# Thermo-hydro-mechanics of multi-phase rock-ice avalanche

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***Abstract:*** I propose a novel physically-based multi-phase thermo-hydro-mechanical model for rock-ice avalanches. It considers rock, ice and fluid; and includes the mechanism of ice-melting and a dynamically changing general temperature equation for the avalanching mass, the first of its kind. It explains advection-diffusion of heat including heat exchange across the rock-ice avalanche body, basal heat conduction, production and loss of heat due to frictional shearing and changing temperature, a general formulation of the ice-melting rate and enhancement of temperature due to basal entrainment. The temperature equation includes a coupled dynamics, considering the rates of change of thermal conductivity and temperature. Ice melt intensity determines these rates as mixture conductivity evolves, characterizing distinctive thermo-hydro-mechanical processes. Fast ice melting results in substantial change in temperature. I formally derive the melting efficiency-dependent general fluid production rate. As properly described with the unified, multi-phase thermo-hydro-mechanical rock-ice avalanche model, a complex interplay between the frictional-weakening and the melt-rate-weakening is revealed determining the net flow mobility. The model includes internal mass and momentum exchanges between the phases and mass and momentum productions due to entrainment. The latter significantly changes the state of temperature; yet, the former exclusively characterizes the rock-ice avalanche. Temperature changes are rapid when heat entrainment across the avalanche boundary is substantial. The new model offers the first-ever complete dynamical solution for simulating rock-ice avalanche with changing temperature. This offers a fundamentally novel understanding of the complex process of rock-ice avalanche, flashing the deep insights into the underlying dynamics. I present the first multi-phase thermo-hydro-mechanical simulation of the 2021 Chamoli rock-ice avalanche event with the comprehensive simulation tool r.avaflow, https://www.avaflow.org.