Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SVC12-01 Room:304 Time:May 26 14:15-14:30

A new method to monitor water vapor cycles in active volcanoes

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The monitoring of multiple gas species from volcanic plumes in real time is crucial to understand the mechanisms involved in persistent degassing, and can be used anticipate volcanic unrest and magma ascent towards the surface. Progress in gas remote-sensing techniques during the last decades has led to the development of ultraviolet absorption spectrometers and UV cameras, which enable to monitor SO2 emission cycles in real time, at very high-frequency (about 1Hz), and from several kilometers away from the volcanic plume. However, monitoring of the more abundant gases, i.e., H2O and CO2, is limited to volcanoes where infrared spectrometers and infrared lamps can be installed at both sides of the crater rims. In this study, we present a new and simple methodology to register H2O emission cycles from long distances (several kilometers), which is based on the light scattered by the micrometric water droplets of condensed plumes. The method only requires a commercial digital camera and a laptop for image processing, since, as we demonstrate, there is a linear correlation between the digital brightness of the plume and its volcanogenic water content. We have validated the method experimentally by generating controlled condensed plumes with an ultrasonic humidifier, and applied it to the plume of Erebus volcano using a 30 minutes-long movie [1]. The wavelet transforms of the plume brightness and SO2 time series (measured with DOAS [1]) show two common periodic components in the bands about 100-250 s and about 500-650 s. However, there is a third periodic component in the band of about 300-450 s in the SO2 time series that is absent in the brightness time series. We propose that the common periodic components are induced by magmatic foams collapsing intermittently beneath shallow geometrical barriers composed by bubbles with high content of both H2O and SO2, whereas the third periodic component could be induced by foams collapsing beneath a deeper geometrical barrier composed by bubbles with high content of SO2 but low content of H2O. This is consistent with the fact that most of the water exsolves at very low pressures. Our new methodology should lead to new insights into magma degassing process and anticipation of volcanic eruptions, in particular when combined with other monitoring methods. [1] Boichu et al. (2010), J. Volcanol. Geotherm. Res. 195:325.

Keywords: volcano, monitoring, phreatic, camera, Mayon, degassing

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CO2/H2O ratio of volcanic gas: Geochemical index for the evaluation of eruptive potential

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The dominant volatile species dissolved in magma is H2O and CO2. The degassing of those species generates bubbles in magma. The bubbles produce the buoyance of magma, driving the magma ascent. Many active volcanoes had been emitting volcanic gas before the eruptions. The amount of H2O and CO2 in the volcanic gas would be affected by the flux of each species degassed from magma. Comparing H2O and CO2, the solubility of CO2 in silicate melt is much lower than that of H2O. If we assume an isolated magma with no supply of volatile enriched magma from a deep source, the CO2/H2O ratio of fluid emitted from the magma will decrease along the progress of degassing. Therefore, the CO2/H2O ratio of volcanic gas could be an index for the remained amount of volatile in magma. I sampled and analyzed volcanic gases at some active volcanoes in Japan. The CO2/H2O ratio of magmatic component in volcanic gas was correlated to the eruptive activity of each volcano. As the result, it is suggested that the volcanoes with the CO2/H2O ratio higher than 0.01 are eruptive. In the following, some examples are described.

Mt Iwate
In 1998, a swarm of volcanic earthquakes happened with the inflation of volcanic body suggesting the intrusion of magma. However, no eruption occurred finally. The fumaloic gas was sampled during the unrest at the geothermal area near the summit. The CO2/H2O ratio of magmatic component was 0.008, which was lower than 0.01. The reason why Mt Iwate had not erupted seems to be the low volatile content by which insufficient of buoyance was generated in magma.

Mt Shinmoe-dake, Kirishima
Before the 2011 eruption, fumaroles with high discharging pressure had been developed within the summit crater. In 1994, the fumarolic gas was sampled and analyzed. The CO2/H2O ratio of magmatic component was 0.03, which was much higher than 0.01. In 1994, a magma enriched in volatile was degassing beneath the volcano, which would be the process of preparation for the eruption in 2011.

Mt Kusatsu-Shirane
Since the steam explosions in 1982 and 1983, no significant eruptive activity happened at the volcano. In 2000, the fumarolic gas was sampled at the geothermal area north of the summit crater. The CO2/H2O ratio of magmatic component was 0.005, which was lower than 0.01. On March 2014, a swarm of volcanic earthquake and the inflation of volcanic body took place. On July 2014, the fumarolic gas was sampled and analyzed again. The CO2/H2O ratio of magmatic component increased to 0.025, which was much higher than 0.01. The low SO2/H2S and H2 concentration were detected, suggesting the temperature of shallow hydrothermal system beneath the summit crater is normal. The increased CO2/H2O ratio suggests an intrusion of volatile enriched magma at the depth.

Keywords: Geochemistry, CO2, H2O, Eruptive potintial, Magma

SVC12-03 Room:304 Time:May 26 14:45-15:00

Temporal variation of the ash component of the 2014-15 Aso Nakadake eruption

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The eruption of Aso Nakadake volcano started in the end of November 2014 and keeps continuous emission of volcanic ash. Most of the volcanic products distributing outside of the crater consist of volcanic ash, though some scoriaceous volcanic bombs are landed on the crater rim.

We trace the temporal change of the grain components of the volcanic ash. The volcanic ash erupted from the onset of the eruption in November till December 10 contains dark-colored opaque glassy grain and cryptocrystalline black grains. Since middle of December, pale-brownish glassy grains occupy the major part of the products. These glassy grains are subdivided into i) blocky grain, with fractured surface, lower vesicle contents, ii) sponge-like grain, with higher vesicle contents surrounded by fractured surface, iii) elongated grain, with smooth surface and elongated bubbles. Some elongated grains show Pele′s hair shape. The volcanic ash erupted in December 15-16, 25-27, January 13-16 contains elongated glassy grains.

Keywords: eruption, volcanic ash, magma, Aso

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Radon monitoring at active volcanoes: achievements and perspectives

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Understanding the behavior of fluids in hydrothermal systems is a key factor in volcano monitoring and geothermal exploration. Moreover, measuring gas emissions in volcanic areas is strategic for detecting and interpreting precursory signals of variations in volcanic activity, including eruptions and flank instabilities of volcanic edifices.

Among gases, a very peculiar one is radon. Radon is a radioactive gas generated from the decay of uranium bearing rocks, soils and magmas. The role of radon as a potential precursor of earthquakes has been extensively debated. At this stage of knowledge, radon anomalies appear to be better suited to forecast eruptive episodes since we know the loci of volcanic eruptions and we can follow the evolution of volcanic activity. Radon mapping is also an effective tool to assess diffuse and concentrated degassing at the surface. We hereby present a collection of data on Somma-Vesuvius, Stromboli, Villaricca (Chile) and La Soufriere (Guadeloupe, Lesser Antilles).

At Somma-Vesuvius, we used a network for radon monitoring to discriminate signals produced by regional earthquakes from those derived by the local volcanic seismicity. Moreover, the duration of radon anomalies have been used, together with other geochemical and geophysical parameters, to infer the permeability of the hydrothermal reservoir and the ascent velocity of fluids. At Stromboli volcano we were able to detect earthquake-volcano interactions: radon anomalies may be coseismic, precursory, and may also occur with a time-delay in respect to the onset of major regional seismic events. In addition, automatic and real time measurements allow us to detect major changes in volcanic activity. The simultaneous collection of environmental parameters substantially increase the potential role of radon in volcano monitoring since the data are easily collected, transferred, elaborated and filtered by applying Multiple Linear Regression analysis on the radon signal. We hereby propose a methodological procedure that can contribute to improve volcano surveillance in the attempt to mitigate volcanic risk.

Keywords: radon, monitoring, diffuse degassing, volcano surveillance, volcanic risk

SVC12-05 Room:304 Time:May 26 15:15-15:30

Near Field Ionospheric Disturbance by the 2014 Kelud Volcano Observed by GNSS-TEC

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The Kelud volcano, eastern part of the Java Island, Indonesia, erupted on 13 February 2014. This Plinian eruption recorded the strength 4 in the Volcanic Explosivity Index (VEI). Ionospheric wave from the eruption was detected by the Global Navigation Satellite Systems - Total Electron Contents (GNSS-TEC) method around the volcano. The ionospheric results were compared with seismic records, and the whole excitation scenario has been studied.

The raw GNSS data files in the Receiver Independent Exchange Format (RINEX) were obtained from 37 GNSS stations, and the TEC information has been extracted from them. These stations were located in the Java, the Sumatra and other small islands around the volcano, and are operated by Badan Informasi Geospatial (BIG), International GNSS Service (IGS) and Sumatra GPS Array (SuGAr).

The ionospheric oscillations were detected from slant TEC time series. They continued from 16:25 UT to 19:00 UT, and propagated as fast as ˜1.0 km/s. The oscillation had frequency peaks at 3.7 mHz, 4.6 mHz, and 6.7 mHz. The former two components coincide with the two lowest atmospheric eigenfrequencies. The 6.7 mHz may correspond to one of the higher modes.

GEOFON (15 broadband seismometers; STS-1) also detected seismic waves excited by the eruption. The time series showed one Rayleigh pulse at 16:15 UT, and following continuous acoustic waves. One of the GEOFON stations, UGM, is located about 200 km away from the volcano. The seismic wave of the eruption was clear and the components with periods 200-300 sec continued from 16:25 to 19:00. It lasted ˜1 hour longer than shorter period components. GSN (78 broadband seismometers; STS-2) recorded the Rayleigh wave from the erupting volcano. Their spectrogram had several clear peaks at frequencies, 3.7 mHz, 4.8 mHz, 6.7 mHz, and so on. Some of the components have been excited by atmospheric free oscillation.

These observations indicate the GNSS-TEC results detected free oscillation of the atmosphere excited by continuous Plinian eruption. This oscillation continued over an hour.

More realistic eigenfrequencies must be inferred in the future considering the atmospheric structure in the region surrounding the Kelud volcano. It must be compared with other observations, for example infrasound data or airglow, and be considered the mechanism of the excitation in detail.

Keywords: GNSS, GPS, Volcano, Ionosphere, Infrasound, Atmospheric resonance

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SVC12-06 Room:304 Time:May 26 15:30-15:45

Combination Mogi and Yokoyama models for ground deformation in 2011-2013 at Merapi volcano

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Merapi is a strato volcano located at the border of central Java Provinces and Yogyakarta Special Region, Indonesia. After a big eruption in 2010, eruptions with VEI I occurred on 15 July 2012, 22 July 2013 and 18 November 2013. Characteristic of eruption is one of the indicators of volcano hazard mitigation; therefore this research has a purpose to estimate locations of pressure source and magma supply volume during the period from 2011 to 2013, based on ground deformation obtained by 3 GPS (Global Positioning System) stations installed in December 2010 and 5 additional stations in June 2013. The baselines beyond the summit crater show extension. This means that Merapi has already entered into inflation process immediately after the 2010 eruption. The amounts of extension of the baselines from the summit area to the navigation stations range from 5 mm to 15 mm and the displacements of GPS point varied in 2 mm to 50 mm.

Locations and volume increase of the pressure source were estimated by using Mogi and Yokoyama models. The depth of pressure source before eruption on 15 July 2012 is 9.8 km and the increase volume is 45 million m^3. Ground deformation related to the eruptions on 22 July and 18 November in 2013 is modeled by two pressure sources; a deep source of Mogi type and a shallow one of Yokoyama type. The pressure sources are located at depths of 10.9 km and 4.5 km for the eruption in July and are 8.1 km and 2.9 km for November eruption. Increase in volume of the pressure sources for these eruptions is 10 million m^3.

Keywords: Ground deformation, GNSS, Merapi volcano, pressure source

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Monitoring system of Kelud volcano, Java, Indonesia before and after the February 13, 2014 eruption

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Kelud volcano is located on the island of Java, Indonesia is a very active volcano. The last eruption occurred on February 13, 2014. Monitoring network of Kelud before the eruption on Feb 13, 2014, consists of five Seismic stations, two Tiltmeter stations, one Water Temperature Sensor, and one CCTV. Tiltmeter data show a gradual change since the beginning of 2011. A few days before the eruption of February 13, 2014 tiltmeter the data showed a sharp rise. Increase in seismic activity observed since the end of November 2013 and then recorded more frequently in mid January up to early February 2014. It made alert level of Kelud was raised to Level II on 2 February 2014. All monitoring stations recorded intensive increase in volcanic activities after the alert level was raised to Level III on 10 February. The appearance of continuous tremors with over scale amplitude on 13 February 2014 at 21:11 WIB (local time) caused alert level was upgraded to Level IV. Eruption started at 22:50 WIB on February 2014, less than 2 hours after upgrading of alert level.

Eruption with VEI of 3-4 destroyed all of instruments, except one seismic station still work which is located 5 kilometers south of the crater. After the eruption, Center for Volcanology and Geological Hazard Mitigation (CVGHM) has added several instruments of monitoring. The monitoring network at Kelud is currently equipped with 5 Seismic stations, 2 Tiltmeters, 2 CCTV, and 3 additional stations which are equipped with seismic and CCTV for monitoring Lahar. In 2015, the network will be added with 3 stations of Seismic, Tiltmeter and continuous GPS as part of Project SATREPS. Until February 2015, activity of Kelud volcano is relatively quiet with volcanic earthquakes less than 10 events/month and domination of tectonic earthquakes. Visually, the actitivty in the crater is weak emission. Alert level of Kelud volcano is Level I.

Keywords: Kelud volcano, Multiparameter monitoring

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Locally-distributed inflational deformation at Midagahara volcano, Japan, detected by InSAR time series analysis

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Preface: Midagahara volcano is an active volcano located in the Toyama Prefecture. Jigoku-dani area is known as an active geothermal area with fumarole and boiling water activity. In these past few years, activity on the ground has become more visibe with burning and flow out of sulfur in 2010 and increased temperatures of fumarole. It is known that phreatic eruptions have occurred historically, and therefor there is a current concern about phreatic eruptions in the near future. Generally, a phreatic eruption is thought to occur by a heat supply to a geothermal system under the ground, probably leading to an inflational crustal deformation due to pressure increase in the crust. Crustal deformation is valuable information to know what proceeds under the ground, and can be an important indicator to assess the degree of activity. However, no significant deformation has been observed in recently-conducted GPS observations which were done in and around the Murododaira area which is about 500 m away from the geothermal area. It suggests that the crustal deformation, if there would be any, occurs in a small area with small magnitude. Thus, InSAR time series analysis may contribute to grasp the whole picture of the crustal deformation with its high measurement accuracy and high spatial resolution.

Data analysis: We used ALOS/PALSAR data observing Midagahara volcano. Only 12 SAR images are available due to the long-term snow cover, acquired from Jul. 2007 to Oct. 2010. We applied a PSI analysis for the observation but made some changes in the processing methodology. The land of the analyzed area is covered by tree/grass, thus it is thought that PS points cannot be extracted well enough to obtain the deformation in detail. Thus we applied the phase linking method in which phases of distributed scatters (DSs) are optimized so that we can handle as a point equivalent to PS point in PSI analysis. To pick up PS candidates, we use the signal-to?clutter ratio (SCR) method in addition to amplitude dispersion (AD), because the AD does not have a good performance for small data set, while SCR can pick up PSCs from a single SLC image. For DSs analysis, we first picked up statistically homogeneous pixels for multilooking by applying the 2-sample KS-test (Ferretti et al., 2011), and then conducted the phase linking. We used the spatio-temporal consistency as a quality indicator (Hanssen et al., 2008) to select final measurement points. Resultantly, the PS of 7094 pixels was obtained in full pixel size of 720000, while we could get the optimized DSs of 82138, leading that the observation density significantly improves.

Results: We detected locally-distributed ground surface displacement in the Jigoku-dani geothermal area, which is close to the satellite, namely, inflational deformation. The deformation speed is estimated to be at about 4cm/yr at maximum. The deformation area is spatially consistent with the area that active fumarole and boiling water are seen on the ground. The time series data of displacement is almost linear, suggesting that there is no significant non-linear deformation. The deformation is locally distributed with the extent of only a few hundreds of meters, strongly suggesting that the deformation source is located at rather shallow. Assuming a sill-shaped source, we constructed the opening crack source model by a simulated annealing method. The estimated optimal depth is 100 m, which supports the above-mentioned idea. To know the more detailed spatial extent, we constructed a distributed opening model that consists of 100 by 100 m rectangular sill-patches. The result shows that the major crack opening concentrates on a local area with the extent of about a hundred meter just below the area centered at Kajiya-jigoku fumarole vent, and the amount of opening is estimated to be about 10 cm/yr at maximum.

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Keywords: Midagahara volcano, InSAR time series analysis, Crustal deformation

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SVC12-09 Room:304 Time:May 26 16:30-16:45

Short-term gravity signal during major eruptions at the Sakurajima volcano since 2012

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We have discussed long-term (timescale >several months) gravity change at Sakurajima volcano, which has been repeating frequent Vulcanian eruptions (500~1,000/year) since 2009 (Okubo et al., IAVCEI 2013). In fact, excellent correlations were found among the records of absolute gravity, ejected weight of volcanic ash, ground tilt, and infrasound air shock amplitude. The long-term gravity data were interpreted in terms of magma head height to explain the close correlation among the variables.

In this paper, we deal with rather short-term gravity signals based on continuous absolute gravity measurements since April 2012. After eliminating hydrological disturbances to the gravity field, we find several major eruptive events were associated with precursory short-term gravity decreases occurring over ~3 hours followed by quick recoveries lasting ~3 hours. The gravity signals occur in synchronization with the volcano's inflation/deflation as revealed by strain and tilt records, which strongly suggests that the gravity signals are due to either building-up of pressure within the volcano or mass transport in the conduit. Since similar precursory gravity changes were reported during the Vulcanian phase of the 2011 eruption of Shinmoe-dake volcano, Kirishima, Japan (Okubo et al., 2013), short-term precursory gravity changes might be universal to major Vulcanian eruptions.

Keywords: absolute gravity, crustal strain, vulcanian eruption, Sakurajima

SVC12-10 Room:304 Time:May 26 16:45-17:00

Source process of small volcanic explosions as inferred from tilt records: Shinmoe-dake, Kuchierabu-jima, and Ontake-san

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Small phreatic explosions occurred at Shinmoe-dake in May 2011 and Ontake-san in September 2014 and phreatomagmatic explosion at Kuchierabu-jima in August 2014 were observed by tilt meters installed at a few kilometers from the active crater of the volcanoes. Temporal characteristics of the tilt motions during these small explosions are characterized by initial uplifts toward the active craters followed by exponential decays indicating deflations of the volcano. The temporal changes of the exponential decays are compared with predictions from an eruption model assuming pseudo ideal gas flow through a narrow conduit from a chamber (Nishimura, 1998). The comparisons indicates that the observed characteristic are well explained by the prediction. This strongly suggests that the processes of these small explosions process is simply expressed by a pressure relaxation due to the withdrawal of ideal gas stored beneath a volcano. The relaxation times, which are related to the cross sectional area of the conduit, chamber volume, initial velocity of the ejecta and specific heat of the ideal gas, are estimated to be about 3 min. for Shinmoe-dake and Ontake-san and 20 s for Kuchierabu-jima, respectively.

Keywords: phreatic explosion, tilt, volcano deformation, small explosion, phreatomagmatic explosion

SVC12-11 Room:304 Time:May 26 17:00-17:15

A fullwaveform seismic event location method for volcano monitoring operations

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Automated seismic event location procedures are very important tasks in almost all seismological applications, including seismic monitoring of volcano activity. The large datasets produced during these operations pushed the development of new automated location methods. Seismic waveforms recorded in volcanic environments are often characterized by low signal-to-noise ratio, thus a successful data analysis requires noise robust automated location procedures. Standard automated location methods based on automated picking of the main seismic phases (generally only P and S first onsets) are prone to fail with noisy data, limiting the location performance. In this work we apply the waveform stacking location method developed by Grigoli et al. (2013, 2014) to volcanic environments. This is a noise robust and picking free location method that exploits the full waveform information content of seismic recordings. Starting from raw seismograms, the first step of the location process consists in the computation of a P-phase and a S-phase stacking functions. For the P phase we use the STA/LTA of the vertical energy trace, whereas for the S we use the STA/LTA of a trace obtained using the principal eigenvalue of the instantaneous covariance matrix (Vidale 1991). For a given source location, we sum both P and S stacking functions along the theoretical travel times corresponding to the selected hypocenter. To locate a seismic event we iterate this procedure for all samples of the recorded traces and for all possible source locations within a predetermined seismogenic volume. In this way we retrieve a multidimensional coherence matrix whose absolute maximum corresponds to the spatio-temporal coordinates of the seismic event. Here we present an application to a sample dataset for the 2011 unrest at Kirishima volcano, Japan. We show that this automated location method is particularly suitable for volcano monitoring applications, where large datasets are produced and need to be processed fastly.

Keywords: Seismic event location, Volcano seismology, Microseismic monitoring

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2D AND 3D SEISMIC ATTENUATION TOMOGRAPHIES IN ACTIVE VOLCANOES

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One of the last major challenges in volcano-seismology has been to obtain the internal structure of volcanoes by using seismic tomographic inversions and discern the role played by the fluids involved in volcanic eruptions. Despite this progress, a few indeterminations are present in the geological interpretation based on the tomography images, due to the resolutions limits of the tomography techniques and the difficulty in associating the physical parameters deduced by the tomography with the rock properties. The most common way to solve this lack of coverage is to perform active seismic experiments. However, working with active data, P-wave tomography images are straightforward, while S-wave images, on the contrary, are almost impossible due to the lack of direct S-wave generation by shots. Moreover, the unclear association of the tomography-deduced parameters with the rock properties is a well know uncertainty of the current seismological research, which despite from lab work carried out till now, needs more advances.

A way to partly overcome these difficulties is to jointly interpret tomography images based on the measurement of different physical quantities. Thus, there are a few (but increasing) cases in which velocity tomography is associated with seismic wave attenuation imaging. This association is essential in volcanoes, where a correct interpretation of the spatial distribution of the physical properties in terms of partial melt materials is necessary.

The Coda-Normalization (CN) method is the more novel method for estimating seismic attenuation, which measures the decrease of the seismic energy. The attenuation parameter can be obtained by measuring the direct P- or S-wave energy and the coda-wave energy, calculating their ratio and inverting the given equation. On the other hand, the presence of magma in volcanic regions leads to the hypothesis that the predominant cause of seismic energy attenuation is the heat dissipation mechanism (intrinsic attenuation), but observations show that in volcanoes the heterogeneities (scattering attenuation) are the widely predominant cause of energy dissipation. Using the Transport equation in the asymptotic diffusion approximation, we are able to obtain which is the contribution of each phenomena to seismic energy attenuation and to separately obtain intrinsic and scattering seismic attenuation 2D images.

Results of the present work will help to better constrain the P-wave velocity images obtained in Deception, Teide, Asama and Stromboli volcanoes (among others) and will give soon other useful quantitative constraints for a complete geological and volcanological interpretation which will help to prepare a more accurate volcano-dynamic models.

Keywords: Seismic attenuation, Scattering, Tomography, Volcano-Seismology

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Preliminary ambient seismic noise study in the Tatun Volcano Group of Taiwan

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The Tatun Volcano Group (TVG) is located in the northern tip of Taiwan and also beside Taipei metropolis. TVG is one of the potentially active volcano regions on the Taiwan Island and was predominantly active in the Quaternary. Besides, an active fault (named Shanchiao Fault) transits the center of the TVG along the northeastern orientation. Since the major geothermal activities expose on the surfaces along the hanging wall of the Shanchiao Fault, it is thought to be a passage for gas, fluid, and magma. But the magma chamber and detailed velocity structures below the TVG are not well resolved.

Studying continuously ambient seismic noise to obtain S-wave velocity structure beneath a densely seismic array is well performed around the world in the past decade. Seismic activity at TVG has been monitored by a dense seismic array with around 20 permanent broadband stations operated by Taiwan Volcano Observatory at Tatun (TVO). Since 2014, there are 20 more temporal broadband stations widely and evenly installed at TVG, supported by Central Geological Survey (CGS) of Taiwan. It is a good opportunity to study ambient seismic noise to investigate more detailed S-wave velocity structure in the shallow crust and searching for possible candidates of magma chamber beneath TGV. In the meanwhile, we can also relocate seismic events and compare seismicity with the newly velocity structure derived from ambient seismic noise. Furthermore, it is a possibility to search any velocity variances relate to large seismic events like Shilin earthquake happened on February 12, 2014.

Keywords: ambient seismic noise, Tatun Volcano Group, Taiwan