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A viscoplastic lubrication model for entrainment by avalanches and debris flows, and comparison with experiments

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Recently, experiments were designed and carried out examining how a viscoplastic avalanche begins to entrain a shallow layer of identical fluid lying in its path, much like a snow avalanche or mud flow which suddenly encounters an entrainable layer, described as a yield stress material. This represents a simplified problem, investigated in order to gain some physical insight into entrainment by avalanches. These experiments serve as a test for mathematical models of entraining gravity currents.

Two classes of entrainment behaviour were observed: either the avalanche "glided" out over the entrainable bed, immediately shearing it in the downstream direction and progressively incorporating fluid down to the rigid base, or the avalanche seemed to "roll" out onto the entrainable bed, with strong motion in the slope-normal direction in the bed after yield.

This difference in behaviour was dictated by the magnitude of the flume's slope. For the steeper flows studied (20 and 24 degrees), entrainment was principally in the former class, whereas for shallower slope angle (12 and 16 degrees) entrainment more closely resembled the latter type. This would suggest that there is a competition between the normal and shear stresses exerted on the bed, with bed-yield and entrainment occurring when these stresses exceed a critical value.

An interesting phenomenon that was observed in all cases was a sort of buckling of the bed, downstream of the avalanche front. This was far more significant in the flows down shallower slopes, and regular waves were created in the bed with wavelength dependent on the flow depth.

Based on theoretical comparisons with non-entraining Herschel Bulkley flows, the physics of entraining flows are investigated numerically for shallow viscoplastic gravity currents on different slopes. The predictions are compared with the experimental values for velocity field and surface height. The model was successful in reproducing velocities of the correct order, but the buckling behaviour was not explained. A further description is thus sought for this.