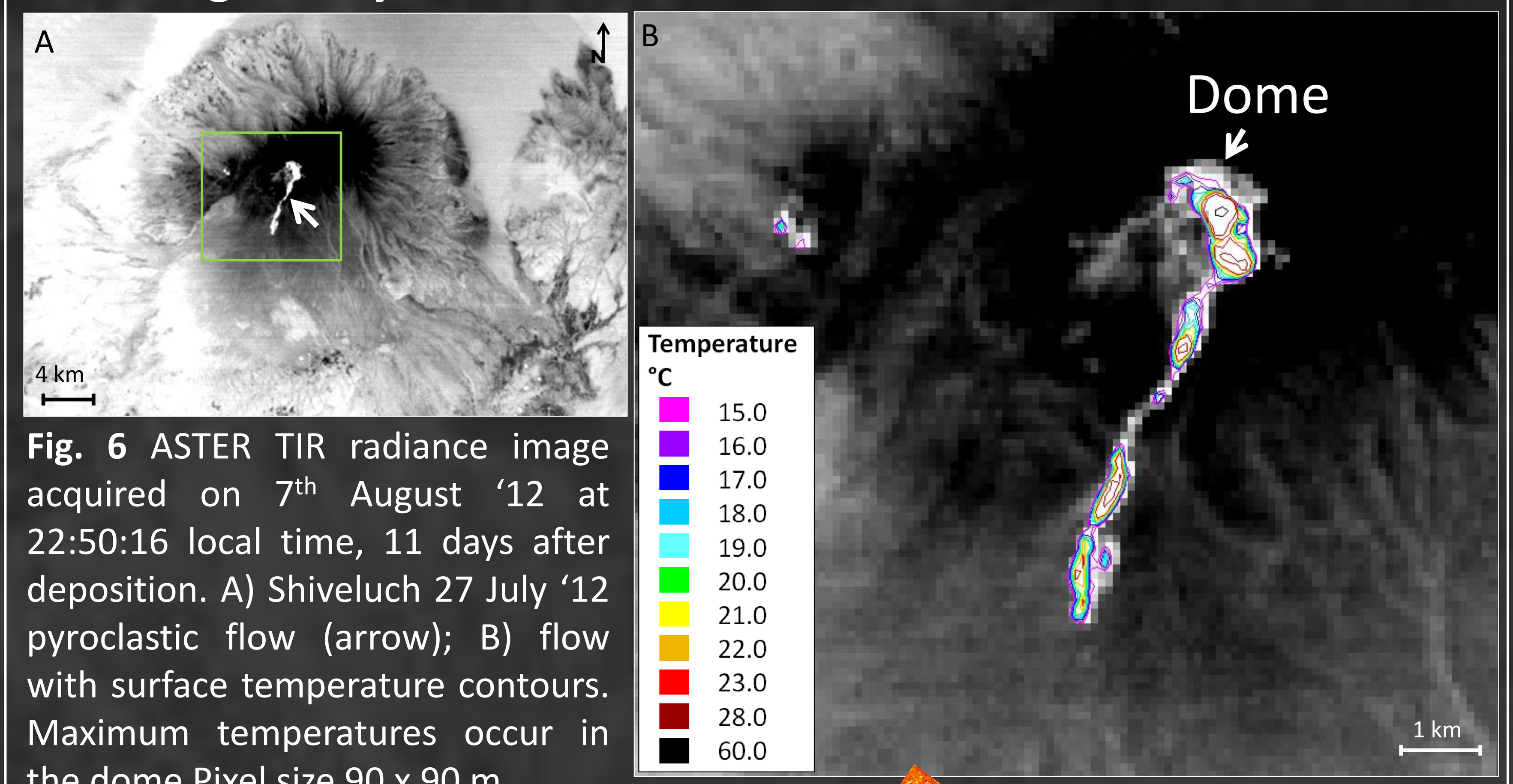
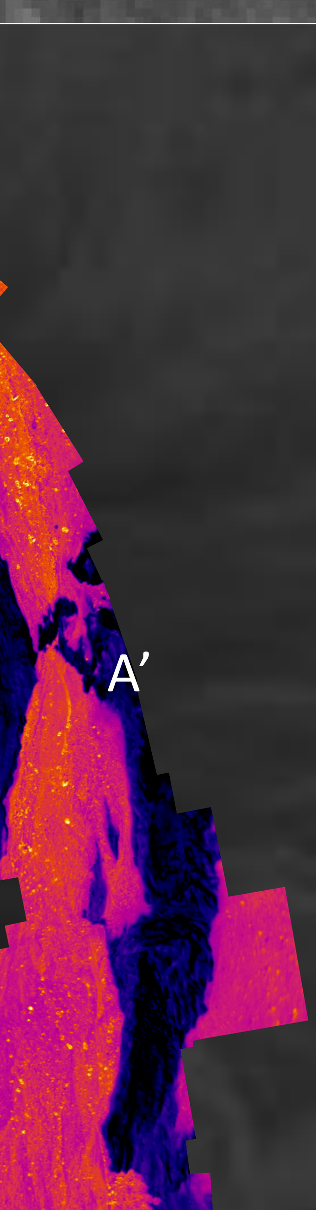
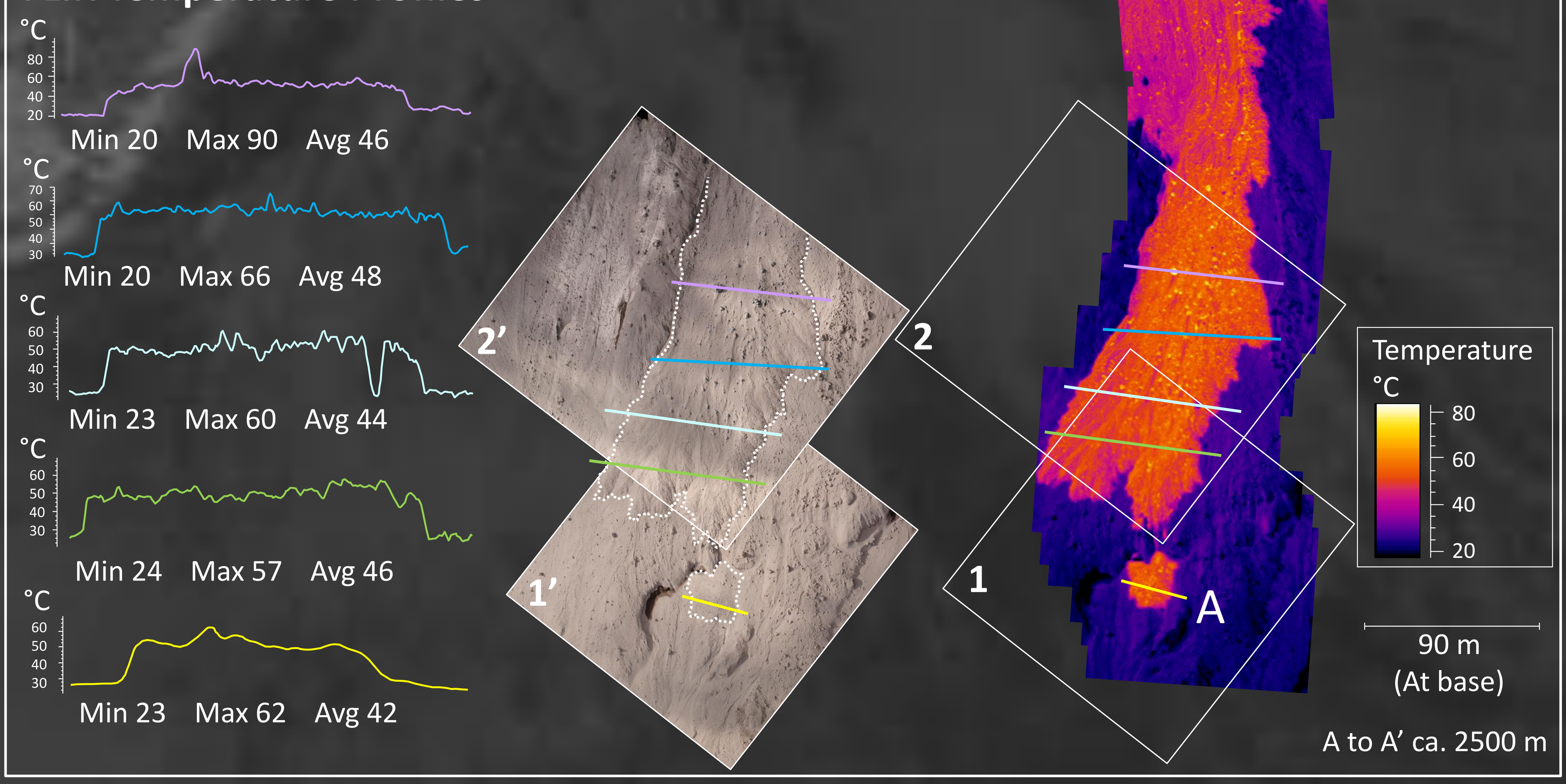


Fig. 6 ASTER TIR radiance image acquired on 7th August '12 at 22:50:16 local time, 11 days after deposition. A) Shiveluch 27 July '12 pyroclastic flow (arrow); B) flow with surface temperature contours. Maximum temperatures occur in the dome Pixel size 90 x 90 m.

The FLIR TIR image mosaic (right) is a compilation of individual motion blur-free images extracted from the high-speed FLIR video dataset collected by Ramsey M.S. on July 28 '12, the day following emplacement. The mosaic is of a pyroclastic flow deposit against the cooler (blue-black) background deposits on the upper, southern slope of Shiveluch. Maximum temperatures >160 °C occur at the top of the flow proximal to the dome (not displayed here) with the majority of the deposit temperatures ranging 40-60 °C. The deposit surface contains higher proportions of larger blocks, and increased surface temperatures, in the proximal and frontal flow thirds. This average temperature heterogeneity is interpreted to be due to differential deposit thicknesses, possibly due to slope changes, and will be investigated further. Boxes 1 and 2 (below, center) correlate with aerial images (courtesy of Anderson, S.) 1' and 2' respectively, collected in conjunction with the FLIR data. Maximum (yellow) temperatures correlate with large blocks. The FLIR temperature profiles (below, left) show temperature variations of 15-20 °C, with extreme values correlating to blocks.

FLIR Temperature Profiles





Further Research

- Investigate the reduction in ASTER image horizontal striping to improve accuracy of emissivity and subsequent decorrelation values.
- Carry out a vesicle spectra morphology study: how does vesicle size, abundance, weathering, and surface ash cohesion affect the laboratory spectral response?
- Shiveluch block and ash distribution field investigation, how do grain size and SEM and thin section-derived vesicularity values correlate to ASTER-derived values.

Conclusions

This research proposes to investigate and improve methods of remotely assessing physical characteristics of PDC deposits to establish surficial post-depositional temperatures, grain-size distributions (block and ash proportions), and vesicularity distributions. These changes are monitored through time to establish post-depositional changes that affect the accuracy of inference to initial deposition conditions. Different satellite sensor and aerial datasets with varying scales and wavelength regions are incorporated and will be validated with field and laboratory studies. The correlation of these parameters to eruption and depositional processes will be examined to improve the monitoring of hazards from a safe distance.

Selected References

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