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Scaling Laws for Lobe and Cleft Patterns at the Front of Particle-Laden Gravity Currents

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There are many examples of gravity currents in geophysics, such as snow avalanches, pyroclastic flows, thunderstorm outflows and sea-breeze fronts. These currents are driven by the buoyancy arising from a density difference, either between two homogenous fluids, or a fluid and particles suspended by turbulence within it. One feature that most turbulent gravity currents share is a pattern of lobes and clefts at the moving front of the current. Basal friction causes the foremost part of the current to rise above the surface, creating a region of unstable stratification at the moving front. It is from this region that the instability which causes the initial lobe and cleft pattern originates. The wavenumber of the lobe and cleft pattern has been shown to be related to the Grashoff number, which is a dimensionless parameter relating buoyancy induced inertia to viscous forces.

Findings from a previous study of unsuspended granular flows of polystyrene particles suggest that, although this instability causes initial fluctuations, vortices formed in the moving front develop these fluctuations into a more stable pattern of lobes. The wavenumber of these lobes is determined by a velocity boundary layer, the thickness of which is determined by the size of the particles.

This study is an experimental investigation of the pattern and development of lobes and clefts found at the moving front of a gravity current of fully suspended expanded polystyrene particles in air. Experiments are performed in order to ascertain whether the wavenumber of the pattern that forms at the moving front of these currents is determined by a velocity boundary layer, as characterised by the Grashoff number of the flow.

Various length scales are considered when determining the Grashoff number in the analysis. One such length scale is based on the diameter of the particles used. Initial results indicate that fluctuations in the moving front of suspended granular flows of polystyrene particles develop into a more stable pattern of lobes, unlike flows of two homogenous fluids which produce a constantly shifting pattern. The size of these lobes scales inversely with the size of the particles, the wavenumber of the pattern decreasing as the particle diameter increases. This suggests that the nonlinear feedback growth of pairs of vortices in the moving front is responsible for developing the initial fluctuations into the more stable pattern observed. The size of these vortices is determined by the thickness of a velocity boundary layer, the thickness of which is determined by the diameter of the granular particles.