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Volcanic supersonic jets: an experimental study of the effect of particles on the shock cell structure and acoustic emissions.

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Explosive volcanic eruptions eject a mixture of gas and pyroclasts into the atmosphere at a range of velocities. Directly above the vent, in the gas-thrust region, a supersonic jet may be generated that strongly controls the eruptive dynamics. To improve our quantitative understanding of volcanic supersonic jets, the effect on particles within them, and their acoustic emission, we have performed small-scale explosive eruptions in the laboratory using a shock-tube. The shock-tube is composed of 3 parts, a bottom (5.6 m long, elevated pressure) and a top (48mm long, ambient pressure) plexiglass cylinder (5 mm inner diameter), separated by an electrovalve.

We have run experiments using ambient air as gas and sand, with diameter between 0.1 and 0.3 mm, as particles. The gas volume was fixed while the pressure ratio (the shock-tube reservoir to ambient pressure ratio) was varied from about 4 to 8.4 to obtain supersonic flows. During the experiments, the jet was recorded with a high-speed camera operating at 34660 fps, and the resulting noise acoustic emission with microphones (6 Hz-140 kHz; 1000 kfps) positioned at 90° from the jet axis.

Among the acoustic signals produced by a supersonic jet (jet noise) we have particularly focussed on the broad-band shock noise (BBSN) that is emitted by the interaction between shock cells and the turbulence in the jet. We estimated the jet velocity using an acoustic model based on the identification of the peak frequency of the BBSN. We also identified the BBSN frequency and its variation over time by applying the complex Morlet wavelet transformation. As expected, the BBSN frequency is inversely proportional to the gas velocity. Concerning the video recording, we analysed the shock cells behaviour and their temporal oscillation due to the presence of particles. Finally, the particle ejection rate was calculated in every video frame.

We found that the acoustic signal and shock cells are influenced by the presence of particles. In fact, fluctuations in particle concentration are well visible and decelerate the flowing gas. As a consequence, there is a temporary decrease of the stand-off-distance between the vent and the first shock-cell and concurrent rise of the BBSN frequency. We noticed, in some cases, that the shock-cells disappear during a short time interval. The BBSN frequency and the stand-off-distance

behaviour over time follow the oscillation of the particle ejection rate confirming their sensitivity to particle load variation.

The future prospectives of this embryonal study could lead to new instruments for determining either the amount of pyroclasts inside the volcanic jets and their exit velocity on the basis of the recorded acoustic signals.