Experiments on volcanic rock detections using X-band marine radars

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Due to the fan shaped beam emitted from its quickly rotating slot antenna, marine radar has the potential to detect targets such as buoys moored in the water and small boats traveling over the sea. By utilizing this capability, it is expected that marine radar can also be used to detect the volcanic rocks emitted during volcanic eruptions. We carried out experiments on the potential ability of marine radar for the detection of volcanic rocks using artificial particles, with known shapes and sizes, were used in the experiments.

The first experiment was for small volcanic rocks. We performed a simulation where artificial particles were dropped from a small airplane (Cessna 172P), flying at an altitude of approximately 1000 m at a speed of 185 km h^{-1}. Three different kinds of artificial particles were examined: water droplets (hereinafter Sample 1), ‘tamakonnyaku’ particles (hereinafter Sample 2) which consist mainly of water, with some glucomannan, and ‘fu’ particles (hereafter Sample 3) which are sponge-like processed foods made from wheat gluten. The size of each artificial particle was around 3 cm in diameter, except for the water droplets. A 5- liter bucketful of the artificial particles and water droplets was ejected from the airplane into the air. The drops were done in such a way that the released particles fell through the fan shaped radar beam. The dropping of particles was done twice for each type of sample. Figure 1-a shows an example of obtained results. The marine radar successfully detected falling ‘Sample 2’ particles, as shown by a time series of RHI images of radar data (Fig.1-a). One can recognize as the airplane, which was traveling from left to right at around 1000 m above sea level. It can also be seen in Fig. 1 that the echoes of Sample 2 particles are descending from the airplane to the ground. It should be noticed that the echoes are stretching vertically during their descent. By identifying sample 2 echoes on a series of radar images, which has a spatial resolution of 4.34 m and temporal resolution of 1.25 s, we can analyze their trajectories and estimate their terminal velocities. The estimated terminal velocities at the upper boundary and the lower boundary of echoes are 14.6 m s^{-1} and 24.3 m s^{-1}, respectively. The marine radar also could detect falling ‘Sample 3’ particles. However, the radar detected no echo from falling ‘Sample 1’ particles. This is probably due to the water turning into mist sized particles immediately following its ejection from the airplane.

The second experiment we conducted was for the detection of large volcanic rocks. Considering a firework ball as representing a large volcanic rock, experiments to detect firework balls with marine radar were conducted at the 19th Kagoshima Kinko-Wan Fireworks Festival (Aug. 24, 2019), at which time several 60 cm diameter firework balls were launched into the air. Two types of radars were employed in the experiment; one X-band magnetron marine radar, installed on the top of the Sakurajima Volcano Research Center building, DPRI, Kyoto University, and one X-band solid state marine radar, installed at the Kagoshima University school ship. Figure 1-b shows the result of the detection experiments with the solid-state marine radar. The radar successfully detected the splendid burst of a firework. From analyses

of the time series of radar echoes, we were able to obtain the trajectory of the firework ball (Fig. 1-c), and were able to estimate that its initial launched speed was 130 m s^{-1}. The theoretical trajectory obtained with the model proposed by Mastin (2001) is also shown in Fig. 1-c. The theoretical trajectory shows good agreement with the observed trajectory.

The results from the two types of experiment suggest that we can estimate the size of volcanic rocks from radar echo trajectory analyses.

References

Mastin, L. G., 2001: A simple calculator of ballistic trajectories for blocks ejected during volcanic eruptions. *U.S. Geological Survey Open-File Report* 01-45, 16p, https://pubs.usgs.gov/of/2001/0045/

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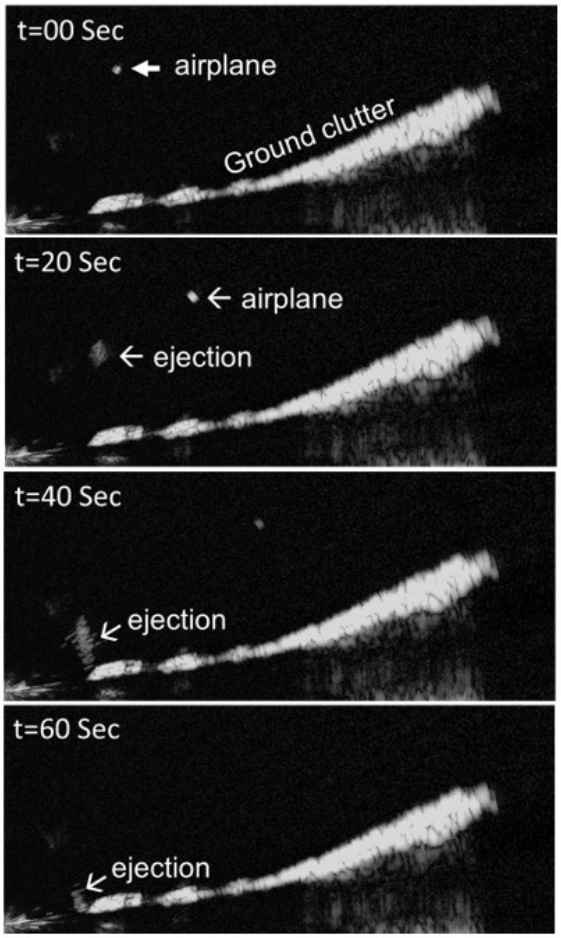

Fig. 1-a A series of RHI images showing the descending echoes of ejections (Sample 2).

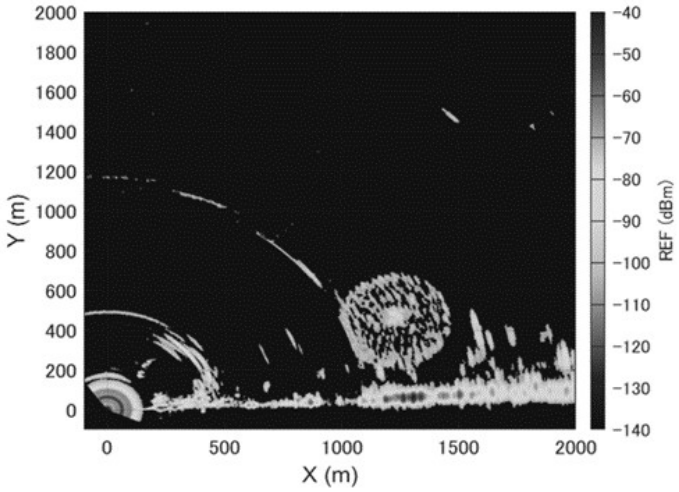

Fig.1-b Splendid burst of a firework detected by solid state marine radar.

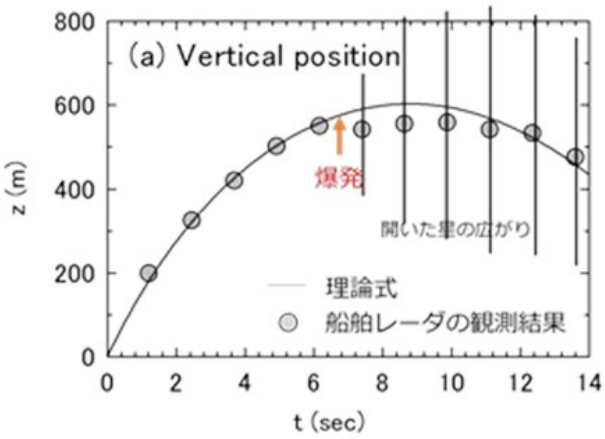

Fig.1-c Comparison of theoretical trajectory and radar observed trajectory of a fireball 60 cm in diameter.

