STRETCHING THE TRUTH: HOW DO PARTICLES AND EDDIES INTERACT TO MODIFY TURBULENT ENTRAINMENT INTO VOLCANIC JETS?

D. E. Jessop[1,2], A. M. Jellinek[2], J. Dufek[3]
[1]*Laboratoire Magmas et Volcans, Clermont-Ferrand, France*
[2]*University of British Columbia, Vancouver, Canada*
[3]*Georgia Institute of Technology, USA*

Key words Turbulent entrainment; volcanic jets; Stokes number effects

Volcanic jets are highly turbulent mixtures of gas and ash, containing a wide range of particle sizes that are formed during powerful explosive eruptions. Turbulent entrainment is arguably the most important factor in determining the stability of volcanic jets as it allows for the initially negatively buoyant jet to undergo a buoyancy reversal through the entrainment and mixing of ambient air. To physically entrainment fluid into a jet requires the eddies that form its edges to do work in overturning and mixing the density interface between the jet and the ambient air. The ability of a jet to do this mixing is characterised through the Richardson number, $\mathrm{Ri} = g'b/u^2$. These eddies overturn the fluid and the mixing is done by smaller eddies which results in an energy cascade from large to small structures. The energy contained by the eddies at the various scales is therefore strongly affected by the particle-fluid coupling as this alters the eddy size and energy. A useful metric for the particle-fluid stress coupling is the Stokes number, St: when St is small, particles follow fluid pathlines exactly whereas at large St particles have important inertia and are unaffected by accelerations in the flow field. However when $St \sim 1$, particle accelerations influence the flow and flow accelerations influence particle trajectories. These inertial particles thus influence the angular momentum, shape and entraining properties of eddies.

Recent experimental work has shown that entrainment into particle-laden jets varies significantly from particle-free jets [1, 2]. These works also showed that whether enmathrmtrainment is increased (promoting the formation of stable plumes) or decreased (promoting unstable collapsing fountains and the formation of pyroclastic mathrmflows) depends strongly on the geometry of the vent. Accordingly, we perform novel laboratory experiments and numerical calculations containing $\mathrm{St} \sim 1$ particles and measure the energy spectra in jets where the particle concentration (ϕ) and Ri are varied (see Fig. 1). We find that an anisotropy is induced in the turbulent structure of particle-laden jets, which is greatest when Ri is large and note that the same anisotropy is not present in particle-free jets at similar Ri. We interpret these results in terms of how eddies are stretched by the critical coupling with $\mathrm{St} \sim 1$ particles and the ability of these stretched eddies to entrain ambient fluid through the overturning and mixing of the density interface.

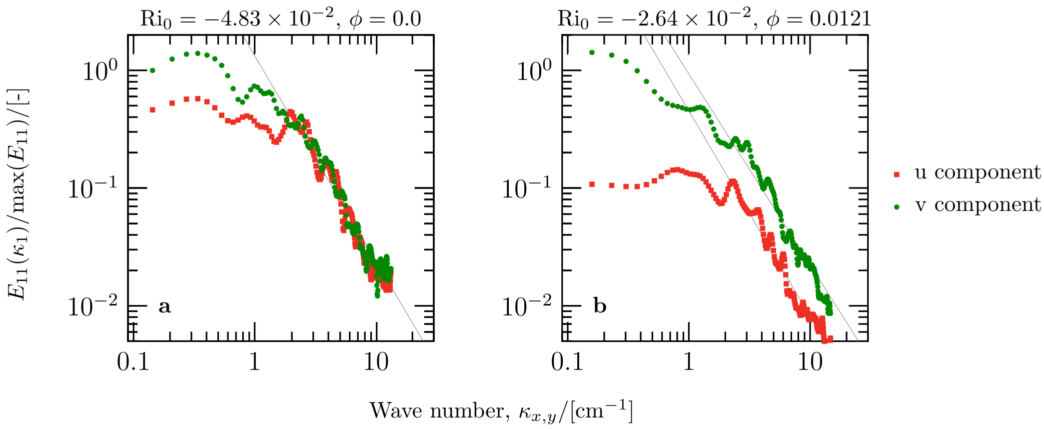

Figure 1. Energy spectra for two jets with equivalent Ri but different particle concentration. The separation of the spectra for the u and v velocity components in the right-hand plot suggests anisotropic turbulence induced by the presence of particles. The lines fitted to the data show approximately -5/3 slopes.

References

[1] D. E. Jessop and A. M. Jellinek. Effects of particle mixtures and nozzle geometry on entrainment into volcanic jets. *Geophys. Res. Lett.*, 41:1–6, 2014.

[2] D. E. Jessop, J. Gilchrist, A. M. Jellinek, and O. Roche. The effect of inertial particles, linear and annular vents on entrainment into volcanic jets. *Earth Planet. Sc. Let.*, in review.