Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2019-423-RC1, 2020

Natural Hazards and Earth System Sciences
Discussions
Open Access

Interactive comment on "Role of friction terms in two-dimensional modelling of dense snow avalanches" *by* Marcos Sanz-Ramos et al.

Christophe Ancey (Referee)

christophe.ancey@epfl.ch

Received and published: 27 April 2020

The paper shows how the Iber numerical code (used in hydraulics) has been extended to cope with snow avalanches. It also presents three applications and discusses the part played by the various contributions to friction.

Major comments

This paper's strength lies in the extension of Iber to model snow avalanches. Iber is a freely available software based on efficient finite-volume techniques for solving the Saint-Venant equations, preprocessing and post-processing tools, and a user-friendly interface. Apart from commercial software such as RAMMS, existing tools are academic tools with no user interface, so Iber as a newcomer is welcome. The paper is also interesting for two reasons:

- Developing numerical avalanche-dynamics models is a longstanding problem. To the best of my knowledge, most existing models are based on finite-volume techniques, following the idea proposed by Jean-Paul Vila in the 1980s (Vila, J.-P., Modélisation mathématique et simulation d'écoulements à surface libre. *La Houille Blanche,* 6/7, 485-489, 1984; Vila, J.P., Simplified Godunov schemes for 2*2 systems of conservated laws, *SIAM Journal of Numerical Analysis*, 23, 1173-1192, 1986. Vila, J.P., *Sur la théorie et l'approximation numérique des problèmes hyperboliques non-linéaires*, application aux équations de Saint-Venant et à la modélisation des avalanches denses, Ph.D. thesis thesis, Paris VI, 1986.). In the early 2000s, a benchmark comparison of numerical models showed how the numerical outcome was sensitive to the algorithm details (Barbolini, M., U. Gruber, C.J. Keylock, M. Naaim, and F. Savi, Application of statistical and hydraulic-continuum dense-snow avalanche models to five European sites, *Cold Regions Science and Technology*, 31, 133-149, 2000.). Today, 20 years later, if I compare my code based on clawpack (available from github) and Shaltop (developed by François Bouchut and Anne Mangeney), I got significant differences in the avalanche deposition zone in many cases. Developing new models and making them available should help us to improve the state of art, and see why (or when) some numerical approaches to the Saint-Venant equations are more efficient.

- Before the advent of commercial software (like Aval1d and Ramms), avalanche engineering was mostly the field of trained and experienced practitioners. The increasing availability of numerical tools has allowed a wider community of users (including untrained practitioners and governmental agencies) to access computational avalanche-dynamics models. Paradoxically, this has led to a significant decrease in the quality of expertise offered. Many people have been fooled by the apparent high resolution of numerical outcomes, confusing numerical resolution and prediction accuracy. Giving access to different avalanche-dynamics codes should make people more aware of uncertainties affecting numerical simulations. As Bruno Salm stated in his last review paper, “The presented models are all—up to the present day—somehow uncertain. Therefore, only relative simple models with few parameters are significant. An increase of complexity of models does not necessarily mean an increase of accuracy or a better hazard mitigation strategy.” (Salm, B., A short and personal history of snow avalanche dynamics, *Cold Regions Science and Technology*, 39, 83-92, 2004.)

That said, I think that the paper suffers from many shortcomings:

1. This paper’s ultimate goal is unclear to me. The introduction does not frame any scientific issue. I understand that the authors want to study the effect of friction on the bulk dynamics, but I have hard time understanding what the problem is. Voellmy’s model is an empirical one. It shows usefulness in many engineering applications, but there is no proof that snow behaves like a Voellmy frictional material (as shown in my 2004 JGR paper, Coulomb performs better in many cases). Although Adolf Voellmy did not present the issue like this, I presume that he was annoyed with Paul Mougin’s model based on Coulomb friction (Mougin, P., *Les avalanches en Savoie*, 175-317 pp., Ministère de l’Agriculture, Direction Générale des Eaux et Forêts, Service des Grandes Forces Hydrauliques, Paris, 1922.) because an avalanche experiencing Coulomb friction cannot reach a steady state. The avalanche accelerates or decelerates. Hence, no possibility of providing analytical estimate of avalanche velocity. By adding a turbulent-like term, Voellmy got around this issue. To date, fitting the Voellmy coefficients or predicting avalanche behavior remains a difficult challenge. Adding new contributions to the Voellmy model would be justified if one can show that there is a clear advantage of using complex frictional models over simpler ones (Occam’s razor). Comparison criteria (Brier skill score, Bayes factor, Akaike information, etc.) could help decide whether adding complexity is useful or not. When I see an empirical equation

like Eq. (2), I wonder how a model involving 5 dissipation sinks can perform better than simpler models like the Coulomb or Voellmy ones. I suggest revising the introductory material, framing general and specific issues, and specifying the scientific issue(s) addressed by the paper.

2. Section 2 needs refinement. The underpinning assumptions and governing equations should be clearly introduced. For instance, do the authors use a Cartesian frame? Curvilinear coordinates? The numerical algorithm used for solving the Saint-Venant equations should be written by keeping mind that the NHESS normal reader may not be familiar with Roe solvers. How the source term is taken into account or how the dry/wet limit is implemented needs to be fully specified.

3. Section 3 presents 3 case studies, and among them only the last one concerns a real-world avalanche. It would be interesting to include further comparison with well-documented avalanches, e.g. those monitored at La Sionne, Col du Lautaret, or Ryggfonn. Using high-resolution data (including front position over time, velocities, depth, etc.) would be useful to test Iber. A recent example of how field data can be used to deduced friction parameters is given by Heredia, M.B., N. Eckert, C. Prieur, and E. Thibert, Bayesian calibration of an avalanche model from autocorrelated measurements along the flow: application to velocities extracted from photogrammetric images, *Journal of Glaciology*, 1-13, 2020.

4. Section 4 contains overly general considerations on avalanche modelling. By focusing on a well-defined issue, applying Iber to several field cases, and discussing how prediction is improved by increasing the number of frictional parameters and how each frictional model performs relative to others would help beef up the discussion and dissipate the impression of rambling considerations.

I took a look at iberaula. I found the mention to Iber avalanche, but there is no information about the status of this code. Will it be available like Iber? Or reserved for collaborators, buyers, etc.?

Further work is required before the paper can be accepted for publication.

Christophe Ancey

Specific comments

1. L9: You probably confuse "Voellmy friction" and "Voellmy-Salm(-Gubler)" model. The latter is a computational method for estimating velocities and runout distances (the avalanche is assumed to behave like a sliding block experiencing Voellmy friction. The avalanche path is split into different parts, and on each part, the momentum balance equation is solved to provide the steady-state velocity.) See Salm, B., A. Burkard, and H. Gubler, *Berechnung von Fliesslawinen, eine Anleitung für Praktiker mit Beispielen*, Eidgenössisches Institut für Schnee- und Lawinenforschung (Davos), 1990. (Hansueli Gubler translated it into English or provided an English summary, if needed).

2. L28: I do not think that the Voellmy model is a "popular model" in the modelling of granular flows. It has mainly been used to model snow avalanches, and to a lesser extent debris flows.

3. L42: what do you mean with the effects of friction being ignored? Can you be more specific when you state that the parameters are nonphysical.

4. L49 a number of words (e.g. retention, detention, accretion, premise) throughout the paper seem to be used out of context.

5. Eq. (1) why do you use the delta symbol instead the partial differential operator. F is the flux function, not a tensor. And in Eq. (3) you do not show F, but its gradient.

6. L85: including snow entrainment into the governing equations involves modifying not only the mass balance equation, but also the momentum equation.

See for instance Iverson Ouyang (Entrainment of bed material by Earth-surface mass flows: review and reformulation of depth-integrated theory, Reviews of Geophysics, 53, 27-58, 2015) for a correct treatment of this problem. Many avalanche-dynamics models involving snow entrainment and deposition are inconsistent from the continuum mechanics viewpoint. The problem is complex (see Issler, D., Dynamically consistent entrainment laws for depth-averaged avalanche models, *Journal of Fluid Mechanics*, 759, 701-738, 2014; Ancey, C., and B.M. Bates, Stokes' third problem for Herschel-Bulkley fluids, *Journal of Non-Newtonian Fluid Mechanics*, 243, 27-37, 2017. Lusso, C., F. Bouchut, A. Ern, and A. Mangeney, A free interface model for static/flowing dynamics in thin-layer flows of granular materials with yield: simple shear simulations and comparison with experiments, *Applied Sciences*, 7 (4), 386, 2017.

7. Section 2.2: this section should describe the numerical methods more clearly. As the model uses the same numerical framework as Iber, it should focus on the papers by Bladé and Cea for the homogeneous equation, and describe more clearly how the source term is taken into account to correct the solution to the homogenous equation.

8. L190 probably better to place the information on the numerical parameters elsewhere

9. L209: Platzer measured the friction forces in a chute. There is no clear evidence that on a larger scale, the friction coefficient holds the same value (in the same way, in a granular packing, there is a weak link between particle friction and bulk friction).

10. L269 what do you mean with “a 2D model in the vertical”

11. L366 if the wet-dry limit is important, why do you mention it just here?

Printer-friendly version

Discussion paper

12. L420: the largest difference between simulated and real-world avalanches is that in the real world, an avalanche release is not like a dam break, in which a wall is suddenly removed. Initial rigidity or cohesion is probably a second-order problem, which does not influence the bulk dynamics significantly at later times.
13. L522: throughout the paper you have used ‘physical’ and ‘non-physical’, but these terms can be understood differently. You should be more specific.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2019-423, 2020.