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Interactive comment on "IMEX_SfloW2D 1.0. A depth-averaged numerical flow model for pyroclastic avalanches" *by* Mattia de' Michieli Vitturi et al.

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Review of "IMEX_SfloW2D 1.0. A depth-averaged numerical flow model for pyroclastic avalanches" by de' Michieli Vitturi et al., submitted to GMD.

Reviewer: Olivier Roche

General comments

This paper presents a new depth-averaged flow model for granular mixtures, with application to geophysical flows. The authors consider in particular pyroclastic avalanches generated during volcanic eruptions. This is a timely contribution because the vol-

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Discussion paper

canological community needs models to simulate dense granular flows. The paper presents the basic assumptions and equations used in the model as well as some validation tests, and as such represents a first step towards more detailed studies in specific volcanic contexts. Given the team's recognized international reputation in modeling of volcanic flows and the success of their previous studies, I have no doubt that the present model will lead to new fundamental understanding of granular flows and will be widely considered by the volcanological community. The manuscript is very well written and organized, and I recommend that the paper be accepted after minor revision. Please find below my general and specific comments.

The depth-averaged approach and the related equations as well as the discretization methods are well explained and justified. The authors discuss in particular how the case of zero flow thickness is treated. The main strengths of the model are the consideration of the effect of topography, which is critical for the simulation of geophysical flows on irregular topographies, the use of Digital Elevation Models, and the possible implementation of different granular flow rheologies. For their first tests and applications the authors have chosen a Voellmy-Salm rheology. This is a sensible choice as this rheology is often used to simulate geophysical flows such as snow avalanches for instance, and also because it involves both velocity independent dry granular friction and velocity dependent turbulent friction, which represent the respective contributions of granular friction and collisions, two mechanisms that operate in granular flows.

Specific comments

In introduction, I appreciate to effort made by the authors to distinguish between "avalanches" and "pyroclastic density currents" (PDCs), but the terms and the related natural phenomena could be introduced in a different way. In fact, the model addresses dense granular flows in general (irrespective of their volume), which are often present at the base of many PDCs, behave as described by the authors in lines 15-17 in page 2 for instance even though they are overridden by a dilute ash cloud (as considered actually in the test simulation presented in section 5), and may form deposits with low aspect ratios. The model presented in this paper as more potential than the present introduction suggests. I think using the term “avalanche” is fine, but the authors could state that their model is applicable to dense pyroclastic avalanches (or “flows”, or “currents”) in general, which are basically concentrated granular flows (with negligible pore pressure in the present case).

In introduction, including a short discussion on the main similitudes and differences with earlier works would be certainly helpful. This would help the reader to appreciate for instance the choice of the spatial and temporal discretization schemes considered here.

The tests and simulations are important parts of this paper. Some complementary information would help to appreciate better some specific issues: - In section 4.2, the terms “wet” and “dry” should be defined clearly to avoid any possible confusion. I am not sure I understand the significance of these terms. - In section 5 on the simulation of pyroclastic avalanche at Etna volcano the authors should discussed, even briefly, the values of the parameters mu and xi they use. Though most readers will certainly appreciate that values of mu=0.2-0.5 are typical of most granular flows, values of xi=300-5000 may be more enigmatic. These values of xi are based on earlier works, but what are their significance in terms of physical processes? - It appears that the presence of a lava flow, not taken into account in the digital elevation model, probably influenced the emplacement of the pyroclastic avalanche. Could the authors run complementary simulations with a DEM including the lava flow, if available?

Page 1 L1-2. Pyroclastic avalanches generated from dome collapse should be mentioned as well. L4. 1 vol. % is a fairly low concentration for granular flows. Say rather 10-50 vol. %? L11. The term “wet-dry” should be defined. L21. Debris flows are water-saturated, which is not the case of the other flows mentioned here. L24. I appreciate this point! I think the term “avalanche” is fine.

Page 2 L4-5. Please see my general comments on application of the model for pyroclastic density currents. L22. There is no section 1.2. Delete section 1.1?

Page 3 L7. Typo (conservative) L28-29. This is certainly of major strength of this new code.

Page 4 L6-8. This sentence is long and not clear. Are there words mission? It could be said also that the St-Venant approach is relevant when the flow depth is significantly smaller than the flow length.

Page 5 L10. To model shallow pyroclastic avalanches (?) L13. Is the term "fits" appropriate? Say rather "relevant"? L20-21. It could be stated that the velocity dependent turbulent friction is commonly considered to correspond to granular collisions.

Page 6. L31. This suggests. . . Page 8. L5. What do you mean by "velocities too large"? Please clarify. Page 9. L12. . . .because such scheme is well-suited. . . (?) Page 10. L9-10. This is an important issue. Is it similar to or different than other models involving a Voellmy-Salm rheology?

Page 11. L4. Andrianov (2004) is not in the list of references. L8-15. In Figure 2, what is the blue line? I guess this is not the initial flow thickness otherwise the initial model solutions would not correspond to this boundary condition. Is it the initial topography as in Figs. 3 and 4? L18. The terms "wet" and "dry" must be defined here.

Page13. L23. . . .the flow reaches. . . Page14. L10. . . .the front reaches. . . Page15. In Fig. 5 at t=7.5 s it seems that the flow thickness represented on the bottom plane is zero at x<17-18 whereas some material is present on the inclined plane. Is it because the flow thickness on the bottom plane is not represented below a threshold value, or else? Page16. L8-9. This sentence may suggest another event. State that the ash cloud was generated by the avalanche.

Page 17. L11-12. Please see my general comments on the rheological parameters. L14-15. The term "extension" may be ambiguous. In fact, the fit is reasonable in terms of the area covered by the model deposit, which is close to that of the pyroclastic avalanche though shifted toward the south because of the absence of the lava flow in the model (please see also my general comments). It could be stated as well that values of mu=0.3-0.4 correspond to fairly low friction coefficients of dry granular materials, which is an interesting result. L16 and next page. I subscribe to this point of view.

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