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Retrieving eruptive vent conditions from dynamical properties of unsteady volcanic plume using high-speed imagery and numerical simulations

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Vent conditions are key parameters controlling volcanic plume dynamics and the ensuing different hazards, such as human health issues, infrastructure damages, and air traffic disruption. Indeed, for a given magma and vent geometry, plume development and stability over time mainly depend on the mass eruption rate, function of the velocity and density of the eruptive mixture at the vent, where direct measurements are impossible. High-speed imaging of eruptive plumes and numerical jet simulations were here non-dimensionally coupled to retrieve eruptive vent conditions starting from measurable plume parameters. High-speed videos of unsteady, momentum-driven volcanic plumes (jets) from Strombolian to Vulcanian activity from three different volcanoes (Sakurajima, Japan, Stromboli, Italy, and Fuego, Guatemala) were recorded in the visible and the thermal spectral ranges by using an Optronis CR600x2 (1280x1024 pixels definition, 500 Hz frame rate) and a FLIR SC655 (640x480 pixels definition, 50 Hz frame rate) cameras. Atmospheric effects correction and pre-processing of the thermal videos were performed to increase measurement accuracy. Pre-processing consists of the extraction of the plume temperature gradient over time, combined with a temperature threshold in order to remove the image background. The velocity and the apparent surface temperature fields of the plumes, and their changes over timescales of tenths of seconds, were then measured by particle image velocimetry and thermal image analysis, respectively, of the pre-processed videos. The parameters thus obtained are representative of the outer plume surface, corresponding to its boundary shear layer at the interface with the atmosphere, and may significantly differ from conditions in the plume interior. To retrieve information on the interior of the plume, and possibly extrapolate it even at the eruptive vent level, video-derived plume parameters were non-dimensionally compared to the results of numerical simulations of momentum-driven gas jets impulsively released from a vent in a pressurized container. These simulations solve flow conditions globally, thus allowing one to set empirical relations between flow conditions in different parts of the jet, most notably the shear layer, the flow centerline, and at the vent. Applying these relations to the volcanic cases gives access to the evolution of velocity and temperature at the vent. From these, the speed of sound and flow Mach number can be obtained, which in turn can be used to estimate the pressure ratio between atmosphere and vent and finally, assuming some conduit geometry and mixture density, the total amount of erupted gas. Preliminary results suggest subsonic exit velocities of the eruptive mixture at the vent, and a plume centerline velocity that can be twice as fast as the one measured at the plume boundary.