Numerical simulation of ballistic trajectories based on wind tunnel experiments

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Ballistic projectiles are large (>10 cm) pyroclasts, ejected from erupting volcanoes, that draw parabolic trajectories without being influenced by the flow of the gas and solid mixture (e.g. Taddeucci et al., 2017). Transport dynamics of ballistic projectiles are studied by observing real volcanic eruptions or numerical simulations. The largest unknown factor of ballistic transport is aerial drag, which is hard to estimate by observation.

There are many examples of drag measurements for artificial shapes such as cylinders and cubes, but only a few examples of drag measurements using real volcanic rocks. Therefore, wind tunnel experiments were implemented using a block obtained from Zao volcano, which erupted in 1895 (Kochibe, 1896). In order to clarify the size effect we used blocks of the same shape but different sizes. The results of these experiments were (1) the drag coefficient depends on the Reynolds number (when the block rotates more than three times per second) and the cross-sectional shape, (2) the lift coefficient of the block is very low compared to the drag coefficient when the block is rotating.

Numerical simulations were conducted using the drag and lift coefficients obtained from the wind tunnel experiments. Based on the numerical simulation results we show how the drag and lift coefficients affect the transport of ballistic blocks with and without rotation, and the condition of the blocks that travel furthest, by varying the block size, the ejection angle, and the rotation status.

Keywords: Ballistic projectiles, Wind tunnel experiments, Drag coefficient, Lift coefficient

