Japan Geoscience Union Meeting 2014
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SVC55-P01 Room:Poster Time:May 1 18:15-19:30

Ground Deformation of Active Volcano in Kunashiri and Etorofu Islands using InSAR time series analysis

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ALOS has an L-band SAR (PALSAR), which is not affected by vegetation, and the interference is good even in mountainous areas. So these methods are effective for the crustal deformation observation of volcanic areas.

In previous studies, we have reported the analysis results about all domestic active volcanic areas, using D-InSAR of ALOS since 2007. However, ALOS has suspended the operation in May 2011. Therefore, we did not do D-InSAR analysis for the period thereafter. In recent years, InSAR time series analysis technique called PS-InSAR and SBAS has been developed, a number of cases have been reported.

There are 11 active volcanoes in the Kunashiri and Etorofu island, Southern Kuril Islands. It has still continued an active volcanic activity in the some volcanoes of them. In this report, we have take advantaged of the archive data of ALOS/PALSAR, and tried to analyze the ground deformation of around these 11 active volcanoes using *StaMPS* program was developed by the Stanford Institute of Technology. Note, we analyzed except for the data captured in the winter in order to remove the effect of the snow. Also, besides PS-InSAR and SBAS methods, *StaMPS* program has the analysis methods to merge these results. Therefore, we will also present about the difference of these results.

Some of PALSAR data were prepared by Japan Aerospace Exploration Agency (JAXA) via the Coordinating Committee for the Prediction of Volcanic Eruption (CCPVE) as part of the project "ALOS Domestic Demonstration on Disaster Management Application" of the Volcano Working Group. Also, we used some of PALSAR data that are shared within PALSAR Interferometry Consortium to Study our Evolving Land surface (PIXEL). PALSAR data belongs to Ministry of Economy, Trade and Industry (METI) and JAXA. In the process of the InSAR analysis, we used "the ASTER Global Digital Elevation Model" was developed jointly by METI and the United States National Aeronautics and Space Administration (NASA), and Generic Mapping Tools (P.Wessel and W.H.F.Smith, 1999) to prepare illustrations.

Keywords: InSAR time series analysis, Ground deformation, ALOS/PALSAR, Domestic active volcano

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SVC55-P02 Room:Poster Time:May 1 18:15-19:30

Preliminary result of resistivity modeling around Ponmachineshiri crater at Meakandake Volcano, Japan

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Meakandake Volcano, situated in Eastern Hokkaido, Japan, is an active volcano where a phreatic eruption occurs in every several years. Volcano-tectonic (VT) earthquakes mainly occurred below Ponmachineshiri crater which is one of active craters of the volcano (Japan Meteorological Agency, 2013). A source region of the tremors occurred before the 2008 eruption was estimated beneath the southern slope of the crater (Ogiso and Yomogida, 2012). Significant changes in the geomagnetic field were observed in 2008 and 2009 around the crater. Hashimoto et al. (2009) pointed out that the temporal variations of the geomagnetic field in 2008-2009 were due to the thermal demagnetization of the material beneath the southern slope of the crater.

These VT earthquake, tremor and rock demagnetization events probably associated with the movement of volcanic fluids such as hydrothermal water, gas and melt. Therefore, understanding of a hydrothermal system of the volcano is a key to reveal the mechanism of the tectonic events occurred there.

Resistivity of rock strongly depends on the fluid inclusion. Therefore, an electro-magnetic measurement is an effective method to image the fluid distribution. We conducted audio-frequency magnetotelluric (AMT) surveys in August 2013 on the western slope of the volcano. The objective of the survey is to reveal the resistivity structure around Ponmachineshiri crater and to infer the relationships among the fluid distribution, the seismic focal area, and the demagnetized area around the crater.

Since we have not finished the AMT survey on the eastern slope of the volcano yet, the resistivity structure around the Ponmachineshiri summit crater is not well-constraint. Therefore, we present the two-dimensional resistivity structure beneath the western slope of the volcano as a preliminary result. The characteristics of the resistivity distribution are described as follow.

1) A resistive (more than several hundred Ω m) layer locates at the top of the western slope of the volcano. Its thickness varies from 100 to 300 m on the profile. This layer can be regarded as a permeable lava or pyroclastic fall deposits.

2) Below the resistive surface layer, two conductive (less than 10 Ω m) bodies are found. One is located to the west of Ponmachineshiri crater at depths of 300-1000 m from the surface. This conductor corresponds to a hydrothermal reservoir which relates to the fumarolic activity in the crater. The second conductor is found beneath the western part of the profile at a depth of about 1000 m from the surface. The discharge of hot spring water at the west of our survey region suggests that this conductor can be explained by the presence of the hydrothermal fluid and/or the altered rocks.

3) A resistive area (more than several hundred Ω m) exists below the two conductors. Causes of this high resistivity are unknown yet.

Keywords: resistivity structure, Meakandake Volcano, volcanic fluid

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SVC55-P03 Room:Poster Time:May 1 18:15-19:30

Variation of Geomagnetic Total Intensity at Meakandake Volcano after the Eruptions in 2008

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This study reports on the geomagnetic total intensity change at Meakandake volcano and its relations with volcanic activity after eruptions in 2008.

Meakandake volcano is located in eastern Hokkaido and is a volcanic complex which consists of eight volcanoes, such as Ponmachineshiri, Nakamachineshiri, Akanfuji and so on. Ponmachineshiri has been active in recent years and minor phreatic eruptions repeatedly occurred in 1988, 1996, 1998, 2006 and 2008.

Kakioka Magnetic Observatory, Japan Meteorological Agency has carried out a repeat observation of the geomagnetic total intensity in one or two times a year since 1992 for the purpose of detecting geomagnetic field changes accompanying the volcanic activity of Meakandake volcano. Twelve repeat stations were installed on the east side of summit crators' edge and south slope of Ponmachineshiri in 1992 and since then we have improved the repeat station network step by step. About thirty stations are used recently. A continuous station of the geomagnetic total intensity (MEA) was installed on the south slope of Ponmachineshiri on October 16, 2003 in order to improve the time resolution of the observation. Then, a new continuous station (ME2) was installed between the 96-1 crater of Ponmachineshiri and MEA on September 28, 2013. The geomagnetic intensities are acquired every 5-minutes at MEA and ME2.

A significant decrease of the geomagnetic total intensity was observed at Meakandake volcano in July, 2013 and continues up to now (January, 2014). The total intensity varied with the eruptive activity in 2008, and no remarkable change of the total intensity was seen for thirty months from January 2011 to June, 2013. There has been no significant variations in volcano-tectonic earthquakes, tremors, volcanic smoke and tectonic deformation at Meakandake volcano since July, 2013 (Volcanic Observations and Information Center, Sapporo District Meteorological Observatory, JMA), which differs from the situation at the 2008 eruptions when significant variations of the total intensity and the other tectonic measurements were observed.

It is assumed that the decrease of the geomagnetic total intensity at Meakandake volcano in 2013 is due to the thermal demagnetization accompanying heating of the inside of the volcanic body. A source of the thermal demagnetization was estimated beneath the southern slope of the 96-1 crater at Ponmachineshiri by using geomagnetic total intensity changes at repeat stations for about 3 months from June to September, 2013. This source location is almost the same as that of the demagnetization in 2008. And it is inside the focal area of migrating volcanic tremors which occurred on November 16, 2008 reported by Ogiso and Yomogida (2012). We used MaGCAP-V (Seismology and Volcanology Research Department, Meteorological Research Institute, JMA, 2013) as a support software for the modelling of the demagnetization source.

It is indicated that the position of the thermal demagnetization source has not changed for last four months, because the difference of the geomagnetic total intensities at two continuous stations (MEA and ME2) has been almost constant since the end of September, 2013.

Only the geomagnetic total intensity detects a possible on-going heating process inside the Ponmachineshiri which commenced in July 2013. This case strongly suggests that the observation of the geomagnetic field is important to monitor heating or cooling of the volcanic body. The observation with two or more continuous stations is effective in order to monitor the source position of the thermal demagnetization. In addition, Hashimoto *et al.* (2009) suggested a possibility of the volcanic eruption prediction at Meakandake volcano, because a decrease of the geomagnetic total intensity was observed two days before the eruption on November 18, 2008 when the amplitude of the volcanic tremors had been increased.

Keywords: Meakandake, geomagnetic total intensity, volcano, eruption, thermal demagnetization

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SVC55-P04 Room:Poster Time:May 1 18:15-19:30

Recent volcanic deformations observed by campaign GPS on and around Mt.Tokachi and Mt.Meakan

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Mt. Tokachi is one of the famous active volcanoes located in the central Hokkaido, Japan. In the recent 100 years, major magmatic eruptions at Mt. Tokachi occurred in 1926, 1962 and 1988-1989. Mt. Meakan sits in the eastern Hokkaido. It is also an active volcano and made phreatic eruptions in 1996, 1998, 2006 and 2008.

In this study, we will discuss the results of the campaign GPS on and around Mt. Tokachi and Mt. Meakan. Each broad area GPS observation had begun at Mt. Tokachi in 2007 and at Mt. Meakan in 2006. The campaign GPS observation for Mt. Tokachi made at 12 sites and that for Mt. Meakan at 8 sites, for several days to weeks in each year.

We used the data of our campaign observations since 2007 for Mt. Tokachi and after the 2008 eruption for Mt. Meakan. For evaluating spatial deformation pattern in more detail, we also used the data of several GPS sites operated by JMA (Japan Meteorological Agency) at the same time. Analyzing these data, annual movements at those stations were estimated. The regional tectonic movement and the coseismic step of Tohoku-oki earthquake on March 11, 2011 are included in those movements. We used the continuous data at GEONET sites by Geospatial Information Authority of Japan (GSI) around the volcanoes to make corrections for non-volcanic deformations. Using the GEONET data from 2007 to 2013, the regional tectonic and the seismic deformations were estimated by linear approximation in space. Seasonal changes should be taken into consideration to study the volcanic deformation. The discussion about deduced volcanic deformations will be made, after the corrections about the regional deformation, the coseismic step and the after slip of 2011 Tohoku-oki earthquake, and the seasonal variations.

Acknowledgements

In this study, JMA, Sapporo District Meteorological Observatory furnish their observation data to us. We would like to express our gratitude to them. Also, we used the data of GEONET sites of GSI with thanks.

Keywords: Mt. Tokachi, Mt. Meakan, volcanic crustal deformation, GPS

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SVC55-P05 Room:Poster Time:May 1 18:15-19:30

The Volcanic activity of Tarumaesan Volcano in 2013 and Trial of Application to the Eruption scenario

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Continuous observation network with tiltmeter and strainmeter in Mt.Tarumae, which is located on the southeastern edge of Shikotsu caldera, operated by Japan Meteorological Agency (JMA) and Hokkaido University Institute of Seismology and Volcanology (ISV) detected volcanic ground deformation during June 19 to July 4, 2013. According to the Mogi model (Mogi, 1958), the ground deformation is interpreted as volume increase of about $10^5 m^3$ at about 3-4km in depth beneath sea level around Mt.Kitayama, is located in about 1.5km northwest from Tarumae summit. It is different from the deformation in shallow region (above the sea level) beneath the summit, reported by MRI (2008), the Meteorological Reaearch Insutitude, and ISV et al.(2011). According to the classification suggested by MRI (2013), it is correspond to slowly accumulation process of magma, as magma chamber or dike intrusion. B-type earthquakes, have been occurred in shallow region (˜sea level) beneath the summit, became active slightly in synchronization with the ground deformation. As a result of the process of volcanic fluid, the actual medium is unknown, rise to the volume increase area (depth 3-4km), it is interpreted as an increase in heat flux to shallow region beneath the summit.

Volcano-tectonic earthquake (VT earthquake) activated at a depth of 3-5km surrounding the deformation area in mid-July, after ground deformation, it is still ongoing. The VT seismicity was very active until August and maximum shock was M3.0 in late September. VT earthquakes have occurred in the relative high resistivity layer (50-500Ωm) of Resistivity imaging by Yamaya et al. (2005, 2012). Whereas, it have not occured in the deformation area and the path to beneath Tarumae summit, that is relative conductive area.

Order to carry out disaster prevention appropriately and promptly in the eruption, JMA has operated the eruption alert level on 31 volcanoes across the country. It is intended to share the consciousness of the local government by flow assuming the transition of volcanic activity, called the eruption scenario. For operating the level effectively, the eruption scenario, flow chart assuming the progress of the volcanic activity of each volcano, has been shared with the local government. As lastest magma eruption is in 1909, major volcanic activity had been occured in the very shallow part around lava dome for a long time. It is unknown what the phenomenon is observed when the magma is supplied to the shallow depth from the deeper. Therefore, the scenario that assumed the magma eruption is supplemented by the general knowledge that was observed at other volcanoes. The mechanism of the deformation and VT-seismicity is not clear. But, it can be considered of the distribution that related to the heat supply system or the geological structure beneath Tarumae. In this study, we tried to apply the interpretation of the ground deformation and VT-seismicity to the eruption scenario. However, our interpretation on the activity is unverifiable evidence so poor at present. In order to improve the eruption scenario certainly, elucidation of the magma supply system in Tarumae is essential, but it is not clear at present. To clarify the magma supply system, it is necessary to more information of geological structures and obseved results such as ground deformation and VT-seismicity in this time. However, we are at present able to investigate detection of the high attenuation region used natural earthquake and to estimate fault plane solutions of VT earthquake (P-axes) using P-waves, and would like to approach. In addition, it is necessary to operate new observation system to capture phenomena such as seismic activity and ground deformation more certainly due to magma rising from the deep.

Acknowledgment:In this study, we use the data of ISV, tiltmeter and strainmeter, and the waveform data. Thank you for permission to use data.

Keywords: tarumae, volcanic activity, eruption scenario, ground deformation, VT seismicity

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SVC55-P06 Room:Poster Time:May 1 18:15-19:30

Volcanic activities of Hakkoda volcano after the 2011 Tohoku-Oki earthquake

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The 2011 Tohoku-Oki earthquake of 11 March 2011 is one of the largest earthquakes in recent times, and it generated large displacements and deformation in and around the Japanese islands. Such large crustal deformation, especially the east-west extension exerted on Tohoku area, raises fear of further disasters including triggered volcanic activities as well as triggered seismicity. To assess the potential risks of triggered volcanic activities, understanding of the behavior of volcanic fluids in the crust and volcanic bodies would be a key. In this presentation, as examples of such possibly triggers volcanic activities, we report the recent seismic activities of Hakkoda volcano, and discuss the relation to the movement of volcanic fluids.

Hakkoda volcano is a group of stratovolcanoes at the northern end of Honshu Island, Japan. There are fumaroles and hot springs around the volcano, and phreatic eruptions from Jigoku-numa on the southwestern flank of Odake volcano, which is the highest peak in the main cones of Northern-Hakkoda volcanic group, were documented in its history. Since just after the occurrence of Tohoku-Oki earthquake, the seismicity around the volcano became higher, and the migration of hypocenters of high-frequency volcano-tectonic (VT) earthquake was observed.

In addition to these VT events, long-period (LP) events started occurring beneath Odake at a depth of about 2-3 km from February, 2013, and subtle crustal deformation caused by deep inflation source was also detected by GEONET GNSS network around the same time. The characteristics of LP events are summarized as follows: (1) The spectra of LP events are common between events irrespective of the magnitude of events, and they have spectral peaks at 6-7 sec, 2-3 sec, 1 sec, and so on. (2) The long-period component of LP events appears as a wave packet of a few cycles, and high-frequency ($>$1 Hz) signals sometimes overlaps it. (3) LP events sometimes occur like a swarm with an interval of several minutes. These characteristics of LP events at Hakkoda volcano are similar to those of LP events at other active volcanoes and hydrothermal area in the world, where abundant fluids exist. Our further analysis using far-field Rayleigh radiation pattern observed by NIED Hi-net stations reveals that the source of LP events is most likely to be a nearly vertical tensile crack whose strike is almost parallel to the direction connecting Odake summit crater and Jigoku-numa. The number of VLPs gradually decreased after September, 2013, and high-frequency VT earthquakes became more dominant in the seismicity around Hakkoda volcano. However, there were a burst of earthquakes beneath Southern-Hakkoda volcanic group, that includes a few low-frequency earthquakes, at the end of December, 2013.

These results suggest that the extensional steress field generated by the 2011 Tohoku-Oki earthquake causes the upward movement of volcanic fluids and heat from the deep, and results in an activation of hydrothermal activities at the pre-existent fracture zone at Hakkoda volcanic group.

Acknowledgment: We used Hi-net data provided by the National Research Institute for Earth Science and Disaster Prevention.

Keywords: Volcanic earthquakes, Volcanic fluids, Geofluids, Long-period events

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SVC55-P07 Room:Poster Time:May 1 18:15-19:30

New knowledge of eruptive sequence in Heian eruption of Towada volcano

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1. Introduction

Heian eruption is the latest activity at Towada volcano, in Heian period (eruptive episode A : Hayakawa,1985). This eruption has been started from Nakanoumi caldera lake (Kudo,2010) filled with lake water, and repeated magmatic and phreatomagmatic eruption alternately. The details of the eruptive sequence have already been shown by Hiroi and Miyamoto (2010), however, we got and report new knowledge about the activity of first plinian phase and the occurrence mechanism of large pyroclastic flow unit.

2. Ash layers within unit OYU-1

The first plinian pumice fall unit OYU-1 has a SW dispersal axis and it achieves 50km farther. OYU-1 in distal shows very well sorting and uniform grain size distribution , but we found plural outcrops that OYU-1 accompanies with fine ash layers within 12km from source vent. Two kinds of ashes are observed, one is a beige colored ash in the lower part of OYU-1. The thickness is about 1-8 cm, and dispersal area is SW-SSE. Others are gray colored ashes and intercalated in the upper part of OYU-1. Their thicknesses are about 1-3 cm, and each dispersal area is SW-SSW.

All of ashes are intercalated in pumice layer, and the boundary between pumice layer and ash one is almost clear. Because OYU-1 without ash layers in distal shows uniform grain size distribution, the extent of these ashes deposit is limited in narrow area if their ash had been accumulated during the plinian column formation. The clear boundaries between pumice and ash suggest that ash layers are not fall deposit accumulated for a long period, but flow deposit piled in a very short time. Ash layers can be found not only a valley, but the little highland such as a mountain ridge line. This feature of distribution shows that they are regarded as surge deposit.

Because the ashes intercalated with pumice layer in OYU-1indicate the feature of density current, they are intra-plinian flow. As one of their origin these ashes are derived from small-scale density current by the partial column collapse. The dispersal area of the ashes is limited adjacent to source vent and just only the direction of dispersal axis. This tendency of distribution seems that it corresponds with the direction of strong wind of 22[m/s] blew.

On the other hand, the source vent within a caldera lake and the fine grain features of ashes indicate a possibility that ash layers are phreatmagmatic base-surge deposit. In that case the occurrence of magma-water explosion might be caused by satisfying a condition of magma-water ratio partially or temporarily on the surface of eruption collumn. Unit OYU-2, overlying OYU-1 pumice fall directly, is phreatomagmatic base-surge deposit. Thus these ash layers may be a precursor phenomenon of eruptive style transition.

3. Distribution and draining style of KPf

Kemanai Pyroclastic flow is the climax deposit of Heian eruption, the total volume is estimated about 5km3(Hayakawa,1985). KPf distributes only the south area of Towada caldera, except for Oirase River to east direction. The Towada caldera rim is lowest at southwest edge (630m above sea level). The highest outcrop of KPf on caldera rim is located in 760m. In spite of adjacent to the source vent KPf cannot be shown on Mt. Akaiwa(785m) on the south caldera rim. These distribution features suggest that KPf flew out over the lower part of caldera rim. KPf deposit has been regarded that it occurred by plinian column collapse of preceded unit OYU-3 (Matsu-ura et al.,2007,etc.). But the column collapse type pyroclastic flow can be accumulated in high-altitude, KPf seems to be piled on only lower portion. Thus KPf is not occurred by column collapse, but derived by currents over the lower caldera wall. This conclusion agrees with the new eruptive sequence by Hiroi and Miyamoto(2010), that the unit just before KPf is not plinian pumice fall OYU-3, but phreatomagmatic base-surge unit OYU-4 without higher eruption column.

Keywords: Towada volcano, Heian eruption, intra-plinian flow, Soufriere-type pyroclastic flow

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SVC55-P08 Room:Poster Time:May 1 18:15-19:30

Petrological study of northern part of ca. 300-100 ka volcanic edifices in Zao volcano.

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Zao volcano is a Quaternary stratovolcano located in the middle part of the volcanic front of northeast Japan arc. The volcanic activity started at about 800 ka, and has continued to present. During ca. 300 to 100 ka activity of the Zao volcano, several middle sized edifices were formed. These volcanic edifices can be divided into northern and southern parts. We performed petrologic study on eruption products of the northern part to reveal the variation of magma compositions along with the evolutionary history.

Eruption products are divided into 8 units from lower to upper: Yokokurayama lavas, Kanshodaira lavas, Jizosan west lavas, Kumanodake west eruption products, Kumanodake main edifice products, Jizosan east agglutinate and lavas, Kumanodake agglutinate and lavas, Umanose eruption products. Yokokurayama lavas, Kanshodaira lavas, and Jizosan west lavas are composed of andesitic lavas. Kumanodake west eruption products are consisted of andesitic lapilli tuff, tuff breccia, agglomerate, and andesitic lavas. Kumanodake main edifice products are consisted of alternation of andesitic lavas and pyroclastic rocks in the lower part, and andesitic tuff breccia and agglomerate in the upper part. Jizosan east agglutinate and lavas, Kumanodake agglutinate and lavas are consisted of basaltic andesitic agglutinate, agglomerate, and lavas. Umanose eruption products are mainly composed of basaltic andesitic lavas, with subordinate amounts of agglomerate.

The eruption center of the Yokokurayama lavas would be located westward from the main chain of eruption centers. The main eruption centers for the other units were located in between the Kumanodake-Jizosan area. Jizosan east agglutinate and lavas, Kumanodake agglutinate and lavas, Umanose eruption products are characterized by the agglutinate and/or agglomerate distributing near the eruption centers.

All of eruption products belong to medium-K calc-alkaline series. All units other than the Yokokurayama lavas are plotted on same general trends in most of the SiO_2 variation diagrams. The Yokokurayama lavas show a lower trend than the other units in K_2O diagram. Other than the Yokokura lavas, the lower four units are andesitic, whereas upper three units are basaltic andesitic. Looking at in detail, slight differences in compositions can be observed among units. Among the four andesitic units, Kumanodake main edifice products show higher trends in the Cr, Ni, Zr, Nb diagrams and a lower trend in Rb diagram than the others. The Umanose eruption products are plotted in higher part in Cr and Ni diagrams from the trends of the other products.

Keywords: Zao volcano, stratovolcano, eruption history, evolution of magma

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SVC55-P09 Room:Poster Time:May 1 18:15-19:30

Characteristics of data observed by multi-component strainmeter installed at Senba, Izu-Oshima

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Meteorological Research Institute installed a multi-component borehole strainmeter at Senba Station in Izu-Oshima, one of the most active volcanos in Japan, in February 2013. By the strainmeter, we aim to research on evaluation of volcanic activity by means of crustal deformation and also to monitor the activity of the volcano. In many cases, unavoidable drift were shown in data of strainmeter installed in a borehole from just after the installation for several years. In order to utilize the strainmeter for volcano monitoring effectively, it is important to grasp the drift and noise quantitatively from early stage of observation. We report a result of research about characteristics of the data observed for about a year.

The strainmeter has 4 sensors which measure linear strains in the horizontal plane in every 45 degrees. In data observed by the sensors, tidal variation of about a day or half day period over 500 nano-strains is obvious, as well as a long term variation. Generally only three components are independent in a plane, the strainmeter has redundancy and it makes us possible to evaluate quality of the data. Examining hourly mean values, all strain components look consistent in the period range of a day or half day. It suggests the data of strain are reliable in the period. On the other hand, the long term variation has an inconsistency as much as 4 micro-strains for 6 month. The inconsistency could be caused by only one sensor of the four, it is difficult to conclude what amount of volcanic deformation is observed at the present stage. In the periods shorter than a half day, almost all variation is less than 2-3 nano-strains. It indicates the accuracy of observation for a short interval.

Keywords: Izu-Oshima, Monitoring of active volcano, Strainmeter, Ground deformation

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SVC55-P10 Room:Poster Time:May 1 18:15-19:30

Gravity changes during magma accumulation period in Izu-Oshima volcano

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Since March, 2004, we have been conducting series of campaign gravity measurements, in order to understand magma accumulation process and to detect eruption precursor of Izu-Oshima volcano. Here, we show calibration results of relative scale factors between gravimeters, and characteristics of temporal gravity changes observed in the volcano.

We have been measuring relative gravity changes in the volcano using three instruments; LaCoste & Romberg Type-D #109, Scintrex CG3M #454, and Scintrex CG5 #033. Gravity differences in our campaign network are about 180 mgal in maximum from the coastal sites to the summit sites. Such large differences easily induce systematic deviations between data obtained by different instruments, when gravimeter scales are not calibrated. Further, temporal changes in the scale factor of Scintrex CG3M have been reported by some previous gravity researches.

Since scale calibrations using absolute gravity networks had not conducted until 2012, we cannot absolutely calibrate for past data. However, we can check relative scales between gravimeters and their temporal changes by comparing campaign data obtained simultaneously. The scale factor for CG3M#454 relative to one for D#109 shows clear temporal decrease. One for CG5#033 also shows change at breakdown occurred in 2010. This can be explained by a parameter change done by the maker during repairing processes. Furthermore, we found a non-linear relationship between D#109 and CG5#033, which implies a non-linear scale factor of either instrument. Probably, the non-linearity occurs in LaCoste & Romberg Type-D, and we should calibrate further.

Although calibrations of each instrument are still not sufficient to discuss smaller gravity changes down to c.a. 10 micro-gal, we can find systematic temporal changes in relative gravity by correcting relative scale factors. Gravity increases at higher altitude sites relative to coastal sites are observed during a two-year period from July, 2008 to June, 2010. Temporal changes in relative gravities reaches up to 100 micro-gal in maximum. A spatial pattern of the changes suggests its center is at the northern caldera, which implies some relationship with ground deformation sources inferred by GPS data. However, both the amplitudes and phases of the relative gravity changes can never be explained by the ground deformation observed during the period. The change seems to be related to temporal changes in precipitation. Increase in water content in vadose zone may be one of possible factor of the changes. Apart from these candidates, we tentatively inferred source location and mass increase by assuming single point mass source. The best fit location after grid searches was at depth of 3 km b.s.l. beneath the northern caldera, where approximately coincides with the ground deformation source. However, the estimated mass increase is as much as 1.8×10^{8} ton, which is equivalent to erupted materials of one large scale eruption of the volcano. It is difficult to accept easily such large amount of mass increase without any another significant signs. To detect signs of magmatic activities and to evaluate volcanic activities appropriately by gravity measurments, it is important to calibrate instruments further and to evaluate effects of environmental factors such as precipitations.

Keywords: Izu-Oshima volcano, gravity change, ground deformation

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SVC55-P11 Room:Poster Time:May 1 18:15-19:30

Preparation for the practical use of unmanned observation robots in the next Izu-Oshima eruption

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In the case of a volcanic eruption, in order to carry out evacuation guidance, it is important to observe the changing situation from just after the eruption to the completion of evacuation. In the 1986 eruption of Izu-Oshima, the explosive eruptions occurred at the unexpected points such as caldera floor and outside of a caldera. Therefore, volcanologists could not approach the vents and the opportunity of observation to gain the precious data for scientific understanding of the eruption phenomenon or disaster mitigation was lost. Moreover, during the evacuation from the island, the situation of the eruption had not been announced correctly to residents, and the mistaken information that the lava flow cut off the traffic between Okada-Motomachi was spread. Today, 20 years or more pass since a previous eruption in Izu-Oshima, and it has become the time to prepare the next eruption. In order to improve the situation at the time of the next eruption, development of the new observation robot which can respond immediately to an eruption and the establishment of an operation framework are required. From such a viewpoint, the author started Izu-Oshima Unmanned Observation Robot Symposium in 2009. This symposium is intended to bring together experts developing unmanned observation robots from different study fields such as volcanology, space engineering, and disaster relief to Izu-Oshima and to provide them the opportunity of field tests and exchange of knowledge to make them accelerate the development of the robots and the establishment of the operation framework. For these four years, many participants gathered to perform field test and to have an active information exchange. 8 UGV and 2 UAV from 9 research groups (2009), 5 UGV and 2 UAV from 5 groups (2010), 13 UGV and 3 UAV from 9 groups (2011), and 13 UGV and 6 UAV from 10 groups (2012) participated in the symposium. In the 2013 fiscal year, Izu-Oshima was hit by the 27th typhoon of the year just before the symposium. While an open lecture meeting was canceled, 5 UGV and 1 UAV from 6 groups performed field tests. In the 2013 fiscal year, we started to obtain an accommodation of the research funds for this activity from the specific joint research B of Earthquake Research Institute of the University of Tokyo. Furthermore, installation of volcano monitor cameras was also begun by inhabitants' cooperation. At the presentation, the results so far and a future view will be shown. For further detail of the symposium in the current fiscal year please refer to the following URL (http://www.volcano-robot.org/index.html). Izu-Oshima monitor camera can be accessed by the following URL (http://www.volcano-robot.org/oshima_camera/monitor_top.php) .

Keywords: Izu-Oshima, unmanned observation robot, robot, Miharayama

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SVC55-P12 Room:Poster Time:May 1 18:15-19:30

Pressure sources of Miyakejima volcano estimated from crustal deformation

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Miyakejima volcano had deflated after the 2000 eruption. The deep region of the volcano has inflated since 2006 (JMA, 2013). It suggests magma accumulation for future eruptions. JMA, GSI, JCG and NIED independently observe crustal deformation using GPS. However, the observation networks are not enough to reveal the magma accumulation model.

A dense GPS campaign observation started in Miyakejima from 2011 associate with Kyushu University, University of Tokyo, Nagoya University and NIED. New GPS observation points have been established every year to improve spatial resolution of crustal deformation and estimation of the magma source parameter. In 2013, our observation network are constructed 21 points in total including new two points near summit crater where no observation after the 2000 eruption.

By assembling all the continuous GPS data that has been observed by each institution, and our observation data, integrated processing was made so as to measure the precise crustal deformation on the island for two years in 2011-2013.

As the result, the obtained deformation in this study indicates inflation in the south region of Miyakejima and deflation around the crater. The estimated magma sources are a shallow deflation sill source under the crater, a southern inflation dyke source and a deep inflation spherical source. Ozawa & Ueda (2011) estimated a flat source under the caldera using InSAR technique. The parameters of this model are consistent with our sill model. Further, only deep spherical inflation source estimated in prior studies cannot be described the observed deformation during this period. We think the supply of magma began to new inflation dyke source from deep spherical inflation source. In order to monitor the inflation source, it is necessary to enhance the southern observation network and obtain more detailed geodetic data.

Keywords: GPS, Miyakejima, Crustal deformation, Volcano, Magma chamber

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SVC55-P13 Room:Poster Time:May 1 18:15-19:30

The products of 2012-2013 mud eruption event at Million Dollar Hole crater, Ioto volcano

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Explosive eruptions occurred several times in the period from February 2012 to April 2013 at the Million Dollar Hall crater in Ioto (Iwo Jima) Island. The situation of eruptions and properties of the ejecta are summarized as follows.

At the eruption occurred in the duration from 7 to 9 February 2012, muddy volcanic ash were erupted from vents arranged NNW-SSE direction. The main vents were consist of follows. Vent A that occurred within the existing crater (25m in diameter, approximately 10m deep) at south-southeast side, vent C that was occurred in center of the existing shallow crater (30m in diameter) at north-northwest side, and vent B that was probably newly formed between the two. Thickness of ejecta layer was 30 or 40 cm on rim of each vent. Because isopach contours are irregularly shaped, tephra are estimated that were emitted directionally from each vent. Then, small scale muddy volcanic ash release and steam plume activities was followed.

The eruption on 17 to 18 February 2013 was the largest. Muddy volcanic ash were erupted from the location of vent A and B, and fell on the western side. Thickness of ejecta layer are 1 to 3 meter on vent rim. Cinders and minor man-made Objects there were possibility of ballistic ejecta reached distant point approximately 220m at the maximum from the vents. After the eruption, vent A and B were combined into a single crater (35m in diameter, 17m deep). In addition, the formation of collapse crater about 40m in diameter began at the location of vent C.

The eruption on 11 April 2013 was occurred at the collapse crater (vent C). Muddy volcanic ash deposited on the southern side. The maximum thickness of ejecta layer is 45 centimeter on the vent rim. Ballistic cinders were witnessed at the eruption, but the limit of distribution was not estimated. Vent C was combined with vents A. Therefore, the whole shape of the crater became a cocoon (60m in major axis, 17m deep). Thereafter, the crater has remained in calm state.

Volcanic ash that erupted in the series of eruptions were wet at the ejection and deposition. They are composed mainly of hydrothermal alteration clay consisting of smectite and kaolin minerals and also includes large amount of lithic fragments, free crystals and volcanic glass fragments that are altered varying degree. In addition, pieces of glass and iron piece of man-made weaponry, which is said to have been abandoned after World War II. In addition, pieces of glass and iron which were derived from weapons abandoned immediately after World War II are also included. Ballistic cinders consists of such as tuffaceous sandstone, tuff and altered trachyandesite.

Eruptive volume of each eruption are estimated approximately as follows. The eruption in February 2012 is 800 m^3, the eruption on 17-18 February 2013 is 11,000 m^3, and the eruption on April 11, 2013 is 2,000-4,000 m^3. Total volume is 14,000 to 16,000 m^3 approximately. On the other hand, total amount of subsidence in this peroid is 10,000 to 15,000 m^3, it is roughly equal to the eruptive volume.

These eruptions are considered phreatic explosion that blew off strongly altered rocks surrounding the hydrothermal reservoir and shallow non- or weakly altered tuffaceous rocks. It indicates that the hydrothermal activity under Million Dollar Hole crater became active in relation to rapid crustal deformation that occurred in Ioto from early 2011 to May 2012.

Keywords: tephra, depositional structure, surface phenomena, eruption record

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SVC55-P14 Room:Poster Time:May 1 18:15-19:30

2013 eruption of Nishinoshima volcano, Ogasawara islands, Japan

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Nishinoshima volcano is a basaltic to andesitic maritime volcano on the volcanic front of the Izu-Bonin arc. For the first time ever, the submarine eruption including movement of vents and development and disappearance of new islands happened off the southeastern coast of the Nishinoshima island in 1973. The eruption stopped in May 1974 and the Nishinoshima island and the new volcanic islands were joined by sand drift in June. Then geographic changes was continued by erosion and sand drift till 1990s.

The eruption column and new volcanic island were firstly discovered by the airplane of Japan Defensive Force on 20 Nov. 2014. Then Japan Coast Guard found the new volcanic island with violent phreatomagmatic eruption. The following day, 21 Nov. 2013, phreatomagmatic eruption had occurred and volcanic edifice was developing. The eruption style changed into the Strombolian-type and lava started to flow from the vent on the eastern flank of main edifice on 22 Nov. 2013. In succeeding days, lava emerged from the western vent and pyroclastic cone was built up in the large crater in the center of main edifice. The vent of the pyroclastic cone effused blue-white volcanic gas consistently and spatter occasionally. On 24 Dec. 2013, new vent started to produce eruption colmun at the north of the central vent. These vents are located on the 1973 vents.

The new volcanic island consists of lava flow and water depth around eruption center may be almost constant, so growth rate of the island and magma supply rate should be equal. The growth rate estimated from the air photo is almost constant, hence the magma supply rate may be kept constant.

It is unclear that when did this volcanic activity start. But high temperature anomaly and difference of normalized water-leaving radiance within sea water are shown at the southern sea area in the satellite images published by the Earth Observation Research Center on Nov. 7. The volcanic activity may start on or before Nov. 7.

Future volcanic scenarios are uncertain, but volcanism is still active and shows no sign of end of eruption as of early-February.

Keywords: Nishinoshima volcano, volcanic island, Izu-Ogasawara arc, phreatomagmatic eruption, Strombolian eruption, maritime volcano

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SVC55-P15 Room:Poster Time:May 1 18:15-19:30

The recent volcanic activities of Mt. Asosan

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Mt. Asosan is one of the most active volcanoes in Japan.

In Mt. Asosan, volcanic tremor amplitude and volcanic earthquakes increased on September 2013. On November 2014, water level of crater lake decreased. On December 2014, volcanic tremor amplitude increased again and the emission rate of the SO2 increased. On January 2014, Mt. Asosan erupted. We report about recent volcanic activity of Mt. Asosan

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SVC55-P16 Room:Poster Time:May 1 18:15-19:30

Gravity variation near the crater of Aso volcano and gravity contribution of precipitation

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We investigated the gravity variation continuously measured near the active crater of Aso volcano. At the period of low volcanic activity, the gravity variation is dominated by a contribution of water mass movement arisen from percolation of rain water and discharge in a permeable layer under about 100m.

In this study, it is used a time series measured by a superconducting gravity meter, CT-200, which installed in Hondo tunnel under 30m located in about 1000m southwest of Nakadake first crater. An analysis period is for 3 years from February, 1998 to January, 2001. Aso volcano was quiet low active for this period. The hot lake in Nakadake first crater, Yudamari, which its state is an index of the volcanic activity, had been in high water level. There were no events of drying up and eructation of volcanic ash. The gravity variation removed tide and air response shows large seasonality, increasing 20 - 40 μGal at July and August after rainy season and decreasing gradually after that. It also has some minor changes in response to precipitation, for example, an increase of about 10 μGal after autumnal rain.

It is known that precipitation has an affect on gravity. However, the effect near the crater of Aso volcano did not well understand. We computed water flux by percolation into underground and water discharge from a permeable layer using a kind of physical model of storage function method known as tank model. Model input is amount of precipitation measured at Asosan meteorological station by Japan Meteorological Agency. The change of water volume contained in underground is computed from input-output difference of tank model. The gravity contribution is obtained from the corresponding density change in a region of 1400km in north-shouth and in east-west around the gravity meter with thickness from surface to 200m depth. It assumes that there is no gravity change by volcanic activity. Outflow resistance of a tank and permeable layer depth are decided so that the gravity contribution fits in the measured gravity variation as much as possible.

The gravity contribution of water mass movement by model computation is well coincident with the measured gravity variation in the case that rainwater percolates under 100m in vertically and is discharged horizontally from the permeable layer at 100 - 110 m depth. The model value correlates highly with the measured gravity value in the coefficient of 0.9. The root mean squares (RMS) are 10.5 μGal for the measured gravity and 11.4 μGal for the model computation, and 4.8 μGal for difference between the two. The model computation overestimates to a certain degree. It is considered for a reason of the discrepancy that percolation and ground water flow in general are complicate and non-linear phenomena in contrast to our linear model. However, the model computation represents sufficiently figures of the measured variation and explains it in accuracy of 14.4 μGal in 3σ RMS of the difference. The contribution of water mass movement in shallow underground to 110m depth is inferred to be main component of gravity change near the crater.

The water mass movement can be computed at any period of time. In this study, we obtained the gravity contribution under 30m where the gravity meter located in. Converting it to on ground, the model prediction is available for use in correction of values measured near the crater in the repeated gravity survey at Aso volcano area. A part of discharge from the permeable layer in the computing region is considered as a source of ground water flow into Yudamari. A seasonal peak of precipitation is for about a month from June to July, however the ground water flow continues for several months after rainy season. This is coincident with the seasonal water level change of Yudamari. It is expected to estimate a possible quantity of ground water flow into Yudamari as time variation.

Keywords: Aso volcano, Gravity, Water mass movement, Precipitation, Groundwater, Superconducting gravity meter

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SVC55-P17 Room:Poster Time:May 1 18:15-19:30

Thermal activities of the Nakadake first crater at Aso volcano, Japan -Unusual heat discharge events in 2012-2014-

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Aso volcano is one of the most active volcanoes in Japan in terms of the persistent release of volatiles and thermal energy from the Nakadake first crater. Throughout most of the calm period, the crater emits significant amounts of volcanic gas, including 200 - 400 tonne/day of SO_2. The first crater contains a hot crater lake, locally referred to as Yudamari with a diameter greater than 200 m. Applying the model of Ryan et al. (1974), which involves the effects of free and forced convection, Terada et al. (2012) estimated that during the calm period, the heat discharge through the lake surface is almost constant, with a value of approximately 220 MW.

The water level falls rapidly preceding an active period. The disappearance of lake water is followed by the emergence of a red-hot crater bottom or wall and a phreatic-to-phreatomagmatic and strombolian eruption sequence that lasts several months. When the volcanic activity subsides to calm period levels, the lake reforms. These dramatic falls/rises in the lake water level are likely caused by increases/decreases in the input of high-temperature steam to the crater bottom (Terada et al., 2012).

In spring of 2012, an unusual event involving the increase in water temperature and rapid decrease in water level occurred at the Yudamari crater lake. The heat discharge rates approached the figure of 600 MW which is three times higher than the representative figure in a calm period. The computational results based on energy and mass conservation indicate that the event is caused by an increase in temperature and flux of fluid inputs from the lake bottom. Preceding the event, silica content in lake water clearly increased, indicating a rise in temperature of hydrothermal system beneath the Yudamari crater lake. The event was accompanied by slight increase in SO_2 emission rate, but seismicity around the crater did not change significantly.

After September 2013, the lake water of Yudamari almost disappeared. Consequently volcanic fluid emitting from the crater bottom ascended as a buoyant plume into the air without transportation of the heat to the lake water. To estimate the rate of heat discharge from the first crater, we applied the plume rise assumption (Briggs, 1969; Kagiyama, 1981). This assumption states that the height h of a given position in a fumarole increases proportionally with time t to the power of 2/3. Video records of surveillance camera operated by Japan Meteorological Agency are used to the analysis.

In September, 2013 and December, 2013 - January, 2014, seismicity including earthquake swarms and volcanic tremors were enhanced, which were accompanied by an increase in SO_2 emission rates up to 2,000 tonne/day. During the periods, heat discharge rates are estimated to be 800-1000 MW which is several times higher than the figure measured in a calm period. The ratio of H_2O/SO_2 has been roughly maintained whereas small amount of volcanic ash including juvenile materials were continuously emitted in January 2014. This may occur as a result of an increase in amount of degassing in the conduit beneath the first crater.

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Keywords: heat discharge rate, Aso volcano, hot crater lake, eruption

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SVC55-P18 Room:Poster Time:May 1 18:15-19:30

The temporal changes of the shallower resistivity structure associated with a small eruptions at Aso Volcano, 2014.

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On Aso volcano, many observations and research have been made to detect the subsurface structure and detailed information about the distribution of the subsurface hydrothermal system have been obtained from previous studies. From the high-density AMT survey, Kanda et al. (2008) found a low resistivity area is localized just beneath the Nakadake first crater. This area is considered as a chamber of the hydrothermal fluid which is formed by a part of the hydrothermal fluid which is supplied from the deeper magma. In recently, the activities of the Nakadake crater were often temporarily increased. Associated with these activities, it is expected that the distribution of the subsurface hydrothermal fluid is changed and subsurface resistivity structure is temporally changed. In order to detect such a temporal change of shallow resistivity structure according to these activities, we carried out the repeated control sourced electromagnetic survey around the Nakadake crater using ACTIVE observation system (Utada et al., 2007). In these observations, we installed electric current transmitter on 1 km NNE from the crater, and magnetic receiver was also installed on the 4 points around crater.

In Aso volcano, a small eruption occurred in January 2014, and this activity has continued after this eruption.

During this activity, we carried out the electromagnetic survey around Nakadake crater of Aso volcano. In our presentation, we will show the observation data and the resistivity structure obtained by the 1-D analysis of our data.

Keywords: registivity structure, Aso volcano

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SVC55-P19 Room:Poster Time:May 1 18:15-19:30

Crustal deformation associated with increase in VLP events activity in Aso Volcano

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Aso Volcano, one of the most active volcanoes in Japan, is located in the central part of Kyushu and consists of an elliptical caldera with a diameter of 18km in E-W and 25km in N-S, and of central cones with more than 10 volcanoes aligned in E-W direction. Among central cones, Nakadake volcano is the only active cone and its recent activity is characterized by ash and strombolian eruptions and phreatic or phreatomagmatic explosions. The last strombolian eruptions ended in the beginning of the 1990s and after that, surface activities have been restricted to the fumarolic gas and ash emission from the northernmost crater of the volcano accompanying activity of long period tremors(LPT) or very long period (VLP) events.

Since 1990s, observations using broadband seismometers have revealed that the source of LPT is a crack-like conduit located at depths of 1-1.5 km beneath Nakadake, with a length of 1km and width of 2.5km. It is also revealed that at this depth a pressure was located and caused long-period displacements a few minutes before phreatic eruption which occurred in 1993 and 1994.

The Japan Meteorological Agency (JMA) raised the Volcanic Alert Level from 1 (Normal) to 2 (Do not approach the crater) based on rapid increase in numbers volcanic earthquakes and volcanic gas emission in September 2013, and based on increase in amplitude of volcanic tremors in December 2013, respectively.

Remarkable ground deformation was detected by water-tube tilt meters and super invar-rod extensometers which were installed in a 30m observation tunnel, 1km southwest from the active crater, in September 2013 and January 2014 associated with increase in VLP events activity.

By comparing the calculated deformation assuming a Mogi source and a dyke, is found that observed deformation can be attributed to the expansion of the crack-like conduit. At the beginning of the deformation, the radial component of the extensometer showed dilatation and converted to contraction, which indicates initiation of expansion at the deeper portion of the crack and propagation to the shallower part.

Keywords: Aso Volcano, Crustal deformation, VLP events, Volcanic gas, Conduit

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SVC55-P20 Room:Poster Time:May 1 18:15-19:30

Remote temperature sensing on fumaroles in active volcanoes using stable isotopes of trace gases in volcanic plume

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Molecular hydrogen (H_2) in a high-temperature volcanic fumarole (>400 degreeC) reach to the hydrogen isotope exchange equilibrium with coexisting fumarolic H_2O under the outlet temperature of the fumarole. In this study, we applied this hydrogen isotope exchange equilibrium of fumarolic H_2 as a tracer for the remote temperature sensing on the fumarolic area in the 1^{st} crater of Mt. Naka-dake (Aso volcano) where direct measurement on fumaroles was not practical, by deducing the hydrogen isotopic composition (dD value) of fumarolic H_2 remotely from those in volcanic plume. The reciprocal of H_2 concentration in the plume samples showed a good linear relationship with the dD values. The linear relationships suggested that both the concentrations and the dD values of H_2 in the plume samples can be explained by simple mixing between two end-members, both of which can be classified to a single category at least for the dD values of H_2. By extrapolating the linear relationship between 1/H_2 and dD to 1/H_2=0 to exclude the contribution of the tropospheric H_2 from the dD value of each sample, we estimated that the dD value of fumarolic H_2 to be -172+-16 per mil vs. VSMOW and the apparent equilibrium temperature (AET_D) to be 868+-97 degreeC. Although the estimated temperatures using the IR thermometers were much lower than the AET_D, we concluded that the AET_D represented the highest outlet temperature of the fumaroles in Aso volcano and that the dimensions of the fumaroles at surface smaller than the pixel of the IR thermometers was responsible for the temperatures lower than the AET_D. That is to say, temporal variation in the dimensions of fumaroles at surface, probably due to variation in the emission flux of fumarolic gases, was responsible for the temporal variation in the temperature determined by the IR thermometers, while the actual outlet temperature of the Aso fumaroles keeps the high temperature almost equal to the equilibrium temperature of fumarolic gases.

Keywords: fumarolic gases, carbon dioxide, molecular hydrogen, stable isotopes, isotopic exchange equilibrium, remote temperature sensing

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SVC55-P21 Room:Poster Time:May 1 18:15-19:30

Strange seismic, infrasonic, and geodetic phenomena observed 3 days before the 2011 eruption of Shinmoe-dake volcano

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Shinmoe-dake volcano started its climatic events on January 26 at 14:49. Some precursory phenomena have been found in petrologic studies. The ash from a phreatic eruption on January 19 contained fresh pumice fragments indicating ascent of new magma to a shallow depth (Miyabuchi et al., 2013; Suzuki et al., 2013). Petrologic analyses of the eruption products from the climatic events showed evidences of magma mixing in two stages before the eruptions; Suzuki et al. (2013) estimated the times of the first and second mixing to the eruption as $>$14 days and 0.7-15 hours, respectively, while Tomiya et al. (2013) conclusively proposed 0.4-3 days and several hours, respectively, and suggested that the first mixing likely triggered the eruption.

On the other hand, no clear precursory signals have been identified in geophysical observations. Considering the above petrologic studies, we reexamined the seismic, infrasonic, and geodetic data in a few weeks to the eruption, and particularly focused on a sequence of strange phenomena on January 23, three days before the eruption. It was the only notable phenomena recognized in several days to the eruption, but has not been reported elsewhere.

Nakada et al. (2013) referred to the JMA report (2012) that volcanic tremor was first recorded at 01:27 on 19 January and continued from the 19 January afternoon to the morning of 23 January. In fact, the tremor started to be recorded at stations around the summit of Shinmoe-dake at 12:45 on 18 January and increased significantly after the phreatic eruption at 01:27 on the 19th. If there was any sign indicating rise of new magma to the shallow depth before the phreatic eruption, the tremor could be the candidate.

On January 23, there was a clear infrasound signal continuing from 4:11 to 4:53 with an amplitude about 1 Pa and a sharp peak frequency at 1.8 Hz. The events was nearly aseismic and the regional seismic stations recorded infrasound shaking of the ground. The bad weather condition prohibited visual observation to see if any surface activity accompanied. At 6:00, the tremor power increased at stations on the north flank while it decreased at a station on the west flank, indicating some change of the source. The tremor power decreased from 8:00 to 8:30, stayed at the low level until 13:15, and then recovered to the previous level by 14:00. It was more distinct at stations close to the summit of Shinmoe-dake; the power decrease was more than an order of magnitude at the nearest station, SMN, 700 m from the summit. After the recovery the tremor stayed nearly same levels until the small eruptive event on the 26th before the main event. During the quiescent period of the tremor, gradual tilt up toward the summit was detected by a broadband seismometer at station SMN. Although, seismic activity except the tremor was low around the days, the quiescent period had more seismic events including relatively low-frequency ones.

Although causal relations among these events or their relation to the magma mixing are totally unclear, the sequence of phenomena on January 23 is potentially important to understand the processes leading to the climatic events of the Shinmoe-dake eruption.

Keywords: Eruption, Tremor, Infrasound, Precursor, Tilt

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SVC55-P22 Room:Poster Time:May 1 18:15-19:30

Relationship between Infrasound Signals and Plume Heights by the JMA's Weather Radar, the Shinmoe-dake 2011 Eruption

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During the continuous sub-plinian eruption of the 2011 Shinmoe-dake eruption, the JMA's weather RADAR detected the sequential echoes from the volcanic plume (Shimbori et al., 2013). We report the brief result of basic analysis for the relationship between the plume heights and infrasound signals.

The eruption cloud echo data observed at the Kagoshima Airport Doppler RADAR (Kagoshima DRAW) were analyzed. While Kagoshima DRAW has the threshold of radar reflectivity factor, its time interval of the volume scan is shorter as 5 minutes. In this study, in order to improve the accuracy of time, the time of the plume top in a volume scan was identified by every scanning time of the antenna.

The relationship between the plume height and discharge rate of magma has the empirical power law, and its power index was estimated to be 0.259 (Sparks, 1997). Assuming that the discharge rate has the proportional relation with the integration of the infrasound signal generated by eruption (Takagi at al., 2013), we estimate the power law between the echo height and infrasound data for this eruption. In the result, the most appropriate power index was estimated to be 0.55, and the delay time and the time window of the infrasound data which make error smaller are 4 minutes and 6 minutes, respectively.

These time delay and window might be subjected to height and velocity of plume top. More advanced analysis for plume heights and infrasound signals would disclose the dynamics of volcanic plume.

Acknowledgements
We would like to thank Drs. Y. Tanaka, O. Suzuki, H. Yamauchi and E. Sato (MRI, JMA) for the use of their "Draft" radar analysis software.

Keywords: lume height, weather radar, infrasound, Shinmoe-dake

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SVC55-P23 Room:Poster Time:May 1 18:15-19:30

Long-period seismic waves propagating over Kyushu as associated with the Sakurajima eruption of August 18, 2013

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We found long-period seismic waves propagating over Kyushu after the explosive eruption from Showa crater of Sakurajima volcano at 16:31JST on August 18, 2013. The eruption is one of the most significant ones that Showa crater has experienced since 2006, and the volcanic plume rose approximately 5000 m high. Showa crater is currently very active, causing more than 1000 eruptions a year.

The broadband seismic network F-net recorded the long-period seismic waves traveling in a very wide area covering Amami and the whole Kyushu region. The dominant periods are longer than 5 s. The apparent propagation velocity is approximately 2.75 km/s. In data recorded by Hi-net tilt meters at shorter intervals of around 20 km, the long-period seismic waves arrived earliest at the station AIRH that is the closest to Sakurajima volcano, and propagated with the almost same apparent velocity as observed by F-net. The long-period seismic waves are, therefore, likely to have been radiated from Sakurajima volcano. Assuming that the source is located at Showa crater, we rotated two horizontal components of the F-net and Hi-net data to transverse and radial components. The long-period seismic waves were observed in the radial and transverse components, and the apparent propagation velocity is slightly faster in the transverse component than the radial one. The waves observed in transverse and radial components can be Love and Rayleigh waves, respectively.

For previous eruptions of Sakurajima volcano, we also examined whether or not long-period seismic waves were recorded by F-net. From 5057 eruptions in the period between 2006 and 2013, we selected 43 eruptions that have large amount and height of a volcanic plume as well as large deflation volume. Long-period seismic waves were found for five eruptions including ones from Minami-dake crater. The maximum distances with the observations of long-period seismic waves range from 150 to 331 km, which are much shorter than for the 2013 eruption. Therefore, the 2013 eruption could excite long-period seismic waves more remarkably, compared to the other five eruptions. Observations of long-period seismic waves, on the other hand, did not have clear dependence on the amount and height of a volcanic plume or the deflation volume.

We observed significant transverse components of the long-period seismic waves associated with the 2013 eruption, which are considered Love waves. We also had similar observations for the five eruptions accompanied by long-period seismic waves in F-net data. Eruptions of Sakurajima volcano have been explained by isotropic explosion and contraction of a vertical cylinder (Uhira and Takeo, 1994; Tameguri et al., 2002), and these models cannot excite Love waves. A model for explaining Love waves observed in the present study is to be investigated.

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Comparison between areas of VT earthquakes around Sakurajima Volcano and a 3-D velocity model of the upper crust

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Volcano-tectonic (VT) earthquakes associated with volcanic activities of Sakurajima Volcano also occur beneath Kagoshima Bay around the volcano (Hidayati et al., 2007). Not only seismic observations on land but also ones using Ocean Bottom Seismographs (OBSs) are need to detect micro VT earthquakes beneath the bay, and to improve accuracies of the hypocenter locations of the earthquakes. Authors therefore have performed OBS observations five times since 2009. In the present study, we summarize hypocenter distributions of the VT earthquakes obtained by OBS observations. We also compare the hypocenters and a three-dimensional seismic velocity model derived from regional earthquake data in order to extend knowledge for active area of the VT earthquakes.

The areas where the earthquakes occurred are summarized as follows: 1) Shallow VT earthquakes generated beneath Wakamiko Caldera. Most of the earthquakes were located shallower than or equal to 5 km depth. 2) Small number of VT earthquakes were also located at 5-10 km depth off the northeastern coast of the volcano. This activity may be steadily. 3) No earthquake was detected beneath the western half of Aira Caldera.

On the other hand, we also analyzed a three-dimensional seismic velocity model by use of regional earthquake data (Mera et al., 2013) to compare the hypocenter distribution and the velocity model. As a result of the 3-D inversions, we obtained reliable P- and S-wave velocities at the depth range of 5-12km under the area in and around the volcano. At shallower than 6 km depth, the model delineates an area of Low-Vp (5.3-5.4 km/s) and Low-Vs (3.0-3.1 km/s) beneath the area of south of Wakamiko Caldera. A peak of the low velocity area tends to close the volcano at the portion deeper than 6 km depth. At 10 km depth, a peak of Low-Vp (5.4-5.5 km/s) and Low-Vs (3.1-3.2 km/s) was imaged beneath an area off northeast coast of the volcano (beneath Shin-jima Island). Obviously low velocity areas also spread from the volcano to the area off the south coast of the volcano.

Because several recorder troubles happened among the five OBS observations, we selected the hypocenters of the VT earthquakes which were located using data recorded at common three OBS stations. As a result of the comparison between the hypocenters of the VT earthquakes and the 3-D velocity model, most of the VT earthquakes were located where intermediate velocities were estimated. Furthermore, some of VT earthquakes occurred in close vicinity of the peaks of Low-Vp and Low-Vs areas. The former suggests that the strains by crustal deformation hardly accumulate at areas of high and low velocities. The latter may reflect the increase of pore pressures and stress changes generated by existence of volcanic fluids.

Keywords: Sakurajima Volcano, Volcano-tectonic earthquakes, Three-dimensional seismic velocity model

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SVC55-P25 Room:Poster Time:May 1 18:15-19:30

Repetitive seismic survey 2013 in Sakurajima Volcano.

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The latest report on structural evolution and on effect of the density reduction in the seismic network will be presented through the sixth round of the repetitive seismic experiment in Sakurajima Volcano. Sakurajima Volcano locates in Kagoshima, south Kyushu, which is one of the most active volcanoes in Japan. The repetitive seismic experiment have been carried out since 2008 in order to detect and research structural evolution along volcanic activity, with using 4.5Hz sensors. This round has carried out as a part of the experiment which presented by Nakamichi et al. in this conference.

The detection and researching the structural evolution approach to magma movement under the ground along volcanic activity and will provide essential measure on development of volcanic activity. Extending its result into evaluation on flux and accumulation will bring significant informations on considering scenario about volcanic activity in progress. And the experiments should be sustainable method because of long time scale of the target.

The latest report about structural evolution will be presented. Details and results of the experiment rounds have been reported in these conferences since 2009. The seismic response along the line in the north flank have changed year by year. Two major sweet spots have been found at 4.9km depth in the northeastern Sakurajima and at 8km depth beneath northern flank of Kitadake, the northern edifice, through these experiments. The changes in seismic response are interpreted as a result of mass movement underground with going volcanic activity. Further change is expected associating with development of volcanic activity.

The effect of density reduction will be also discussed. Though the repetitive seismic experiments with two lines have been done with about 250 stations every December until 2012, the latest experiment with the most sensitive line with 74 stations on the northern flank was carried on December 2013. Discussions on the effect of density reduction in the seismic network is necessary in order to have a style of sustainable execution of the research.

Keywords: Sakurajima Volcano, Reflection seismology, Dynamic structure, Controlled source seismology

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SVC55-P26 Room:Poster Time:May 1 18:15-19:30

Active source seismic experiment in and around Sakurajima volcano in 2013 and comparison with the experiment in 2008

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We conducted active seismic experiment in and around Sakurajima volcano in December 2013, five years after the similar experiment that was conducted in 2008. We deployed 280 temporary seismic stations, 90% of which were located at the same locations of the experiment in 2008. Six explosive shots with 200 kg or 300 kg charges were detonated in December 5. The 2013 shot locations (S1, S2, S4, S5 and S6) are less than 60 m from the 2008 shot locations except for 1 shot (S3). We successively observed the explosions and volcanic events during nighttime nine hours continuous recording. The continuous records contain not only waveforms excited by the six shots but also by an explosive eruption and volcanic tremor. We evaluate cross-correlations of waveforms at the same station locations that obtained in 2008 and 2013 to detect temporal change of subsurface structure beneath Sakurajima volcano except for S3.

Member organizations of the Research Group of the Seismic Dynamic Structure in Sakurajima Volcano: Graduate School of Science, Hokkaido University, Graduate School of Engineering and Resource Science, Akita University, Graduate School of Science, Tohoku University, Earthquake Research Institute, University of Tokyo, Volcanic Fluid Research Center, Tokyo Institute of Technology, Graduate School of Environmental Studies, Nagoya University, Graduate School of Science, Kyoto University, Disaster Prevention Research Institute, Kyoto University, Graduate School of Science and Engineering, Kagoshima University, and Japan Meteorological Agency

Keywords: active seismic experiment, temporal change, volcanic activity, eruption, Sakurajima volcano, Aira caldera

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SVC55-P27 Room:Poster Time:May 1 18:15-19:30

Active monitoring by using ACROSS in Sakurajima volcano - observation report 3 -

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In 2012, in order to realize quantitative monitoring of magma transport process, we deployed the ACROSS (Accurately Controlled Routinely Operated Signal System) vibrator system composed of two vibrators in the site that is 3.6 km apart from the northwest of the Minamidake crater of Sakurajima.

On September 2012, we have started the full-scale operation under synchronized control of two vibrators with a frequency modulation, in which the modulation period is 50 seconds and the frequency range is 5 to 15 Hz, to produce broad frequency range of signal: one vibrator 'SKR1' with a signal frequency range of 7.510Hz +/- 2.50Hz and the other 'SKR2' with the range of 12.505Hz +/- 2.50Hz. The signal from the ACROSS source is routinely monitored with more than 20 permanent seismic stations in and around Sakurajima volcano. Five temporal seismic stations are also deployed to increase the spatial coverage of monitoring. The signals recorded at the seismic stations are deconvoluted with the source function to obtain the transfer function between the source and the receivers.

In this report, we estimated the daily transfer functions for the SKR2 vibrator at each station by every 5 days stacked data during a whole period (400 days from September 19, 2012 to October 23, 2013) of the operation. It is obviously found that these daily transfer functions vary temporally. To detect quantitatively the temporal variation of the transfer functions, we analyzed the variation of the transverse component (Tt) of the transfer functions at 7 seismic stations located in Sakurajima Island as folllows:

(1) We analyzed the transfer function obtained at temporal seismic station 'GOMI' located at about 50m apart from the ACROSS source to verify the stability of power of the seismic waves generated by the ACROSS source. According to the result, we rejected the transfer function evaluated during a period of the unstable power condition from a whole period of the operation.

(2) We visually inspected arrival times and amplitudes for the specific phases in the transfer functions at each station during the period of the stable power condition of the ACROSS, and obtained the quantitative temporal variation for the specific phases.

(3) On a simple assumption that the specific phases are SH waves (the transverse component of the transfer functions), we presumed the depth range where each specific phase propagated in the 5 horizontally layered model simplified from the results of the exploration seismic experiment (Miyamachi et al., 2013).

(4) We compared the temporal variation of the specific phases with activity of volcanic eruptions by JMA, the temporal change of the N-S and E-W horizontal distances (GPS data) in Sakurajima Island, and the temporal change of strain at the HAR station measured by Kyoto University.

In the presentation, we will show the observation results in detail. This ACROSS research project in Sakurajima volcano is still in a pioneering stage, and we have plans in the future to continue our project.

Keywords: Sakurajima volcano, ACROSS

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SVC55-P28 Room:Poster Time:May 1 18:15-19:30

Vertical ground deformation in Sakurajima volcano and around Aira caldera: results of leveling survey in Oct.-Nov. 2013

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We conducted the precise leveling survey in Sakurajima volcano and around Aira caldera in October and November 2013, following the repeated leveling surveys to evaluate the vertical ground deformation associated with the recent eruptive activity of this volcano. The leveling routes measured in 2013 survey are about 117 km long in total, including Sakurajima coast route, Sakurajima western flank route, Sakurajima northern flank route, Kagoshima Bay western coast route (BM.2469 - BM.2474 - BM.J), Kagoshima Bay eastern coast route (BM.2500 - BM.J.2797) and Soo route (BM.J.2797 - BM.2785). These leveling routes were measured by the joint university team during the period of November 5-22 and by Geospatial Information Authority of Japan (GSI) during the periods from October 25 to November 7 and of November 13-26.

The obtained survey data are compared with those of the previous surveys conducted in October-December 2007 and November-December 2012, resulting in the relative vertical displacements of the bench marks. The resultant displacements show the ground uplift around Aira caldera as well as the ground subsidence near the central part of Sakurajima. From the analysis based on Mogi's model, the inflation and deflation sources are located beneath the center of Aira caldera and beneath the center of Sakurajima, respectively.

These results indicate that the magma storage at the magma reservoir beneath Aira caldera is still progressed. On the other hand, they also suggest the increase of the amount of ejected magma at the magma reservoir beneath the center of Sakurajima volcano, reflecting the recent increase of the eruptive activity at Showa crater.

Keywords: Sakurajima volcano, Aira caldera, precise leveling survey, vertical ground deformation

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SVC55-P29 Room:Poster Time:May 1 18:15-19:30

Movement of pressure source at Sakurajima volcano after 2006 revealed by continuous GPS observation data

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Ground deformation around Sakurajima has been mainly detected by precise leveling, and has been modeled with 2 spherical pressure sources at the center of the Aira caldera (about 10 km depth) and at beneath the summit crater (about 4 km depth) (Eto, 1989, Annuals of DPRI, Kyoto Univ.). The ground around the Aira caldera turned to uplift since 1993. After continuous GPS observation started at Sakurajima in 1995, explosive activity at summit crater temporally increased at the end of 1999, and Showa crater started eruptive activity at June 2006. Large deformation rate was obtained prior to these eruptive activities, and a pressure source was located at depths 6-8 km near the northern coast of Sakurajima by assuming a spherical source (Hotta et al., 2013, Annual of DPRI, Kyoto Univ.). It is thought that both of pressure sources at the center of the Aira caldera and at beneath the summit crater expanded, and a pressure source apparently moved toward northern coast of Sakurajima. Eruptive activity at Showa crater has increased since 2009. In this study, we analyzed GPS data to make clear process of magma movement accompany with eruptive activity of Showa crater.

GPS data observed by SVO (Sakurajima Volcano Observatory) and GEONET data during 2006-2012 were analyzed by using PPP-AR analysis of GIPSY OASIS II ver. 6.1.2. Although no significant deformations are found during 2006-2009, variable deformation rates are found after around 2009.

Here, we focused on the period of the largest deformation rate after eruptive activity at Showa crater started (from October 2011 to March 2012). At first, we searched average positions of pressure sources whole the period by using GA. Pressure sources located at the center of Aira caldera (8.3 km depth; source A) and beneath Sakurajima (2.9 km depth; source B). Next, fixing the position of source A at the average position (because previous studies also obtained pressure source at the center of Aira caldera around this average position), we set a time window with 4 month period, and shifted it by 10 days. Source B moved from around Kitadake toward the northern part of Sakurajima during 1st time window (October 1, 2011-January 31, 2012) to 6th one (November 21, 2011-March 21, 2012), and then moved toward beneath Minamidake at 7th one (December 1, 2011-March 31, 2012). During the period of November 26, 2011-March 25, 2012, which is middle of 6th and 7th time windows, source B located around Kitadake. Deformation pattern of GPS stations at the northern part of Sakurajima changed around the end of December 2011. Moreover, eruptive activity at Showa crater increased from December 2011. These suggest that magma migrated from Aira caldera toward Sakurajima at around December 2011.

Keywords: Sakurajima volcano, Aira caldera, ground deformation, GPS, Mogi's model

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SVC55-P30 Room:Poster Time:May 1 18:15-19:30

The importance of hydrological disturbance corrections for relative gravity data: A case study at Sakurajima Volcano

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An empirical water balance model was created to correct for hydrological disturbances in relative gravity data repeatedly measured at Sakurajima Volcano, southern Japan. This study aims to quantitatively monitor gravity signals due to magmatic activities of Sakurajima Volcano, and we here present the first applied results of the empirical model. The hydrological disturbances were simply calculated by the product of the instant gravity response to unit precipitation and land water storage, which were estimated using digital topography and observed meteorological data. The calculated hydrological disturbance was consistent with the observed absolute gravity data at Harutayama Station from 2010 to 2011 within 8 micro-gal (1 [micro-gal] = 1 E-8 [m/s2]), which was smaller than the typical accuracy of relative gravity measurements (~10 micro-gal). In addition, after we subtracted (i.e., corrected) the calculated disturbances from the measured relative gravity data at Sakurajima Volcano, the average amplitude of the corrected gravity changes during 2007-2009 was reduced by 90 % compared with that of the original gravity data. Since gravity changes have been measured using both absolute and relative gravimeters at volcanic areas these days, hydrological disturbance corrections should be applied to the relative gravity data, not only to the absolute one. By sophisticating the effects of spatiotemporal variations in precipitation, evapotranspiration, and infiltration capacity, this model will enable us to robustly monitor long-period and wide-spread gravity variations associated with volcanic activities.

Keywords: Sakurajima Volcano, gravity change, hydrological disturbance, relative gravity measurement, absolute gravity measurement, infiltration capacity

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Automated sulfur dioxide flux observation at Suwanosejima volcano, Japan, and comparing to seismic data

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Suwanosejima is a remote volcanic island located about 240 km south-southwest of Kagoshima city, Kyushu Island, Japan. This volcano has been erupting very frequently since early-1950s, and is one of the most active volcanoes in Japan. Previous studies on sulfur dioxide (SO_2) flux measurement of Suwanosejima are very limited and reported that daily average SO_2 flux from this volcano ranged about 5–15 kg/s [Mori et al., 2004; Hirabayashi et al., 2005]. Therefore, we conducted automated SO_2 flux measurement at Suwanosejima volcano to understand SO_2 flux variation with long-term observation at Suwanosejima volcano and to evaluate a relation between SO_2 flux and seismic data.

We developed automated SO_2 flux measurement system to conduct automated observation in such a remote island. The power consumption of the scanning instrument was significantly improved compared to that in the previous studies. The observation was conducted for January 21, 2013–May 7, 2013 (Period I) and November 5, 2013–the present (Period II). The observation system has been working without any trouble for more than 200 days in total showing robustness of the developed system.

SO_2 flux was calculated with a corrected differential optical absorption spectroscopy method for radiative dilution effect [Mori at al., 2006; Kern et al., 2009]. In the observation period of over 200 days, SO_2 flux was calculated for 40 days. The average SO_2 flux in the total observation period was 13.4 kg/s, which ranged from 5.9 kg/s to 34.5 kg/s. The average and the standard deviation in Period I were 16.9 kg/s and 6.2 kg/s, and those in Period II were 14.0 kg/s and 5.7 kg/s, respectively.

Since previously reported SO_2 flux in 2000s [Mori et al., 2004; Hirabayashi et al., 2005] were not corrected for the dilution effect, these values might be significantly underestimated. The average and the standard deviation of uncorrected SO_2 flux for the dilution effect in this study were 9.7 kg/s and 4.3 kg/s. This range was comparable to the range of the previous studies in 2000s. Considering above, SO_2 flux range has been stable since at least 2000s.

Surface and seismic activities in Period I (January 21–May 7, 2013) significantly differed from those in Period II (November 5, 2013–the present). Period I was in a continuous volcanic tremor period (September 2012–July 2013), and Period II was in an intermittent explosions and volcanic tremors period. In contrast to the surface and seismic activities, SO_2 flux variations in Period I and II were almost in the same range. This implies that degassing rate of magma for these two periods were similar. Therefore, the difference of surface and seismic activities which was observed in these periods needs to be explained considering the stable degassing magma rate.

Keywords: Volcanic gas, Sulfur dioxide, Flux, Suwanosejima volcano, Automated observation, Seismic data

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Shallow active magma body beneath Taal Volcano Island, Philippines

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Taal volcano, Philippines, is one the world's most dangerous volcanoes in view of its explosive eruption history and close proximity to populations. Electromagnetic, geodetic, and seismic studies have been extensively conducted at this volcano to reveal its magma system. Recent deployment of a realtime broadband seismic network has detected long-period (LP) and volcano-tectonic (VT) events that occurred beneath Taal. Our source location analysis of VT events using both onset arrival times and high-frequency seismic amplitudes points to the existence of a strong attenuation region with a shear-wave quality factor (Q) of around 10 near the surface at the eastern flank of Volcano Island in Taal Lake. This region is located just beneath the active fumarolic area and LP source and above inflation and deflation pressure sources, and is coincident with a low resistivity region. The attenuation region matches with that inferred from an active seismic survey conducted in 1993 at Taal volcano. These features strongly suggest that the attenuation region represents an active degassing magma body near the surface, which persistently existed for more than 20 years. Our study synthesized with previous studies clarifies the magma system beneath Taal, which further addresses volcanic risk at Volcano Island sitting on a shallow active magma body.

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SVC55-P33 Room:Poster Time:May 1 18:15-19:30

Waveform analysis on initial phases of explosion earthquakes at Lokon-Empung volcano, Indonesia

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Excitation mechanism of explosion earthquake that often accompanies explosive Vulcanian eruptions is understood to be macroscopically explained by a downward single force acting in the vent. In the meantime, it is revealed that the excitation of initial phases of explosion earthquake occurs earlier than the explosion at the crater [e.g. Tameguri et al., 2002]. So the excitation of the initial phases of explosion earthquake can be regarded as one of the most important processes to understand the initiation of Vulcanian eruption. However, the researches focusing on the initial phases are not so common in spite of their scientific importance. In this study, we implemented temporary observation of Vulcanian eruption at Lokon-Empung volcano in Indonesia and estimated source parameters of the initial phases of explosion earthquakes to compare them to the previous works at Sakurajima volcano and Suwanosejima volcano.

Lokon-Empung volcano located in the northern part of Sulawesi island is known as one of the very active volcanoes in Indonesia. We deployed seismic and infrasound observation network around Lokon-Empung in September 2012. During about one-year-long observation, 46 events of explosion earthquakes associated with Vulcanian eruptions had been recorded. Seismograms of explosion earthquakes have common features in the initial phases at all stations; the compressional P phase arrives first, and a larger dilatational phase follows it. Comparison between seismic and infrasound record shows that the excitation of the P phase occurs about 1 second earlier than that of infrasound which is thought to be excited by the explosion at the crater. Particle motion analysis reveals that these initial phases consist of P wave and propagate from the direction of the active crater. Since signal to noise ratio of the first compressional wave (P phase) is not good at some distant stations, we focus on the second dilatational phase (D phase). We performed waveform fitting on the D phase using synthetic seismogram to estimate source depth, shape of source time function, contraction mechanism and seismic moment.

For most events, we obtained the best fitting solution with cylindrical contraction source located at 1 km below the crater. We compared the estimated seismic moment of D phase and the amplitude of seismogram and infrasound with those reported in the previous works, and found that the strength of the explosion of Lokon-Empung ranks between those of Sakurajima and Suwanosejima. At Sakurajima volcano, Tameguri et al. (2002) showed that the amplitude of infrasound is independent from the moment of D phase. On the other hand, Hirai (2013) reported a positive correlation between them at Suwanosejima volcano. Estimated focal depths of D phase at these two volcanoes are 2 km and 100 - 400 m, respectively. At Lokon-Empung volcano, we recognized a weak positive correlation between the amplitude of infrasound and the moment of D phase. The comparison suggests that the shallower focal depth of D phase becomes, the stronger the correlation between moment of D phase and strength of infrasound appears. This result we obtained here will provide a new insight into the unrevealed process between the excitation of D phase and the surface explosion.

Keywords: Vulcanian eruption, Explosion earthquake

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SVC55-P34 Room:Poster Time:May 1 18:15-19:30

Recent eruptive activity at Sinabung Volcano, Northern Sumatra, Indonesia

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Sinabung in the Northern Sumatra of Indonesia began its eruptive activity with phreatic events in August and September 2010. It resumed its activity in September 2013 with phreatic events. In November 2013, eruption columns stood about 5 km above the volcano. Volcanic ash issued since the middle November contained juvenile particles, and pumice fragments were ejected on to the NE flank of the volcano by the vulcanian event on 23 November 2013. Small-scale pyroclastic flows descended during the events. Though the eruptive activity had declined since early December, occurrence of low-frequency earthquakes replaced high-frequency events common during explosive events. Following partial collapse of the summit crater outer-slope repeated, lava appearance was confirmed in late December. Lava appeared in the summit crater grew as a dome and started its partial collapse on 30 December, generating pyroclastic flows which descended on the SE slope of the volcano. The lava dome grew into a lava flow moving to the SE, repeating its partial collapse. The horizontal length of the lava flow exceeded 1 km in late January 2014.

Several tens collapses occurred everyday in January 2014. Relatively large collapse (pyroclastic flows) generated on 7, 11 and 21 January and 1 February. Pyroclastic flows on 1 February traveled about 4.5 km, according to newspapers, and 15 local people who invaded into the danger zone, 5 km from the summit, were involved in the flows.

The present eruption at Sinabung is close to the eruption of 9 to 10th Century of this volcano in terms of both eruption site and scale. It is also similar to lava-dome eruptions at Unzen, Japan, in 1991-95 and at Soufriere Hills, Montserrat, West Indies, in 1995-present, where lava dome/flow growth associated with pyroclastic-flow events continued for several years.

Based on the chemical analyses of pumice of the Vulcanian event on 23 November 2013 and pebbles included in pyroclastic flow event on 11 January 2014, magma of this eruption (hornblende andesite) is similar to but a little poorer in SiO_2 (58-59%) than the magma of the 9 to 10th Century (59-60%).

Keywords: Indonesia, Sinabung, volcanic eruption, pyroclastic flow, lava flow, hornblende andesite