Morphological analysis of debris flow deposits in steep headwater channel using multi-temporal terrestrial laser scanning: a 4-year case study at Ohya-kuzure Landslide, central Japan

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Since the formation of the Ohya-kuzure landslide in 1707, its steep, rugged terrain has continued production of a vast amount of sediments by frequent debris flows. Recent works of erosion controls have resulted in vegetation recovery in many slopes in the landslide terrain, but in some subcatchments with very steep slopes, slope deformation and sediment transportation by debris flows are still frequently observed. The Ichinosawa subcatchment shows the highest frequency of debris flows in the recent decade. We focus on this subcatchment, in which numerous debris flows occur by several causes favorable for the initiation, including heavy rainfalls, steep channel slopes and frequent recharge of sediments from steep landforms with deformed sedimentary rocks. In this study site, detailed monitoring and related topographic measurements have previously been performed, yet the details of geomorphic processes are still in progress to be further investigated.

Here we perform terrestrial laser scanning of channel bed sediments in the Ichinosawa subwatershed to examine volumetric and morphological changes in the sediments. The TLS data were collected for 3 seasons each year since November 2011, hence comprising 12 datasets. Every point cloud data for different time is georeferenced using GNSS-derived ground control points, while if applicable, alignments of point clouds for adjacent time are further refined by cloud-based registration using the inertial closest point algorithm for unchanged slope characteristics. While the point cloud analysis shows a high potential of morphological measures in the study reach, we also carry out a DEM-based analysis at a resolution of 0.1 m for the basic volumetric and morphometric measurements. Estimated annual sediment storage and yield in the study reach falls into the order of thousands of cubic meters, which corresponds well with the measurements by other approaches. Longitudinal and transverse profile analyses demonstrate the segmentation of the study reach bounded by the narrowing of valley width with bedrock exposures (knickpoint) on the valley floor. Topographic metrics including stream gradient, surface roughness and openness are also examined to show distinctive characteristics of sediment transportation induced by debris flows along the study reach. This study is supported by JSPS KAKENHI Grants (26292077 and 25702014).

Keywords: debris flow, TLS, point cloud, DEM, geomorphometry

Single-frequency GNSS monitoring of the Guvano coastal landslide (Vernazza, Italy)

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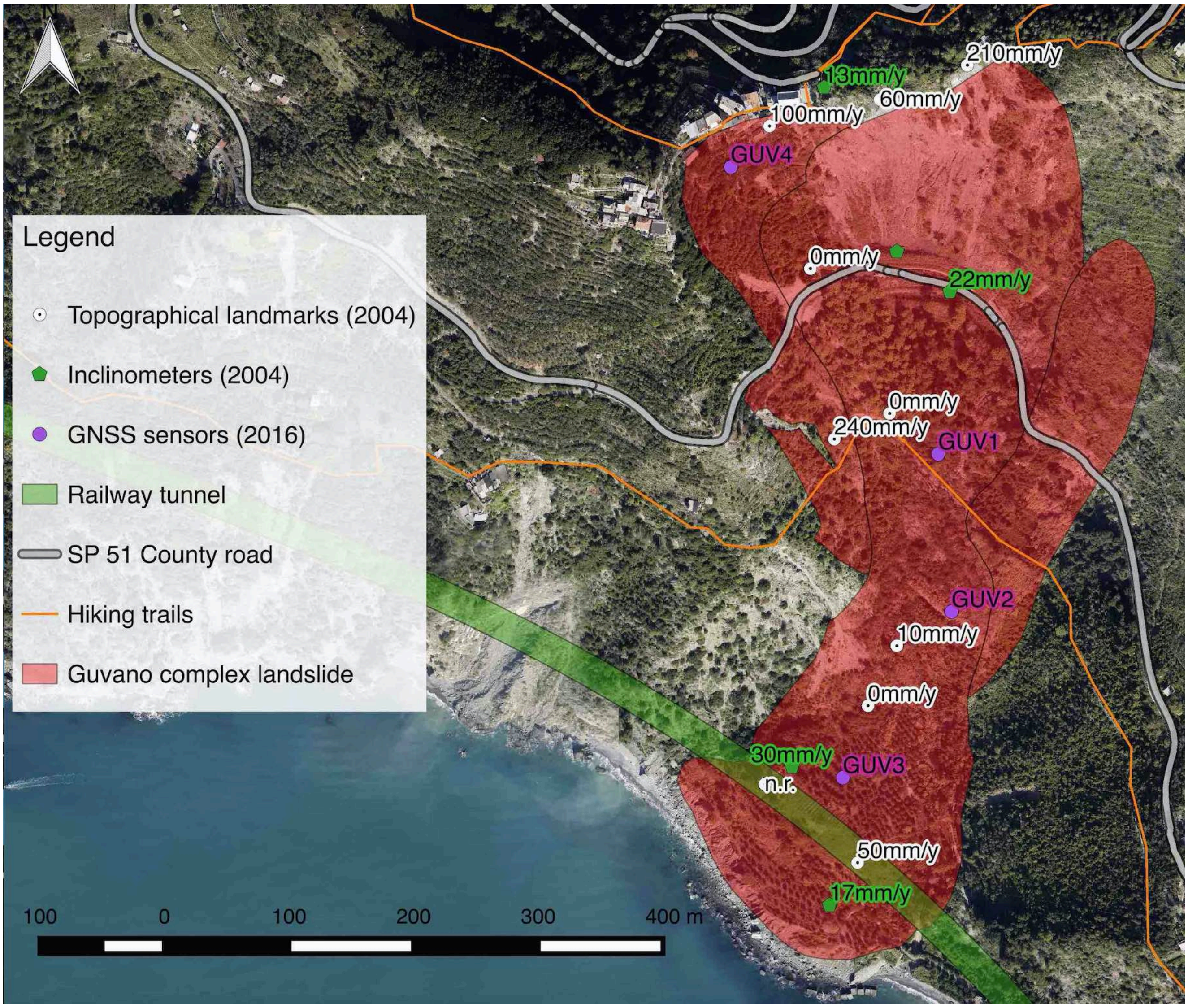
The use of Global Navigation Satellite Systems (GNSS) has become a popular technique in landslide monitoring in recent years: application of low-cost GNSS sensor technology (simple L1 receivers) has remarkably improved during the last few years and has considerably reduced the cost of GNSS sensors; the deformation monitoring with GNSS measurements is a well-known method which can be employed for both extended and local phenomena such as landslides, where a high level of accuracy is needed.The Guvano coastal landslide is a complex slow gravitational phenomenon located between the hamlets of Vernazza and Corniglia; it shows an extension of approximately 0.15 km2, a maximum length of 650 m measured across the upper portion and a width ranging between 120 m and 400 m at slope toe.From a kinematic point of view, the landslide evolution is characterized by a rock planar slide occurred in 1853 and whose fracture surface was set up of a translational fault plane between shales and argillites (Argille e Calcari di Canetolo Formation) and sandstones (Macigno Formation); at present time, three main sectors are identified: the upper one, characterized by rockfalls and topples along an active scarp, the medium one (medium to high slope angle, characterized by soil slips and earth flows) and the lower one (low slope angle, earth flow reaching the coastline). Collapses related to the right flank usually start as rockfall and then evolve in rock avalanches.An original engineering geomorphological map has been realized: actually a retrogressive failure, consequence of several crown collapses, is well visible and could represent a risk for the village of San Bernardino, located just above the main scarp, and for the safety of cars and pedestrian along a portion of the SP51 County Road. The erosion of the landslide toe by the sea waves action and subsequent offshore transportation of sediments has determined a dangerous condition in terms of remobilization of the landslide mass.Between 2003 and 2004 a geotechnical investigation (soil borings and installation of inclinometers and piezometers) was performed in order to examine the soil and rock stratigraphy of the area and to obtain information about the displacement of the landslide mass, which has alternated active phases with dormant periods: the sliding surface was identified at a depth of 11 meters.The main objective of this work is to detect displacements of the order of a few millimeters by relative positioning of low-cost receivers over a short baseline (about 2-3 km): the monitoring program has started in October 2015 when four GNSS sensors (GeoGuard Monitoring Units - GMU) were positioned along the landslide body.The GMUs include low-cost single-frequency hardware for both receiver and antenna. The receiver module is a u-blox LEA-6T, providing GPS observations which are transferred by mobile connection to the control center (GeoGuard Cloud) and processed by a customized version of the free and open source software goGPS. Single-shot displacement data and trend analyses are then processed and managed by the GeoGuard Cloud, which send it to the end-user service interface.The first results assess the activity of the landslide through the relative displacement detected between two of the deployed GMUs along a vertical (z) component (1 cm/month). With the aim of reducing the RMSE affecting the positioning estimates (currently of the order of 1-5 mm), the baseline length is planned to be further shortened by installing a dedicated reference GPS station outside the landslide mass.

Keywords: GNSS monitoring, rockslide, earth flow, landslide, geomorphology


N
Legend
Topographical landmarks (2004)
Inclinometers (2004)
GNSS sensors (2016)
Railway tunnel
SP 51 County road
Hiking trails
Guvano complex landslide
210mm/y
13mm/y
60mm/y
100mm/y
GUV4
0mm/y
22mm/y
0mm/y
240mm/y
GUV1
GUV2
10mm/y
0mm/y
30mm/y
GUV3
n.r.
50mm/y
17mm/y
100 0 100 200 300 400 m

Detection of landslide surface deformation in Kathmandu triggered by the 2015 Gorkha, Nepal earthquake using InSAR image

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A previous study has reported that the 2015 Gorkha earthquake (Mw7.8), which occurred in Nepal, triggered more than 4000 landslides in mountain areas. In Kathmandu, another previous study also identified earthquake-induced land subsidence by interpreting local phase changes in interferograms that were produced from Advanced Land Observing Satellite-2 (ALOS-2)/Phased Array type L-band Synthetic Aperture Radar-2 (PALSAR-2) data. However, ground deformation was not discussed in detail. We studied line-of-sight changes from InSAR images using RINC 0.41 software (Ozawa 2014) and performed 2.5D analysis (Fujiwara et al. 2000) using these images, and we were able to obtain detailed local surface deformation data. Judging from the deformation data and field survey, we concluded that the surface deformation was not caused by land subsidence but by a landslide, specifically, a lateral spread. PALSAR-2 data used in this study were provided by JAXA in the framework of special collaborative research (B) “Surface deformation study using a new generation SAR” by Earthquake Research Institute, the University of Tokyo. This study was also supported by "the Nepal Earthquake and Hazard Mapping of Future Landslides for Making the Plan of Better Reconstruction” (Principal investigator, Prof. Chigira) related to the April 2015 Nepal earthquake in the J-RAPID Program by Japan Science and Technology Agency (JST).

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Keywords: SAR, Landslide, Gorkha, Nepal, Earthquake

High-definition topography applied to landslide hazard assessment around Aso Volcano

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In the last few years, small unmanned aerial vehicles (UAVs), and structure from motion and multi view stereo (SfM-MVS) photogrammetry have attracted a tremendous amount of interest for the creation of high-definition topographic data. This study was conducted to detect temporal changes of topography around shallow landslides using small UAVs and SfM-MVS photogrammetry. Study areas are the Sensuikyo area (1.2 km^2) and the Saishigahana area (0.06 km^2) around Aso Volcano, where many shallow landslides occurred because of heavy rainfall in July, 2012. During 2014–2016, field surveys were conducted using small UAVs. After acquiring high-definition DSMs and ortho-rectified photographs, we analyzed the topographic changes of shallow landslides in comparison to LiDAR-based DSMs in 2004.
We obtained ortho-rectified photographs and DSMs with spatial resolutions of 4 cm and 10 cm, respectively. In the Saishigahana area, 20 landslides (20–4,600 m^2) occurred. The ratio of the total landslide area reached 30% of the area. These landslides tended to occur specifically on 40-degree slopes. The landslide depth was ca. 1.0 m. The estimated total landslide volume was 1.5–2.8x10^5 m^3/km^2. In the Sensuikyo area, 300 landslides (10–10,000 m^2) occurred. The estimated total landslide volume was 1.1–1.4x10^5 m^3/km^2. In the Sensuikyo area, the landslide distribution was not uniform. Our results indicate that topography and past landslide history affected these landslide occurrences. Additional studies must be conducted to detect temporal changes of topography and vegetation around shallow landslides based on multi-temporal ortho-photographs and DSMs.

Keywords: shallow landslide, UAV, SfM-MVS photogrammetry

Impact of glacier recession on debris-flow fan morphology at Fox Valley, New Zealand, using airborne photogrammetry

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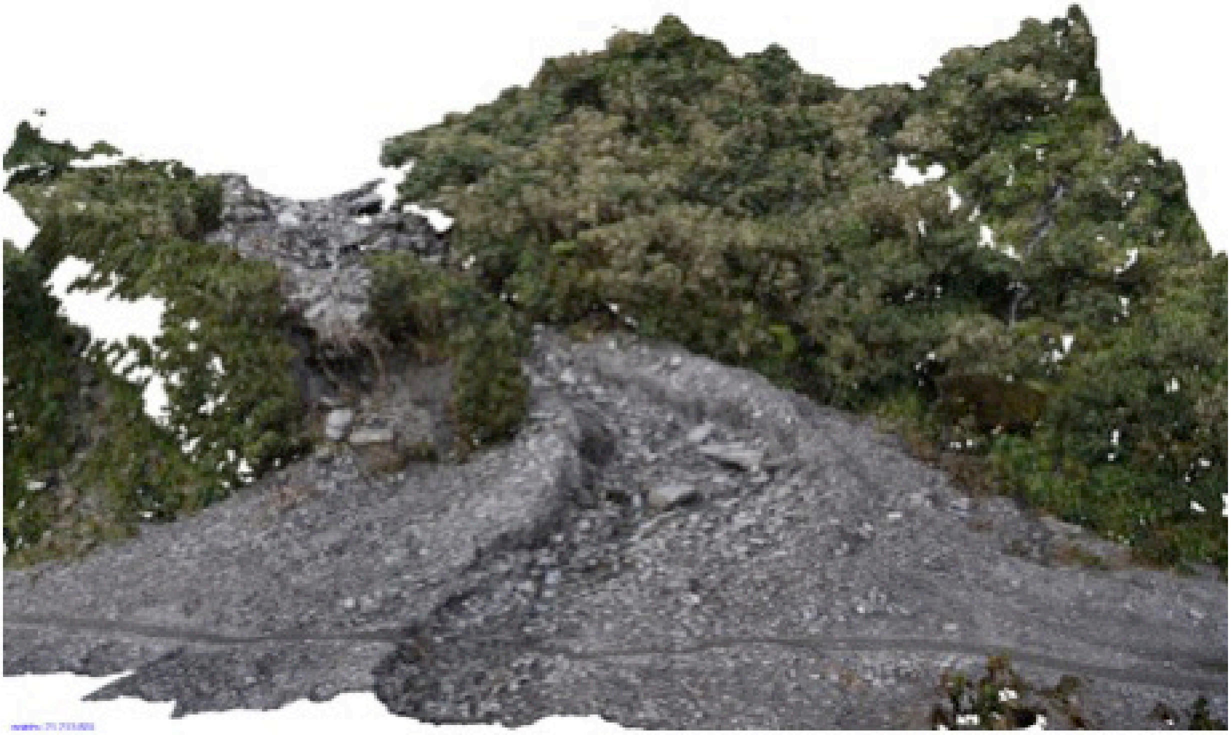
The West Coast of New Zealand annually experiences ~3,000 mm of rainfall at the coast and up to 12,000 mm near the Alpine ridge. Although those important precipitations have helped glaciers reaching 300~400 m asl at Fox Glacier and Franz Josef, present conditions have pushed the glacier terminus of Fox Glacier about 800 m upstreamward from where it was in 2000. This recession has freed a number of tributary valleys that were plugged by the ice. The junction between the main valley stem and the tributary is now occupied by exceptionally large fans, which were generated during the ice recession phase.
In order to understand how the ice recession and the debris-flow have created the debris-flow fans and what morphology was created, we have used an analysis of high-resolution topography.
Because of the quasi-omnipresence of low-clouds in the valley, there are very few aerial data available for the lower Fox Valley. Consequently, we flew in 2015 a commercial helicopter, from which we collected 150 photographs with a SLR camera 35 mm focal. This first dataset was completed by a series of photographs taken from a DJI Phantom2-Vision+ (~350 photographs). Finally, thirty Ground Control Points and 220 Quality Control Points were collected using RTK GNSS (Trimble R8).
The data was then processed using the SfM software Photoscanpro, from which the dense pointcloud was exported in ArcGIS, where a DSM was generated. As most of the fan is “vegetationless”, the DSM was considered as the DEM.
Results have shown the presence of a series of terraced surfaces imbricated with each other, and which correspond to the past-limits of the glaciers. Those surfaces are now eroded by the debris-flow that reaches the lowered base level. This has therefore resulted in an increase of material reaching the river-bed, generating sediment waves in the sediment cascade.

Keywords: debris flow fan, glacier retreat, sediment cascade, photogrammetry, Fox Glacier, New Zealand



Multi-resolution analysis of landscape characteristic length scales

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The wide availability of high resolution topography data has revolutionized the way we analyze landscapes. Information at fine scales allows the extraction of geomorphic features such as channel heads and the detection of geomorphic process transitions.
Here we present a technique called multi-resolution analysis (MRA) to analyze landscapes across scales, quantify how the probability density function of topographic attributes changes with scale, and identify characteristic length scales. The method consists of convolving high resolution data with Gaussian kernels of increasing standard deviation to obtain topography data at different scales. At each scale, we compute the probability density function of curvature and topograhic index, defined as the ratio of slope and contributing area in logarithmic scale. By analyzing the probability density function of each attribute across scales, we detect scaling breaks. Through the analysis of 1D and 2D synthetic signals as well as the analysis of numerically simulated landscapes under controlled initial and boundary conditions, we equate the detected scaling breaks to the scale of surface roughness and the median hillslope length scale. The MRA approach is then applied to various real landscapes to quantify their characteristic length scales.

Keywords: high resolution topography, roughness, hillslope

Simulating and Quantifying Legacy Topographic Data Uncertainty: An Initial Step to Advancing Topographic Change Analyses

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Integrating the disparate datasets (e.g. aerial photographs and point cloud data gathered with a variety of more recent sources) to unravel topographic changes in varying geomorphic contexts involves a number of issues. These issues range from data compatibility associated with the different data collection techniques, to legacy data that contain unknown error, unreported error, or in some cases known deficiencies, to integrating this information in a manner whereby scientists can definitively derive the extent to which a landform or landscape has and will continue to change in response natural and/or anthropogenic processes. Here, we examine the question: how do we evaluate and portray data uncertainty from the varied topographic legacy sources and combine this uncertainty with current spatial data collection techniques to detect topographic changes? Digital terrain model (DEM) uncertainty can be modeled as a stochastic process. The uncertainty model tends to vary across the region of interest, and yet remain locally correlated. We consider the spatial variability and correlation on a grid of anchor points. The elevation uncertainties observed on the anchor points are modeled using “states” in a stochastic estimator. This type of estimators is used track the evolution of the uncertainties. The estimator is natively capable of incorporating sensor measurements with various times of validity. Even when a sensor does not directly observe an anchor point, the geometric relationship between the anchor point and the sensor measurement can still be approximated, thanks to spatial correlation. Our results show it is indeed possible to incorporate measurements and data from a variety of sources and quality. The estimator provides a history of DEM estimation as well as the uncertainties and cross correlations observed on anchor points. Our work provides preliminary evidence that our initial approach is valid and warrants further exploration. Our intent is to corroborate and further develop this work with data and results from physical models and multi-temporal field data and analyses.

Keywords: data uncertainty, topography, geomorphology

Increasing the Impact of High Resolution Topography through Open, Online Access to Data and Processing

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The availability of high-resolution topography has been revolutionary for Earth science, environmental, and engineering applications. These data are powerful tools for studying the earth’s surface, its vegetation cover, and the built environment. Typical surface processes act at fine spatial scales (<1m) to produce intricate landforms. High-resolution topography measures the three-dimensional geometry of the earth’s surface and overlying features at appropriate resolutions. In addition, surface changes due to erosion, transport and sedimentation, as well as displacements due to earthquakes, landslides, volcanoes are often <1-10 m. Temporal comparisons of high-resolution topography enables scientists to quantify such changes in unprecedented ways that inform our understanding of surface, volcanic, and tectonic processes.
Technologies such as airborne, terrestrial, and mobile laser scanning, structure from motion photogrammetry, and multi-beam sonar are becoming increasingly accessible, making the collection of high-resolution topography more common. Open access to these data and a cyberinfrastructure platform that enables users to discover, manage, share, and process them increases the impact of investments in data collection and catalyze scientific discovery. Furthermore, open and online access to data enables broad interdisciplinary use of high-resolution topography across academia and in communities such as educators, public agencies, and the commercial sector.
OpenTopography (OT) was initiated in 2009 with funding from the US National Science Foundation to democratize access to Earth science oriented high-resolution topography data and processing tools. Hosted at the San Diego Supercomputer Center (SDSC) at University of California San Diego, OT utilizes cyberinfrastructure, including large-scale data management, high-performance computing, and service-oriented architectures to provide efficient Web based access to large, high-resolution topographic datasets. OT colocates data with processing tools to enable users to quickly access custom data and derived products for their application, with the ultimate goal to make these powerful data easier to use.
OT's rapidly growing data holdings currently include 188 lidar point cloud datasets (>835 billion points) covering 180,381 km^2. Shuttle Radar Topography Mission (SRTM) global datasets, as well as pre-computed lidar DEMs are also available. Data come from a variety of providers through strong partnerships, including NSF supported projects and numerous US federal, state, and local agencies. As a testament to OT's success, several groups rely solely on OT to deliver data to their users. More than 10,000 OT registered users and tens of thousands of anonymous guest users have run 60,000 point cloud jobs, accessing over 2.5 trillion lidar points. This use has resulted in more than 151 per reviewed publications across numerous academic domains including Earth science, geography, computer science, and ecology.
As OT matures and high-resolution topography becomes more ubiquitous in Europe and Asia, we seek new partnerships to increase access to high-resolution topography outside the United States.

Keywords: topography, lidar, OpenTopography

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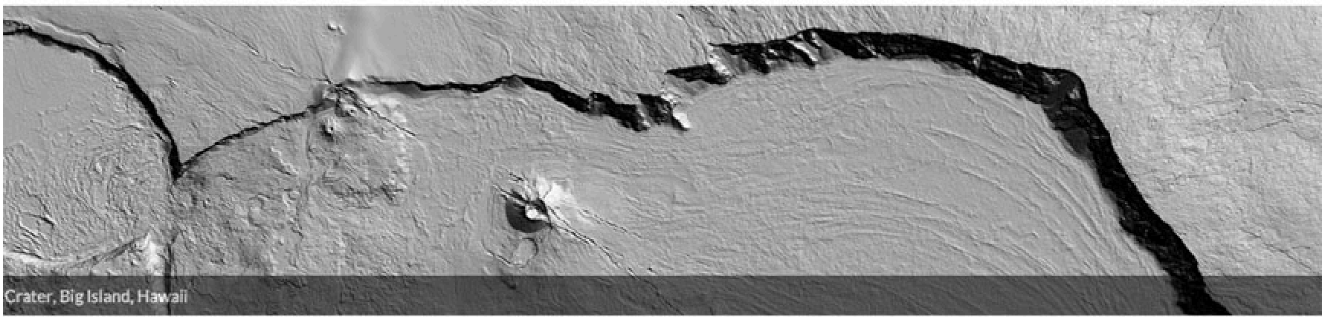
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