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Modelling the influence of snow temperature in avalanche flows

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Avalanche classification schemes implicitly use snow temperature to distinguish between different avalanche flow types. For example, wet snow avalanches contain warm moist snow while mixed flowing-powder type avalanches contain dry, cold snow. Although temperature effects are clearly important in understanding the behaviour of flowing snow, avalanches dynamics models typically ignore temperature, using ad-hoc adjustments to friction parameters to match recorded velocities or runout distances of observed events. In this paper we present a model of avalanche flow that includes the energy fluxes associated with the change in avalanche temperature. These include the internal energy input by snow entrainment, the dissipated heat energy by frictional processes and the decay of kinetic energy associated with granular fluctuation energy. This allows us to investigate how different processes – entrainment, friction and snow granularization – influence the flow behaviour of both wet and dry snow avalanches. A phase change equation is included to account the excess of thermal energy when the snow cover reaches the melting point. We investigate the initial (release) and boundary (entrainment) conditions for the production of meltwater. We demonstrate that the melt water produced and transported within the flow affect the flow velocity and run out distances by lubricating the sliding surface. The snow field temperature varies between the release area and runout zone; therefore we can model the effect of snowcover temperature elevation gradients. By simulating real case studies in the Swiss Alps we show how the relation between the released snow temperature and the entrained snow during the flow can modify avalanche deposition patterns, speed and run out distance even the important case of dry snow avalanche release followed by wet snow entrainment can be studied.