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Influence of vent geometry on volcanic jet dynamics

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Explosive volcanic eruptions are commonly impulsive and highly dynamic events that eject volcanic particles into the atmosphere. The efficiency of conversion of potential energy (overpressurised gas stored in porous magma) to kinetic energy (acceleration of gas and particles) is deprived of direct observation as it takes place inside the volcano. To date, direct observations are limited to the dynamics of pyroclast ejection from a volcano. Additionally, scaled laboratory experiments have shed some light on the governing parameters. However, a quantitative understanding of the physical processes during explosive eruptions as well as the influence of boundary conditions (fragmentation depth, gas overpressure, vent geometry, etc.) is still lacking. We focus here on the influence of the vent geometry on volcanic jet dynamics. For this purpose, we performed large-scale numerical simulations of impulsively starting gas jets at volcanic conditions (ratios reservoir total pressure p_{0r} to ambient pressure p_∞ up to 80) that allowed us to study the properties of the fluid flow when being ejected through different vent geometries. We focused on three geometries: (i) one straight vent and two divergent vents with an exit to throat area ratio of (ii) 2.36 and (iii) 4, respectively. There is a positive correlation between the exit to throat area ratio and the adapted pressure ratio $(p_{0r}/p_\infty)_a$. The corresponding adapted pressure ratio for geometries (i), (ii) and (iii) are 1, 20.31 and 54.74, respectively. For $(p_{0r}/p_\infty)_{a,ii} = 20.31 < p_{0r}/p_\infty < (p_{0r}/p_\infty)_{a,iii} = 54.74$, the flow at the vent exit is supersonic in case (ii) and subsonic in case (iii). This condition affects the entire flow field. For the same set of parameters, a change in the vent geometry can lead to drastically different results and this parameter has to be taken into account for correct predictions and analysis of the flow of volcanic jets. Our modelling has shown the influence of different vent geometries on the jet properties at otherwise comparable starting conditions (pressure ratio, tube length). The combination of the results presented here and scaled laboratory experiments will allow for a better understanding of explosive volcanic eruptions where jet dynamics and crater geometry can be observed directly and at high precision and real time. Being able to quantify boundary conditions and their influence on eruption dynamics will also provide advancement in volcanic eruption hazard assessment.