**A hierarchy of debris flows models with dilatancy effects**

**Authors:**

- François Bouchut, Laboratoire d'Analyse et de Mathématiques Appliquées (UMR 8050), CNRS, Université Gustave Eiffel, UPEC, F-77454, Marne-la-Vallée, France (`francois.bouchut@univ-eiffel.fr`)

- Elias Drach, Laboratoire d'Analyse et de Mathématiques Appliquées (UMR 8050), CNRS, Université Gustave Eiffel, UPEC, F-77454, Marne-la-Vallée, France (`elias.drach@univ-eiffel.fr`)

- Enrique D. Fernández-Nieto, Departamento de Matemática Aplicada I, Universidad de Sevilla. E.T.S. Arquitectura. Avda, Reina Mercedes, s/n. 41012 Sevilla, Spain (`edofer@us.es`)

- Anne Mangeney, Université Paris Diderot, Université Paris Cité, Institut de Physique du Globe de Paris, Equipe de Sismologie, 1 rue Jussieu, 75005 Paris, France (`mangeney@ipgp.jussieu.fr`)

- Gladys Narbona-Reina, Departamento de Matemática Aplicada I, Universidad de Sevilla. E.T.S. Arquitectura. Avda, Reina Mercedes, s/n. 41012 Sevilla, Spain (`gnarbona@us.es`)

**Abstract:** In this work, first we present here a modification of the two-layer model for grain-fluid flows with dilatancy effects derived in [1]. This model solves the depth-averaged mass and momentum conservation equations for both a grain-fluid layer and an upper fluid layer as well as the exchange of mass and momentum between these layers. In this model the fluid can be expelled from the mixture during contraction and to be sucked into the mixture during dilation thanks to the presence of a thin fluid layer on top of the mixture layer. It appears a non-hydrostatic contribution in the solid and fluid pressures in the mixture, defined by a dilatancy closure equation. Secondly, a hierarchy of models is presented, in terms of several simplifications and the relationship with other models in the bibliography (see [2]). Finally, several numerical tests are presented.

**References:**

[1] F. Bouchut, E.D. Fernández-Nieto, A. Mangeney, G. Narbona-Reina. *A two-phase two-layer model for fluidized granular flows with dilatancy effects.* Journal of Fluid Mechanics (801):166–221, 2016.

[2] R. M. Iverson, D. L. George. *A depth-averaged debris-flow model that includes the effects of evolving dilatancy. I. Physical basis.* Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences (470): 2170, 2014