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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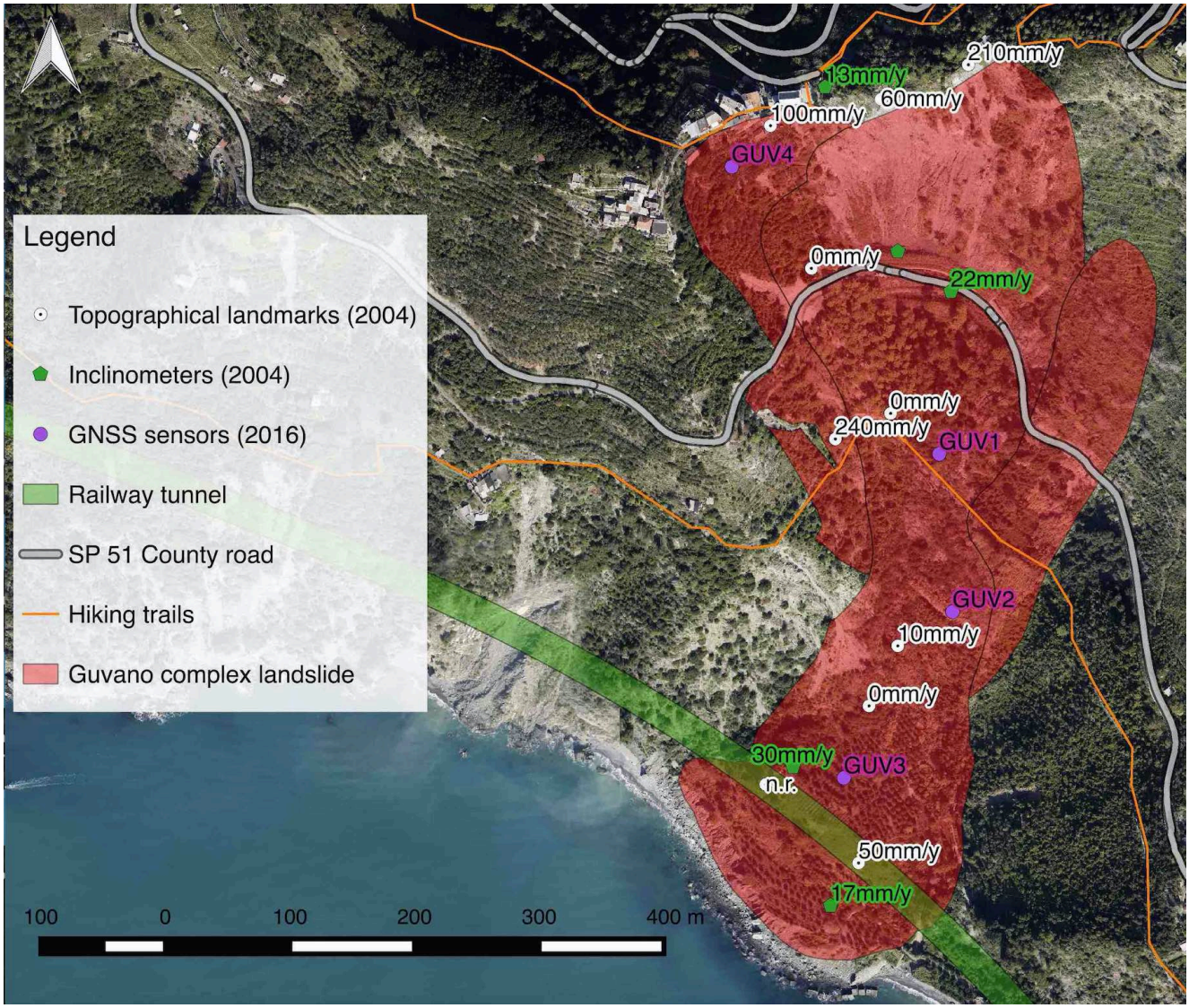
The use of Global Navigation Satellite Systems (GNSS) has become a popular technique in landslide monitoring in recent years: application of low-cost GNSS sensor technology (simple L1 receivers) has remarkably improved during the last few years and has considerably reduced the cost of GNSS sensors; the 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



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 $1.5–2.8×10^5$ m^3/km^2. In the Sensuikyo area, 300 landslides (10–10,000 m^2) occurred. The estimated total landslide volume was $1.1–1.4×10^5$ 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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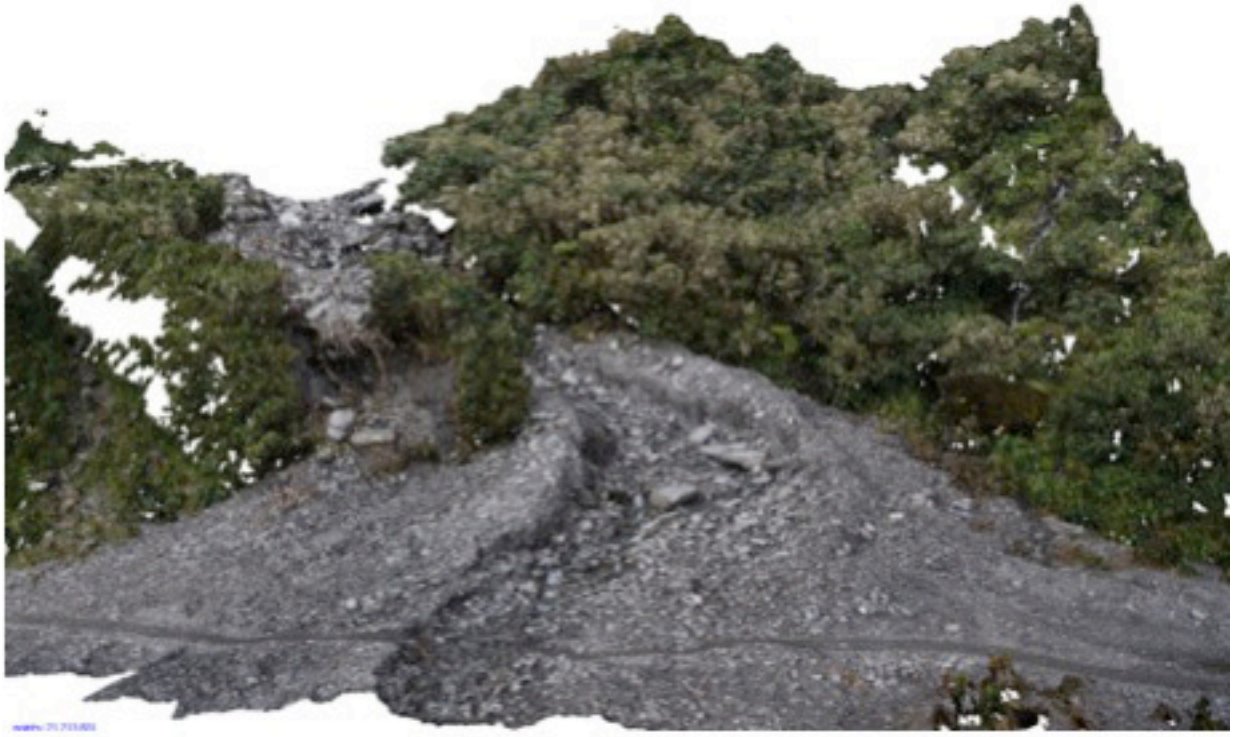
The West Coast of New Zealand annually experiences ~3,000 mm of rainfall at the coast and up to 12,000 mm near the Alpine ridge. Although those important precipitations have helped glaciers reaching 300~400 m asl at Fox Glacier and Franz Josef, present conditions have pushed the glacier terminus of Fox 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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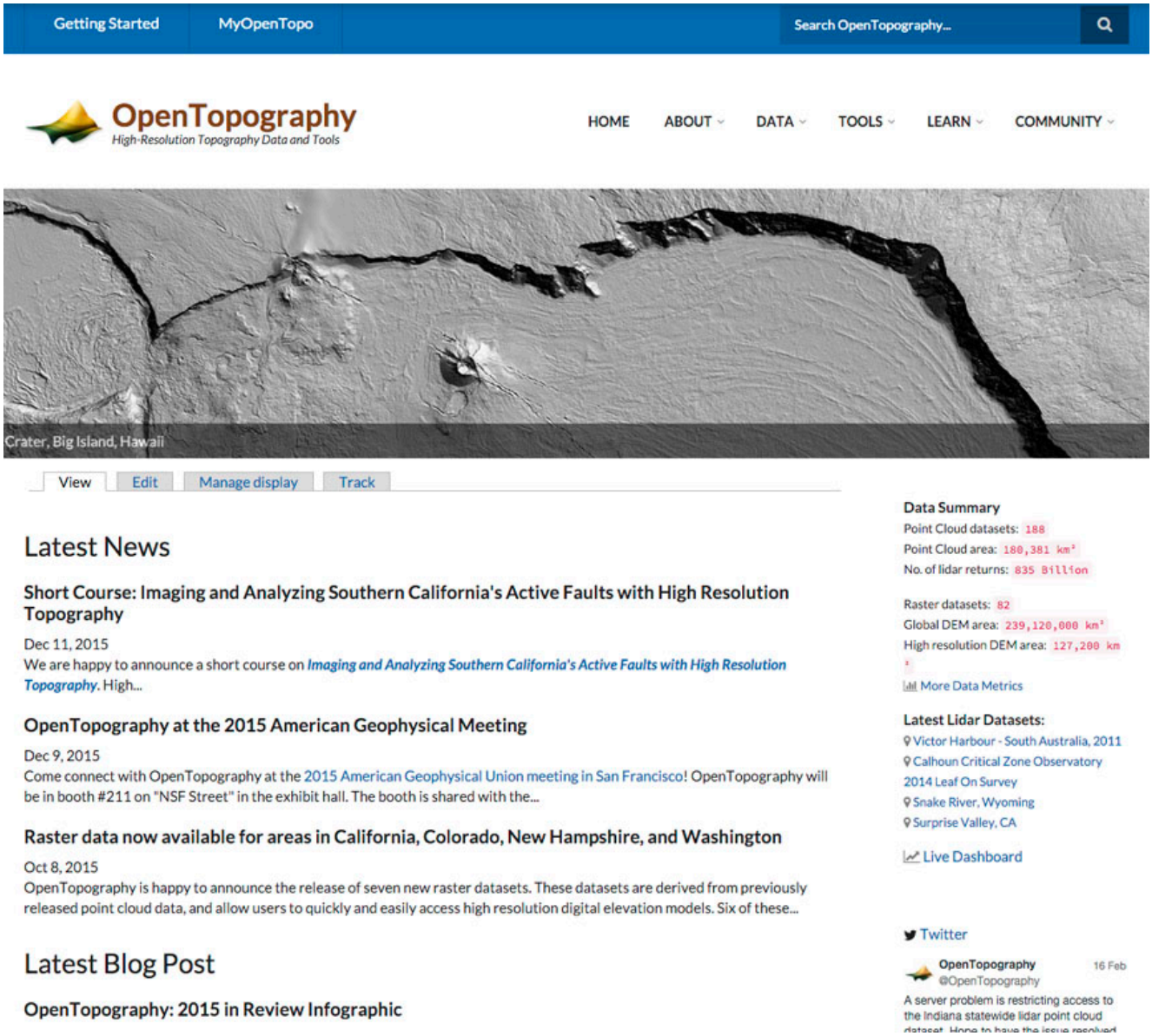
The availability of high-resolution topography has been revolutionary for Earth science, environmental, and engineering applications. These data are powerful tools for studying the earth's surface, its vegetation cover, and the built environment. Typical surface processes act at fine spatial scales (<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



Micro-topographic survey on the block slope using UAV-SfM method: a case study on the west face of Mount Higashi–Nupukaushi, Shikaribetsu volcanic group, Hokkaido, Japan

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In the topographical analysis, it is definitely effective to employ the conventional methods such as total station combined with transit and laser ranger, for their systematized procedures with a high degree of precision. However, in hardly accessible areas, it is often difficult to survey using such above equipment. Instead, aerial photogrammetry and laser scanning with manned flight are normally used for surveying. But this method is too costly for independent researches to implement. In the last few years, SfM (Structure from Motion) based on photographs taken from UAV (Unmanned Aerial Vehicle) has attracted an interest for the creation of DSM (Digital Surface Model) and other morphometric products, as a much less labored and less expensive method than the above. There are a number of reports to testify the method in various environmental settings, showing enough accuracy to be discussed from a viewpoint of micro-topography. This presentation shows a result to have surveyed the block slope on the west face of Mount Higashi-Nupukaushi, Shikaribetsu volcanic group, using UAV-SfM method. Although it is conventionally considered that block slope has been formed under periglacial conditions, there are circumstances when it makes sense to understand the involvement of rapid mass movements in some cases. Anyway, detailed surveying has not been carried out in almost all block slopes on the steep mountain slopes. In a survey conducted by the authors in September 2015, 1124 airphotoes were obtained by a UAV (Phantom3, DJI), producing DSM (Digital Surface Model) and an ortho-image for a detailed, high-definition topographic mapping of characteristic landforms.

Keywords: UAV-SfM method, block slope, Shikaribetsu volcanic group

A survey for the larger block distribution on the block slopes around the summit area of Mount Tateshina, central Japan: an application of combined on-site measurements with UAV-SfM method providing clues as to the understanding of block slope development

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There are a number of studies concerning the “block slope”. Some studies indicate that the block slopes are formed by material transport due to rapid mass-movements such as slope failures and landslides, while the others conclude that the periglacial processes are highly involved to their formation. However, in fact, the conclusive or clear-cut idea has not been presented. The block slopes generally develop in the relatively inaccessible sites, with steep slopes around and larger than 30 degrees. Besides, large blocks occasionally over meters in diameter are unsteadily scattered and numerous gaps among them are sometimes unfilled by topsoil. In such circumstances, the topographic survey with commonly used tools, such as theodolite or totalstation, requires the greatest time and energy. It must be now requested the more sophisticated measurement techniques to realize the higher degree of understanding of the formation processes of the block slopes.
In this study, we carried out an on-site measurement investigation how located the larger blocks on the block slopes, around the top of Mount Tateshina, central Japan. At the same time, in order to recognize the panoramic surficial characteristics of the studied block slope, aerial photographs of the south part of the summit area were obtained by a UAV (Phantom3, DJI), producing DSM (Digital Surface Model) with an orthophoto by SfM software. These were used for validation with field data to testify the usability of this new remote technique. In the field, we established two line transects along the west and south slopes of Mount Tateshina from near the mountaintop to the lower altitudinal parts. On-site measurements along these transects were accomplished for major axis length, its azimuth orientation, and the relative degrees of weathering of selected block surface. The tentative results are as follows, though more detailed investigations will be planed in the near future.
1) Larger blocks are generally distributed in the lower altitude in both slopes, which is also recognized by the areal photos (orthophoto) by UAV. The major axis direction of the larger blocks is roughly parallel to the maximum slope direction. Based on the produced DSM, it becomes much clear the direct relationship between topographic condition (slope, direction and so on) of the block slope and the alignments of surficial blocks on the slope.
2) A possible process of block slope formation is a bit complicated. Firstly, a large number of blocks were produced and concentrated in the lower part of slopes, probably due to the rapid mass-movements after the emergence of summit dome of Mount Tateshina (ca. 40 ka). After that, the major axis direction of such larger blocks was arranged parallel to the slope orientation by a strong periglacial process perhaps during the LGM. Distal end of the block slopes has the tongue-shape with a small cliff, indicating that the periglacial process had likely to played an initiative role as a formation factor of the studied block slopes.

Keywords: block slope, photogrammetry, rapid mass-movement, periglacial process

The Application of Unmanned Aerial Vehicle (UAV) for Biotope Monitoring Program

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Nature conservation is carried out at Miyagase Dam area, Kanagawa Prefecture since 1996. Construction work is held in 1992-1994 period for nature restoration works, and its effect is monitored by biotope mapping survey. Observation of living organisms and region temperature at study area are done during 1996-2014 period. In 2014, UAV aerial imaging has been deployed for additional 2D/3D data analysis. The observation used three cameras, e.g. optical camera (Canon S100), Near Infra-Red (NIR) camera (Canon S110 Yubaflex) and a thermal camera (Thermo Shot F30S) board on a Multicopter, which flew with flight altitude of 100m. The 2D/3D mapping products from optical images were derived using Structure from Motion (SfM) method and its results are used for spatial distribution of vegetation and habitat mapping (Fig.1a). Ground moisture and thermal mapping using NIR camera and thermal camera are used in thermal habitat study (Fig.1b, Fig.4). This observation method can be used for monitoring of biotope's environment on the finest scale. In this study, to observe the effect of local temperature changes, we observed the population and habitat of *Poikilotherm*, organisms which have body temperature that can be affected by the surrounding temperature, such as dragonflies.

The observation result shows that the combination of UAV data and field survey data of biotope give a new perspective and good accuracy on 2D/3D data analysis, i.e. 5-31 cm resolution on vegetation and habitat mapping. Normalized Difference Vegetation Index (NDVI) map derived from optical image shows spatial distribution of chlorophyll content which correlates with tree canopy structure (Fig. 2). High NDVI index shows spatial vegetation distribution of Japanese cedar (*Cryptomeria japonica*). Whereas, the distribution of autumn leaves (e.g. konara oak (*Quercus serrata*), etc.) is shown as high normalized index of band red and green ((b2-b3)/(b2+b3)) retrieved from NIR image (Fig. 3a). The analysis of ground moisture level of study area is derived using the normalized difference of green and red band of NIR image. On Fig. 3b, red area shows high moisture level which is habitat preference of dragonfly. Since band math calculation can be affected by tree shade, masking is suggested on preprocessing. Thermal camera captured optical and thermal images simultaneously. Field temperature measurement was held during flight time and its result shows good correlation with thermal map. Although thermal mapping with 31 cm resolution can provide good temperature distribution on observed area, the development of thermal camera sensor is needed for higher accuracy, enable image metadata (Exif) modification for GPS recording to provide 2D/3D thermal mapping using SfM method.

Long term monitoring is useful to detect changes in biotope presence and structure. We observed population increase of species which has strong adaption to high temperature, e.g. Ito Tombo *(Coenagrionidae)*. This species usually lives in or near pond and waterbody without streams, where temperature is warmer during spring to fall compare to the river area. Although few literatures addressed about the change of dragonfly population due to temperature, we conclude that the increase of dragonfly population possibly affected by the increase of temperature at observed area about 1.5℃ during 1996-2014.

Keywords: UAV imaging application, biotope monitoring, optical image, nir image, ndwi/ndvi, temperature rise effect

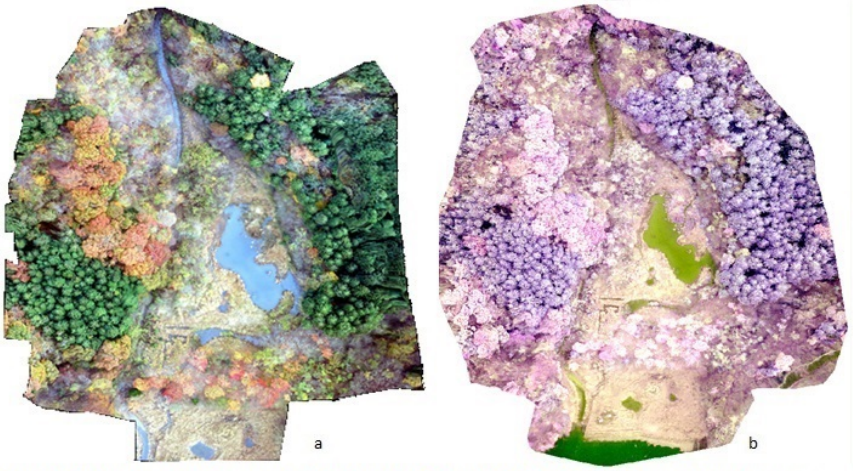

Fig.1 UAV photo result; a) optical image (RGB=123) and b) NIR image (RGB=NIR\R\G). Cooperation with Sagami River Water System Wide Area Dam Administration Office, Ministry of Land, Infrastructure, Transport and Tourism.

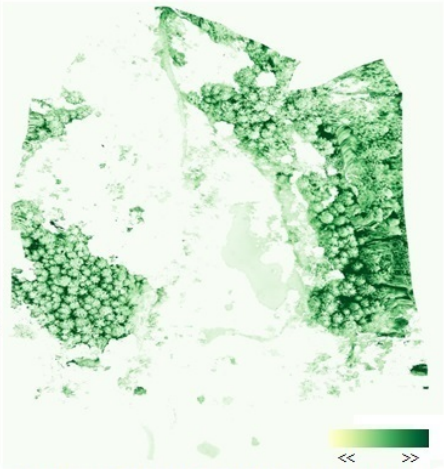

Fig. 2 Chlorophyll distribution of NDVI map (optical image)

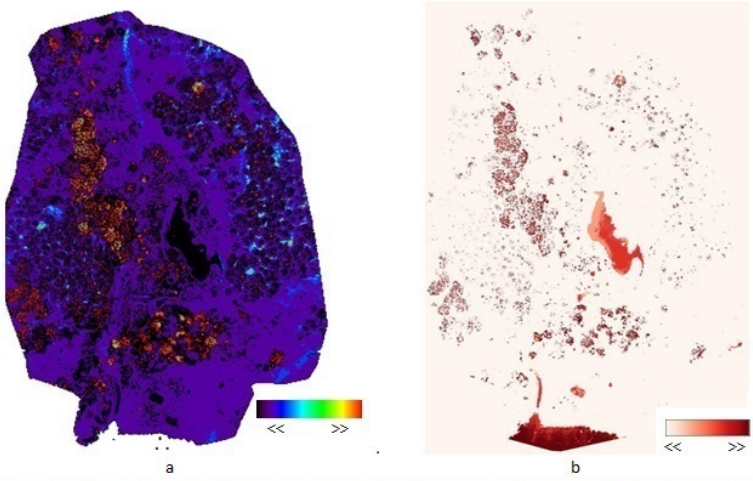

Fig.3 a) Autum leaves map (konara oak, etc.) and b) ground moisture level map (red is habitat preference of dragonfly) derived from normal difference index of green and red band of NIR image.

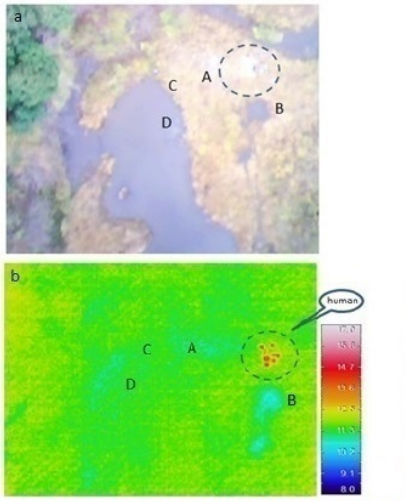

Fig.4 Thermal camera imaging result: a) optical image and b) thermal map. Field temperature measurement (2014/11/28) of A (soil): 10.8 °C, B (grass): 12.3°C, C (near pond): 11°C, and D (pond): 11.5-11.8°C, show good correlation with thermal map.

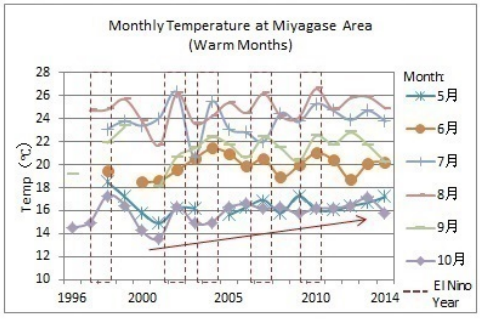

Fig. 5 Monthly temperature at Miyagase area during 1996-2014 period

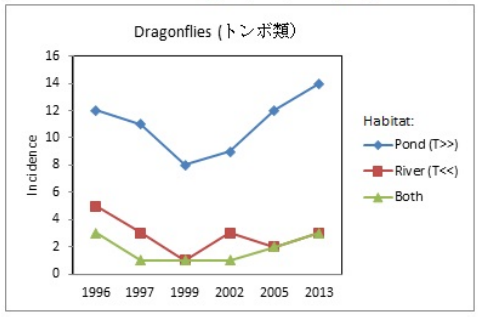

Fig. 6 The incidence index of dragonflies in various habitats during 1996-2013 period

Measurment of snow distribution using small UAV

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Recently aerial photography using small UAV (Unmanned Aerial Vehicle) carrying a compact camera and SfM (Structure from Motion) technique has been carried out in many areas. As one of the advantages of the small-multicopter survey it can closely shoot and measure the mountain slope where the existing manned airplane cannot survey enough because its flight height is relatively high and so it cannot come close to the object. In addition, because running cost of the small UAV survey is far less and its operation is relatively easy, repetitive measurements are easier than the existing methods such as aerial photogrammetry and laser scanning with a manned airplane. We have carried out the topographic measurements using the above advantages at snow covered area in Niigata Prefecture, Japan. By the repetitive UAV measurements we have constructed the multi-temporal 3D models of the surfaces of the ground and snow field and could quantitatively clarify the snow distribution with higher spatial and temporal resolutions. The snow-depth values estimated by the UAV surveys corresponded reasonably well with the actual data measured by snow probe. The UAV-SfM technique has a great potential for a wide range of application, because of its high data accuracy, low initial and operational costs, allowing high spatial and temporal data recording.

Keywords: UAV, SfM, snow distribution

Using an unmanned aerial vehicle to examine influence of topography on development of debris flows in a initiation zone of Ohya landslide, Japan

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In debris flow initiation zones, flows alter the topography of deposited sediments through their development by entrainment. Although it is possible that such topographic changes influence the magnitude of subsequent debris flows, this influence is not well understood because of the difficulty in conducting a temporal series of high-definition topography measurements. Therefore, to examine how topography affects the development of debris flows, we carried out structure-from-motion (SfM) photogrammetry from aerial shoots by an unmanned aerial vehicle (UAV) in the Ichino-sawa subwatershed of the Ohya landslide, in central Japan. Debris flow occurrences and rainfall were monitored using interval cameras and a rain gauge. In the gully in the hillslope, the sediment discharge was dominated by entrainment due to the deposited sediments that were gradually discharged by storm rainfall events. In comparison, deposition several meters thick typically occurred in the main channel. Consequently, the topographic changes in the main channel were more complex than those of the gully. Furthermore, in the main channel, the trends in the changes regarding the amount of sediment differed in the upper and lower parts of the confluence of the gully. In the upper part of the main channel, sediment entrainment and deposition occurred repeatedly after each debris flow, whereas entrainment by such flows dominated the topographic changes in the lower part. Consequently, deposited sediment supplied by a previous debris flow in the upper part contributed to the development of the subsequent debris flow. The results indicate that the magnitude of the debris flow was affected by the topography of the main channel created by previous flows, including flows from the gully.

Keywords: Debris flow, Deep-seated landslide, SfM-MVS, UAV

Machine Learning Algorithm for impact crater extraction from high resolution DEM derived from SfM data in Vanuatu

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As the 2015 Ontake eruption unfortunately reminded us, volcanic balistic impacts are serious threats to humans and infrastructures alike. To improve disaster risk management, probablisitic and physical models calibration, data on the spatial distribution of ballistic impacts are essentials. Investigating this issue, the present contribution explains the usage of a crowd-sourced high-resolution close-range photogrammetric technique (Structure from Motion), which was used to collect 3d Data of impacts in Vanuatu around an active volcanic vent, and for which a machine-learning algorithm was developed.
The dataset used in this presentation was collected using a GoPro3 camera, which was chosen as it is easy to operate and relatively low-cost, with the goal to simulate a crowd-sourcing exercise. For the present experiment, a student with no experience of SfM and to whom only simple information was given, collected the data at 12 different sites. Out of 12 investigated sites, 8 provided images of sufficient quality, number and overlap.
Using half of the 8 succesfull survey sites as training sites and the other half as test sites, the developed algorithm detects the lowest point in a depression and try to determine whether it has been created by a volcanic bomb or whether it is an unrelated depression. This choice is based on a comparison with an existing dataset of angles of curvatures of the radii of the depression.
The algorithm is meeting some success, increasing the information productivity - which is often an issue in post-disaster management - although its scalability remains to be proven at other volcanoes.

Keywords: close-range photogrammetry, Structure from motion, Machine learning, Vanuatu Volcano

Comparison of DEMs derived from simultaneous airborne LiDAR survey using two types of laser scanner

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Airborne Light Detection and Ranging (LiDAR) survey provides geomorphic information with fine details even for forests; thus, it is being increasingly used in measuring landscape. Recently, the survey was operated sequentially for rivers to evaluate geomorphic changes from the difference of elevation, by using digital elevation models (DEMs) derived from each survey. However, it is difficult to apply the difference of DEMs to hill slopes as it often presents unrealistically large values. This is due to errors of DEMs, which can be expected to be higher for hill slopes, considering that denser vegetation cover and steeper slopes prevent the laser beams from the scanner from reaching the ground surface and less ground points are used to produce the models. In addition, it is difficult to estimate the error ranges of DEMs for hill slopes as there are fewer ways to crosscheck the values. To examine the ranges, this study conducted airborne LiDAR survey in four locations in Hokkaido by using two types of laser scanner, old and new version of SkEyes Box (SkEyes Unlimited), and compared the DEM products. One site was located on a volcano fan while three were on mountain slopes that were prone to landslides and covered by trees. The survey was carried out on the same day in each site in October 2015. The laser scanner was mounted on an unmanned helicopter (YAMAHA RMAX G1), which made it possible to operate the survey twice in a day. After ground data was extracted from the survey data, DEM of 1 m, 2 m, 5 m and 10 m sizes were produced for each case. When comparing between DEM values of the same location, finer DEM sizes showed less elevation difference in all the sites. However, 10 to 20% of the 1 m DEM sets presented more than 0.7 m of difference in each site. They were likely to appear along stream banks, slope breaks, and the rim of the survey areas. In addition to elevation, the slope angle was obtained on ArcGIS software using the DEMs and was similarly compared for each site. The larger DEM presented a better agreement for the values at the same locations, although 5 m DEM was considered to be better for analysis to avoid losing the information of fine geomorphic features. In this case, 10 to 20% of the DEM sets in each site presented a difference larger than 5 degrees. These analyses suggested that the DEMs for hill slopes contained the degrees of errors, which were difficult to use for volumetric evaluation from a sequential survey. However, the difference of DEMs from the survey could be still useful to extract the locations of moving slopes as the information of change in the ground surface should be reflected in a group of DEMs on those hill slopes.

Spatial pattern analysis of wall surface modification by weathering in Yoshimi-Hyakuana cave using terrestrial laser scanning

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Detection and quantitative evaluation of actual changes in rock surface morphology are crucial for understanding weathering processes. Repeated measurements by terrestrial laser scanning (TLS) were performed at test sites in the Yoshimi-Hyakuana cave in Saitama Prefecture, central Japan. Six time series of point clouds were obtained in 3 years, and those point clouds were finely aligned to each other at millimeter-scale accuracies applying the ICP algorithm for unchanged domains. Digital elevation models (DEMs) were then produced by projecting the point cloud on a vertical plane at a resolution of millimeters. Centimeter-scale changes in the wall surface were successfully detected. Such changes are particularly active at a wall close to the outlet of the cave, and are found to be concentrated on a certain height above ground. This indicates that the rock surface modification is actively induced by salt weathering where groundwater evaporation is favorable. In contrast, walls located more inside of the cave show less or almost no changes in their surface. The air temperature and humidity monitoring at the wall surfaces supports this fact, suggesting the decreasing effects of environmental fluctuations which are higher around the cave entrance but lower in the inner side. This study is supported by JSPS KAKENHI Grants (20312803, 25702014).

Keywords: terrestrial laser scanning, weathering, point cloud, digital elevation model

A Diversified Approach to Generate High-Resolution Topographic Data on the Maunakea Summit, Hawai‘i Island

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The Maunkea summit (3200-4205 m) of Hawai'i Island is a unique aeolian-driven stone alpine desert ecosystem created by late stage volcanism and glaciation. The summit area geomorphology contains steep cinder cones, scoria, and glacial moraines and erosional features, producing a somewhat complicated pattern of surface mineralogy. The summit is also home to the world's most advanced constellation of telescopes and numerous endemic or rare plants and arthropods. Surprisingly, little high-resolution topographic data exists over much of the area, which are needed to further understand summit erosional processes and to better conserve and manage endemic species habitat. To rectify this situation, we used a VZ 400 Riegl terrestrial laser scanner to collect a high-resolution lidar dataset (33 pts/m^2 average) over ~15 km^2 across the summit area in 2014. The lidar coverage contained occlusions due to environmental obstacles and perspective issues. To 'fill' two of the largest/important occlusions (36,081 m^2 within the interior crater of a cinder cone and a 256,485 m^2 exterior slope of another remote cone) we generated new topographic datasets vie Structure from Motion (SfM) by taking photos of the missing areas from ground and airborne (unmanned aerial vehicle) camera campaigns. The lidar and SfM-derived point clouds were then merged together to create a blended and continuous topographic dataset. Vertical errors from the ground-based photo campaign were generally higher than for the UAV survey, ranging between +3.76 & -1.75 m, though after geoprocessing the average vertical errors for both datasets was <0.05 m. Lessors learned include the importance of creating enough overlap between the raw lidar and SfM point cloud datasets to be able to register them together, instead of solely relying on differential GPS coordinates for ephemeral ground control points. The merged dataset will be compared to future topographic survey campaigns to detect areas of active geomorphic change and quantify contemporary erosion rates. These data are also being used to define quality habitat for the endemic wekiu bug and serve as a template for habitat restoration following future telescope decommissioning.

Keywords: UAVs, Geomorphic, Lidar

Estimation of dip angles of faults near the surface in Toyama by eigenvalues and eigenvectors of the gravity gradient tensor

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The Toyama prefecture, central Japan, hosts several active faults, including the Kurehayama fault, the Isurugi fault, the Takasyouzu fault, and the Kurobishiyama fault. Many researchers have studied these faults, with investigations having been performed into their morphological, geological, and geophysical characteristics.
Numerical simulations of intense ground motion caused by fault activity play an important role in planning how damages can be mitigated in the event of an earthquake. In such simulations, the length, width, and dip angle of a fault are important parameters. Fault dip angles would usually be estimated by geophysical techniques, such as seismic and gravity exploration. Seismic needs large expense. Although gravity exploration does not need so large expense, this exploration needs seismic exploration data because the gravity is a function of density and structure (distance) and the gravity exploration can't determine unique solutions from gravity anomaly data only.
A new method for estimating the dip angle of a fault using eigenvalues and eigenvectors of the gravity gradient tensor has recently been developed by Beiki and Peterson (2010: Geophysics), Beiki (2013: Geophysics), and Kusumoto (2015: Butsuri-tansa). This method relies upon the maximum eigenvector of this tensor being parallel to the orientation of the causative body, from which the dip angle of a fault or structural boundary can be estimated without supplemental geophysical and geological data.
A gravity gradient tensor can be obtained via gravity gradiometry, which measures the gradient of a gravity field in multiple directions. Three gravitation components (g_x, g_y, and g_z) form around a causative body, with the combined set of x-, y-, and z- derivatives of each forming the gravity gradient tensor. This tensor is known to be symmetric, with its diagonal components summing to zero in order to satisfy Laplace's equation. Thus, the gravity gradient tensor consists of five independent components, which can be obtained for any subsurface structure using gravity gradiometry at a single observation point. By contrast, a conventional gravity survey can only identify one out of three gravitational components, which must then be used to estimate the nature of any subsurface structures. A gravity gradiometry can thus obtain five-times as much information as a gravity survey can.
Since no gravity gradient surveys have yet been undertaken in Toyama, we derived gravity gradient tensors by calculations based on the study of Mickus and Hinojosa (2001: Jour. Appl. Geophys.). The method described therein estimates a gravity gradient tensor as follows: (1) a Fourier transformation is made of a gravity anomaly, (2) an estimation of gravitational potential is made by integration of the gravity anomaly in the Fourier domain, (3) calculation of gravity gradient components is achieved by calculating second-order derivatives of the potential in each direction, and (4) the acquisition of all components of the tensor in the spatial domain is performed by applying Fourier inverse transformation.
We applied this technique to the Kurehayama fault, Isurugi fault, Takasyozu fault, and Kurobishiyama fault, and estimated that they have dip angles in the range of 45-60°. Our results are consistent with dip angles obtained by surface geomorphological and geological surveys.

Evaluation of TWI-Derived Soil Depths and DEM-Assisted Terrain Slopes in Tainan Mountain Areas

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The study is aimed at evaluating the soil depths from topographic wetness index (TWI) method, and the terrain slopes from a 5m resolution digital elevation model (DEM) in Tainan mountain areas, located in southern Taiwan. The field surveys (field work) for validating the results have been being implemented in recent months. During the field surveys, a soil auger and a Nikon laser rangefinder are used for obtaining the soil depths and terrain slopes, respectively. The related methodologies for obtaining TWI-derived soil depths and DEM-assisted terrain slopes (office work), and the comparison results for office and field works will be well described in this paper. We hope that the research is able to determine the accuracies of the TWI-derived soil depths and the DEM-assisted terrain slopes in Tainan mountain areas.

Keywords: TWI, DEM, Soil Depth, Terrain Slope

Interpretation of Terrain Features by Self-Developed Red Relief IMAGE MAP

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We produce the Red Relief Image Maps (RRIMs) to aid terrain feature interpretations, especially in potential landside areas. RRIM is generated based on openness and slopes derived from a digital elevation model (DEM). In this study, we use software of Fortran and generic mapping tools (GMT) to produce the Self-Developed RRIMs. The related programs and theories are being constructed and are going to be completed. All kinds of terrain features will be well chosen and analyzed in the following tests. The purpose of this research is to develop a new visualization of topographic maps to provide subtle and useful terrain information and further bring contributions to the regions of disaster prevention, soil and water conservation, environmental monitoring, and resource exploration.

Keywords: RRIM, DEM, GMT

Shallow water bathymetry derived from visible satellite image: toward application to the waters around Japan

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Hydrographic organisations and their affiliated institutes are stepping up development of the technology of Satellite Derived Bathymetry (SDB).
In SDB, water depths are estimated from visible satellite images based on the basic principle of exponential attenuation of light. In practice, however, the intensity of light detected by the satellite sensor is affected by various local conditions; for example, attenuation rate in water varies with the water quality, and reflection rate on the seabed differs according to the types of sediment and benthos.
Toward the application of SDB to the waters around Japan, we have been developing and verifying the technology of SDB based on the methods by Lyzenga (1978) taking into account of the environmental characteristics of Japan. We analyse the images obtained by WorldView-2, equipped with optical sensors of eight bands (six of them are visible bands) at 1.8m of horizontal resolution, which are available since October 2009. We expect SDB will be a rapid and cost-effective solution for surveying shallow water topography and navigational obstructions, producing dense bathymetric dataset for tsunami simulation, etc.
In our presentation, we show the recent analysis results of SDB in several sea areas around Japan, as well as the evaluation of the results by comparison with multibeam or LiDAR surveys. Based on that, we will discuss the future utilisation of the SDB data.
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Keywords: bathymetry, shallow waters, satellite imagery, visible bands