Unsteady turbulent jet dynamics with implications for volcanic plumes

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To investigate the response of volcanic plumes to unsteady vent conditions, an analogue study of laboratory jets was conducted. Lab jets were driven with injection rates that varied over time in a Gaussian-like history. Resultant jet heights showed a logarithmic dependence on time; this trend is in contrast to the power law dependence on time expected for jet heights from steady-state or instantaneous injection rates. The logarithmic time dependence may reflect the dominance of coherent vortices that were detected in the unsteady jet interiors. These vortices are large and extend from beyond the visible boundary of the jet through the jet interior. They are also persistent with lifetimes that are comparable to the jet rise time. The large and long-lived coherent vortices may not transport mass, momentum and energy in a way that is reasonably described by homogeneous turbulence concepts that underlie steady-state and instantaneous models of volcanic plumes and jets. Consequently, this work implies that it is first necessary to understand transport by large and long-lived coherent vortices before that process can be parameterized for use in models of unsteady turbulent jets. Despite this need for a complex transport description, the behavior of the flow front can be described with a simple expression that consolidates the jet rise behavior from a range of experimental conditions to a single trend. This expression is non-dimensional using a length and time scale derived from a linear fit of jet height and the logarithm of time. Data from a single volcanic plume observation (Mori and Burton, 2009, JVGR, 188, p. 395-400) also follows the same trend as that discovered in the laboratory. This synthesis lends a tenuous confidence to the relevance of the experimental model to the natural system. Successful comparison with a larger natural data set may better delimit the model applicability but such data is absent from the literature. Nevertheless, the logarithmic time dependence contrasts the power law dependence commonly employed to interpret volcanic plume observations, and suggests that this new experimental model may be more appropriate for interpreting short-lived volcanic events.