Fluid structure in volcanic eruption column observed by Ka-band Doppler radar

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Volcanic ash dispersion and falling with the explosive eruption affect aviation safety, so it is urgent necessary to develop its observation and prediction methods with high accuracy. For these problems, volcanic plume and ash dispersion modeling have been studied. The former physically solves the fluid-dynamical structure and the ash advection in the plume under the given condition of magma burst, however it is difficult to validate the results comparing with the observation data. The latter simulates the advection and dispersion of the ash, but the reliable initial conditions (e.g., three dimensional distribution of ash density) are needed for the accurate simulation. The ash observation by radar remote sensing are expected to be a solution for these problems.
So far some observational studies for the volcanic ash were demonstrated by using ordinary weather radar. But those could observe only relatively dense volcanic smoke, because radar reflectivity of the volcanic ash is smaller than that of the precipitation. In 2000, NIED developed Ka-band (35 GHz) Doppler radar, which can observe not only precipitations but also clouds. This radar is expected to detect the weak eruption. Moreover it is expected to retrieve a fluid structure in the smoke by detecting the Doppler effect of the radio wave. We deployed the radar at Kurokami branch observatory, Sakurajima Volcano Research Center, Kyoto University during March-June in 2014 for the observation of the Sakurajima eruption. In this presentation, our application of the meteorological radar analysis technique to the volcano eruption and the retrieved fluid dynamics will be reported.

Keywords: Volcanic eruption column, Meteorological Doppler radar, Ka-band

Microphysical Studies of Volcanic Ash Clouds by X-band Polarimetric Weather Radar Observation

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It has been recognized since the 1970’s that weather radars can detect volcanic ash clouds. However, it is only since the 1990's that weather radars have been used in studies of quantitative ash cloud estimation. The present paper investigates the microphysical properties of volcanic ash clouds, the knowledge of which is necessary for quantitative ash cloud studies. Two volcanic eruptions at the Showa crater in Sakurajima, Kagoshima, Japan are analyzed. Both eruptions were observed by X-band operational polarimetric radar, which is installed by the Ministry of Land, Infrastructure, Transportation and Tourism approximately 11 km from the crater.
In the first eruption, which occurred on August 18, 2013, the ash column rose to a height of 5500 m above the crater. In the second eruption, which occurred on August 29, 2013, the ash echo and the precipitation echo coexisted. Analysis was performed on polarimetric radar parameters that were obtained by PPI scan at an elevation angle of 6 degrees. Radiating echo patterns, which extended from the north-northwest direction to the south-southeast direction through the crater, are found in the reflectivity factor (ZH) and the differential reflectivity (ZDR) immediately following the eruption. The direction of the radiating echo corresponds to that of a line connecting the radar and the crater. The radiating echo is probably due to the effect of the range side lob of the transmitted pulses. A similar radiating pattern was also found in the correlation coefficient of the horizontal and vertical polarization (RHOHV) immediately after the eruption. The radiating echo patterns had almost disappeared by 6 minutes after the eruption. Interesting time changes of ZH and ZDR were found during the period from 6 minutes to 24 minutes after the eruption: While the ZH decreased with time, ZDR increased with time. The RHOHV values were 0.8-0.9 until 24 minute after the eruption. This value decreased to 0.7-0.8 at the central region of the echo and to less than 0.5 at the outer edge of the echo. On the other hand, the time change of the specific differential phase (KDP) of the ash smoke was quite different from those of the other polarimetric radar parameters: it was too small to be detected immediately after the eruption, while it was 0.5deg/km at 14 minutes after the eruption before increasing to about 1deg/kmk. The present paper explains these polarimetric radar parameter time changes by time changes of the microphysical properties of ash particles.
While the first eruption studied occurred in dry environmental conditions, the second occurred in wet conditions. Before the eruptions, precipitation echoes were generated to the west of Sakurajima and passed over Sakurajima immediately after the eruptions. The subject radar could detect the precipitation echoes and the eruption echoes independently. However, it was difficult to distinguish between the ash smoke and the precipitation because both ZH patterns were quite similar. We attempted to discriminate them using polarimetric radar parameters.

Keywords: radar, volcanic smoke, volcanic eruption, three dimensional

Information of volcanic ash material from satellite infrared sounder data

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Brightness temperature (BT) spectrums of the volcanic ash clouds in the IR window region measured by a satellite infrared sounder has been simulated in detail from the radiative transfer calculations by taking into account the appropriate atmospheric profiles, sea surface temperature/emissivity, atmospheric gas absorptions, and ash-scattering properties. From iterative least-square calculations using measured and simulated BTs, we made estimations of the ash refractive index (RI) as well as the ash cloud parameters (optical depth, particles effective radius, and ash cloud pressure heights). The absorption spectral feature of the RI in wavelength region around 10 micron depends on the Si-O bond characteristics of the erupted silicate material and therefore it is correlated with the mineral type and SiO2 content. From the retrieval analysis, it is found that some estimated RIs were consistent with the reported rock types of the volcanoes, which had been previously classified by compositional analyses in the literature. Furthermore, weak absorptions likely due to Si-O and/or Al-O vibrations, which have been proposed in reports from previous laboratory FTIR experiments for some silicate glass samples were identified. The spectral RI estimated from the analyses of data from a satellite infrared sounder can be used to analyze other satellite measurements. In particular, information for the detailed RI in the infrared region contribute to ash cloud quantification and monitoring from measurements by next-generation geostationary satellites, such as the Japanese HIMAWARI-8. Moreover, it is possible to discuss the time evolution of components of the eruption products from changes in the RI estimated from IR sounder measurements.

Keywords: volcanic ash, satellite infrared sounder, refractive index

Influence to GNSS signals by volcanic ash plume

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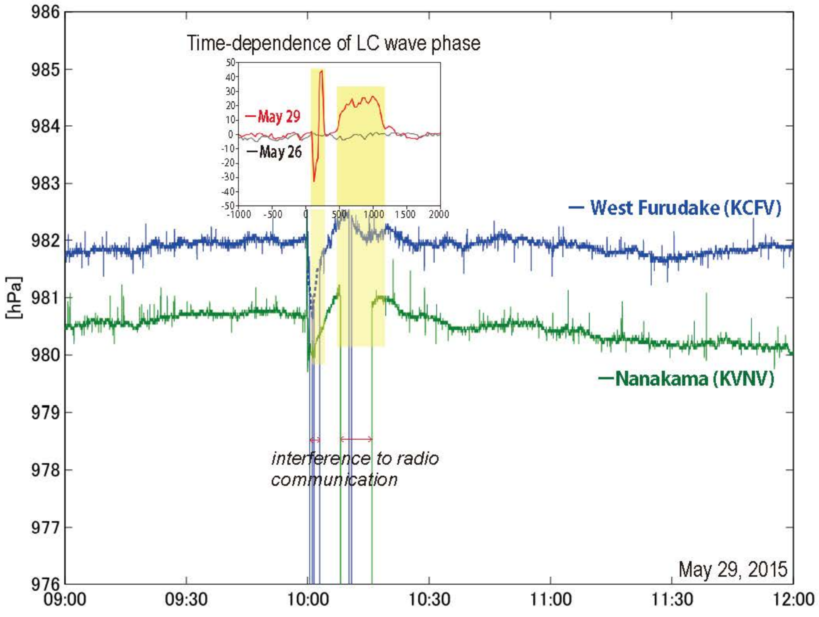
Recently,GNSS data of the continuous observation system GEONET are utilized for monitoring and study of crustal deformation. Oota et al.2013 presumed the GPS carrier phase balance residual and found conspicuous phase Post fit Phase Residual with the about 24 th July 2012 eruptive event in the Minami crater of Sakurajima Volcano by using PPP.
The purpose of this study is to presume LC PPR by using a same method as the above, and to deliberate the factor of LC PPR change.Eruptive event is a large typical volcanian that occurred at Shintake crater of Kuchinoerabujima on May 29,at 9:59 local time JST.Volcanic ash diffused from WNW to ESE.
This study analyzed the GEONET GPS data acquired on the observation station at Kuchinoerabujima by using GAMIT software ver.10.5.
A result of the analysis,LC PPR of PRN18,22,26,29 changed conspicuously.LC PPR of PRN18,22,26 increase about 20cm. But It LC PPR of PRN29 decreases minus 32cm,and increases 42cm for during a short term, increases about 20cm for long term. These changes were almost synchronous with the abnormal changes of atmospheric pressure changes recorded at the northeastern foot of volcano. It is for the first time that the variation of such extreme LC phase residuals detected by this study along with volcanic eruption.
From the space images of the weather satellite HIMAWARI, it was confirmed that, just after the eruptive plume was started to form, the umbrella ash cloud was once spread around the volcanic body, and that the ash cloud flew from WNW to ESE direction. Checking both the behavior of this plume and the results of GAMIT analysis, it was found that radio waves from the PRN18,22,26 reached the observation station through
the spreading umbrella cloud, while those of PRN29 had reached through the eruption column.
Based on the video recording immediately after the start of the eruption and the timing of the communication failure of barometer system, rapid reduction and recovery of the air pressure or strong electrification including volcanic lightening, caused by over expansion of air accompanied with the sudden towering of plume pillars could account for the cause of the sharp minimum and maximum within a short time in the variation of LC PPR of PRN29 passed through the eruption column.
Moreover, from the fact that the maximum of PRN29 was synchronous with the maximum of about 1 minute seen in PRN18,22,26 which passed through the spreading umbrella cloud, a possible factor for delay is considered due to water vapor increase or the temperature rise in the plume. For the broad increase in a long time of PRN29 was considered related to factors such as an increase of volcanic gas concentration, the subsequent rise in temperature or water vapor increase due to the diffusion of long plume umbrella.
The present study suggested a correlation between the events of the growth and towering of the volcanic plume and the LC PPR variation of GNSS radio waves. However, in order to elucidate the causes of changing the LC PPR it is necessary to perform a detailed study about the relationship between the LC PPR and dynamics of the eruption plume.



Time-dependence of LC wave phase
May 29
May 26
West Furudake (KCFV)
Nanakama (KVNV)
[hPa]
interference to radio communication
May 29, 2015

Transition process of parent cloud causing tornadoes accompanied by Typhoon, 'Neoguri'

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Two tornadoes simultaneously occurred near Kochi airport when the outer rainband of ‘Neoguri’ passed through the Kochi plain on 10 July 2014 (Yuasa and Sassa 2014). These tornadoes correspond to the vortices in their parent cloud, mc1 and mc2. The parent cloud was found to one of mini supercell when mc1 was observed at first. However, it did not have the feature of supercell when it landed (Yuasa and Sassa 2015). The present analytical study aims to clarify the transition process of the parent cloud with the data of Muroto Doppler radar.
We used the polar coordinates data of JMA Muroto radar obtained from NICT archives and analyzed with Draft software developed by MRI. We also used the initial GPV data of JMA meso scale model obtained from the RISH archives.
Fig.1 shows the PPI scan data of elevation angle 0.4 deg. Strong wind of over 38 m/s in Doppler velocity approached to the parent cloud from southwest and weak echo region was observed just south side of mc1 until just after mc2 appeared as shown in Fig. 1a,b. Moreover, the strong echo more than 40 dBZ formed hook like echo pattern around mc1. The diameter of mc1 was about 10 km which corresponded to that of mesocyclone. These features of the parent cloud in the horizontal plane show those of supercell though the arrangement of hook echo is opposite to that of normal supercell. The diameter of mc1 became rapidly smaller at 5:45 JST, and then strong echo in the south portion of the parent cloud left from the parent cloud and hook echo disappeared as shown in Fig. 1c. The strong echo in the south portion disappeared when the parent cloud landed and the cyclonic horizontal shear in which the southerly wind at the east side was stronger than that at the west side. The MSM data also showed the cyclonic horizontal shear in the outer rainband in which the parent cloud located (Yuasa and Sassa 2015).
Figure 2 shows the vertical cross section of the parent cloud around mc1. Just after the genesis of vortices, vault structure was clearly observed around mc1 as shown in Fig.2a,b. But, the strong wind of more than 30 m/s approaching to the vault from southwest became weaken at 5:41JST. Though the area of strong horizontal wind was still observed at 5:45JST after mc1 became smaller, vault structure already disappeared and the echo top was apart from mc1 as shown in Fig. 2c. The parent cloud did not have the feature of supercell at all when it landed but it had the cyclonic horizontal shear as shown in Fig. 2d.
Conclusively, the parent cloud was founded to have the feature of supercell at first and then lost it because the strong inflow from south. The cyclonic horizontal shear, however, still existed in the outer rainband and it kept the vortices. Finally, the tornadoes were kinds of non-supercell ones but their generation process was different from that of the ordinal non-supercell tornadoes (Wakimoto and Wilson 1989).

Keywords: radar observation, tornado, supercell

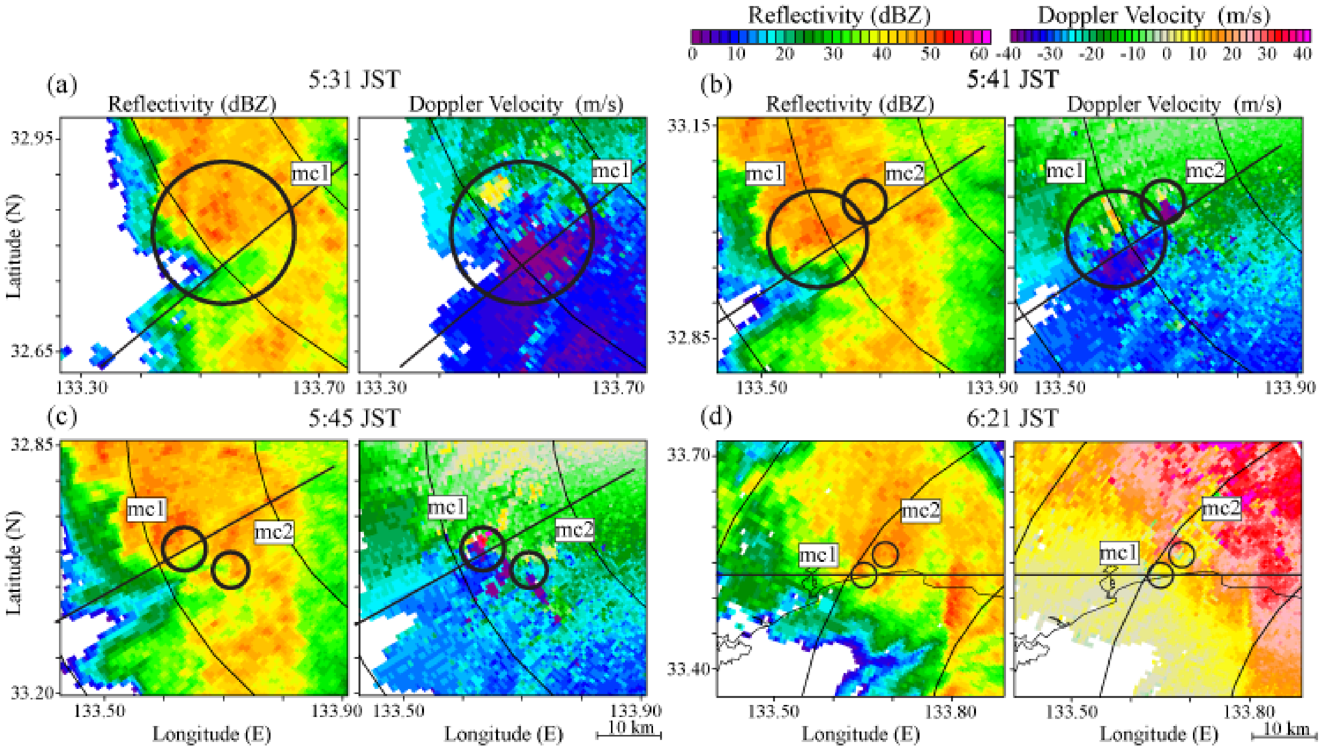

図 1　渦発生後の室戸レーダー画像 (仰角 0.4deg.)。(左 ; レーダー反射強度 , 右 ; ドップラー速度) 図中丸はドップラー速度の極大極小から判断した渦付近を囲んだもの。実線は図 2 の鉛直断面の領域。

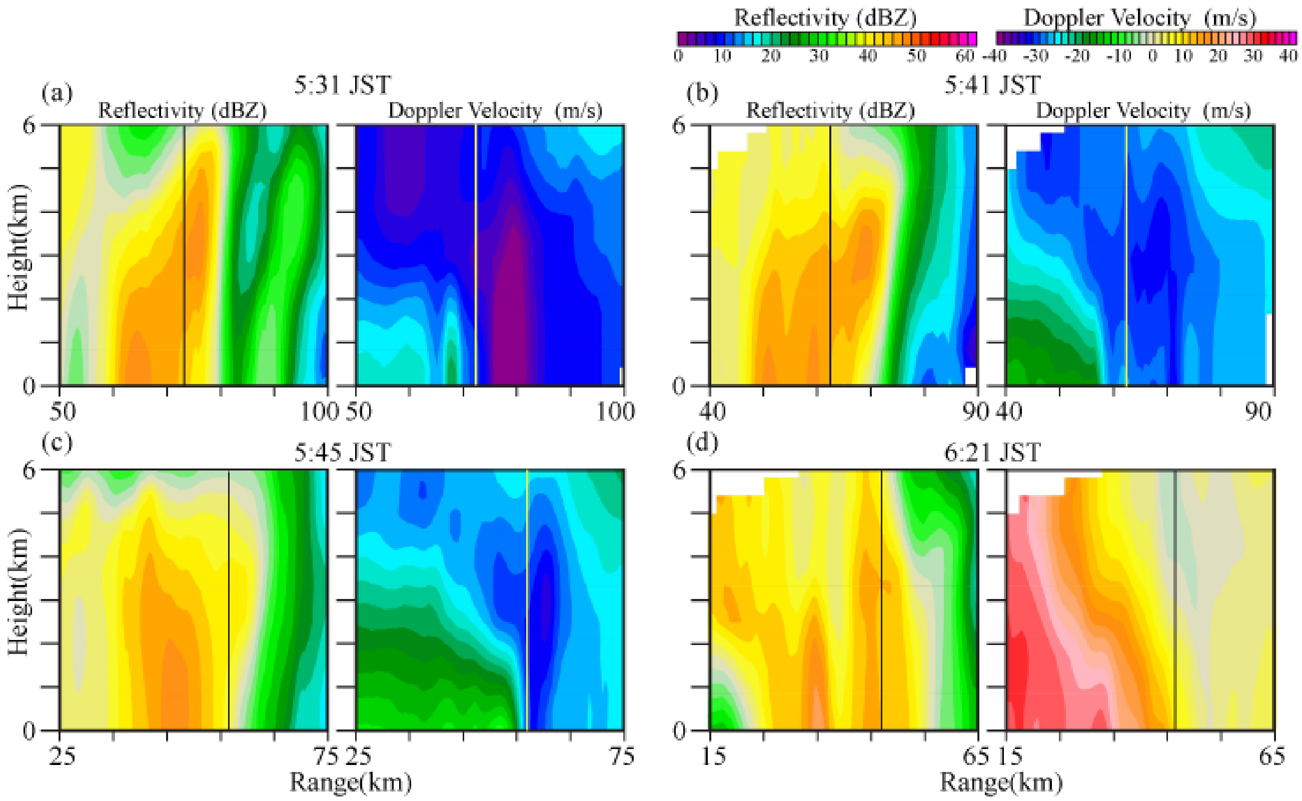

図 2　mc1 渦中付近の室戸レーダーの断面図。図 1 の実線部 (30km) を高度 6km まで切出し、北から見た断面を示す。実線は mc1 の渦中心。(左 ; レーダー反射強度 , 右 ; ドップラー速度)

Observation of Volcanic Ash Clouds by Himawari-8

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Volcanic ash released by volcanic eruptions not only fall and accumulate on the ground over a wide area, but also float and disperse in the air for a long period. Since an encounter between aircrafts and volcanic ash clouds could result in a serious accident such as damage on the aircraft body and engine failure, information of distribution and altitude of volcanic ash clouds is essential for the safe operation of aircrafts. Geostationary meteorological satellites are one of the most important tools to monitor volcanic ash clouds, in the point that they can observe the wide range on the earth homogeneously and continuously.
Japan Meteorological Agency (JMA) began operation of the new-generation geostationary meteorological satellite, Himawari-8, on 7 July 2015. This year, JMA is also planning to launch Himawari-9, which is a backup system of Himawari-8. The imager on board is called Advanced Himawari Imager (AHI), whose observation performance is highly improved compared to that of the predecessor MTSAT-series satellites. For example, the number of observation bands is increased from 5 to 16, the spatial resolution is almost doubled, and the full-disk observation frequency is improved from hourly to every 10 minutes. Furthermore, for the small region including Japan, high-frequency observation as much as every 2.5 minutes is carried out. These high-resolution and high-frequency observations enable us to observe relatively small-scale and quickly changing phenomena, such as volcanic plumes and rapidly developing cumuli.
Volcanic ash clouds can be detected from satellite observation data using wave-length dependence of light absorbance of volcanic ash. With numerical weather prediction data and sea surface temperature data, we estimate volcanic ash cloud height, optical depth and several other quantities. Utilizing 16 bands observation data of Himawari-8, improvements in accuracy of volcanic ash clouds detection and estimation of those altitudes can be expected.
In this talk, I will show some cases of volcanic plume observed by Himawari-8. A basic concept of volcanic ash detection from satellite observations and how to generate volcanic ash RGB composite imageries will be explained. Additionally, I will briefly introduce satellite volcanic ash products which include physical quantities of volcanic ash clouds such as altitude and optical depth.

Keywords: volcanic ash clouds, remote sensing, geostationary meteorological satellite, Himawari-8

Current state and problems of field examination concerning tephra dispersal after pyroclastic eruptions

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Dispersal pattern and volume or mass of tephra are fundamental factors determining type and magnitude of pyroclastic eruptions. However, the investigation method is outdated, and various problems exist to obtain highly precise data. This paper presents examples of field examination immediately after pyroclastic eruptions including Kirishima and Aso Volcanoes in Kyushu, SW Japan, and discusses the problems that appeared through the fieldwork.
The 2011 Shinmoedake eruption at Kirishima Volcano (southern Kyushu) was one of the largest eruption in Japan during the latest decade. Multiple subplinian eruptions occurred on January 26-27 and the tephra was dispersed throughout an area extending more than 20 km southeast from the source crater. Fieldwork was undertaken immediately after the eruption and a few months after the eruption. The eruption products were well preserved even a few months after the eruption, and it was possible to understand the tephra dispersal and correlate several fall units at different sites. Especially, it was clarify that the dispersal axis of the maximum size of pumice was slightly more northerly than that of thickness. This fact is consistent with the result of eruption plume simulation conducted by Suzuki et al. (2013). Our estimated volumes of the subplinian pumice-fall deposits on January 26-27 are one order of magnitude smaller than those of other studies probably because we use thickness data obtained at sites more than 2.5 km of the Shinmoedake crater. This suggests that proximal tephra data would be needed to give accurate estimates of the volume and mass of eruptive deposits.
Following the 1989-1995 eruptive sequence, multiple small ash emissions occurred at Nakadake crater, Aso Volcano (central Kyushu) in 2003-2008. A series of magmatic eruptions including ash, strombolian and phreatomagmatic eruptions occurred from November 2014 to December 2015. These eruptions provided valuable opportunities to examine eruption deposits in different volumes. It was useful to observe and sample ash deposited on artificial constructions or snow cover in the case of July 10, 2003 and January 14, 2004 small eruptions although it was difficult to recognized the ash on the natural surfaces.
In the initial stage of the 2014-2015 magmatic eruption at Nakadake, the ash-fall deposits could be easily observed and sampled on artificial surfaces at more than 40 sites, and the eruptive mass could be calculated using the isopleth map. Since subsequent ash-fall deposits could not be separated from the initial ash, ash samplers were installed at about 20 sites around the Nakadake crater. Although the ash observation system could be maintained, a big problem that fieldwork for ash sampling is restricted by road network has appeared. In the case of Nakadake, the eastern side of the crater is usually located downwind, and the downwind area has no road. Therefore, it is difficult to obtain the proximal data by fieldwork using cars. Moreover, it was experienced that ash sampling in the proximal area (<1 km of the crater) could not be often performed due to the risk of further eruptive activity. It is clarify that eruptive masses calculated by using both proximal and distal data are 1.4 times larger than those estimated by using only distal data. These evidences indicate that proximal tephra data would be needed to give accurate estimates of the volumes and masses of eruptive deposits as well as the 2011 Kirishima eruption.
As mentioned above, there is only one method to estimate distribution and mass of tephra deposits by fieldwork although the fieldwork immediately after pyroclastic eruptions has several serious problems. Therefore, it is expected to develop tephra plume simulation technique as well as

geological examination to give accurate estimates of eruptive volume and mass.

Keywords: pyroclastic eruption, tephra dispersal, eruptive volume

Reconstruction and estimation of physical parameters of a phreatic eruption on 27 September 2014 at Ontake volcano, Central Japan, based on pyroclastic density current and fallout deposits

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The phreatic eruption at Ontake volcano on 27 September 2014, which caused the worst volcanic disaster (58 deaths and 5 missing persons) in Japan in the past half-century, was reconstructed based on observation of proximal pyroclastic density current (PDC) and fallout deposits. Witnesses' observations were also used to clarify the eruption process. The deposits are divided into three major depositional units (Units A, B, and C) which are characterized by massive, extremely poor-sorted, and multimodal grain-size distribution with 30–50 wt.% of silt to clay component. The depositional condition was initially dry but eventually changed to wet. Unit A originated from gravity-driven turbulent PDCs in the relatively dry, vent-opening phase. Unit B was then produced mainly by fallout from a vigorous moist plume during vent development. Unit C was derived from wet ash fall in the declining stage. Ballistic ejecta continuously occurred during vent opening and development. As evidenced in the finest population of the grain-size distribution, aggregate particles were formed throughout the eruption, and the effect of water in the plume on the aggregation increased with time and distance. The lithofacies and grain-size characteristics of the poorly-sorted deposits observed in the proximal area are similar to those of mudflows or fallout tephra from past phreatic events. It is important to understand the similarity of the deposits when we interpret this type of poorly-sorted deposit solely based on geological records. Using geological records, witness observations, and a theoretical approach, the physical parameters of the Ontake eruption can be constrained. Based on the deposit thickness, duration, and grain-size data, the particle concentration and flow velocity for three PDC lobes in the initial phase were estimated to be 2×10^{-4} to 2×10^{-3} and 24–56 m/s, respectively, applying a scaling analysis using a depth-averaged model of turbulent gravity currents flowing down slopes. The tephra-thinning trend shows a steeper slope in the proximal area than on the trends of similar-sized magmatic eruptions, indicating a large tephra volume deposited over a short distance owing to the wet dispersal conditions. The Ontake eruption provided an opportunity to examine the deposits from a phreatic eruption with a complex eruption sequence that reflects the effect of external water on the eruption dynamics. Further studies may enable to quantitatively evaluate the major factors that caused the many casualties and severe damage to buildings near the eruption source.

Keywords: phreatic eruption, Ontake, pyroclastic density current, pyroclastic fallout, grain-size distribution

Transport and resuspension of ash particles from the 2014 phreatic eruption at Ontake Volcano, inferred by pollen sensor data

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Behavior of ash particle from explosive eruptions is considered to influence many environmental and economic factors (e.g., Rose and Durant, 2011). Field survey on eruptive deposit have been performed to evaluate the behavior of ash particles and obtain ground truth for numerical simulation and satellite observation during explosive eruption (e.g., Gudmundsson et al. 2012). However, it is generally difficult to reconstruct timing and strength of ash transport from the field survey for small phreatic eruption, because ash deposit by such small eruption is easy to suffer reworking by wind and rain water. So, method which can detect ash particles *in situ* is favorable to infer the behavior of ash particles during the small phreatic eruption.

We examined time series data of pollen sensor to infer the transport and resuspension of ash particles from the 2014 phreatic eruption at Ontake volcano. The pollen sensor has been developed for *in situ* detection of pollen particle which causes allergy. The pollen sensor (PS2 by Shinyei technology Co. Ltd) is laser optical analyzer for particle matters, and consists of one light emitter and two light receptors. The particles are introduced into the chamber, and shot by linear polarized light emitted by the light emitter. The number of particles introduced into the chamber by intake of air are counted from the number of outputs recorded by a receptor every second. The combination of output voltage from the two receptors brings in a polarization factor (PF) reflecting shape of the particle matter. The polarization factor of pollen and water drop with spherical shape are higher (around 0.3 and 0.8) than that of soil particle from Kanto plain (around 0) (see HP of Shinyei technology Co. Ltd).

We analyzed pollen sensor data recorded by NTT Docomo Ltd from September 21th to October 19th, 2014 with a sampling frequency of 1 Hz at Kaida-kogen site which locates 11 km away from the summit of Ontake volcano. To remove the particle counts due to pollen and water drop, we recalculated hourly counts of particles having < 0.3 of polarization factor. Strong noise of the particle count prevents us to insight into behavior of ash particles in other 150 pollen sensor sites around Ontake volcano.

The time series of pollen sensor data from Kaida-Kogen allows us to infer the transport and resuspension processes of ash particles from the phreatic eruption. We find a sudden increase of the hourly count of particle matter with low polarization factor changing from few tens to maximum value of 5355 particles at 12:00-13:00 September 27th. Because the onset of the 2014 phreatic eruption at Ontake is 11:52 Sep 27th, we consider that unusual supply of particle matter by the eruption causes the sudden increase. In detail, count value by ten minutes interval provides maximum value of the count 80 minutes after the phreatic eruption. So, transport velocity of ash particles can be estimated to 2.3m/s which is comparable with velocity of local wind around the Ontake volcano. After the sudden increase, the particle count gradually decreases with some fluctuations, and becomes few particles per hour within 1 week. The fluctuations are well correlated with temporal variation of wind velocity in Kaida-Kogen, showing wind blowing induces resuspension of ash particles. Because the wind direction at the fluctuation are randomly oriented, we consider that ash particles on the leaf, tree and load around pollen sensor were resuspended by the wind blowing. Finally, we conclude that pollen sensor data can be used to evaluate behavior of ash particles even in small phreatic eruption.

Keywords: Volcanic ash, Pollen sensor, Phreatic eruption

An examination of the impact of initial size distribution of volcanic ash particles on volcanic ash transport simulation in the case of Sinmoe-dake eruption 2011

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The volcanic ash cloud appeared during the eruption event at Mt. Shinmoe-dake from 26 to 27 January 2011 was simulated using Japan Meteorological Agency Non-Hydrostatic Model (JMA-NHM), which is coupled with a volcanic ash source model, to validate the model performance, based on satellite observation data. The source model was made up of a function of the height at which ash particles are released and the size of particle, based on Suzuki, (1983) and Shimbori et al., (2010).
Applying the model to the volcanic ash transport simulation, reproducibility of the observed ash cloud was insufficient, because the model assumes a vertical eruption column that is not affected by cross wind and a simple air velocity profile in the eruption column, while the actual eruption event occurred in the environment with vertically sheared cross wind and the air flow in eruption column is not so simple as assumed in the model. To overcome the shortcomings of the model, new source model was developed based on the three-dimensional direct numerical simulation of a major sub-Plinian eruption during the period at Mt. Shinmoe-dake (Suzuki and Koyaguchi, 2013). The new model releases more ash particles in the middle troposphere than the usual model. This brought improvement of the reproducibility of the ash cloud.
For more improvement of the simulation result, the authors are examining the sensitivity of the resulted ash cloud distribution to another factor prescribed in the model; the initial size distribution of ash particles. As a preliminary result, it is found that doubling the variance of log-normal size distribution of ash particles improves the resulted ash cloud distribution. A systematic examination and its results on the impact of the initial size distribution on the ash transport simulation will be presented at the meeting.
Acknowledgement
This study was supported by the Earthquake Research Institute cooperative research program.
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Keywords: volcanic ash transport and dispersion model, Shinmoe-dake volcano, particle size distribution

Estimation method of tephra deposition using photovoltaic power generation data for model validation of tephra fall simulation.

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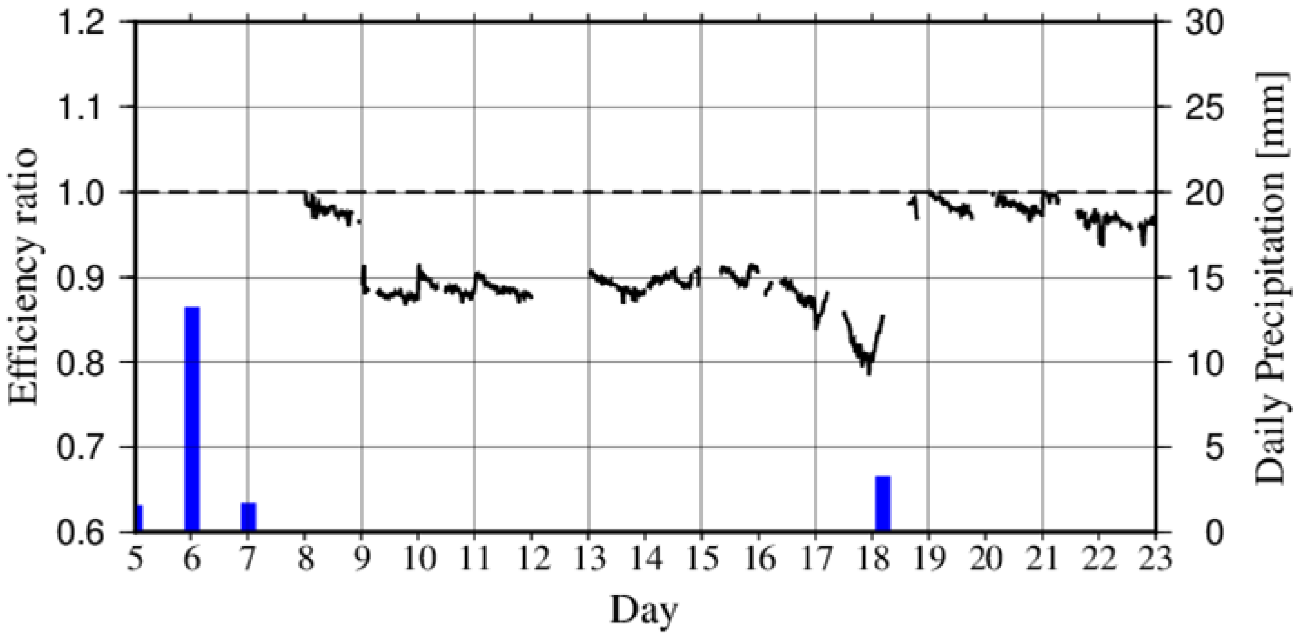
Operational and research-based tephra fall forecast and hindcast were performed for recent major eruption events in Japan using tephra transport and dispersion models. For a model validation, several data sets are already available such as the space-bone and ground-based remote sensing data as well as in-situ measurement data, however the temporal and spatial resolutions of those data are insufficient for precise quantitative evaluation of tephra fall. It is desired to develop new data representing tephra fall in higher resolution.
The authors propose an application of photovoltaic (PV) power data to estimation of tephra fall. Kaldellis and Kapsali (2011) indicated liner relationship between tephra deposition amount and PV power efficiency. In generally, numerous PV systems have been installed in the Japan and its PV output data has been also monitored at several minute intervals. This approach makes it possible to obtain the tephra fall data in high resolution without new instruments.
We investigated a relationship between tephra deposition and PV module efficiency at Kirishima exposure site in Kyusyu region (on the western part of the Japan islands) in July 2013. In case of a volcanic eruption event of Mt. Sakura-jima (on the southern part of Kyusyu region), it was confirmed that PV power output was on the decrease. PV power output restituted after rainfall event in 18 July, (see Figure). The number of events that PV power output was decreased more than 20 % compared with an initial condition is 72 days in 2013.

Keywords: Estimation of tephra fall, Photovoltaic power generation



Figure, Comparison of time series of PV module efficiency and daily-accumulated precipitation in July 2013. The solid black line indicate PV module efficiency (see left axis), and blue bar indicate daily precipitation (see right axis, mm), respectively.

The feasibility study for the estimating the grain-size distribution of volcanic ashes with the wind profiler LIDAR

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There are some earlier studies of the observations of volcanic plume with the Mie LIDAR, such as Sakai et al. (2014), and most of them reported about the altitude of the volcanic-ash cloud, but there are not much studies about estimating the grain-size distribution of the volcanic ashes in troposphere with LIDAR. Doppler LIDARs are used to estimate the wind profile using the spectral analysis of the backscatter by aerosols. Aoki et al. (2015 a,b) demonstrate the estimation of rain drop size distribution using Gaussian Mixture Model (GMM) fitting of Doppler spectra. This suggests the possibility of the estimation of the grain-size distribution of aerosols.
As part of the joint research project by Meteorological Research Institute and Kagoshima Meteorological Office, the observation of wind around Sakurajima volcano using the Wind Profiler LIDAR (Doppler LIDAR, hereafter WPL) was done on March, 2015. The eruptions were observed by 32 times in the observation period, so WPL observed the atmospheric flow including volcanic-ash. In this study, the estimation method of volcanic ashes size distribution using spectral analysis is tested.
At first, the observed spectral power distributions are fitted to GMM, and derived Doppler speed (V_r) for each mode. The falling velocities of ashes (V_F) are derived from Vr and the environmental wind (V_e). The grain-sizes of ashes (D) are estimated using the relationship of D and V_F in Shimbori et al. (2014). In this study, the analysis data of the Japan Meteorological Agency (JMA) Local Forecast Model (LFM) are used as V_e. For the verification, the analyzed distribution is compared with one using the volcanic-ash prediction of the JMA Regional Atmospheric Transport Model (RATM) driven by LFM.
In the case study for the data between 14:50 –15:00 JST on 26th March, the peak of the distribution is about 0.1mm in the both results of WPL analysis and RATM prediction, so they are almost consistent. But the D in WPL analysis is widely distributed, up to 20mm. This ‘unreliable’ D is thought to be caused by the noise in spectra. In addition, some possible reasons to affect the analysis like the fluctuations of wind and the difference between the ‘real’ wind over WPL and the LFM analysis data must be considered. And the observed grain-size distribution data is needed for the further verification.
Although there are some points to be noted like the measures to the accumulation of falling volcanic-ashes on WPL antenna in the observation of the volcanos, there are advantages like the portability and the possibility to observe the lower wind profile. So it is worth to consider the applications WPL to the observation of the volcanic plumes.

Keywords: Volcanic ashes, Doppler LIDAR

Results of the eruptive column model inter-comparison study

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Plume heights developed during explosive volcanic eruptions are key observable data for estimating crucial parameters such as mass eruption rate, and they are commonly used as input for dispersal models of tephra particles. Therefore, the accurate description of the relationships between plume heights and eruption conditions has been required. In the past decades, several volcanic plume models have been developed, including the more recent sophisticated computational fluid dynamics models. In this study, we presents results of the volcanic plume model inter-comparison study promoted by the IAVCEI Commission on Tephra Hazard Modelling.

This study compared empirical parameterizations (0D), and simulations of one-dimensional (1D) and three-dimensional (3D) numerical models in a set of inter-comparison exercises to evaluate model capabilities and highlight aspects requiring improvement and future research. The study involved four 0D, nine 1D models based on different extensions of the Buoyant Plume Theory (Morton et al,, 1956), and four 3D models describing the transient dynamics of volcanic plumes. The exercises were designed as tests in which a set of common input parameters was given for two reference eruptions, representing a strong and a weak eruption column, under different meteorological conditions.

Despite their different formulations, the 1D and 3D models provide reasonably consistent predictions of maximum height of plume. Variability in plume height, estimated from the standard deviation of model predictions, is within ~20% for the weak plume and ~10% for the strong plume. Predictions of neutral buoyancy level where the plume density is equal to the atmospheric density, are also in reasonably good agreement among the different models with a standard deviation ranging from 9 to 19%. There are important differences amongst models in terms of local properties along the plume axis, particularly for the strong plume. Our analysis suggests that the simplified treatment of air entrainment in 1D models is adequate to resolve the general behavior of the weak plume. However, it is inadequate to capture complex features of the strong plume such as large vortices. There is a need to more accurately quantify entrainment rates, improve the representation of plume radius, and incorporate the effects of column instability in future versions of 1D volcanic plume models.

Keywords: explosive volcanism, eruptive plumes dynamics, fluid dynamic models, model inter-comparison, eruption source parameters

Consideration of Wind Effects on the Eruption Source for the Lapilli Fall Prediction

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When volcanic eruption occurs under strong wind condition, lapilli falling relatively in a short time are transported to a distant place. In several cases of recent eruptions in Japan, a few cm-sized lapilli fall were observed at resident area located a dozen km away from vent and caused human or property damage such as broken windshields of cars (e.g. JMA, 2013). For the purpose of mitigation of lapilli-fall disaster, the Japan Meteorological Agency (JMA) has been issued Volcanic Ash Fall Forecasts (VAFFs, Hasegawa et al., 2015; Sugai et al., 2015). In the scheduled and preliminary VAFFs, potential areas of lapilli fall are indicated with volcanic-ash fall area or quantity. The VAFFs are based on the calculations by the JMA Regional Atmospheric Transport Model (JMA-RATM), however, effects of wind are not considered in the eruption source which is the initial condition of the RATM. Then there is a problem which tends to underestimate the predicted volcanic-ash and lapilli fall areas.

In order to address this problem, we observed the wind around Sakurajima volcano with Aerological Observatory’s Doppler LIDAR (Hoshino et al., this volume) and have been improving of the eruption source of the RATM in the joint research of the Meteorological Research Institute and the Kagoshima Local Meteorological Office (FY2014-16). Instead of currently used empirical model of eruption source by Suzuki (1983), we consider the effects of wind especially for weak plume case based on the following methods; (i) not change the vertical distribution (i.e. Suzuki distribution) of volcanic ashes and lapilli, and (ii) shift only the horizontal distribution of them with wind GPVs according to Ida (2014). In this presentation, we will show the verifications of volcanic-ash and lapilli fall predictions for case studies of the eruptions at Sakurajima volcano in 2013, Kuchinoerabujima volcano in 2015 and so on.

Researches on the eruption column considering wind effects have been done by more sophisticated models, for example, BENT (Bursik, 2001), SK-3D (Suzuki and Koyaguchi, 2015) and JMA-NHM (Hashimoto et al., this volume). In order to apply the results of these physical models to the initial conditions of the operational RATM, under various weather conditions, it is required to make an eruption source immediately from observables for any active volcanoes in Japan. Therefore we consider that the eruption source including wind effects in this research is impermanent and provide a bridge from empirical models to physical ones. Furthermore improvements of eruption source make more accurate first guess in the volcanic-ash data assimilation system (Ishii et al., this volume) inputted the data observed by weather radars (e.g. Sato et al., this volume) and Himawari-8 (e.g. Hayashi et al., this volume).

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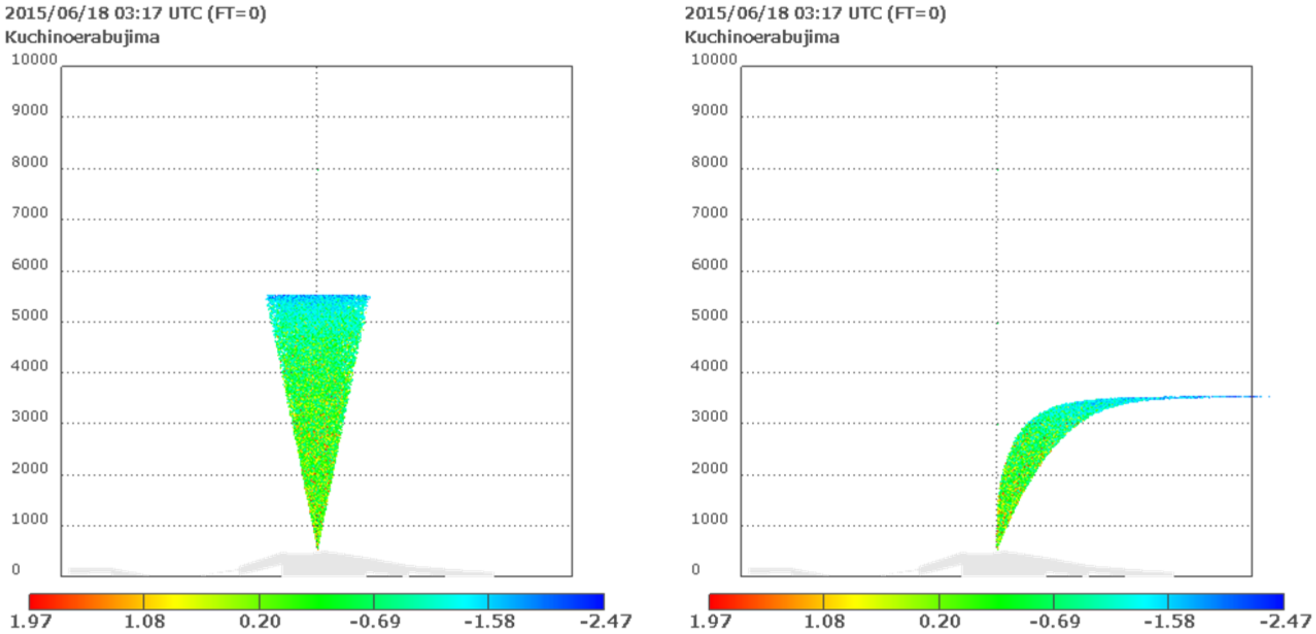
Keywords: Atmospheric Transport Model, eruption source parameter, effects of wind, lapilli, volcanic ashes, Volcanic Ash Fall Forecast



Examples of eruption sources (vertical cross-sections of initial tracers) in the JMA-RATM. Left: without wind effects based on Suzuki distribution. Right: with wind effects in this research. Colors indicate the logarithmic grain-sizes of tracers.

Bayesian Estimation of Volcanic Ash Plume Height by Weather Radar Network

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In order to make an initial condition of volcanic ash fall forecasts, Japan Meteorological Agency (JMA) basically uses volcanic ash plume height observed by highly sensitive cameras. This method has a disadvantage that, in the case of poor visibility, volcanic ash plume height would not be determined by the visual observation. In such a circumstance, volcanic ash plume detection methods using remote sensing technology such as weather radars are desired. Since weather radar uses a radio wave, volcanic ash plume can be detected in the case of cloudy weather. However, it should be noticed that single polarization radars, such as JMA weather radars, are not useful at rainy conditions.

The authors analyzed a case of the eruption at Mt. Ontake, and concluded that JMA radar echo height showed an over-estimated value compared to the ash plume height deduced from a photo taken at Mt. Aino. Since the data observed by Tokyo radar had a bias because of an anomalous propagation, the composite radar echo height was over-estimated.

To estimate volcanic ash plume height more accurately, the authors introduce a Bayesian estimation method. The procedure to estimate a volcanic ash plume height is as follows: 1. assume that a probability density function (PDF) of each radar echo height follows a normal distribution; 2. multiply the prior probability by the PDFs; 3. normalize the composite PDF. Moreover, Bayesian updating can make the prior probability better. Using the Bayesian method, we can eliminate effects of anomalous propagations. The disadvantage of this method is that, in the case of fewer radar coverage, we can't get accurate estimation. In such a case, the prior probability become more important.

In this presentation, preliminary results of the method will be shown.

Keywords: Volcanic Ash Plume Height, Weather Radar Network, Bayesian Estimation

Real-time data assimilation of radar-based volcanic ash data in an atmospheric transport model

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Improving the forecasting accuracy of volcanic ash and speeding up the issuing of volcanic ash advisories is vital not only for world aviation but also for people living in volcanic areas. In Japan, the Tokyo Volcanic Ash Advisory Center (VAAC) is responsible for atmospheric volcanic ash forecast in civil aviation flight paths. For this purpose, we developed an atmospheric transport model: the JMA-GATM.

The JMA-GATM uses the volcanic ash source function of Suzuki (1983), which uses assumptions of size distribution, shape of ash clouds, etc. The model shows good performance, but still has the room for improvement in volcanic ash source as initial condition.

We plan to start radar observation of volcanic plume of the Sakurajima volcano from March 2016. The observational data will be assimilated into the model to improve the initial conditions which is essential for realistic forecast.

We have selected the three-dimensional variational method (3D-var) from several data assimilation methods. The 3D-var is a low-costs and speedy methods, and can create initial conditions soon after an eruption occurs.

In this system, analysis variables are density of ash and size distribution parameters (median particle size and dispersion) which are independent of each other. It is assumed that observation error covariance is diagonal. Another important parameter is background error covariance, where the relationship between correlation and distance has the gaussian form.

We use the eruption source model or forecast value as the first guess in 3D-var. Because there is no value of size distribution parameters at the grid points where there is no ash, near first guess or observation values are interpolated.

Currently, we are validating the assimilation system using hypothetical radar observation data, we are developing and checking validation of the data assimilation system.

Acknowledgments
This study was supported by the Earthquake Research Institute Cooperative Research Program.

Keywords: data assimilation, Atmospheric Transport Model, radar, volcanic ash, numerical simulation

An algorithm for detecting the onset of volcanic eruption from digital images

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Near real-time monitoring of active volcano is necessary for understanding of eruption mechanisms and mitigating of volcanic disaster. However, volcanic eruptions usually restrict access to the near-crater, which prevent scientists from setting or repairing observation devices. We aim for realizing volcanic plume observations using digital images taken from an unmanned-copter-portable device, which could be placed at a new observation point around crater in spite of dangerous volcanic activities. In this study, we developed an algorithm for detecting the onset of volcanic eruption and discriminating volcanic plume from the images. We also validated the algorithm on the images of the Aso volcano eruption on 14 September, 2015.

This algorithm is organized in two steps: detection of eruption onset and discrimination of volcanic plume areas. First, newly defined three parameters that represents scattering properties on the sky (the intensity index, small particle index, and molecular index) are calculated from the RGB (red-green-blue) digital counts of digital images with JPEG format. Empirical thresholds of six parameters including the three indices and RGB counts can roughly discriminate cloud parts, clear sky parts, and volcanic plume parts from the images. The time derivative of the volcanic plume area calculated from the succeeding images can detect an onset of eruption. Second, once an onset of eruption is detected, the pixels detected as volcanic plume gives the most appropriate threshold for detecting volcanic plume part based on statistical features in the six parameters. The detection of volcanic plume with optimized threshold is more accurate than the first discrimination based on empirical thresholds, since optimal thresholds can avoid misclassification of volcanic plumes and perform well under various solar conditions.

We applied the algorithm to the images of Aso volcano eruption captured by JMA (from 09:04 to 10:08 JST in 2 minutes, on 14 September, 2015). Until 09:44, continuous white plumes have been observed, and all the area of analyzed images have been illustrated as blue color indicating normally active. On the other hand, the algorithm detected the onset of eruption at 09:46 when explosive gray plume was observed, and the volcanic plume part and the other parts were shown as red and white, respectively. These continued as long as the volcanic plume part was above sequential calculated threshold. When the volcanic plume covered the image, the time derivative of volcanic plume part fell below the threshold, resulting in blue. This analysis shows that the algorithm appropriately detected the change of eruption style from the continuous white plume to the explosive gray plume based only on digital images. Additionally, the analysis time is a second per an image, which is applicable for near real-time monitoring.

We have already developed the device equipped with a digital camera which can be load on an unmanned multi-copter. Therefore, we plan to analyze the images captured by the device using the algorithm and validate the volcano observation system.

Keywords: volcanic plume, digital camera, near real-time

Numerical simulations of a two-layer shallow-water model for pyroclastic flows by column collapse

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Pyroclastic flow is one of the most hazardous volcanic phenomena. During explosive volcanic eruptions, a mixture of volcanic particles and gas is ejected from the volcanic vent and develops an eruption column. When the eruption column collapses, the mixture falls to the ground and produces pyroclastic flows that propagate as gravity currents. Pyroclastic flows are characterized by strong density stratification, consisting of a dilute flow in the upper region and a dense flow in the lower region. The dynamics of pyroclastic flows is affected by physical processes within each of the dilute and dense parts, such as basal friction and entrainment of ambient air in the interfacial surface. It also depends on the particle transport between the dilute and dense parts. We aim to understand these effects on pyroclastic flow dynamics using numerical simulations.
We have developed a two-layer model to describe the gravity current which has a strong density stratification. In this model, each of dilute and dense parts is assumed to be uniform in any vertical section and is formulated as shallow-water equations. The equations are numerically solved by the finite volume method using the HLL scheme. In the dilute part, the effects of settling of particles, entrainment, and the interfacial drag between the dilute and dense parts are taken into account. In the dense part, the effects of basal friction, sedimentation, and the particle supply from the dilute part are included. In addition, to reproduce the dynamics of gravity current, the balance between the driving force and the resistance of ambient at the flow front should be correctly expressed in the model. In the dilute part, the balance is solved as a boundary condition with the Froude number proposed by Huppert and Simpson (1980). In the dense part, the balance is approximately calculated by setting a thin artificial bed ahead of the front.
We performed numerical simulations for a release of stationary fluid consisting of the dilute part in the rectangular-lock domain on a horizontal ground surface. As a result, the expansion of dilute part, the development of dense part below the dilute part, and the deposition of particles on the ground were reproduced. In addition, the behavior of pyroclastic flows is classified into two regimes: the regime where the dilute part always reaches the head of the flow and governs the total propagation of the flow, and the regime in which the dense part outruns the parent dilute part. The results of our parameter study indicate that which regime can occur mainly depends on particle size. When the currents contain fine-grained particles, the total propagation is dominated by the dilute part. This is because the lower particle-settling velocity of fine particles reduces particle transport from the dilute part to the dense part so that the development of the dense part is limited. When the currents contain coarse-grained particles, owing to a higher particle-settling velocity, particle transport from the dilute part to the dense part becomes substantial, so that the development of the dense part is enhanced. When the dense part becomes thick, it can outruns the parent dilute part. The difference of these regimes determines which one of the two parts forms the lowermost part of the deposits, because the lowermost part of the deposits is formed by the preceding flows. Therefore, the difference may explain the diversity of depositional facies formed by pyroclastic flow.

Keywords: pyroclastic flows, shallow-water model, two-layer model, numerical simulation, volcanic column collapse, pyroclastic flow deposits

