**PRE-ERUPTION TOPOGRAPHY AFFECTS LAVA FLOW THICKNESS.** J. A. Richardson[1], J. Kubanek[2], P. L. Whelley[1], and J. E. Bleacher[1], [1]Planetary Geology, Geophysics, and Geochemistry Lab, NASA Goddard Spaceflight Center, Greenbelt, Maryland, USA; jacob.a.richardson@nasa.gov, [2]Geodetic Institute, Karlsruhe Institute of Technology, Karlsruhe, Germany.

**Introduction:** Topography confines flowing lava, alters its flow direction, limits its ability to spread or channelize, and modulates its surface morphology. The extent to which topography controls a lava flow depends on flow dynamics, including viscosity and volume flux, and the prominence of the topography itself. At different spatial scales, the surface upon which lava flows might have a distinct influence on the flow. Large scale topographic rises or falls, such as other volcanoes or graben, will nearly always divert lava. Topographic irregularities with heights of 10s cm have also been observed to halt the lateral advance of pāhoehoe flows and initiate inflation to several meters thick [1,2], though such small topographic irregularities don't always have this effect.

New satellite and aerial remote sensing (InSAR, lidar, and structure from motion techniques) are now wide-spread enough that digital elevation models (DEMs) exist for surfaces that have subsequently been overrun by lava. We seek to use these data, and DEMs produced after recent lava flow emplacement, to analyze the relationship between pre-flow topography and lava flow thickness. Quantifying this relationship, often stated as "lava inverts topography," can lead to a better understanding of which topographic irregularities will serve as obstacles to the advancement of lava flows and which will be overrun. This in turn might help in the estimation of pre-eruptive topography, lava flow dynamics on other planets [3] and lave flow hazard models on Earth.

*Study flow*. The 2012-3 Tolbachik eruption took place over 9-months and emplaced a 14.5-km-long lava flow in the Kamchatka Peninsula, Russia (Fig. 1). This flow ended with a total volume of ~0.55 $km^3$ [4], was emplaced over 28 $km^2$, and exhibits a modal thickness of 7.8 m and a mean thickness of 14.5 m [5]. Before, during, and after the eruption, the TanDEM-X InSAR satellite constellation was active and, with an 11-day repeat cycle, it collected multiple data sets. This enables the creation of pre- and post-eruption DEMs [5].

**Methods:** Kubanek et al. [5] processed a pre- and post-eruption bistatic radar images of the Tolbachik region to generate two DEMs from November 2012 and February 2014. Each DEM has a spatial resolution of 15 m and covers the entire lava flow. Vertical uncertainty for each DEM is ±2 m.

The 15-m pre- and post-flow DEMs of the Tolbachik region are then used to create coarser DEMs

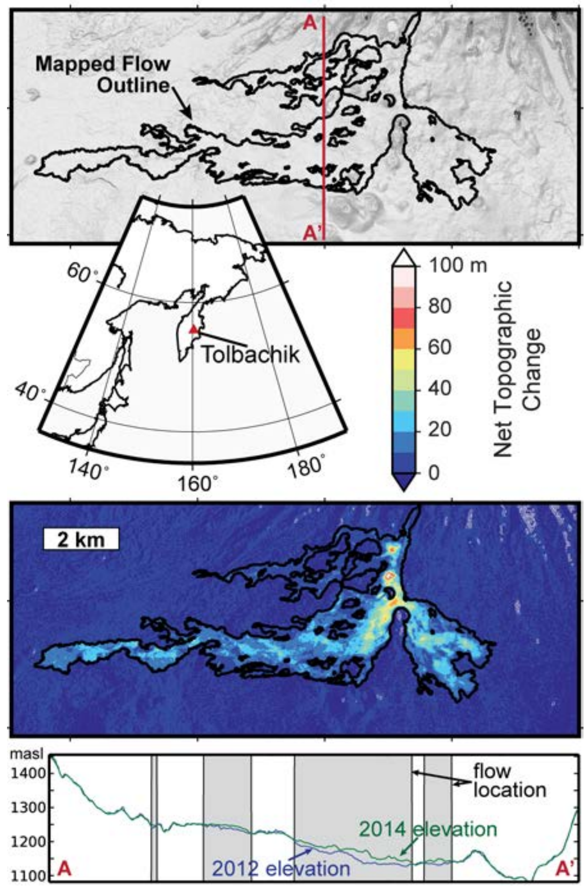


*Figure 1: Lavas at the Tolbachik volcano, Russia, flowed over pre-eruptive topography (shown in shade relief at top) to the extent outlined in black. Net topographic change between Nov. 2012 and Feb. 2014 is mapped in color (middle) and pre- and post- eruption topography are shown as a profile (bottom).*

at 30, 60, and 90 m spatial resolution. This resolution decrease was performed through gdal with a cubic spline interpolation. Pre-flow DEMs from each spatial resolution pair are subtracted from post-flow DEMs to produce an elevation change raster.

An algorithm has been developed as a python script to measure relative relief between a location on a DEM and its nearest neighbors, as well as relative change in elevation. Each neighbor-to-neighbor relationship is then plotted as relative elevation change with respect to pre-flow relative relief. If it is true that lava inverts topography at the spatial resolution of the DEM, then it can be expected that inside the lava flow 1) cells previously higher than their neighbors have more negative elevation changes, 2) cells lower than their neighbors in 2012 should have higher elevation changes, and 3) cells outside of the lava flow should have elevation changes that don't correlate with their 2012 elevation.

As a test case, this script is run for a profile (A-A' in Fig. 1) that transects the 2014 lava flow and includes areas outside the lava flow for comparison. The script is run for each spatial resolution (15, 30, 60, and 90 m) data set.

**Results:** Plots of relative elevation change with respect to relative relief for points along the A-A' profile are illustrated in Figure 2. At each spatial resolution, an inverse relationship exists between topographic change and pre-flow topographic relief for points in the lava flow; locations that are higher than their adjacent neighbors ultimately have a negative net elevation change relative to those same neighbors.

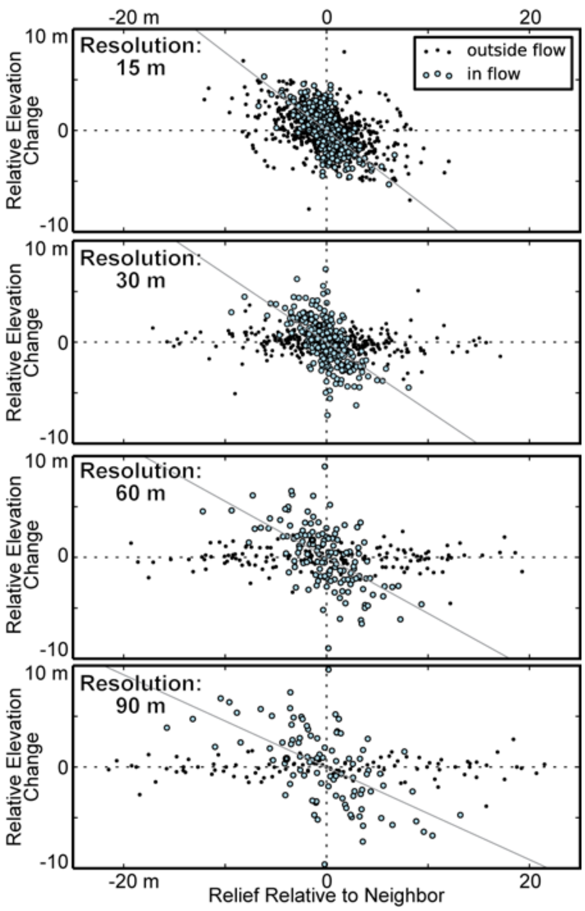


*Figure 2. Relative elevation change from 2012-2014 plotted with respect to relative relief between neighboring locations along Profile A-A' (Fig. 1). Inverse relationships between relief and elevation change are found at all spatial resolutions from 15-90 m.*

For each spatial resolution, the inverse relationship of relief and elevation change between locations inside the lava flow maintains a correlation coefficient of $r^2$=0.5-0.7. At 15-m resolution, for every meter lower a pixel is from its neighbor, it is expected to receive 0.77 m more lava. This amount decreases for each coarser spatial resolution to 90-m spaced pixels, where an expected 0.46 m increase in lava is given to a location 1 m lower than its neighbor.

At spatial resolutions of 30-90 m, the correlation between pre-flow elevation and net elevation change is demonstrably different for locations inside the flow and those outside the flow. For locations outside the flow at these resolutions, pre-flow relief and net elevation change do not correlate ($r^2 < 0.2$) Difference between the four scales, stats. In the 15-m resolution dataset, however, points inside the flow cannot be distinguished from points outside the flow based on this correlation alone. The inverse relationship between pre-flow relief and net elevation change might be due to the fact that relative relief between two pixels 15 m apart is often on the order of the vertical accuracy of the TanDEM-X data product.

**Discussion:** We find that lava does invert topography on spatial scales between 30 and 90 m. This effect is less certain at a resolution of 15 m as locations outside the lava flow also exhibit an inverse correlation between pre-flow elevation and net elevation change. This correlation could be due to random vertical misfits between the pre- and post-flow DEMs.

The decrease in slope of the relationship between relative relief and net elevation change as spatial resolution coarsens might indicate that topographic anomalies at 15-30 m horizontal wavelengths influence flow thickness more than anomalies at 90 m. This could be related to the viscosity of the flow or the fact that the mean thickness of the flow is ~15 m. It could also be due to the fact that 90 m wide topographically positive landforms halt lava all together.

Because all spatial resolutions display the inverse relationship between relief and elevation change, it remains unclear what the spatial limits of the relationship are. Increasingly small topographic irregularities should affect flow propagation less, though whether this is at the spatial scale of several meters or submeter cannot be tested with the Tolbachik example. Higher resolution data sets might be needed to test this hypothesis.

**References:** [1] Hon K. et al. (1994) *GSA Bull, 106*, 351-370. [2] Hamilton C. W. et al. (2013) *Bull Volc*, *75*, 756 [3] Glaze L. S. et al. (2003) *Icarus, 1*, 26-33. [4] Belousov A. et al. (2015) *JVGR*, *299*, 19-34. [5] Kubanek J. et al. (2015) *Bull Volc, 77*, 106.