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"INVISIBLE" VOLCANIC ERUPTION PLUME/CLOUD OBSERVATION WITH POLARIMETRIC WEATHER RADAR

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1. INTRODUCTION

Monitoring volcanic eruptions is important for disaster prevention, but it is difficult to detect eruptions visually in cloudy conditions, thus development of monitoring methods using weather radar is required.

In 2016, Meteorological Research Institute (MRI) installed two advanced weather radars around Sakurajima volcano, and has been conducting observational research on volcanic eruptions. In this presentation, some results of “invisible” eruption cases observed by MRI X-band polarimetric radar (MRI-XMP) will be shown.

2. BACKGROUND

On evaluation of volcanic activities, it is important to evaluate volcanic eruption scales. Generally, they are measured by the amount of ejecta. It is usually obtained from field surveys after the eruption, but can also be estimated from the plume height. Morton et al. (1956) showed that the eruption height is proportional to the 1/4th power of the energy (i.e. mass) discharge rate. Roughly speaking, this relationship can be applied to actual eruption cases (e.g., Sparks et al., 1997; Mastin et al., 2009). This relationship indicates that the amount of ejecta can be estimated if a set of plume heights and a duration time is given. This principle is used to create an initial condition for ash fall forecast by Japan Meteorological Agency (e.g. Shimbori et al., 2010). Although this method is simple and useful, there is a big problem that the eruption scale cannot be estimated if the eruption plume/cloud is invisible in cloudy conditions. In such a case, it is expected that the system will be more robust by using weather radars.

While there is a merit that weather radars enable us to obtain plume heights in cloudy conditions, they are accompanied by errors due to the beam width and refractivity of the atmosphere. In order to mitigate such errors, MRI developed a probabilistic estimation method for volcanic eruption plume height (Sato et al., 2018). Using this method, a probability density of the plume height is estimated by using each weather radar data, and by combining the results (probability densities) of multiple radars, the plume height is estimated accurately.

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Even if the estimation accuracy of maximum plume height is improved, the total mass derived by the 1/4 power law is not strictly accurate. In order to obtain the total mass immediately and accurately, it is necessary to highly estimate the amount of volcanic ash inside the plume/cloud using "advanced" instruments such as polarimetric radar. MRI installed two "advanced" weather radars around Sakurajima Volcano in 2016, and has been conducting observational research on volcanic eruptions. In this presentation, we will show the analysis results of “invisible” eruptions observed with one of the radars, MRI-XMP.

3. METHODOLOGY

3.1 MRI X-band polarimetric radar (MRI-XMP)

Figure 1 shows a layout of weather radars around Sakurajima. MRI has installed MRI-XMP (Fig. 2) and a Ku-band “fast scan” radar. The main specifications of MRI-XMP are shown in Table 1.

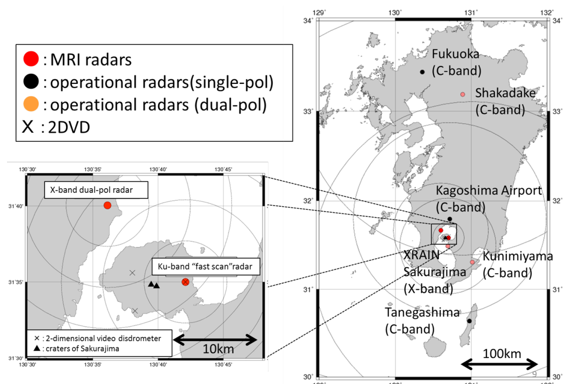

Fig. 1. MRI and operational weather radars near Sakurajima volcano.

Fig. 2. MRI-XMP and Sakurajima volcano.

Table 1. Main specifications of MRI-XMP

Frequency	9.47 GHz
Band width	< 4.4 MHz
Peak power	200 W (H / V)
Pulse length	0.5 - 2.5 μsec (short) 32 – 128 μsec (long)
Beam width	1.2 °
PRF	< 20,000 Hz
Observation parameters	Z_H, Z_V, Z_{DR}, V_D, W, ρ_{HV} and Ψ_{DP}

3.2 ρ_{HV} noise correction

In general, values of correlation coefficient (ρ_{hv}) decrease due to noise. Here, as described in Shusse et al. (2009), we correct them by

$$\widetilde{\rho_{hv}} = \rho_{hv}\left(1 + 10^{-x/10}\right).$$

Here, $\widetilde{\rho_{hv}}$ is the correlation coefficient after the correction, and x is signal-to-noise ratio (in dB). With this method, it is possible to correct a decrease due to static noise.

4. ERUPTION CASE ON NOVEMBER 13, 2017

On November 13, 2017, an eruption occurred at Minamidake crater of Sakurajima at 22:07JST. In this case, the plume height was unknown due to clouds (Fig. 3), however, judging from the magnitude of ground deformation associated with the eruption, it may be one of the largest eruptions of Sakurajima in 2017.

Fig. 3. Photograph by JMA distant camera.

5. RESULTS

Figure 4 shows the observation results by MRI-XMP. From these results, it is revealed that ρ_{hv} decreased at the peak area of reflectivity (or SNR). Furthermore, Z_{DR} of this strong echo was near zero or slightly negative.

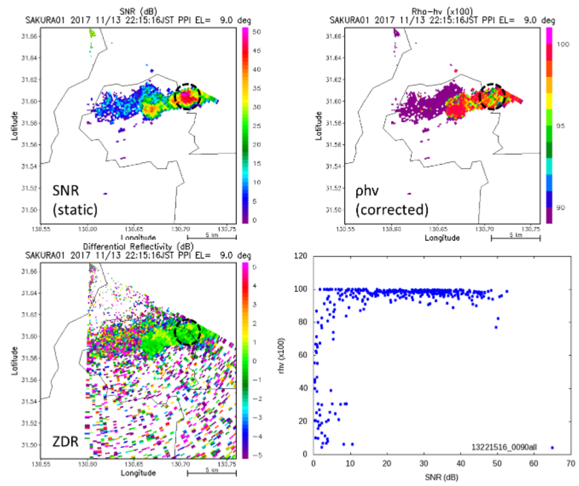

Fig. 4. SNR (top left), ρ_{hv} (top right), Z_{DR} (bottom left), and scatter plot of SNR and ρ_{hv} (bottom right) by MRI-XMP.

6. SUMMRY AND DISCUSSION

Some "invisible" eruptions were captured by XRI-XMP. In the case of Sakurajima eruption on November 13, 2017, we found that the ρ_{hv} of the strong echo decreased. If there had been many large raindrops in this region, the ρ_{hv} should have been higher, and furthermore, the Z_{DR} should have been positive. Considering consistency with other parameters, we conclude that this phenomenon occurred due to the aggregation of volcanic ash particles in the clouds (Fig. 5). Volcanic ash particles may have been aggregated due to mediation of water droplets inside the clouds.

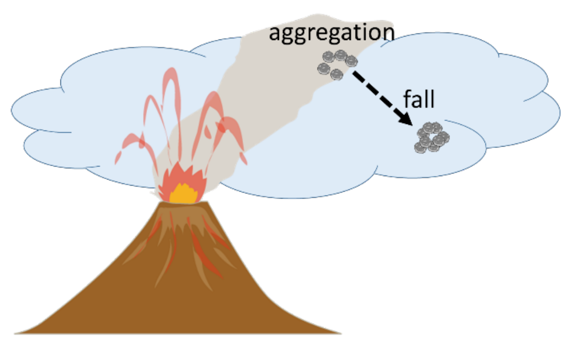

Fig. 5. Conceptual image of the process inside volcanic plume/cloud.

References

Mastin, L.G., M. Guffanti, R. Servranckx, P. Webley, S. Barsotti, K. Dean, A. Durant, J.W. Ewert, A. Neri, W.I. Rose, D. Schneider, L. Siebert, B. Stunder, G. Swanson, A. Tupper, A. Volentik, C.F. Waythomas (2009). A multidisciplinary effort to assign realistic source parameters to models of volcanic ash-cloud transport and dispersion during eruptions, *Journal of Volcanology and Geothermal Research*, **186**, 10-21, doi: 10.1016/j.jvolgeores.2009.01.008.

Morton, B. R., Taylor, G. I. and Turner, J. S. (1956) Turbulent gravitational convection from maintained and instantaneous sources. *Proc. R. Soc. London Ser. A*, **234**, 1-23.

Sato, E., K. Fukui, T.Shimbori (2018) Aso volcano eruption on October 8, 2016, observed by weather radars, *Earth, Planets and Space*, **105-70**, 1-8, doi:10.1186/s40623-018-0879-4.

Shimbori, T., Y. Aikawa, K. Fukui, A. Hashimoto, N. Seino and H. Yamasato (2010) Quantitative Tephra Fall Prediction with the JMA Mesoscale Tracer Transport Model for Volcanic Ash: A Case Study of the Eruption at Asama Volcano in 2009. *Papers in Meteorology and Geophysics*, **61**, 13-29, doi: 10.2467/mripapers.61.13. (In Japanese)

Sparks, R. S. J., Bursik, M. I., Carey, S. N., Gilbert, J. S., Glaze, L. S., Sigurdsson, H. and Woods, A. W. (1997) Volcanic Plumes. Wiley, Chichester, 574p.

Shusse, Y., K. Nakagawa, N. Takahashi, S. Satoh, and T. Iguchi (2009) Characteristics of polarimetric radar variables in three types of rainfalls in a Baiu front event over the East China Sea. *J. Meteor. Soc. Japan*, **87**, 865–875, doi: 10.2151/jmsj.87.865.