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Modelling the evolution of temperature in avalanche flow

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Because the mechanical properties of snow are temperature dependent, snow temperature has a strong influence on avalanche flow behaviour. In fact, snow avalanche classification schemes implicitly account for the below-zero temperature regime, i.e. wet snow avalanches contain warm moist snow, whereas dry flowing or powder avalanches consist of colder snow. Although thermal effects are an important feature of avalanche flow behaviour, the temperature field is usually not considered in avalanche dynamics calculations. In this presentation we explicitly model the temperature evolution of avalanches by extending the basic set of depth-averaged differential equations of mass, momentum and fluctuation energy to include a depth-averaged internal energy equation. Two dissipative processes contribute to the irreversible rise in internal energy: the shear work and the dissipation of fluctuation energy due to random granular interactions. Snow entrainment is also an important source of thermal energy. As the temperature of the snow can vary between the release area and runout zone, we model the effect of snowcover temperature elevation gradients. Additionally we introduce a physical constraint on the temperature field to account for phase changes: when the temperature of the avalanche flow surpasses the melting point of ice, the surplus rise in internal energy is used to produce meltwater. We do not consider heat losses due to sensible heat exchanges between the atmosphere and the avalanche. Using numerical simulations we demonstrate how the temperature of the snow in the release area in relation to the temperature of the snowcover encountered by the avalanche at lower elevations can modify avalanche velocity and runout behaviour. We show how the production of turbulent fluctuation energy, which separates dense and dilute, fluidized flow regimes, can be controlled by temperature, creating a wide-range of avalanche deposition patterns. Finally, we investigate under what thermal conditions meltwater can be generated during the runout phase of the avalanche.