X-band Marine Radar Detection of Ejected Lapilli and Volcanic Blocks

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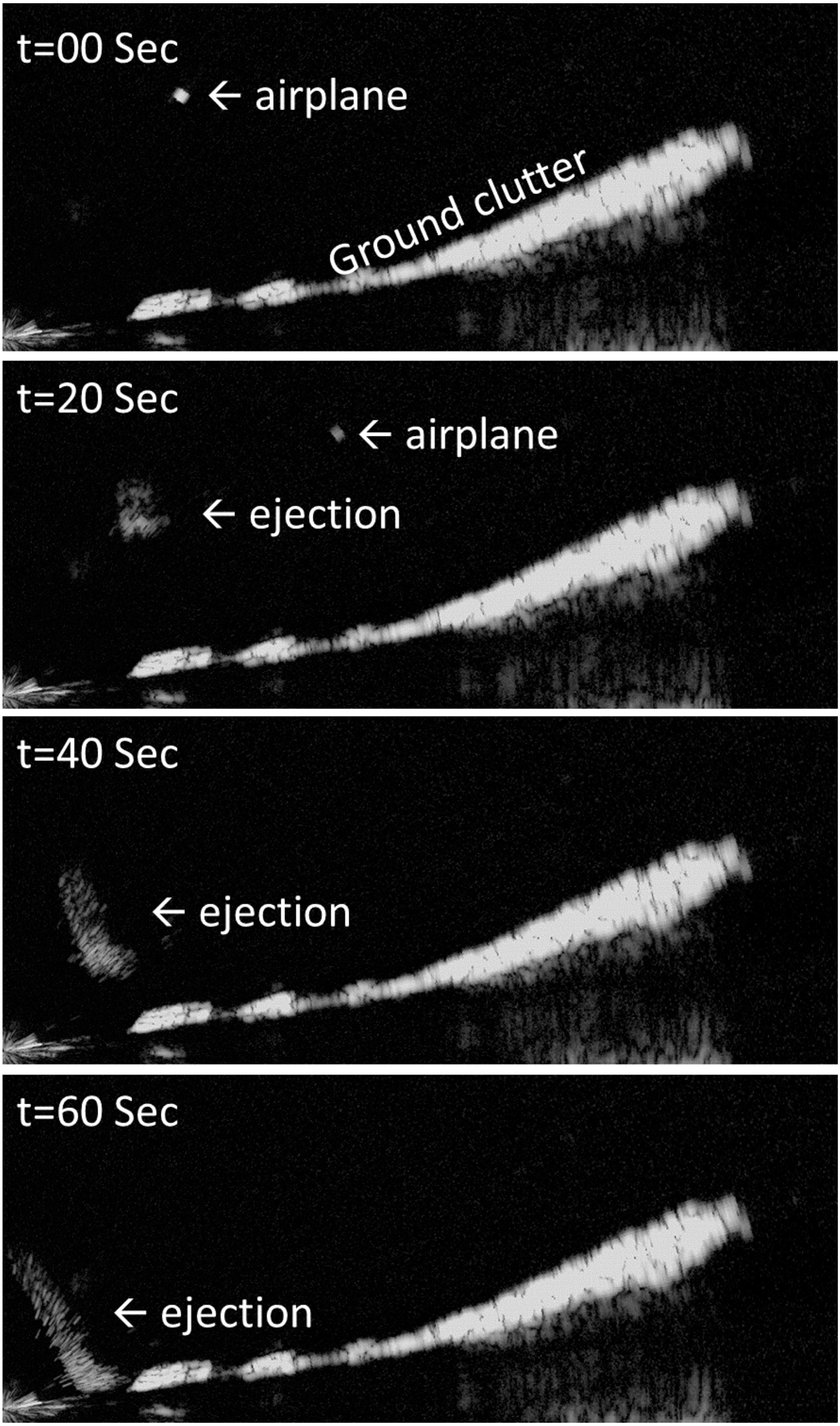
Pyroclastic materials (or tephra) are grouped into three categories, based on size: volcanic ash (≦2 mm, lapilli (2 mm- 64 mm), and volcanic blocks (≧64 mm). Following volcanic eruptions, volcanic ash particles suspended in the atmosphere cause aviation accidents and force airports to shut down, and volcanic ash deposited on the ground causes traffic disturbances. On the other hand, larger tephra such as lapilli and volcanic blocks (hereinafter ‘large tephra’ for convenience sake), which are ejected from volcanic vents just after explosive volcanic eruptions, cause direct damage to human life and property. For example, in the eruption that occurred at Mt. Ontake, Japan on September 27, 2014, sixty‐three hikers were killed or went missing as a direct cause of the large tephra ejected during the eruption.

Although recent studies demonstrate the usefulness of weather radars for monitoring volcanic ash and estimating quantitative ash falls, the methods available for monitoring large tephra have basically been limited to camera and naked eye observations, which are ineffective in cloudy or rainy conditions. The present study tries to solve this limitation by utilizing a marine radar, which has a fan beam and fast scanning capabilities. The marine radar used in the present study is an X-band non-Doppler radar, which has a slot antenna with a vertical beam width of 22° and a horizontal beam width of 1.2°, a minimum range resolution of 8 m, and a PPI scanning speed of 48 rpm. We manually changed the rotational axis of the slot antenna, from vertical to horizontal, to achieve an elevation angle resolution of 1.2°. The resulting image data files, recorded at 1.25-second intervals, make it possible to detect an eruption and the large tephra being ejected above the vent.

Before utilizing the marina radar to carry out observations of actual volcanic eruptions, we examined its capabilities by performing a simulation where artificial particles were dropped from a small airplane (Cessna 172P) flying at an altitude of approximately 1000 m. Three different kinds of artificial particles were examined: water droplets, ‘tamakonnyaku’ particles (consisting mainly of water, with some glucomannan), and ‘fu’ particles (a sponge-like processed food made from wheat gluten). The size of each artificial particle was around 3 cm in diameter, except for the water droplets. A bucketful of the artificial particles and water droplets was thrown out of the airplane into the air. The marine radar was able to detect the falling artificial particles at 1.25-second intervals; the measured radar data clearly showed their trajectories from the airplane to the ground, from which data we could calculate the terminal velocities of the particles. Attched figure shows the trajectories of 'fu' particles dropped from a small airplane. The particles were a cylindrical, sponge-like processed food soaked in water and they split up immediately after they were ejected from the airplane. The radar could not detect the water droplets because they became mist sized particles immediately following their ejection from the airplane.

Next, in order to detect actual vented large tephra, the X-band marine radar was set up at the Kyoto University Kurokami observatory, located about 4km from the vent of Sakurajima volcano, in Kagoshima, Japan. We collected data from a total of 229 eruptions during an observation period of approximately fifty days, of which 83 eruptions were explosive. We identified large tephra ejected from the vent in a total of 95 eruptions, in 24 of which we were able to identify large tephra and draw their distinct trajectories. As far as we know, this study presents the first successful detection of a volcanic eruption and the simultaneous detection of falling large tephra. The radar also revealed the fine structure of an ascending eruption column, which implied another advantage of marine radar to monitor volcanic eruption columns.

Keywords: Volcanic eruption, Sakurajima, fan beam, tephra, volcanic ash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