General Collaborative/New Exploratory Research (Project No.: 28W-01)

Project name: Geophysical observations of unsteadiness timescales in volcanic explosions: toward an integral dynamic model of mass flow variations in volcanic plumes

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Research location: Sakurajima volcano

Number of participants in the collaborative research: 5 DPRI: 2; non-DPRI: 3

- Number of graduate students: MSc Students 1, PhD students: two positions, both still to be filled
- Participation role of graduate students: [model development, lab experiments] Anticipated impact for research and education

Observations indicate that mass flux of gas-particle outputs during explosive volcanic eruptions can dramatically change showing high unsteadiness even during short-lived explosions. How the timescale of these fluctuations imprint on the development of the resulting volcanic plume is far from being well understood. Understanding these fluctuations will allow for better estimates of maximum eruption column height.

Research report

(1) Purpose

The purpose of this project was to license and install a Doppler radar system at Sakurajima volcano to observe the variation of mass flux during eruptions which is indicative for eruption column height. The system is complemented by a high speed video system triggered by the radar.

(2) Summary of research progress

The project started in May 2016 and we developed a mounting system for the radar which was shipped to Japan at the end of 2016 and installed at Sakurajima in March 2017. The licensing of the radar systems was finally initiated in May 2017 and the licensing procedure took place early October 2017. Unfortunately, we were not able to install one of the radar systems immediately following the licensing procedure due to technical difficulties. In addition, the calibration unit broke and the radar as well as the calibration unit had to be shipped back to Germany for repair. Both were fixed in Germany and sent back to Japan for installation in Feb. 2018. The installation at Kurokami branch observatory, about 4.5 km away from the crater, was completed in late February of this year (see Fig. 1). Since then the system is continuously recording the activity above Minamidake crater at Sakurajima. The inclination of the radar beam is about 12° (pointing upward) and has a width of about 120 m above Minamidake crater.

Activity was low during the first month of operation picking up in April 2018. In late May 2018 it was possible to compare directly observed explosions (observation made by CoPI Dr. Cimarelli from the University of Munich) to those recorded by the radar system. Through direct observation it was possible to optimize the processing parameters of the radar in order to improve the detectability of eruptions. This specifically involved adjusting the range gate length as well as the so called nyquist velocity. As the system is equipped with a high speed video system, it was necessary to determine the correct trigger settings to start the camera at the onset of the eruptions. An often difficult task is the discrimination between the rain

fall and ash fall across the radar beam. Optimization of the trigger system is still under way and currently live rain radar information available on the net are used to verify ash versus rain events. A more reliable version of the trigger is in operation since June 22nd.

(3) Summary of research findings

Figure 2 shows an example of an eruption recorded by the radar system on May 25 at around 13:10 UTC. The eruption started at about 13:01:30 (note that 0 s equals 13:00 UTC) with a strong initial pulse of material leaving the vent lasting about 30 s. The onset of the eruption is again shown in Fig. 3. There one can clearly distinguish between different pulses (a total of 4 pulses with the second one showing the highest velocities). Pulse 3 and 4 are significantly smaller and hard to distinguish. The first 2 pulses last for about 10 s each and the later ones are somewhat shorter, but as stated above they are really hard to distinguish. They could also be interpreted as one single pulse lasting almost 20 s. It is worth noticing that measured velocities are not the velocities right at the source, but about 150 m above the crater rim (see Fig. 2), i.e. several tens to hundreds of meters above the erupting vent inside Minamidake crater. The total sequence of eruptive events lasts for about 25 min.

In addition to the clearly visible pulses of material released from Minamidake crater there is an initially faint signal starting almost immediately with the first pulse at around 80 seconds (see Fig. 2 and 3). It occurs at a radial velocity of about 4 m/s and is associated with particles moving towards the radar. If converted to vertical velocities this is equivalent to 18 m/s. The signal becomes very strong at about 1600 sec and then lasts for about 1200 sec (20 min). Based on our experience from other observations at Sakurajima and other volcanoes, this signal is possibly originating from the sedimentation of ash. The signal could alternatively be interpreted as a rain event, but no rain was reported during this time over Sakurajima. Under the assumption that there is no horizontal wind the observed radial velocity can be converted into a sedimentation velocity which, assuming low Reynolds number flow, can again be converted into a particle size. The particle size conversion gives values of the order of 26 cm, which is probably too large for the expected ejected particles. Therefore, there must have been some horizontal wind contributing to the radial velocity observed by the radar. Radiosonde data from 12 UTC from the JMA branch in Kagoshima (about 10 km away from Sakurajima), indicate a wind speed of about 4 m/s at the height of the vent, at the 300 m above ground its about 2 m/s. Taking this horizontal wind into account particles sizes should be between 0.1 to 1 mm which is a realistic size.

In addition to the observations above the vent we also record strong signals at distances closer to the radar i.e. further away from the vent. There are two interesting observation to be made when looking at the strong signal associated with ash sedimentation. In addition, the sedimentation velocity associated with this signal occurring closer to the radar decreases which could be interpreted as a decrease in particle size, i.e. we observe a sorting of particles while being dispersed away from the vent. Decrease in particles size is about a factor of 1.5 over a distance of 2 km.

Figure 4 finally shows the reflected power recorded above the crater during May 2018. The plot is similar to a typical drumplot used in seismology to display seismological data. The main difficulty is to discriminate between rain (marked in red) and eruptions marked in green and missing data (blue). An automatic algorithm for discriminating between the different events still needs to be improved (see above). Right now, the discrimination between rain and ash is not perfect. So far it is only based on the activity above the vent. Improvement is to be expected when taking into account the whole data set, a development which is still ongoing.

(4) Publications of research findings

So far no publications have been written summarizing the research findings. We are planning to submit either an abstract to this fall AGU in Washington DC or the upcoming EGU 2019. A manuscript will be prepared if data from all 3 radar systems to be installed are processed.

Figure 1. Left: Radar installed in the field. Top: Orientation of the radar beam above the rim of Minamidake crater. Opening of the radar beam is about 120 m at that distance.

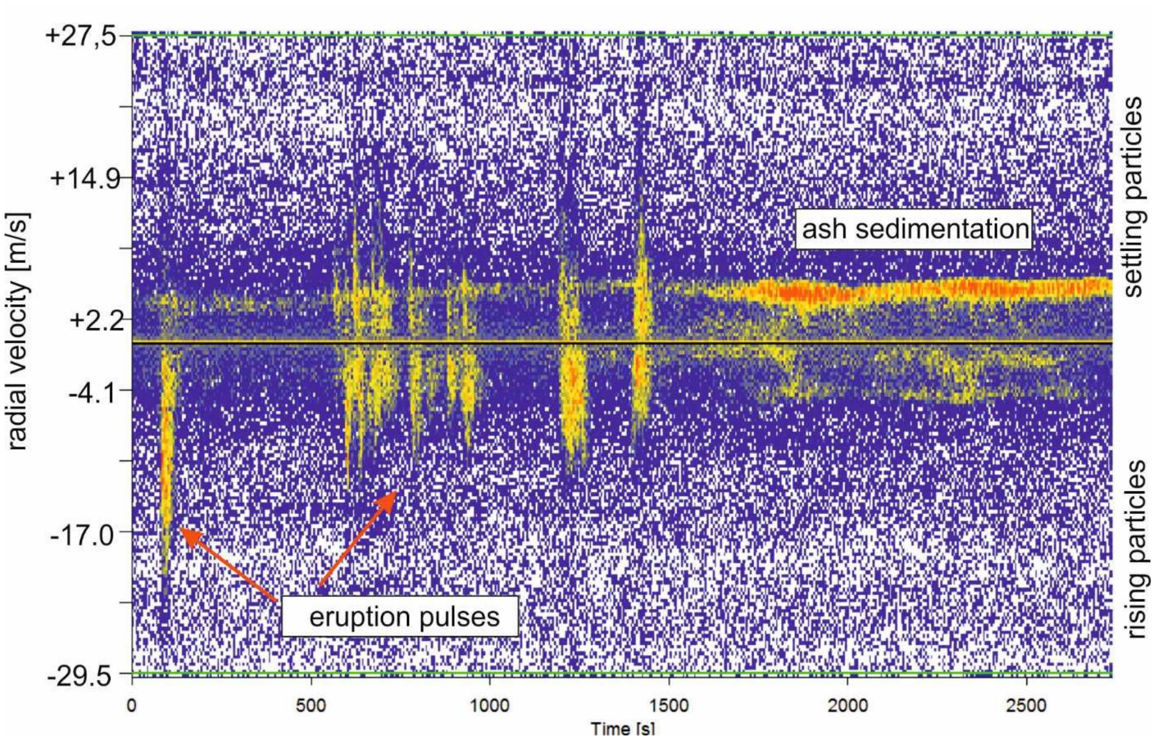

Figure 2: Spectrogram of an eruption on May 25th between 13:00 and 13:45:39 UTC shown as a function of time and radial velocity for activity above the Minamidake crater. Conversion of the radial velocities to vertical velocities is about 132.75 m/s and -123,75 m/s (minus is here upward, plus downward). Maximum vertical eruption velocities are about 80-85 m/s. Color codes the reflected energy given in dB.

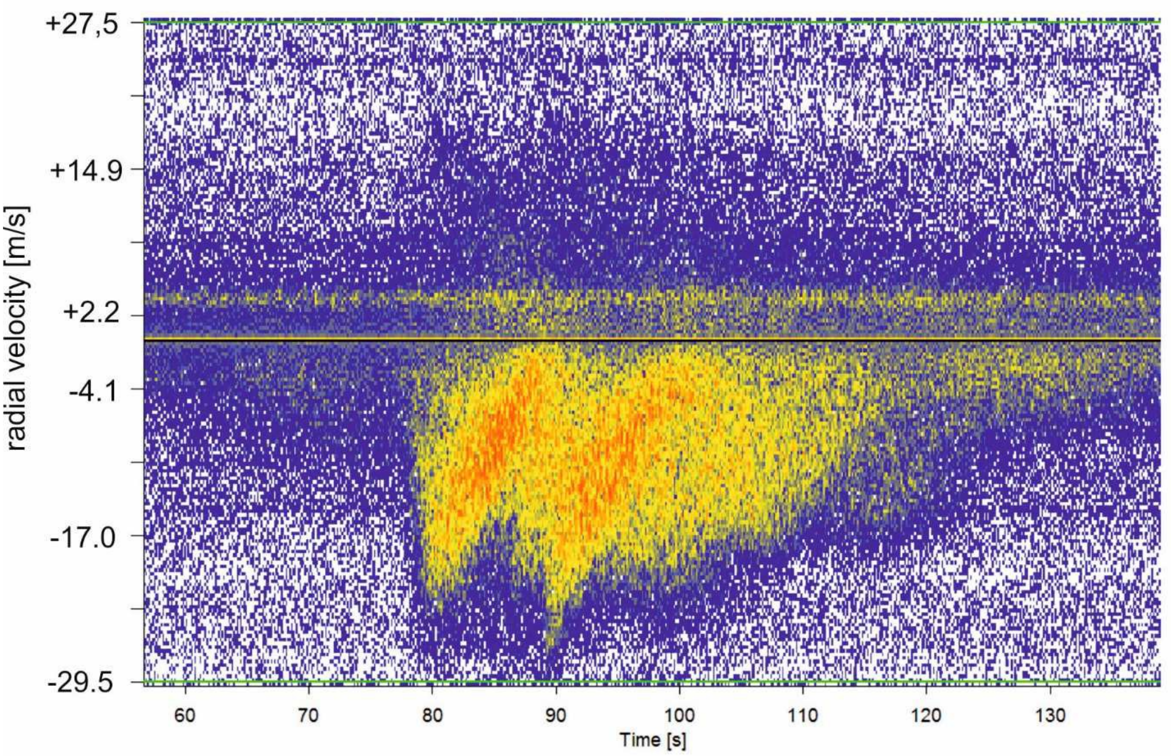

Figure 3: Detail of the eruption shown in Figure 2. One can clearly see how well the radar resolves the onset of the eruption as well as single pulses occurring during the onset. Sampling rate is about 10 Hz.

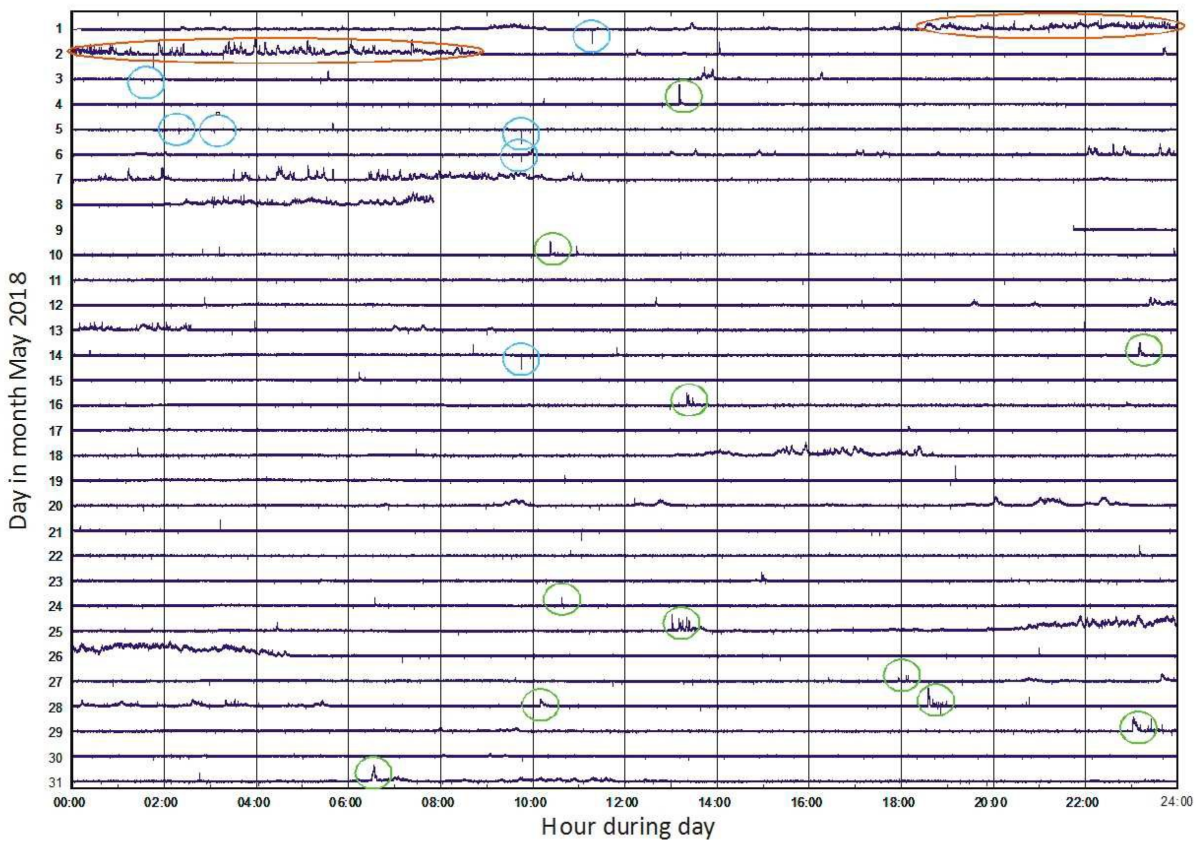

Figure 4: Reflected power recorded above the vent during May 2018. Display is similar to the drumplot representation of seismological data. The x-axis is the time during the day and the y-axis is the recoding for each day. The reflected power shows certain fluctuations some of which are marked by different colors. Red indicates rain, blue marks short periods where data are missing and green marks eruptions. Each of the so far not marked fluctuations still needs to be verified by looking at the raw data in detail.