Quantitative detection of debris flow by using tilt and strain meters

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Instruments for volcano monitoring are available to detect debris flow at Sakurajima where vulcanian eruptions and debris flow frequently have occurred since 2009. Seismic observation is conventional method to detect debris flows as shown by high-frequency tremor-like waves. However, seismic waves are insufficient to estimate volume of debris flow. Here, I will propose a method to estimate volume of debris flow by using ground deformation associated with debris flows.
Upward tilts of the crater side of Sakurajima have been detected 5 min to 1 day before volcanic eruptions. Upward tilts of the crater side were also detected at the same site associated with debris flows streaming in Arimura river, opposite side of the crater in the view of the tiltmeter, because deposits of debris flows induce downward tilt of the river side. On the other hand, radial strain shows different change patterns between precursory inflation of eruptions and debris flows. Radial strain shows contraction prior to eruptions, but extension of radial strain is recorded associated with debris flows. Such deformations are detected for 65 debris flows in the Arimura river except for 4 minor flows during the period from 2009 to 2016. Amounts of tilt changes ranged from 4 to 409 nano radian. The downward tilt vectors are oriented to the no.1 Sabo dam and it is inferred that the deformation is caused by deposit of debris flow at the Sabo dam. Extension changes of radial strains ranged from 3 to 138 nano strain and are almost 1/3 of the tilt changes. Assuming a point mass applied to the river surface, increase of weight on the river is estimated to 60 thousands ton in case of strain change of 30 nano. Total weight of debris flows is estimated to be 2 million tons during the period from 2009 to 2016.

Keywords: ground deformation, debris flow, Sakurajima

Rainfall-runoff-inundation model application for volcanic debris flow assessment in Mount Merapi

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Volcanic debris flow or lahar is a hydrometeorological disaster happened in the rainy season in Mount Merapi. Following the 2010 eruptions more than 50 lahar events happened and caused material loss and casualties. Although the frequencies are decreasing, but in 2016 the disaster still happened as the unstable material from the volcano eruption remains at elevation higher than 1200 m above mean sea level (amsl).

Lahar is a Javanese term used to describe a rapidly flowing, high concentration, poorly sorted sediment-laden mixture of rock debris and water from a volcano that goes along river stream. It is a continuum flow type which covers debris flows, hyperconcentrated, streamflow, and mudflows. It comes as series of surges with maximum frontal velocity ranges from 5 m/s to 15 m/s. At Merapi lahar is likely to trigger by rainfall intensity of 40 mm in 2 h. Two types of triggering rainfall are: local stationary or orographic confined to slopes above 1200 m amsl and regional, migratory rainfall that moves from the northwest or the southwest. The latest mention usually leads to large-scale debris flow (>80,000 m^3 of deposits) (Lavigne et al. 2007).

Hydrological model such as rainfall-runoff-inundation (RRI) could be a useful tool for analyzing hydrometeorological disaster. The model uses full dynamic equations that based on diffusion wave assumption which are effective for flood assessment in both mountainous slopes and lowland plains. However, the application on flash-flood and debris flow is difficult because of the short duration and small area. The RRI model relies on satellite-rainfall and rain gauge data, while lahar occurs in a small-scale that constrained the use of coarse resolution of satellite-rainfall or poor resolution rain gauge network.

Previous studies confirmed that rain gauge-rainfall caused uncertainties and underestimated rainfall threshold for debris flow occurrence (Nikolopaulus et al., 2014; Staley et al., 2013; Marra et al., 2014). On the other hand, remote monitoring by weather radar such as an X-band multi parameter (X-MP) radar gives higher spatial and temporal resolution, which is desirable by lahar studies. It offers advantage to monitor rainfall in the initiation area and it could measure debris flow during short duration of storm event (David-Novak et al., 2004; Chiang and Chang, 2009).

In this paper, we improved the RRI model by applying X-MP radar information. A new submodule of debris flow assessment has also been introduced based on Takahashi theory (Takahashi, 2009). The theory considers debris flow initiation criteria depends on average slope, particle size and discharge per unit width. We used the improved model to analyze hydrologic condition in Gendol Catchment for 2 weeks observation in May 2016.

The radar-rainfall based model gave comparable results with the rain gauge-rainfall based model and the

observed water depth information in the downstream area. The discharge information calculated by RRI model were not only useful for direct lahar assessment but could be important boundary information for other numerical model in ungauged sub-basin. Although direct verification in the ungauged upstream area is difficult, but in the future applying the model for real lahar event could be useful to test the improved RRI model performance in small-scale catchment.

Keywords: Rainfall-runoff-inundation model, X-MP radar, volcanic debris flow, rainfall, merapi

Detecting interior structure in Iwate volcano using muon radiography.

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Recently, radiography for the internal structure of volcanoes using cosmic ray muons has developed and it has produced results in case of Asama volcano and Satsumaioujima (Tanaka et al.2008). We have setup the muon detector in east foot of the Iwate volcano, about 6km from the summit and detected since October 14, 2016. Besides this, our objective is to understand deep underground water flow system on the interior of the volcano, by performing continuous observation of chemical composition of spring water originating from Iwate volcano. And this results of spring water composition compare to the image of the internal structure of Iwate volcano obtained from muography.
The present data taking is stabilized and simple two dimensional image can be obtained.
However, the density length of volcano body obtained from the measurements shows a value considerably different from the actual thickness of the mountain and it is influenced much by the muons coming in from electromagnetic shower or scattering from the surroundings. On the other hand, a comparison of the actually measured density length and distance from the topographic data used a 10m mesh DEM of volcano altitude and from the density distribution, difference of density distribution appeared from the younger volcano body between the elder.
From the chemical composition of the spring water can be divided to two groups as $Ca(HCO_3)_2$ type and the SO_4^{2-} in addition to $Ca(HCO_3)_2$. When tritium dating shows values of 13.9-23.5 years were obtained. Particularly for the Oide and Kanazawa springs, the values were respectively 19.4 years and 23.5 years and this indicates the possibility of the groundwater recharged during 1998-2003 eruption crisis to gush out now onwards.

Keywords: muon, spring water, chemical analysis

Low-temperature fumaroles and diffuse H_2S degassing associated with recent volcanic activity at Iwo-Yama, Kirishima Volcanoes, Japan

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Iwo-Yama is one of active volcano belonging to the Kirishima volcano group (the Kirishima Volcanoes), Kyushu Island, Japan and located in the Ebino Highland, a famous tourist destination. At the volcano, seismic activity increased in December 2013, and volcanic tremors were observed several times in 2015. Also, fumaroles were found at the crater in December 2015 after twelve year’ s absence, and an expansion of thermal and fumarolic activities have been observed around the summit area since then. Meanwhile, the diffuse degassing area with a high H_2S concentration was found at the western outer wall of the mountain. The area lies in the altered zone formed by the past hydrothermal activities. A small acidic spring with high dissolved H_2S content is also found in the altered zone.

The Miyazaki prefectural government started the fix-point observations of the atmospheric H_2S and SO_2 concentrations in and around the fumarolic and degassing areas in March 2016 because the areas are located near a road for tourism and mountain trails, and someone may suffer accidents with gas poisoning. Initially, the atmospheric H_2S concentration at 30 cm height from the ground surface at the center of the diffuse degassing area had not exceeded 200 ppm. However, the concentration has drastically increased in October 2016 and showed 1400 ppm maximum. In response to this, the prefectural government settled policies for setting out restricted areas according to the H_2S and SO_2 concentrations and started the automatic measurement of the atmospheric H_2S concentration at the two fixed point located in and beside the diffuse degassing area in January 2017.

The author has been monitoring the state of changes in the low-temperature fumarolic activity and the diffuse degassing area since March 2016 together with the prefectural government from the viewpoint of safety of tourists. In this presentation, the author would like to discuss the state of diffuse degassing activity with a high H_2S content and report on the approach to volcanic gas disaster prevention by Miyazaki prefecture and the regional community of Ebino Highland.

Keywords: Iwo-Yama, hydrogen sulfide, volcanic gas disaster, low-temperature fumarole, Ebino Highland, gas poisoning

Critical review of disaster mitigation for Hakone Volcano and its eruption occurred in 2015

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A critical review was made on the disaster mitigation for Hakone Volcano and its eruption occurred in 2015. Hakone Volcano, one of the active volcanoes in Japan, has repeated phreatic eruptions 5 times since the last magmatic eruption at about 3ka. All these eruptions occurred near Owakudani Valley, which is a famous geothermal area for tourists. A volcanic hazard map, which estimates dangerous areas under a similar situation of the past phreatic eruptions, was made in 2004 by the Hakone Town Office. On the basis of this hazard map, Disaster Mitigation Council for Hakone Volcano made an evacuation plan under each volcanic alert level, which is given by Japan Meteorological Agency. Because all these countermeasures had been prepared before the 2015 eruption, evacuation of tourists and residents was successfully made under the earthquake swarm and abnormal fumarolic activity in the pre-eruption stage. This success, however, was fortunately made under the conditions stated below:
1) The 2015 eruption of Hakone Volcano was a weak phreatic eruption, of which discharge mass was only 100 ton. No base surge and no large lahar occurred. Duration of the eruption was short (about 2 days).
2) There are 10 plus and 11 minus social factors, which affected the development of the systems and urgent actions for disaster mitigation of Hakone Volcano. Through the history since the early 20th Century, the persons or parties, all who concerned the disaster mitigation of Hakone Volcano, suppressed the minus factors and reinforced the plus factors.

Keywords: Hakone Volcano, disaster mitigation, 2015 eruption, critical review, natural and social conditions, plus and minus factors

Review on pre-cursor events of Krakatau1883 caldera-forming eruption —Can we catch the precursor events of caldera-forming eruption?-

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Caldera-forming eruptions, erupted volume more than 10km3, occurred once or twice during 100 years. Indonesia was suffered twice for the last 200 years, and three times within 1,000 years from caldera-forming eruption. I compiled the precursor process to the caldera-forming eruptions of Krakatau 1883 after a dormant period or a long-time low activity stage (Nishimura, 1980, Yokoyama, 1981, Simkin and Fiske, 1983;Carey et al., 1996; Mandeville et al., 1996). During the last a few months, we may have caught geologically the short-term process as the progressive activity to the climax eruption in cases of Krakatau 1883 eruption (Takada, 2010; Takada et al., 2012). For Krakatau eruption, earthquakes increased; wide-range hydrothermal activity occurred; small-scale eruptions increased. However, the problem is to evaluate or predict when the volcano reaches a climax condition, and how much the volcano erupts. The evacuation plan depends on them.

Keywords: Krakatau, caldera-forming eruption, large volume eruption, precursor events, Indonesia

Physical parameters analysis of volcanic ash particles measured by 2D-Video Disdrometer

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Weather radar is one of powerful instruments for measuring volcanic ash columns and ash clouds. However, we need fundamental physical properties on ash particles for the quantitative analysis of weather radar data of volcanic ash: necessary information are terminal velocity, axis ratio, and canting angle including density and dielectric constant of target to detect volcanic ash column correctly. In the present study, the basic features of volcanic ash particles are analyzed to develop quantitative ash fall estimations (QAEs).
The data were collected by a number of automatic tephrometers at Sakurajima volcano, Japan and reanalyzed with a 2D-video disdrometer (2DVD) in the large-scale rainfall simulator of NIED. The entire volcanic ash particles were classified as five types based on shape and orientation: Horizontal Oblate (OH), Vertical Oblate (OV), Horizontal Prolate (PH), Vertical Prolate (PV), and Sphere (Sp).
Dominant particle shape was OH (71.5%) and the next was PH (17.0%). It should be noted the horizontally oriented type was 88.7% of all sampled data. The 64.4% data are concentrated on $D < 0.5$ mm. The number of PV and Sp particle is increased with D. The relationships of terminal velocity are dependent on particle shape types: Prolate spheroid (vertical orientation) particles were faster than those of oblate (horizontal). The distribution of γ is from 0 to 1.5 at $D < 2$ mm, but these are concentrated to around 1 for $D > 2$ mm. The deviation of canting angle for OV (OH) is around two times larger (smaller) than raindrops. It is inferred that there would be not much rotating phenomenon.
The features of ZH and dual-pol radar variables (ZDR, KDP, and AH) were analyzed. ZH is around 4.3 dBZ smaller than that of raindrop and there is no resonance effects with radar frequency. There are large variabilities in ZDR depending on the particles shape for $D < 2$mm and these were close to 0 for $D >$ 2mm. KDP and AH are variable with radar frequency but these magnitudes are almost 0 regardless of D. These results will be utilized to develop QAE methods, to detect volcanic ash column and predict its activity.

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Keywords: Volcanic ash, basic feature, 2DVD

Orographic Effects on the Transport and Deposition of Volcanic Ash - A Sakurajima Case Study

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Introduction

Volcanic ash is a major environmental hazard that acts over both short (hours-days) and long (months-years) timescales and, directly or indirectly, affects life, livelihoods, and infrastructure (Wilson *et al.*, 2015). After an eruption, airborne ash can cause major disruption for international aviation, and in the long term can exacerbate existing respiratory conditions (Hillman *et al.*, 2012). Accurate prediction of the transport and deposition of volcanic ash is therefore vitally important for hazard management and mitigation.

Transport and deposition of volcanic ash are complex processes, depending heavily on the size of the particles (Bonadonna and Houghton, 2005). Heavy ash is deposited quickly within a few 10s of kilometers from the vent, while lighter ash tends to have longer flight times and is more directly influenced by local as well as regional wind fields. Atmospheric flow is heavily influenced by complex terrain creating a number of complex phenomena, such as flow spitting, gravity waves and downslope winds (Smith, 1980). These orographic effects have been seen to affect the deposition of volcanic ash (Watt *et al.*, 2015)

In the study presented we examined the impact of orographic effects on the transport and deposition of volcanic ash from the Sakurajima volcano in Kyushu, Japan. Sakurajima is one of Japan's most active and closely monitored volcanoes. The frequent activity, surrounding mountainous topography, and large amount of observational data make Sakurajima an ideal natural laboratory for the study of these effects.

The August 2013 eruption and ash dispersal modelling

On 18th August 2013 Sakurajima erupted at 1631 JST with a plume height of 5 km - the highest plume height recorded since 2006. Ash was advected W-NW and ashfall was recorded as far as the Koshikijima islands 90 km in the west. This eruption was studied in depth using the Weather Research an Forecasting (WRF) model (Skamarock *et al.*, 2008), coupled with "online" chemistry and aerosol calculations (WRF-chem; Grell *et al.*, 2005). A nested domain setting with high horizontal (12500, 2500, and 500 m) and vertical (90 levels starting at 50 m height increments) resolution was used in order to resolve the orographic effects, while a series of simulations with zero topography were carried out to show the influence of these effects.

Results

Simulations have shown that orographic effects can act in two ways: strong gravity wave activity close to

the volcano act to keep ash afloat, while downslope winds closer to the surface can advect ash downwards and force deposition (Fig. 1; Poulidis *et al.*, 2017). Orographic effects were seen to increase both horizontal and vertical diffusion of volcanic ash. Due to its low residence time, heavy ash was seen to be relatively unaffected by orographic effects: in terms of deposition, the most readily affected size ranges for particles were of grain size between 3-5 ϕ (ie. between 0.125 and 0.03 mm).

Resolving orographic effects over the volcano leads to a “gray area” over the volcano: the initial plume height set at input can be changed due to gravity wave activity over the volcano, leading to a different simulated plume height, something that could affect similar simulations, especially for eruptions with low plume heights.

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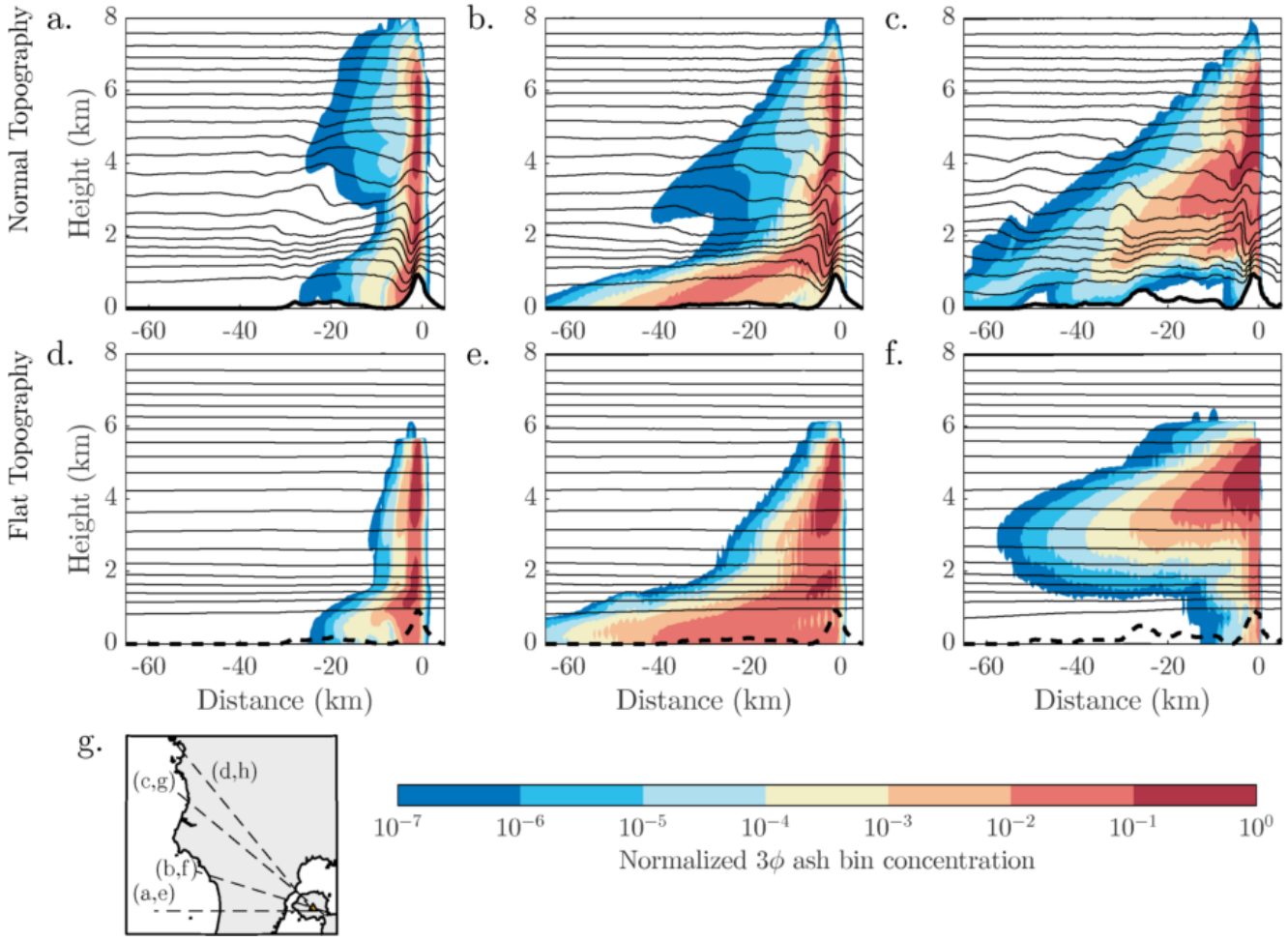
Keywords: Ash dispersal, Sakurajima, WRF, Orographic effects



Attempt of earth and planetary science education by dispersion simulation of pyroclastic materials emitted from the volcanic eruption

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In recent years, simulations of the dispersion of pyroclastic materials released by volcanic eruption have been actively carried out, and they are used for disaster hazard maps. Among them, Tephra 2 (Ref 1, 2), which is often used, is based on advection + diffusion model of pyroclasts in the atmosphere. It does not require much computer resources and its internal processing is easy to understand. Based on this Tephra 2, I made a simulation program called 55Tephra which is more compact, easy to use, easy to read and remodel its code. I am planning to use this 55Tephra (Fig.1) for high school students as a teaching material to teach how to model natural phenomena and the problem on modeling. Because there are some high schools that are interested in simulation of extraterrestrial volcanic eruptions such as on Mars, there is a possibility that it will become a good teaching material for earth and planetary science, that simultaneously cultivates a sense of disaster prevention modeling. In presentation, introduce 55Tephra and present various ideas of utilization.

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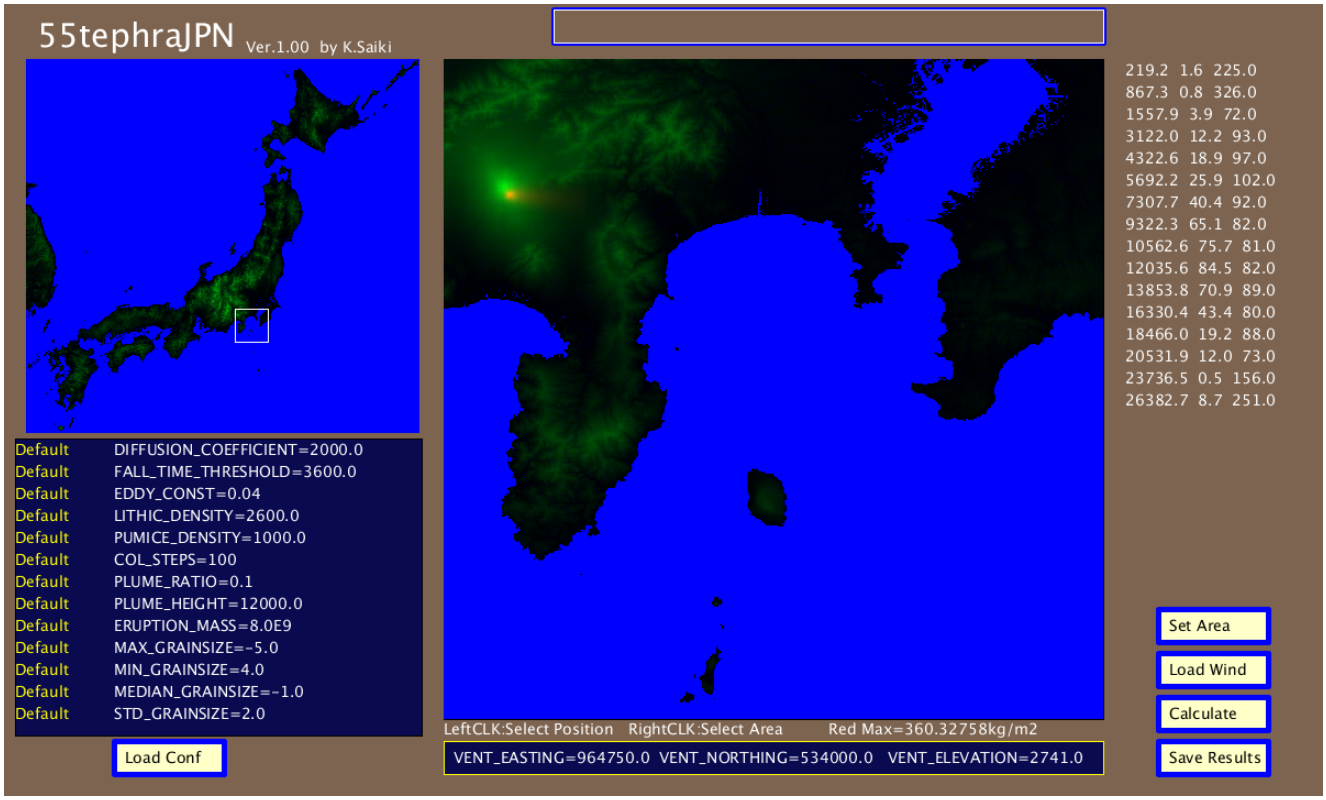
Keywords: tephra, simulation, high school students



Features of Numerical Model “Ballista”; the Ballistic Simulator of Explosive Volcanic Eruption

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Ballistic projectiles are emitted from the vent of the volcano when an explosive eruption occurs. Their sizes range from a few centimeters to several meters, and the landing velocity of these pyroclasts can exceed 100 km/h. Therefore, for hazards and disaster risk management it is essential to estimate the affected area of ballistic projectiles. To reach this goal the ballistic trajectory simulator “Ballista” was developed. This model can calculate the trajectory and deposition condition of multiple ballistic particles in three dimensions using a momentum equation including air friction solved by the Runge-Kutta method, and particles are transported by the Lagrangian method. Ballista was programmed using Java to increase portability and includes complementary modules, such as a topographic effect, which is also taken into account by the simulation. As a result, the model can constrain the ejection angle and direction bearing of ballistic projectiles released during the Ontake 2014 eruption (Tsunematsu et al., 2014), not only using ballistic physics but also realistic terrain data.
In the presentation, we show how local conditions and terrain can affect the model by running the same simulations with and without topography, but also by modifying the resolution of the topography to study these effects. The resolution of the digital elevation model (DEM) only changes the large scale distribution of ballistics on the ground when the grid size is fairly large (> 100 m). Results also show that including topography in the calculation changes the travel distance and the spatial distribution of particles significantly. When examined in detail, in particular locations the high resolution DEM can be used to identify shelter areas where ballistic hazard is reduced, for example, behind large boulders or buildings - risk reduction strategy that proved successful for hikers caught in the 2014 eruption. In our presentation, we discuss such topographic dependency of the Ballista quantitatively.
Finally, we have made the model public by a creating graphical user interface and a user guide in order to contribute to the disaster risk management.

Keywords: Ballistc projectiles, Explosive eruption, Topography, Resolution, Numerical Model, Graphical User Interface

Characteristics of damage caused by lapilli fall of the October 8, 2016 eruption of Aso Volcano, Japan

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We examined about characteristics of damage caused by lapilli fall of the October 8, 2016 eruption of Aso Volcano, Japan. Lapilli fall arrived at the remote residential area more than 4 km from the Nakadake crater of the Aso volcano, and the damage to a building or agriculture facilities occurred. In the National Aso Youth Friendship Center (from the Nakadake crater to the northeast approximately 4.5 km), one piece of windowpane and screen door was damaged by lapilli of approximately 3 cm in diameter. It is estimated that the lapilli dropped from the north, but does not agree with the direction of the Nakadake crater. At the roofed passage connecting buildings of the National Aso Youth Friendship Center, the polycarbonate board that ultraviolet rays deteriorated was damaged. The damage of solar panels was confirmed at the point of approximately 6.5 km from the Nakadake crater to the northeast. More than 1500 solar panels were damaged by lapilli fall at this point. As a future problem, it is necessary to investigate relations of collision energy of lapilli fall and strength of glass or polycarbonate board.

Keywords: lapilli fall, damage to buildings, Aso volcano

Safety of wooden buildings roof subjected to ballistic block collision

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Damages and destruction of as-built wooden buildings caused by volcanic activities are due to various factors. Especially, at the phreatic eruption of Mt. Ontake in September 27, 2014, most of the damages were caused by collision of ballistic block.
In order to prevent these damages, it is suggested that evacuation to a mountain hut is effective. Thus, evaluation of safety for wooden buildings (e.g. mountain hut) against ballistic block collision is necessary. Previously, we reported the protective abilities of as-built wooden buildings, which were reinforced with high performance fabric using aramid fiber. However, the safety of unreinforced as-built wooden buildings has not been clarified.
In this study, safety of wooden buildings roof subjected to ballistic block collision was experimentally investigated.
A collision test was carried out at the velocity of 10 to 90 m/s using a large scale launching system. In this system, a projectile was accelerated by compressed air and then collided with the target. The projectile velocity was measured using two lasers and light receiving parts.
At the volcanic eruption, the diameter of ballistic block was approximately ϕ100 mm under normal circumstances of phreatic eruption. Therefore, abrasive materials similar to the common ballistic block (density: 2400kg/m3, diameter: 90mm, mass: 2.66kg) was used as the projectile.
For the target, typical wooden roof structure (e.g. cedar boards, waterproof sheet, galvalume steel plate and cedar rafter) was used. The thickness of the cedar board, waterproof sheet and galvalume steel plate were 18 mm, 1 mm and 0.4 mm, respectively. The components were fixed with nails and its spacing was approximately 150 mm. The dimensions of the specimen were 600 mm ×600 mm.
From results of collision tests, it was revealed that the penetration boundary energy of the specimen was approximately 1200J. When the collision energy was smaller (440, 818 J) then the penetration boundary, several deformation due to bending at rafters was dominant. On the other hand, when the collision energy was larger (10512 J), local shear failure was observed at the vicinity of the contact surface. It was clarified that fracture mode changed when the collision energy was increased.
In previous study, it was shown the maximum collision energy of volcanic lapillus (ϕ2-64 mm) was 1700 J (in the case of ϕ64mm, 100 m/s), and average collision energy was less than aproximately1200 J in many case. Therefore, it was revealed that the roof of cedar board having a thickness of 18 mm could prevent penetration of volcanic lapillus.

Keywords: Ballistic block, Wooden buildings roof, Collision

The mayor who confront the crisis of the volcano that did not erupt; Sakurajima 2015

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1. Commentator ,Jiji Press

The mayor who confront the crisis of the volcano that did not erupt; Sakurajima 2015

Keywords: Sakurajima, Inclinometer, Mayor of Kagoshima

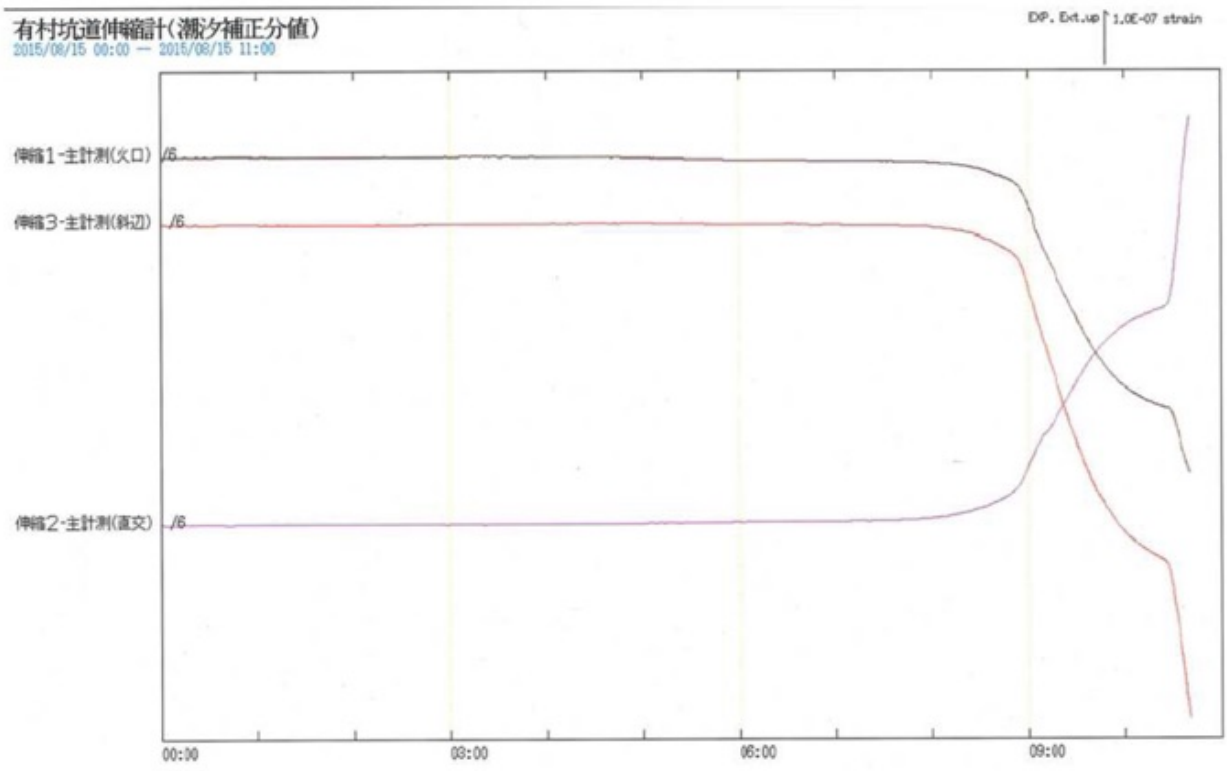

図1　桜島　有村坑道の伸縮計の変化（2015 年 8 月 15 日 0 時～11 時）

Development of mobile sensor for volcanic observation “HOMURA”: operation at Kirishima Iwo-yama and test for a long-term operation at Kyoto University

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Monitoring of phenomena near craters of active volcanoes is important to learn symptoms of volcanic eruptions and to understand eruption dynamics. At present, some devices such as crater camera, volcanic gas sensors, and seismographs have been installed in calm periods of volcanic activity. On the other hand, there are some cases where we cannot install new monitoring devices at volcanoes without enough devices after volcanic eruptions occur. In this case, unmanned robots are useful. We are trying to develop a practical unmanned-ground-vehicle-type robot for volcanic observation that carries out monitoring near active craters. We named this system "Homura". In this presentation, we report results of test campaigns for operation of Homura in outdoor fields.

At present, we have developed a prototype of Homura. It is a small-sized, vehicle-type robot with six wheels (750 x 430 x 310 mm in dimensions and a weight of about 12 kg). It is remotely controlled with mobile phone radio waves; it can move in volcanic fields and send real time data of sensors (camera, thermometer, and CO2 gas sensor for test) equipped in the vehicle to the base station. Power consumption of Homura is about 20 W in an operation state and less than 0.1 W in an idle state, so that we can use Homura for a long time by intermittent operation.

We carried out two test campaigns of Homura at Kirishima Iwo-yama from Feb. 19th, to May 5th (49 days) and from Mar. 3rd to Apr. 14th (37 days). Iwo-yama is one of craters in the Kirishima volcanic field, SW Japan; after 2014 volcanic seismicity sometimes increases around Iwo-yama and there is danger of eruptions. We carried and put Homura at the rim of the crater. Unfortunately, mobile phone connectivity was not entirely stable around Iwo-yama. Then, we decided not to move Homura and only to obtain real time data of the sensors. After we returned to our office, we operated Homura for one to two hours every day. Although the weather was often bad (rain, fog, or cold temperature) during the test campaigns, we could completely operate Homura without any trouble. In order to use Homura for longer period, we installed a small solar panel on Homura. Since Oct. 10th, we have been operating Homura at the roof of a building in Kyoto University. Homura obtain sensor data for 4 minutes every 6 hours. Up to the present (128 days), we can stably operate Homura.

The results of these test campaigns indicate that Homura steadily functions for a long time in volcanic fields. Homura is useful as a simple monitoring station in volcanic fields where mobile phone connection is available.

This work was supported partly by a grant-in-aid for scientific research from the Japan Society for the Promotion of Science and the Earthquake Research Institute cooperative research program.

Keywords: Robot for monitoring volcanoes, Kirishima Iwo-yama, communication with cellular phone

Facies and thickness variations and emplacement mechanism of Aso-4 pyroclastic flow

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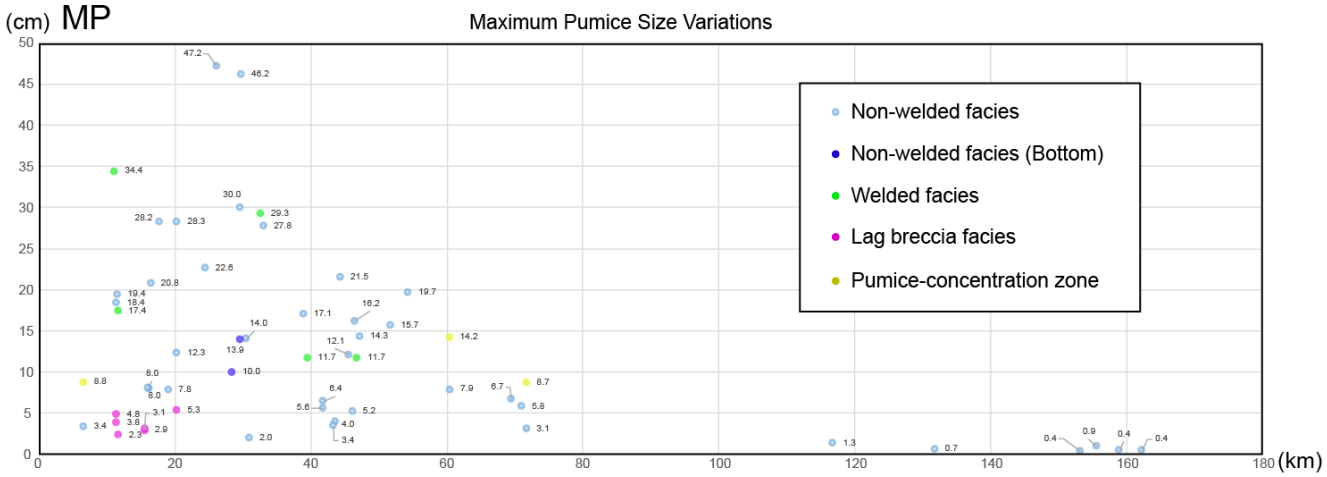
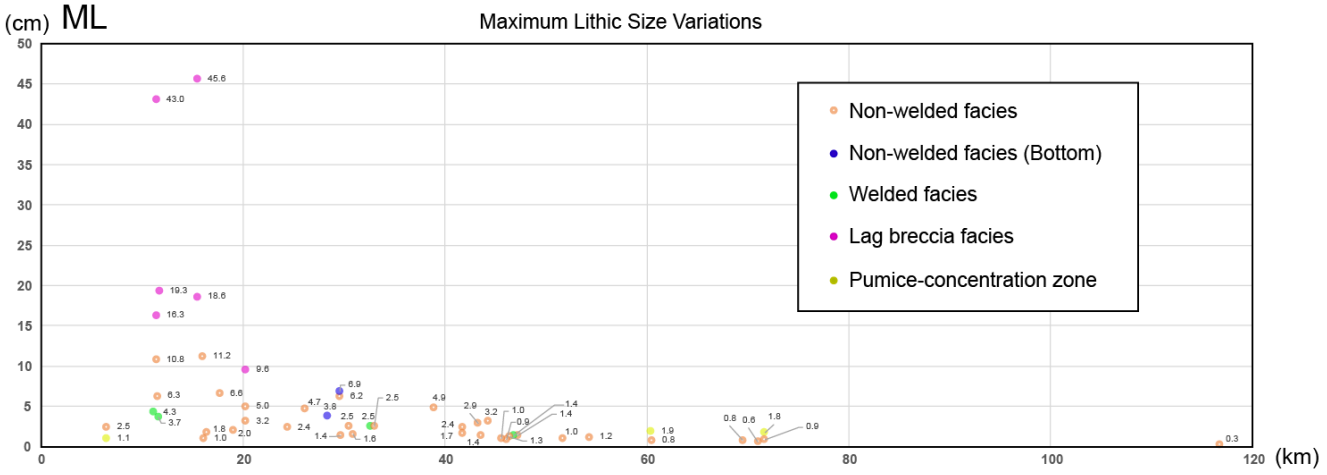
Pyroclastic flows, normally high-temperature and high-speed, cause devastations in and around the volcanic area. Especially, caldera-forming, large-scale pyroclastic flows (ignimbrites) affect quite large areas, and more precise evaluation of affected area and understanding of emplacement mechanism are needed. The 90ka Aso4 pyroclastic flow is one of the largest volcanic events in Japan (VEI=7), and reached as far as 160km from the source. We studied emplacement mechanism of Aso4 pyroclastic flows based on facies and thickness variations.
The total number of 3,596 thickness point datasets was collected using geological maps, boring data, published papers and topographic maps. The thickness of the welded points was converted to non-welded condition based on average densities of welded part (1,800 kg/m^3) and non-welded part (1,200kg/m^3). The thickness variation map was made based on point datasets using Kriging method. The maximum thickness locations that is thicker than 60m were distributed not near the caldera, but NNW 42.5km from source (NW of Oguni town), SSW 33km (N of Kunimi dake) and SE 29km (Takachiho valley). These areas are located relatively deep valley. The reason of the thick deposit in the deep valley can be explained more than a few hundred meters-thick turbulent pyroclastic flows were cascaded the caldera outer slope and most of the deposits in the relatively steep slopes were concentrated in the deep valley. The deposit thickness in the wide valley in eastern and western parts were relatively thin (<40m).
The grain size variations were studied mainly on Aso4A deposit from NW, N, E and SE directions. The maximum pumice and thick sizes were examined at 55 outcrops in total. The maximum size of pumices and lithics of 8 samples in each outcrop were measured (Fig.). The maximum size of pumices (47.2cm and 46.2cm) are located not near the caldera, but about 25-30km from the source. The maximum size gradually decreases up to 3 cm at 72km. The maximum size of pumices at outcrops in Yamaguchi prefecture (132-162km from the source) show 0.4-0.9cm. The maximum size of pumices varies vertically in an outcrop. The pumice sizes in the basal part was relatively smaller than the main part. The pumice sizes in the pumice-concentration zone were relatively larger than the main part. The pumice sizes in the welded and non-welded parts show minor differences. The maximum pumice size in the lag breccia facies located within 20km from the source show small values (2.3 to 5.3 cm). On the other hand, maximum sizes of lithics show maximum of 43 and 45.6cm at 10-15 km from the source. The maximum size of lithics gradually decreased with travel distance and showed 0.3 cm at 117 km from the source. A 8m-thick lag breccia facies are observed at the bottom of 15m-thick Aso4A pyroclastic flow deposit located at 11 km SE from source. The lag breccia facies were subdivided into 3 units and bottom of the basal unit was not observed. The lag breccia facies consist of fines-depleted matrix and subrounded large-amount of large lithics (70cm in maximum) and small amount of pumices. Large lithics in the lag breccia units show stratified structures such as horizontal alignments with 20-50cm thick intervals.
The lag breccia facies are located within 20km from source. The facies are formed due to detachment of large lithics from the highly turbulent pyroclastic flow near the source. The fines-depleted facies support the highly turbulence. The subrounded lithics in the lag breccia facies indicate that the lithics were not fall origin, but rounded due to interaction at the bottom of turbulent pyroclastic flow. The horizontal alignments of large lithics indicate the lag breccia facies were not formed in mass freezing, but formed incrementally at 20-50cm-thick intervals (depositional subunits; DSU). The alignment of large lithics suggest that lithics were concentrated at the bottom of the turbulent pyroclastic flow (boundary layer) and

increased the interaction between the lithics and formed concentrated at the top of the DSUs. The maximum size of the pumices was observed at Oguni town (North) and Taketa town (East). These areas located topographical barriers and change of the slope points. The pyroclastic flows stagnated temporarily and accumulated the large pumices at these areas. (The relationship between the maximum size of pumices and lithics and thickness of the deposit are planning to be examined). The gradual decrease of maximum size of pumices and lithic sizes with the travel distance suggests the basal accumulation of pumices and lithics from the turbulent pyroclastic flows.

Keywords: Aso4, Pyroclastic flow, facies, thickness, emplacement mechanism





Characteristics of lahar and avalanche from snowmelt in Mount Fuji

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In Mount Fuji, a large isolated mountain, mudflow disasters occur subsequent to major snow avalanches. Such avalanche and related phenomenon, in other words “slush lahar (Anma, 2007)” is found to be caused by contraseasonal warm weather with heavy rain of extratropical low in the Sea of Japan (Hirose, 1970). In addition, the climatic condition in case of the avalanche, it is clarified from the weather data of the summit and the piedmont area. This presentation shows a tendency to appearance of these pressure pattern based on long-term data in Japan Meteorological Agency. Furthermore, the author tries to explain the tendency of the collapse location and time of these avalanches, based on the data of field survey and seismic data of NIED in Mount Fuji.

Keywords: slash avalanche, volcanic mudflow, yukishiro, spatiotemporal trend, extratropical cyclone, ice layer

Vesiculation experiments of rhyolitic melt: constraints on the conditions for lava dome explosions

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Background
Lava domes often explode violently after emplacement, causing pyroclastic flows (e.g., 1902 Mt. Pelee, 1973 Santiaguito, 1991 Mt. Unzen; Ui et al., 1999). Such explosions are considered to be triggered by overpressures developed in bubbles (e.g., Sato et al., 1992). Therefore, to predict dome explosions, it is necessary to investigate the vesiculation kinetics of silicic magma. Previous experimental studies investigated the kinetics of vesiculation of rhyolitic melt, but their experimental conditions are not necessarily adequate for lava domes, because their starting obsidian was too H_2O-poor (0.1 wt%; Bagdassarov et al., 1996; Ryan et al., 2015) or too H_2O-rich (1.8 wt%; Stevenson et al., 1997). In this study, we carried out similar experiments under the condition close to the inside of lava domes (H_2O contents and temperature), and applied the results to lava explosions.

Experimental
Starting material was rhyolitic obsidian obtained from Wada Pass (H_2O contents=0.59 wt%). A slab was prepared from a chank of obsidian, and it was heated in a muffle furnace at 750, 800, 850, 900 deg C for 15 min ~ 95 hours. After quenching, vesicularity was measured with image analysis.

Results
Vesicularity increased with heating duration. At first, vesicularity increased slowly. And then, it increased rapidly and reached the equilibrium vesicularity (estimated by assuming all H2O exsolved). The vesiculation rate was strongly dependent on temperature, and was high when temperature was high.

Discussion
The Avrami equation was applied to the time-vesicularity relation, and the rate constant was estimated for each temperature. The activation energy was calculated from the rate constant and temperature, and it was 304 (+/-9) kJ/mol. This value was much closer to the activation energy of viscous flow of the rhyolitic melt (338 kJ/mol, Giordano et al., 2008) than that of water diffusion (88 kJ/mol, Zhang et al., 2007). Therefore, the vesiculation is considered to be rate-limited by viscous flow.

Application to lava domes
Experimental results were applied to prediction of lava dome explosions. After emplacement, dome surface immediately cools and vesiculation ceases, and thus the overpressure dose not increase any further. On the other hand, in the dome inside, vesiculation proceeds smoothly because temperature is maintained high, and thus the overpressure soon decreases. In the intermediate region, temperature decreases slowly, and thus the vesiculation rate decreases slowly. As a result, the overpressure and the explosion potential are maintained for a long period. We modelled these processes based on thermal conduction and the temperature-dependence of vesiculation rate, and calculated the duration during which the risk of explosions is reduced. Calculation results showed that when initial temperature of lava dome is 900 degC, the duration is 5 hours. When initial temperature is 750 deg C, the duration is 11 days.

Keywords: vesiculation, lava, explosion

Geological identification of ash-fall particles of the Tenmei eruption of Asama volcano in distant area: An attempt at Abiko, Chiba

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Volcanic ash-fall can reach a distant area and has great adverse effects on human health and society. Therefore, it is important to investigate properties of volcanic ash-fall of past eruption in extensive area for volcanic hazard assessment. However, thin ash-fall deposit in a distant point is not preserved as a visible layer. Instead, particles of ash-fall are mixed in topsoil. In order to examine whether ash-fall particles are detected by analysis for topsoil at a distant point, we investigate forest topsoil sampled at Abiko, Chiba. Old documents describing ash-fall phenomena in the Tenmei eruption of Asama volcano located ca. 150 km from Abiko are found in the Abiko and neighboring areas (Tsukui, 2011). In this paper, we report identification of ash-fall particles of the Tenmei eruption of Asama volcano, based on chemical analysis of glass composition. The particles of Tenmei ash-fall are free crystal (plagioclase, orthopyroxene and clinopyroxene) with fresh glass attached on the surface. The compositions of attached glass are consistent with those of groundmass glass in pumice lapilli sampled in proximal area. This feature is useful for identification and investigation on the properties of Tenmei ash fall, especially particle size, in extensive area.

Keywords: volcanic ash-fall, Asama volcano, volcanic glass

3D modeling around Aso crater with SfM of UAV

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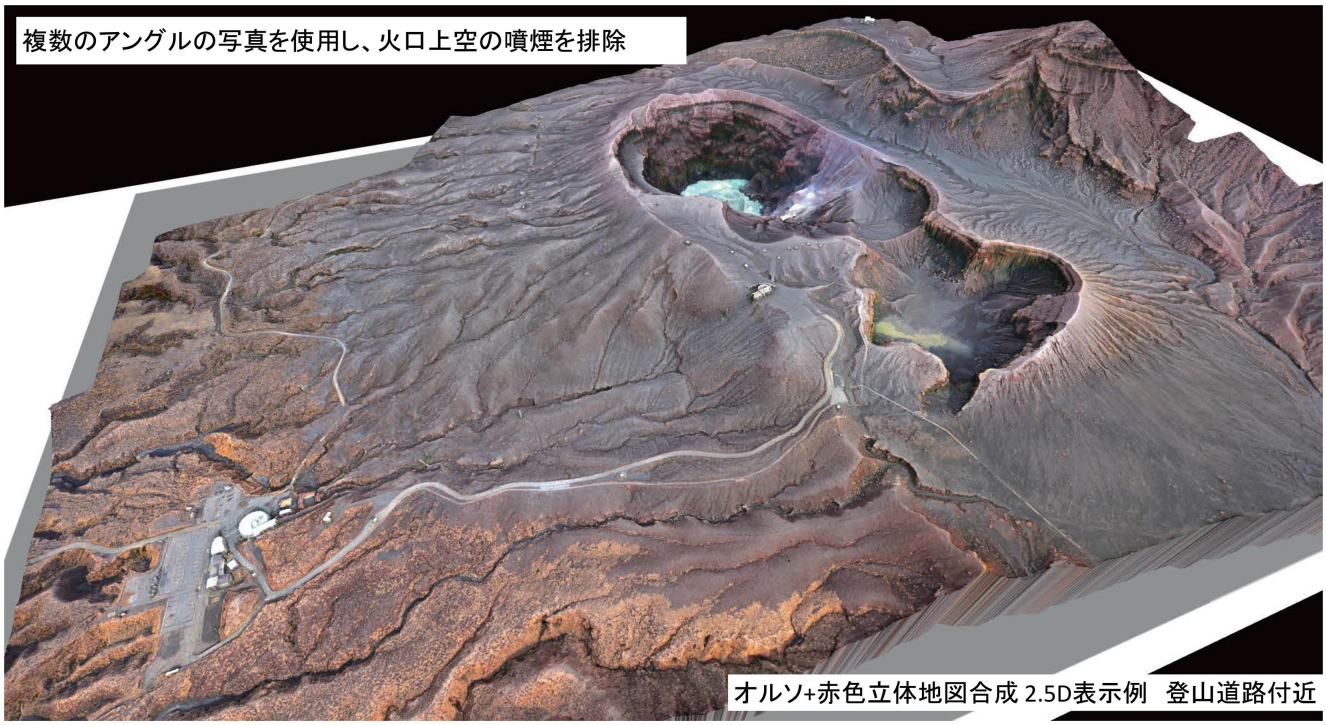
1. Introduction
For volcanic disaster prevention, surveying situation near the crater just after eruption is very important. However, there is a risk of on-site investigation into the site and flight over the crater by a manned aircraft. For this reason, oblique photographing from a place away from the crater and laser measurement at high altitude have been performed. However, it was insufficient to capture detailed information near the crater. Although high resolution satellite photographs can be taken from directly above, there was a drawback that it is susceptible to the influence of clouds. To solve these problems, it is considered effective to take photographs from low altitude and create 3D models using unmanned aerial vehicles (UAV).

2. Mt. Aso volcano and UAV shooting
Mt. Aso erupted early on October 8, 2016. The erupted volcanic ash reached 11000 m above the ground and spread to the Shikoku area. From the image from the helicopter after the eruption, the volcanic bullets and ash fall were confirmed at the crater edge and its vicinity, the situation had changed completely. A big hole was found on the roof of the ropeway station building.
Therefore, in order to grasp the situation of 2 km square around the crater urgently, we took pictures using UAV. To create 3D models and grasp the damage situation, 5 or more images with ground resolution of about 1 cm are required per point. It was a single lens reflex with a full size CCD equipped with a 24 mm lens and it was necessary to keep the ground altitude below 350 m. Considering the payload of UAV and the duration of the battery, the flight time is 15 minutes / times, and it is necessary to take off from a safe place as close as possible to the crater. Therefore, we selected the parking lot in front of the station building under the ropeway as a takeoff point from the crater. The warning level became 3 after the eruption immediately, and that point was in a no-entry area. Then after discussing with the Aso Volcano Disaster Prevention Council, the Kyoto University Volcano Research Center, and the Meteorological Agency, we got a special permission for entry, and took pictures on December 8, two months after the eruption
.
3. Data processing and interpretation
A 3D model was constructed by SfM processing from 1,000 or more photographs taken. Furthermore, 20 cm DSM data and orthophotos were prepared, and topographical interpretation was carried out together with the red color map. At the valley near the crater, we were able to confirm the micro topography such as pyroclastic flow or mud flow, which seems to be a flow deposit.
Volcanic bullets and craters formed at the time of falling were also confirmed. On the other hand, due to gully erosion and secondary migration of descending volcanic ashes formed during the two months after the eruption, it was also confirmed that some of the craters were buried. Mt. Aso had erupted in 2015, and the calculation of the amount of blowout by comparison with the last topography is currently under construction because it requires the creation of a new model.
4. Future tasks
It took two months from the recognition of the eruption to the actual shooting. This is a major reason why it took time to consult with relevant organizations for access and to apply flight application and permission etc. In advance, the development of the aircraft, such as setting rules for emergency photography at the time of eruption or capable of autonomous flying over long distances and long hours

from outside the danger area is an issue. This work is part of MEXT projiect ,Integrated Program for Next Generation Volcano Research and Human Resource Development.

Keywords: UAV, SfM, Aso volcano



The case study of the volcanic disaster on Mt. Unzen and implications for disaster mitigation

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1. Mt.Unzen disaster memorial hall

The dome building eruption of Unzen Volcano (1990-1995) displayed destructive aspects of Pyroclastic flows. The eruption resulted in the deaths of 44 people by pyroclastic surge. It is one of the most important problem to predict the risk from surges for hazard assessment. This study focuses on the impacts of surges and human injurer. A detailed analysis of the distribution and damaged houses of the surges on June 3, 1991 was used to study on the characteristics of surges. The result revealed that human injurer related the topographic effects of pyroclastic surge. Flow direction of the surge based on damaged trees and houses show a straight pattern from the Mizunashi River. But the direction changed a little after contact of mound of Mt Mayu. It is important study for future implication for volcanic hazard assessment.

Keywords: volcano, disaster

Development of a new tephra fall simulation code considering bending of eruption column under windy condition

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Today’s tephra fall simulation codes assume eruption columns that rise vertically from the source vent. This assumption is simple; however, under windy condition, eruption column bents in the downwind direction. The present advection-diffusion models, which assume relatively weak plume thus more or less fail to reconstruct observed thickness distribution. Tephra2, which is one of the most popular simulation codes, is not an exception.
Recently, several models that formulate column bending under windy condition have been proposed. Here I include bending of eruption column modeled by Woodhouse et al (2013) in Tephra2 and developing a remodeled code named wt (=windy tephra).
Woodhouse (2014) calculate coordinate of column center, column radius, upward velocity of the column, column temperature and etc. as a function of height. Tephra2 calculate coordinate of distribution center as a function of released height and particle diameter. wt calculate coordinate of distribution center based on column bending (Woodhouse, 2014) and atmospheric advection (Tephra2). Also, distribution width in Tephra2 is a sum of column radius and atmospheric diffusion. In wt, column radius is based on Woodhouse et al. (2014).
In the presentation, application of wt to the 2011 Shinmoedake eruption and the comparison of calculation results and observation will be discussed.

Keywords: Tephra2, weak plume, tephra fall simulation

Publication of a Japanese Website on the Protocol for Analysis of Volcanic Ash Leachable Elements

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I will report on the translation of the protocol for analysis of volcanic ash leachable elements of International Volcanic Health Hazard Network (IVHHN), which is revised in 2013, into Japanese and its publication on the Japanese website of IVHHN. Freshly-erupted ash contains a range of potentially toxic soluble elements, and thus, the public, civil authorities and agricultural producers will often have major concerns about the effects of volcanic ash on human and animal health, drinking water supplies, crops, soils and surface runoff following an eruption. As part of the immediate emergency response, there should be rapid dissemination of information about the physical and chemical properties of the ash and its hazardous potential. For example, some scientists received direct contacts from civil authorities in Oita prefecture and asked the degree of influence of volcanic ash on crops after the eruption of Aso volcano in October 2016. However, few Japanese scientists know the standard method for the rapid assessment of hazards from leachable elements, and as a result, we do not have a database, with which we quantitatively compare the toxicity of volcanic ash of each eruptions. The purpose of this presentation is to spread clear and reliable international standard protocol, which has been discussed in a workshop in Durhram, UK in 2011 and published in 2013 by IVHHN. The four applications considered in the protocol are (i) A ‘general purpose’ water leach, relevant to assessing impacts on drinking water supplies, livestock drinking water and fish hatcheries, and availability of soluble elements for plant uptake, (ii) Assessing ingestion hazards to livestock, (iii) Assessing ingestion hazards to humans, and (iv) Assessing inhalation hazards to humans. The adoption of standardized methods will improve and facilitate the comparability of results among different studies and enable the ongoing development of a global database of leachate information relevant for informing improved volcanic health hazards assessment.

Keywords: Volcacnic Ash, Leachable Element, Environmental Assessment, Analysis Protocol

Text mining analysis of newspaper coverage with volcanic disaster risk

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Japan has been hit by many deadly volcanic eruptions. Public awareness of volcanic disaster risk and the volcanic risk reduction education are important to strengthen disaster preparedness for effective response. Mass media are one of primary channels in the permeation of expert knowledge to public. Mass media are therefore considered to have large influence on the public understanding of risk, leading to preventing and mitigating harm from volcanic disasters. Transmission of volcanic risk knowledge to public through media coverage is a key component of risk communication. During volcanic crisis, risk related information is frequently released through news media by experts or administrative agencies. Previous studies have paid attention on the risk communication in a short period just after large volcanic disasters. However, risk communication in peace time is also very essential in order to achieve the volcanic disaster reduction and risk awareness of citizen to the higher level and how volcanic risk related issues are framed by mass media in peace time as well as at the time of crisis remains still unsolved.
The Asahi Shimbun, Mainichi Shimbun, and Yomiuri Shimbun were chosen for this study. They are the representative national newspapers in Japan and have a circulation of several million. Almost all news articles published by these newspaper companies have been archived from the 1990s onward. These databases allow us to design the comprehensive research. Although it seems that volcanic risk may be the local problem, damages of volcanic ash widely spread once massive eruption occurs. In addition, an evacuation plan must be supported by not only municipality but also government. Thus, volcanic disaster risk can be a non-negligible national political concern. By examining the national newspaper, one can find which agenda related to volcanic disaster risk typical newspaper media extensively set as the national political concern.
The newspaper articles including two keywords “eruption” and “volcano”, which are published from January 1990 to December 2016, were selected, using these databases. The research methodology is the quantitative text mining analysis with the help of the LDA (Latent Dirichlet Allocation) which is a way of automatically extracting topics that texts potentially contain, on the base of distinctive patterns of lexical density. LDA can divide articles into several sub-groups of objects that share common characteristic and enables to identify volcanic disaster risk related articles. This study will exhibit when they are intensively distributed and what types of issues in the volcanic disaster risk are significantly framed by newspaper media. In this presentation, the feature that newspaper media mainly take up the volcanic hazard topic of Mt. Fuji will be presented.

Keywords: text mining, volcanic risk, mass media, news analysis

Prototype training program of the human resource development for volcanic disaster management officers at Mt Fuji

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The disaster management officers will change their working section each 2 to 3 year in Japan. If they respond appropriately to volcanic disasters, they need specialized knowledge compared to other natural disasters. However, they have to learn the knowledge of taking over form former officer when they start to work at the new section. We feel the need for a training program of human resource development that can respond accurately to volcanic eruption. We created a prototype training program based on interviews with the related organizations, and tried it in January 2017 at the northern foot of Mt. Fuji. The contents of the program consist of the lecture of volcanic eruption and disaster, actual eruption disaster responses and disaster prevention plan, and Disaster Imagination Game with a world cafe method. Finally, we carried out a questionnaire. As a result of the questionnaire, the people wish to take a training regularly, and they hope to attend such course once or twice per year. Especially they prefer to have it in the spring when they change the working section. We need to provide the lecture of volcano information released from the Japan Meteorological Agency and public information to residents as a future issue.

Keywords: Volcanic disaster, disaster management, training program

