## abstract

Debris flows, avalanches, landslides, and other geophysical mass flows can contain $O(10^6 - 10^{10})\,\mathrm{m}^3$ or more of material. These flows commonly consist of mixture of soil and rocks with a significant quantity of interstitial fluid. They can be tens of meters deep, and their runouts can extend many kilometers. The complicated rheology of such a mixture challenges every constitutive model that can reasonably be applied; the range of length and timescales involved in such mass flows challenges the computational capabilities of existing systems. This paper extends recent efforts to develop a depth averaged "thin layer" model for geophysical mass flows that contain a mixture of solid material and fluid. Concepts from the engineering community are integrated with phenomenological findings in geo-science, resulting in a theory that accounts for the principal solid and fluid forces as well as interactions between the phases, across a wide range of solid volume fraction. A principal contribution here is to present drag and phase interaction terms that comport with the literature in geo-sciences. The theory is tested against a well documented, highly channeled mud flow at Ruapehu, New Zealand, it is verified with data from artificial channel experiments. And is validated with data from one dimensional dam break solutions.