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High-speed imaging of Strombolian eruptions reveals gas-pyroclast interactions in volcanic jets

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Volcanic jets of pyroclasts and hot gases are injected in the atmosphere during explosive eruptions. Despite aerodynamic gas-pyroclast interactions exert a prime control on eruption dynamics and pyroclast emplacement, field-based parameterization from direct measurements are still challenging. Here, we report detailed measurements of pyroclast and gas motion in volcanic jets from persistent activity at Stromboli volcano. High-speed videos were collected at 500 frames per second with a resolution of 1.7 cm/pixel in an area of 9x9 m right above the active vents in June 2009. Images of ash-free jets allowed the tracking of individual pyroclasts and to outline the velocity field from the core to the margins of the jet, while specific video-processing evidenced the motion of the ambient air upon entrainment at the jet boundaries. Overall, fluctuating gas-pyroclast velocity trends reveal the pulsating nature of Strombolian jets. The front of the jet shows initial velocities in the order of 100-200 m/s that decrease step-wise while mixing with the surrounding atmosphere. Pyroclast exit velocities are as high as 350 m/s and represent the best available constraint for the minimum gas velocity. Pyroclasts display distinct velocity and deceleration patterns over time, dependent on their position relative to the jet boundaries: pyroclasts within the jet core travel at constant velocity, dictated by the local gas drag conditions, while they experience sudden deceleration as they cross the jet boundaries. Complex deceleration patterns, which are more commonly observed during the late phases of individual explosive events, testify the dynamic evolution of highly turbulent entrainment zones at the jet boundaries. The above parametrization put constraints to the modelling of ballistic emplacement, air entrainment and overall jet dynamics, with implications for hazard assessment.