TOPOGRAPHIC AND THERMAL INVESTIGATIONS OF ACTIVE PAHOEHOE LAVA FLOWS USING COUPLED LiDAR/FLIR DATASETS

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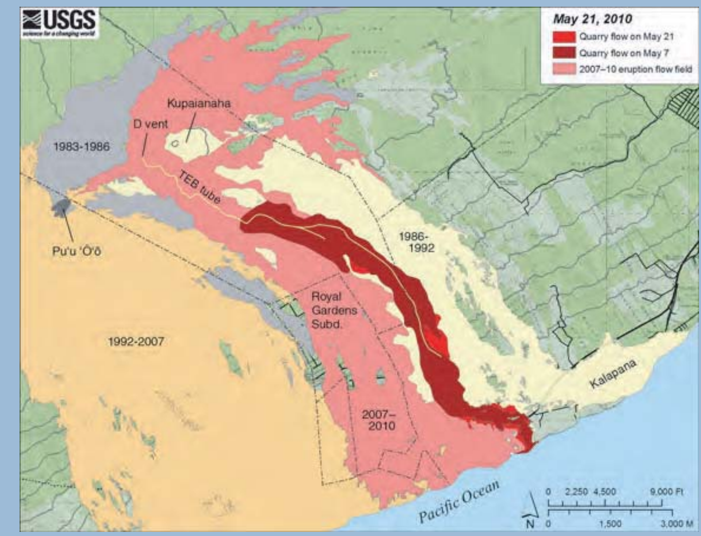
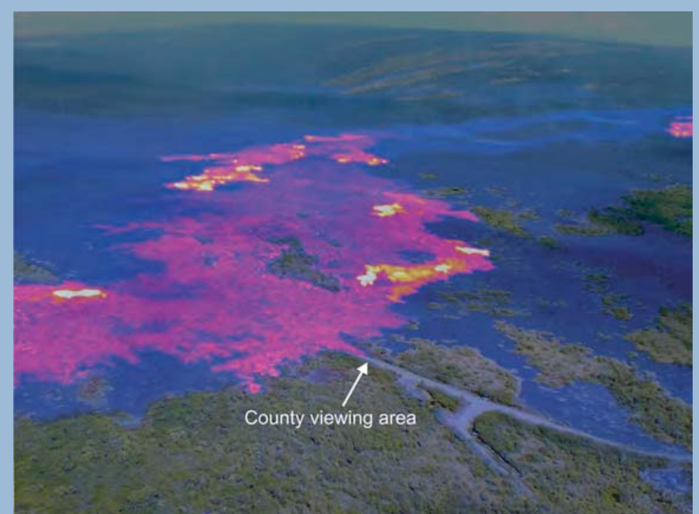
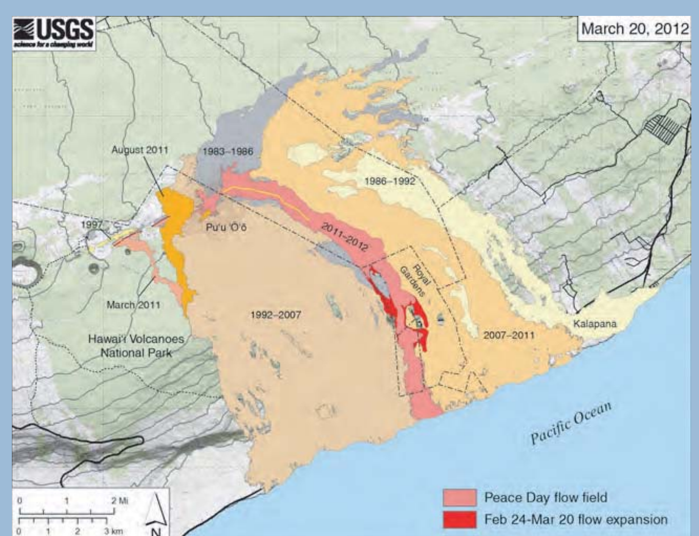




Images and maps courtesy of USGS Hawaiian Volcano Observatory (HVO) [see volcanoes.usgs.gov/hvo/activity/kilaueastatus.php]. Upper left: Aerial photograph of active Thanksgiving Eve Breakout (TEB) flow field on May 7, 2010. Left: View of active TEB flow field on May 21, 2010. Above: USGS map of east rift zone eruptive phases since 1983 showing locations of new flows in May, 2010. Below left: USGS map showing locations of new flows in March 2012. Below: View of active flows in Royal Gardens subdivision on February 24, 2012. Composite images (left and below) show merged thermal infared image and aerial photograph. Note for thermal infrared images: recent flows: are magenta; active flows are yellow and white).

Study Locations: Active Pahoehoe Flows, Kilauea Volcano



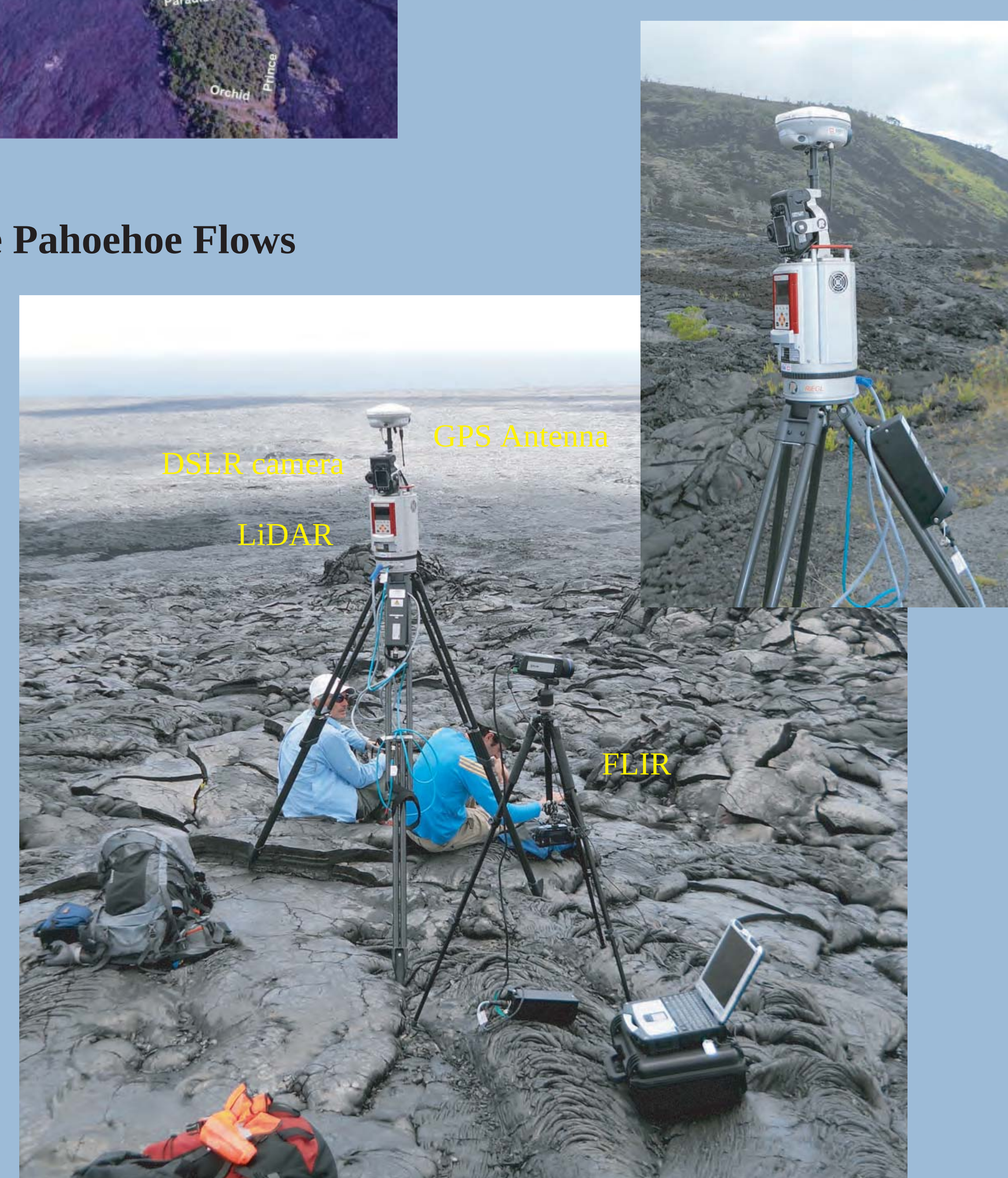
Instrumentation for Field Investigations of Active Pahoehoe Flows

Digital Photography
- DSLR Camera (12.1 megapixels)
- HD Video

Thermography - FLIR SC 645
- Object Temperature Range: -20° to +2000°C
- Accuracy: ± 2°C
- Field of View: 15° x 11°
- Spatial Resolution: 0.41 mrad

LiDAR - Riegl VZ-1000 Laser Scanner
- Range: up to 1400 m
- Measurement Rate: up to 122,000 points/sec
- Accuracy: 8 mm
- Precision: 5 mm
- Field of View: 360° horizontal, 100° vertical

GPS - Global Navigation Satellite System Base and Rover Receiver
- RTK surveying system used to provide precise location of scan position and georeference LiDAR point cloud to real-world coordinates



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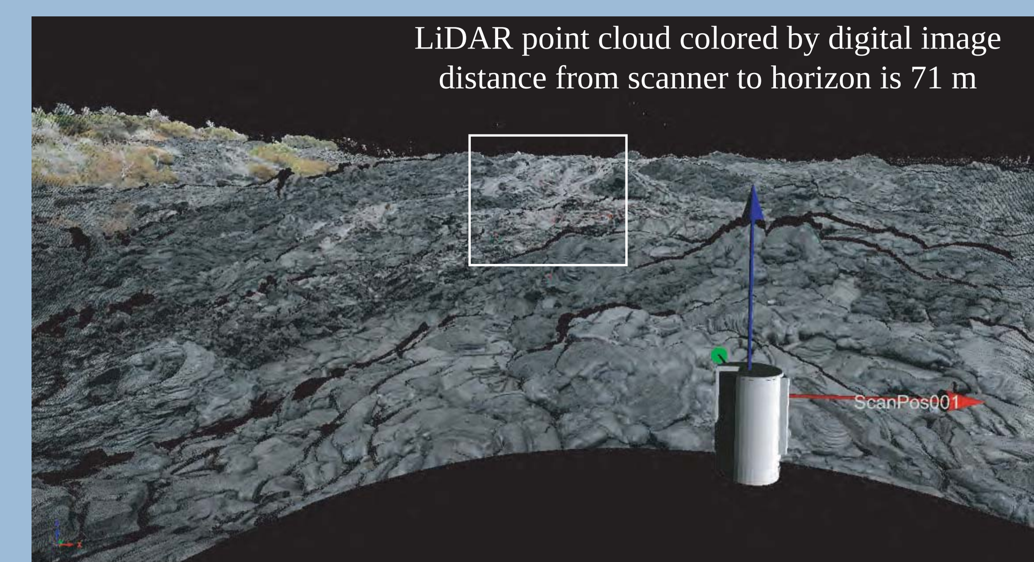
Overview. Pahoehoe lava flows consist of multiple overlapping and interfingering lobes and exhibit morphologically diverse surfaces characterized by channels, smooth-surfaced sheets, and numerous, small networks of interconnected pahoehoe toes [e.g., 1-3]. Previous work compiled detailed planform maps of solidified pahoehoe toe networks to document their morphology, morphometry, and connective relationships [4] to provide constraints on lava transport models [5]. In order to incorporate and analyze the thermal characteristics and temporal variability of pahoehoe lava, we have collected new datasets from active tube-fed pahoehoe flows on Kilauea Volcano near Kalapana, Hawaii.

The complementary use of a) high-definition, visible video footage, b) high-speed, high-precision thermal infrared (TIR) data using a FLIR camera, and c) rapidly acquired high-resolution ranging data using a LiDAR scanner provides the following constraints on pahoehoe flow emplacement:

1) quantitative characteristics of the pre-flow surface;
2) morphologic, morphometric, thermal, and kinematic characteristics of invididual pahoehoe elements (toes, sheets, small channels);
3) detailed documentation of the growth and development of compound flow lobes, including the effects of flow inflation at various scales [6].

Digital Color Image

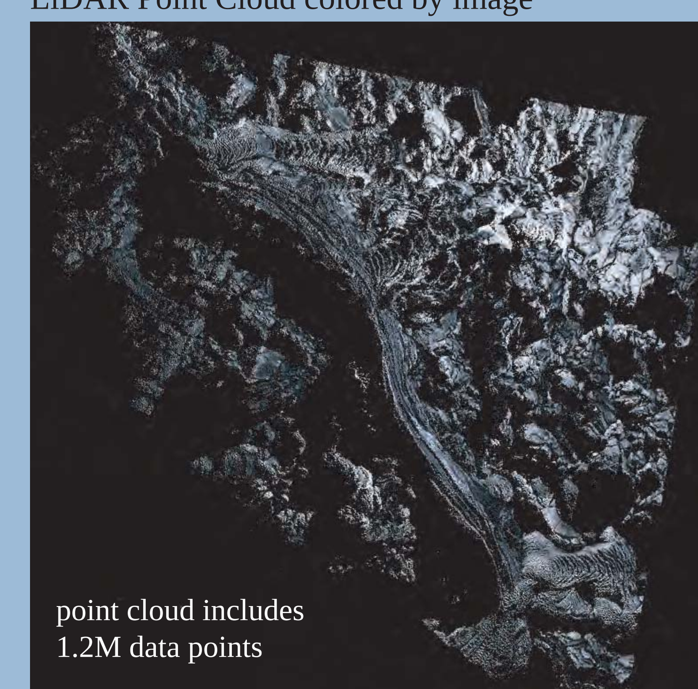
FLIR Image



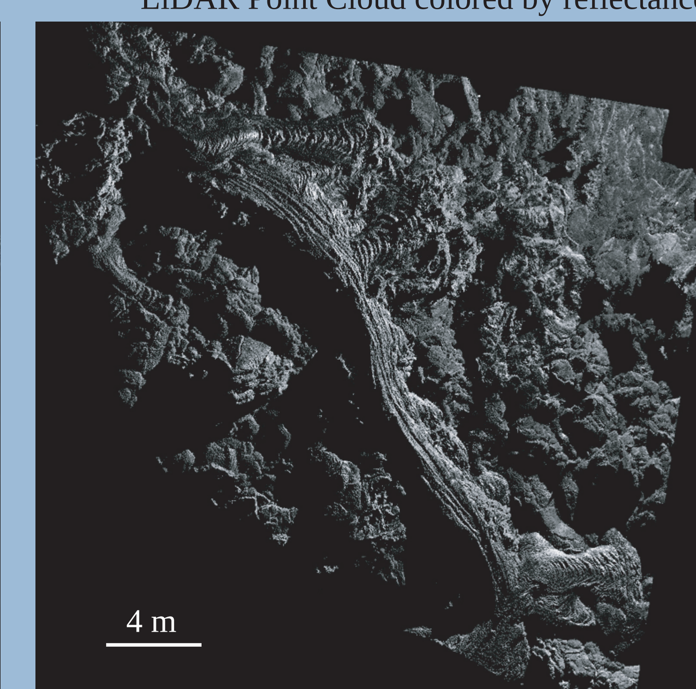
LiDAR Point Cloud

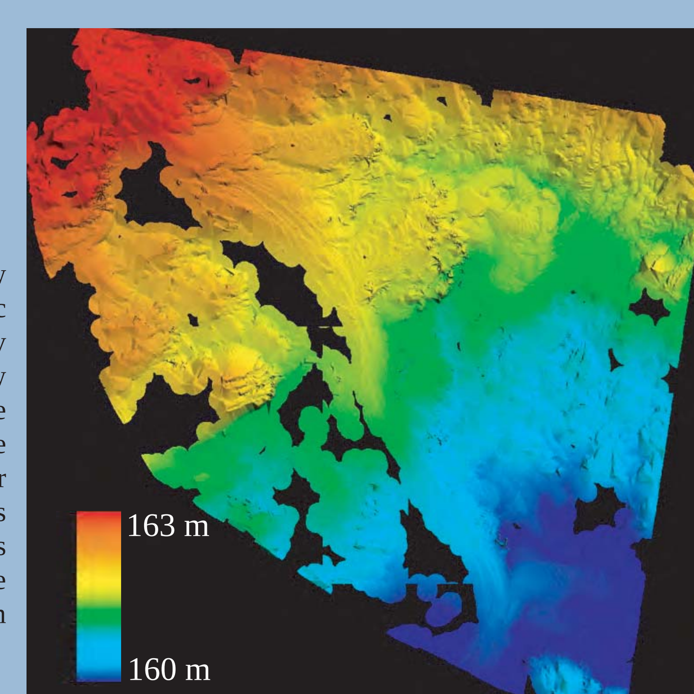
LiDAR Data Products for Pahoehoe Flows

LiDAR Point Cloud colored by image

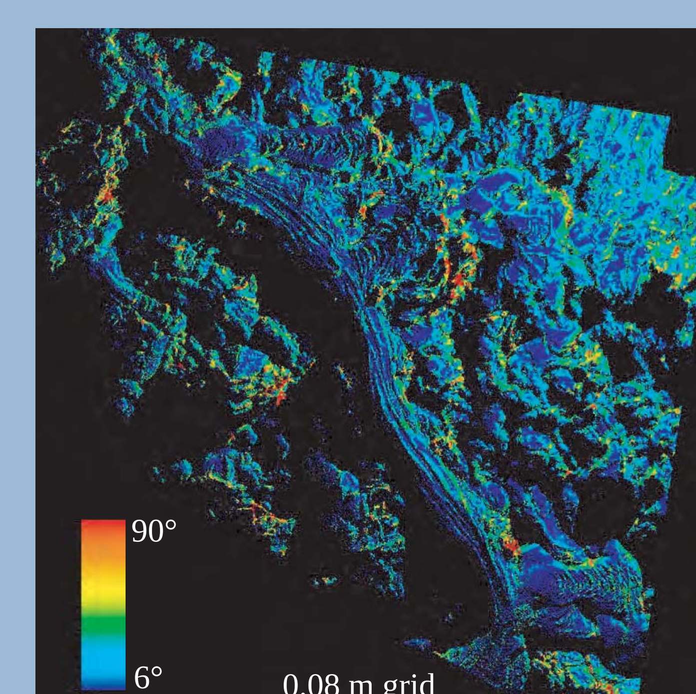


LiDAR Point Cloud colored by reflectance





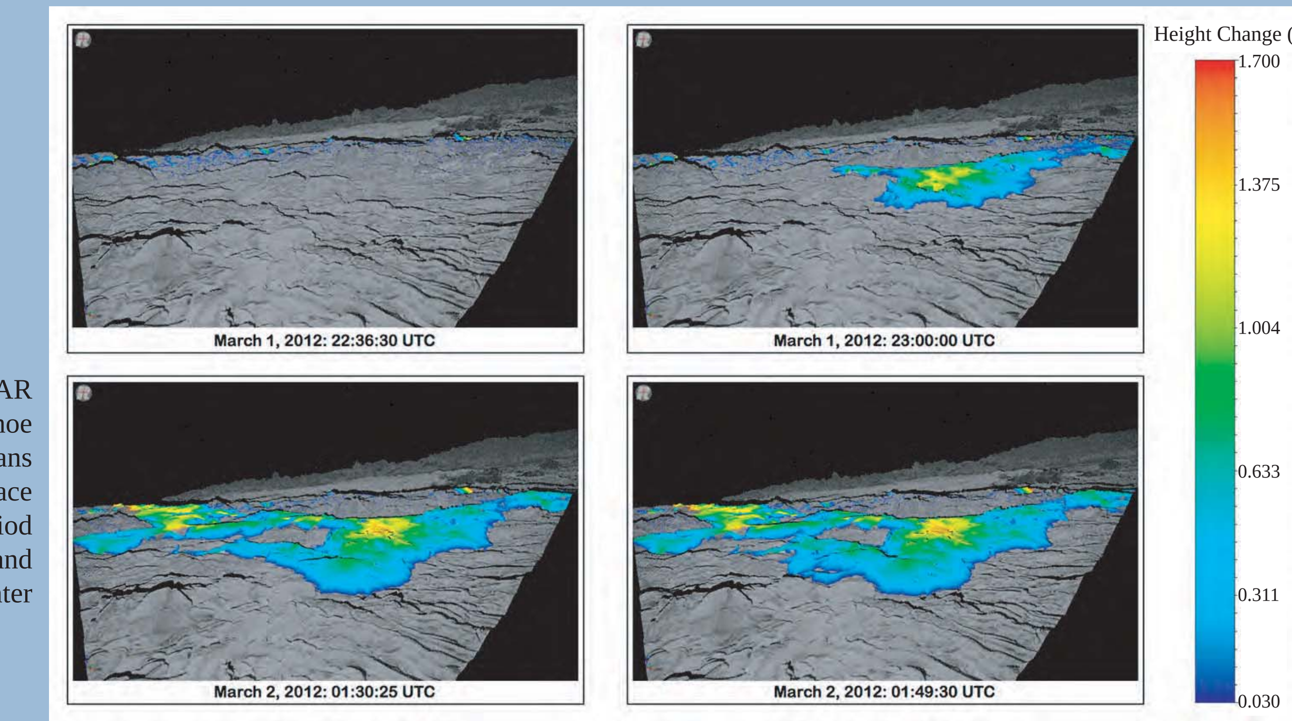
DEM derived from LiDAR data



Slope Map derived from LiDAR data

Repeated LiDAR scans at regular intervals during flow emplacement can be used to document the morphometric characteristics of advancing pahoehoe lobes and to directly link quantitative morphometric measurements to other flow characteristics (e.g., flow morpholgy, temperature). The LiDAR point cloud collected at a given time interval can be easily manipulated and displayed in different ways for geological analyses. Shown at the top are two different ways to display the LiDAR point cloud; surface temperatures collected by the FLIR camera can also be mapped to the LiDAR point cloud in a similar manner. Shown at the bottom are a DEM and slope map derived from the LiDAR data.

Comparison of four LiDAR scans for advancing pahoehoe lobe in March 2012. The scans show the change in flow surface height over a 209 minute period of active flow advance and inflation. Scene width at center is ~37 m.

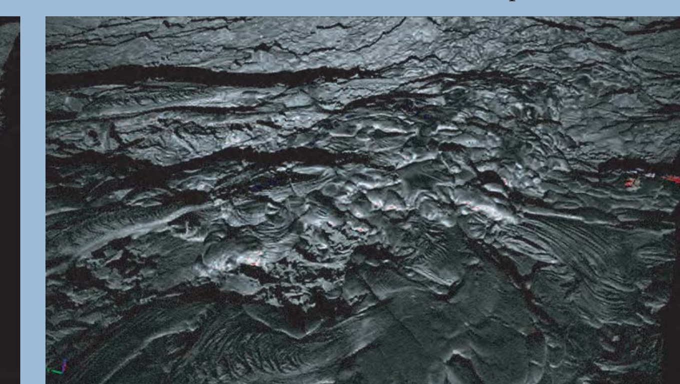


March 2012 Observations of Pahoehoe Flows: Documenting Flow Lobe Emplacement using LiDAR Data

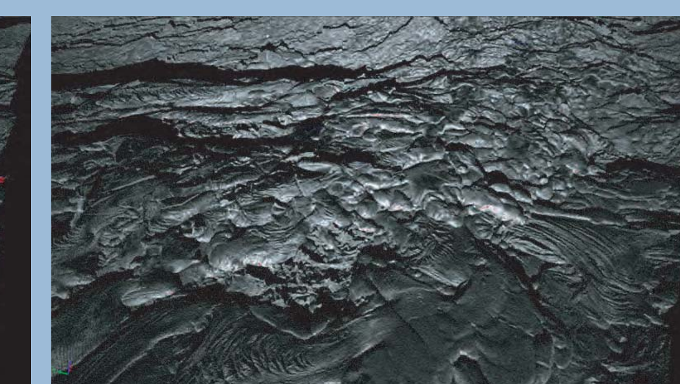
The series of LiDAR scans below shows the emplacement of pahoehoe flow lobes in March 2012. Images show the flow surface at the beginning (A), mid-point (B), and end (C) of ~3.5 hour time period. LiDAR scans were collected every ~108 secconds to document flow emplacement. Images show the LiDAR point cloud colored by laser reflectance (bright = high laser reflectance, dark = low laser reflectance).

The flow surface changes in a variety of ways during the time interval shown, including: a) by inflation of the flow surface throughout the scene, b) by breakouts of new pahoehoe toes, mostly at the margins of the inflating lobe at center, and c) by advance at the flow front (center left) initially by a spreading pahoehoe toe network, then by formation of a small channel, and finally by upstream inflation and breakout of a new pahoehoe toe network that inundates the previously emplaced lava.

A



B

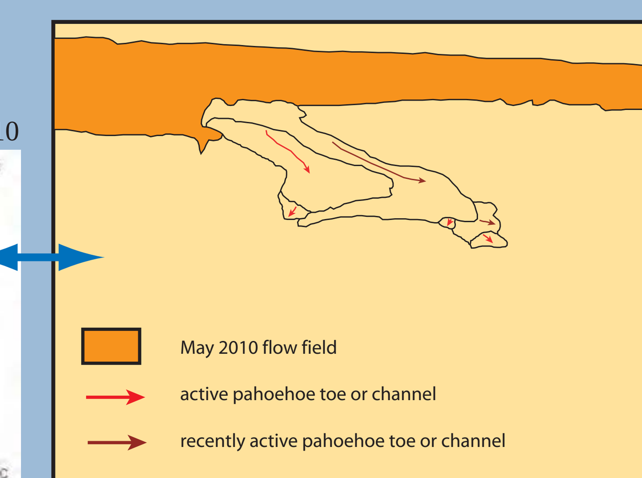


C

May 2010 Observations of Pahoehoe Flows: Active Pahoehoe Network Mapping using FLIR Images

T = 0 sec

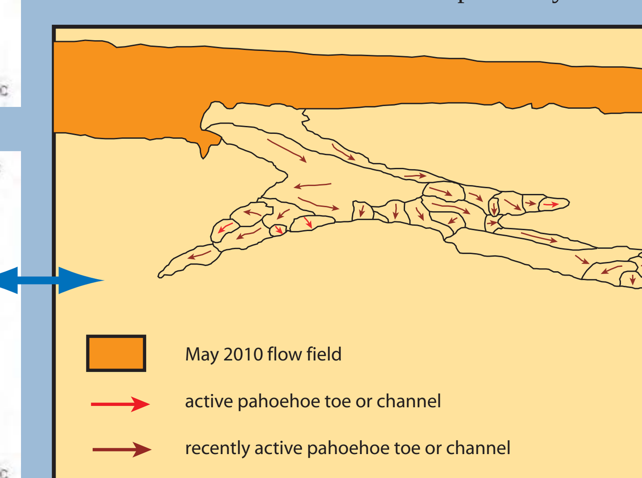
May 18, 2010



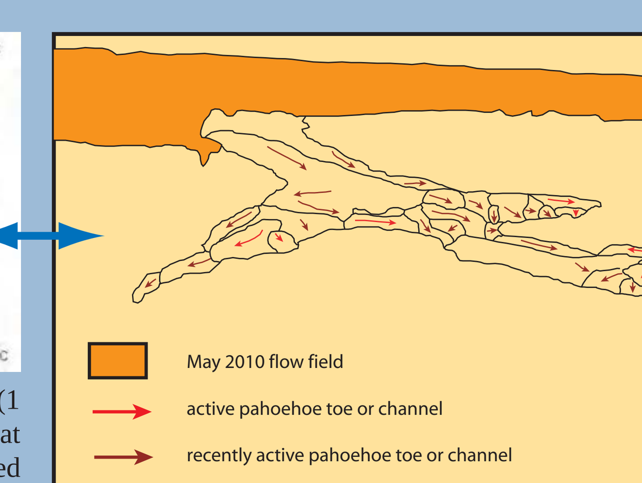
T = 300 sec

High-definition video and high-speed thermal infrared data are being used to construct detailed maps of pahoehoe lobes at various intervals over their emplacement history. The maps document lobe development, connective relationships, and rates of flow advance, lateral spreading, and vertical growth due to inflation. LiDAR data can be used to incorporate detailed measurements of flow morphometry.

T = 600 sec



T = 900 sec



On May 18, 2010, we acquired ~2.5 hours of mostly continuous visible and thermal video footage (1 frame per second) along the front of an advancing pahoehoe flow [7]. Analysis shows a sequence that includes: 1) spreading of a mostly unconfined lobe that fills a low-lying area (shown above), 2) pulsed local inflation with some lateral confinement of the lobe, 3) inflation across most of the lobe width at a stage when the lobe is topographically confined, and 4) cycles of inflation and breakouts across the full lobe that extend it beyond a zone of confinement and allow continued spreading.