Investigating the formation and evolution of channel networks in Hawaiian lava flows with airborne LiDAR analysis

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New ways of imaging lava flow morphology are providing important new insight into lava flow dynamics and emplacement conditions. Here we focus on airborne LiDAR data for recent lava flows at Mauna Loa and Kilauea, Hawaii, USA, which highlight both the complexity and diversity of lava channel networks. Importantly, the form of the channel network geometry — broad and distributary or narrow and confined — appears to exert a primary control on both the rate of flow advance and the final flow length.

We map channels using flow morphology, LiDAR intensity, and aerial and satellite imagery. Extracted channel cross-sections provide data on the final state of individual channels. Analysis of lava channels as interconnected networks, with tools developed for studying brain connectivity, can be used to determine the best-connected channels, most important junctions, and simplified flux distribution. To quantify the influence of pre-eruptive topography, we have constructed DEMs using aerial photographs calibrated by LiDAR data outside the extent of the flows. From these data we can measure both pre-eruptive slopes and the scales of obstacles in the flow path. Subtraction of the pre and post-emplacement DEMs also provides whole-flow thickness maps.

Our analysis of Hawaiian channel networks reveals that regions of higher slope tend to generate multiple parallel channels. The ratio of the flow height to obstacle height, as well as the size and geometry of the obstacle, determines whether the flow will surmount or split around the obstacle. From this we infer that obstacles are more likely to influence the flow path on steep slopes where flows thin and speed up. We have also combined our flow thickness maps with the results of channel network analysis to show that the most built-up parts of the channels occur at major bifurcations along high-flux channel reaches. These results have important implications for understanding lava flow emplacement, developing predictive models of flow advance, and designing flow diversion barriers. By controlling the distribution of lava flux from the vent through the flow, the channel network governs both the final flow length and advance rate. Channel bifurcations cause flows to slow down and shorten; conversely, topographic focusing may allow flows to travel further and faster than in distributary networks. For this reason, understanding the relationship between the topology of the channel network and the underlying topography that produces it, are critical for developing accurate models of lava flow field development. The scale and geometry of underlying topography that can split or confine the flow could also inform the size and placement of diversion barriers. Finally, understanding the relationship between eruption parameters and channel network morphology facilitates the interpretation of these features in planetary flows, where observations are limited to those made by remote sensing.