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Interactive comment

Interactive comment on "DebrisInterMixing-2.3: a finite volume solver for three-dimensional debris-flow simulations with two calibration parameters – Part 2: Model validation" *by* Albrecht v. Boetticher et al.

Anonymous Referee #2

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The present manuscript applies the model and simulation technique described in Part I by von Boetticher et al. (2016) that is based on an adaptation of the interMixing-Foam, OpenFOAM solver in combination with a stable implementation of the pressure-dependent rheology model of Domnik et al. (2013) to describe the gravel phase as a Coulomb-viscoplastic fluid, combined with a Herschel-Bulkley rheology implementation for the interstitial slurry of water and fine sediment. Three different experimental setups are chosen to illustrate how sensitively the modeled flow and depositional processes react to changes in water- and clay-content in the mixture, channel curvature and roughness. The first experimental validation is based on flume experiments

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Discussion paper

from Hürlimann et al. (2015). The second experimental case used for validation was designed to study the sensitivity of debris flows to channel curvature (Scheidl et al., 2015). The third, with large scale out-door USGS flume experiments for debris mixtures. The audience of GMD may benefit from the publication of this MS. However, it needs a major revision.

As the present MS is the application of Part I, the Introduction/Discussion should briefly mention the need of the full 3D simulations, modeling assumptions, simplicity for application as well as the scopes/limitations of the modeling and simulation approaches as mentioned in Part I. This would help the audience who may only focus on application, to directly follow this paper.

Writing could be substantially improved in concept and content. Figures are not enough explained in the text. Figures quality and arrangements could be improved. Some important dynamical aspects observed in the simulations would have been explained in a better way with elaboration. Several figures/texts are not needed, so could be removed.

Some of the experiments considered here contain relatively low water content, however in reality debris flows may contain large amount of water, and may transform to debris floods, or locally fluidized. It would be appropriate to discuss this aspect that would probably highlight both the strength and limitations of the presented model and simulation aspects in relation to the experiments. In a debris flow body, water contain may evolve strongly (Pudasaini and Fischer, 2016; Mergili et al., 2017), and the characteristic may range from dense to dilute flows. These aspects need to be clearly mentioned in the MS. Recent and relevant literatures could be included and discussed.

Further detailed suggestions for possible improvements:

Title: Part 2: Model validation –> Part 2: Model validation with experiments

Abs.: material properties were known –> material properties and compositions were

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known

(including ist mineral composition): R (R = Remove).

(including its friction angle): R.

two model parameters are sufficient for calibration –> two model parameters are used for calibration

the angle of repose: is this 'the angle of repose' of 'internal friction angle'?

Main text:

P1:

L14: a partly fluidized mass –> a partially or fully fluidized mass

The mix of –> The mixture of [?]

L17: Would be relevant to include recent works by Kattel et al. (2016, Anal. Glaciol.), Mergili et al (2017, GMD)

P2:

L3: Coulomb-viscoplastic rheology –> Coulomb-viscoplastic rheology (Domnik and Pudasaini, 2012; Domnik et al. 2013)

L7: (I= Insert): 'For the dynamic evolution of the solid and fluid concentrations and phase velocities we refer to more general model and simulations (Pudasaini, 2012; Mergili et al., 2017).'

L9: The object of this study –> The objective of this study

L10: sensitivity to water content, gravel- and clay-fraction –> sensitivity to water content, gravel- and clay-fraction (also see de Haas et al., 2015, JGR).

L11: the interaction between the three-phase rheology –> the interaction between the bulk rheology of the mixture

L15: Here more clearly and quickly mention about Part I

L23: The only parameter –> With this, the only parameter

L24: a restricted multiplication factor: Explain.

L28: ‘side-wall effects’: What is the difference in side-wall effects in single-phase flows and a kind of three-phase mixture flows of gravel, sand and water as considered here? Better to explain.

L33: I: We mention that super-elevation has been analytically modeled and validated for dry granular flows and flows of mixtures by Pudasaini et al. (2005, NHESS; 2008, PoF) with detailed discussions on the effect of channel curvature and twist for different channels and fluid fractions in the dynamics and super-elevation of the flow.

P3:

L1: sediment –> sediment water mixture

L4: flume –> two-dimensional rectangular flume

L5: a planner run-out area –> a planner three-dimensional run-out area

L9: is linked –> is often linked

L21: I: Since, in the mixture, largely the solid particles exhibit slip, viscous fluid exhibits no-slip along the basal surface such distinct basal boundary conditions can only be included with real two-phase mass flow models (see, e.g., Pudasaini, 2012; Mergili et al., 2017).

P4:

The mixture effectively consists of water, fine particles and gravel with different physical parameters and mechanical, hydrodynamical response to applied loads. In such a complex situation, how a simplified model with two free parameters can capture the flow so nicely. It needs to be discussed.

L1-2: ‘angle of repose’ and ‘friction angle’: they are not the same. One of them should be used consistently.

L6-11: Improve.

L11: According to equation 1, –> according to

L12: Bit strange notations.

L23: decay –> decrease [?]

L25: flow depths –> hydrographs

L26: (Figure 5). –> (Figure 5). Effect of the water content and geometry on the flow dynamics and super elevation have also been previously simulated by Pudasaini et al. (2005).

L31: a transition began towards the stable level of about 11 mm flow depth –> a transition began towards fluctuation around 11 mm flow depth [also explain panel (b) and (c) . . ..].

Even if the flow height is twice the maximum grain size what about the experimental simulation reliability/reproducibility/accuracy?

P5:

L1-2: However, the simulated front also temporarily paused at x = 2.04 m, until it was overrun by a second wave 0.1 s later: Not shown.

L2-3: There is an almost perfect fit between the shapes of the experimental and simulated deposits in the calibration case (Figure 5 center).: Explain the reliability of the perfectness, because the other two panels do not so strongly support this statement.

L3-4: The maximum flow depth and the subsequent decrease are well reproduced (Figure 4 center): There is no flow depth here; in Fig. 4 hydrograph, in Fig. 5 only deposition areas are shown.

L3-9: There is a non-logical switching between Fig. 4 and Fig. 5; difficult to follow.

L5: in the wet experiment: both experiments were wet, or?

L12: I: However, super elevation also occurs in dry granular flows as this phenomenon is primarily induced by the geometry of the channel (curvature and twist) rather than the viscous or frictional properties of the material. Nevertheless, super elevation is amplified by the fluid component in the mixture flows (Pudasaini et al., 2005, 2008).

so it can be viewed as a further indicator for model quality. –> so it can be viewed as a further indicator for model quality (from geometric point of view).

L14: pressure-dependent rheology. –> pressure-dependent rheology. This in fact has first been analytically and explicitly included in Pudasaini et al. (2005) where the pressure (normal load) increases as explicit functions of slope curvature and twist. Such model has further been extended in Fischer et al. (2012). This aspect has further been explored here by implicitly connecting the surface geometry induced curvature, and possibly also twist, to viscosity via its pressure dependence (Dominik et al., 2013).

L18: I: However, for the rigorous mathematical derivation of the slope induced super elevation we refer to Pudasaini et al. (2005).

P6:

L6: (Fig. 7 right). –> (Fig. 7 right). For this a mechanical phase-separation model (Pudasaini and Fischer, 2016) would be required.

L7: in the experiments or simulation –> in the experiments

L14: the front volume: not clear/not seen.

L21-22: Does it upscale?

P7:

L18: Separation between solid- and fluid-type materials may lead to this discrepancy that can be described with phase-separation model (see literature mentioned above).

L23-32: Description could be improved.

P8:

L8: I: in the early stage of front arrival but substantial later.

L14-15: without any time delay. –> almost with no time delay.

L15-16: I: This discrepancy could have been emerged due to the fact that there could be substantial interactions and also separation between solid- and fluid-type phases that has not been considered in the simulations.

L27: a widely applicable –> a potentially widely applicable [needs to be applied to different flows and real events].

L28: two-phase flow –> two-phase bulk flow

L29: are surprising, as it appears to be possible to produce accurate front velocities –> produce appreciable front velocities

P9:

L7-8: Only grid-resolution (numerical) is explained as a possible source of discrepancy. But this discrepancy could also be reduced by applying real two-phase models with explicit phase-interactions. Needs discussion.

L20: As mentioned previously other relevant works could be discussed.

L21: Discuss the work by de Haas et al. (2015) and for grain sorting and phase separation that can be modeled by the phase-separation model mentioned above.

L26: from the experiments. –> from the experiments. This is clear because, to improve this it requires explicit inclusion of both the curvature and twist of the channel with full control over these geometric properties in the model equations (Pudasaini et al., 2005, 2008; Fischer et al., 2012) that has been included here implicitly through the three-dimensional flow simulations.

L27: by the no-slip boundary condition, –> by the no-slip boundary condition, that could be improved by applying the automatically evolving pressure- and rate-dependent Coulomb-viscoplastic mechanical basal slip conditions developed by Domnik et al. (2013).

P10:

L10-11: I: Such discrepancy could be reduced with phase-separation model.

L25: Also discuss phase-separation effects that might dominate the flow dynamics.

L29: I: This clearly demands for two- or, multi-phase flow model with phase-separation mechanisms.

P11:

L3: model that can be applied to a wide range of debris-flow simulations. –> model that can be applied to a wide range of debris-flow simulations. However, a one or two parameter model, although simple and cheap, may not certainly capture all the more complex debris flows where complexities arise from different material or mechanical parameters and dynamically and locally evolving flow quantities (including the solid, or fluid fraction, and phase velocities, etc.).

L6-11: The new model overcomes a weak point of debris flow modeling: These statements are not fully valid. This discussion should be compatible with Part I. It would be better not to state 'overcomes a weak point' but in practical applications 'just reduces the complicities'. Drag is an essential component of mixture flows. To simplify the situation, and also depending on the flow type, it could be considered to be negligible. Except in local regions, globally flows are essentially thin that can be very economically simulated with real two-phase models that also includes drag (Mergili et al., 2017). So, such descriptions on drag do not help so much in the MS.

L10: difficult to quantify –> difficult to quantify. However, Pudasaini (2012) developed a generalized drag model that overcomes these difficulties. Real complex flows cannot always be modeled by just applying largely oversimplified models. These are different modeling approaches.

L12-14: Not fully true, see other works mentioned above.

L20: The Conclusion needs to be improved accordingly.

P13:

References: Enhance accordingly.

Fig.1: What is 'isometric' here? Mark points for Fig. 4, etc.

Fig. 2: Explain in caption what is: nuˆ2.

Fig. 3: Caption: Reformulate, difficult to understand.

Fig. 4: Write (a), (b), (c) in Fig. panels and improve text accordingly. Also write 'w = 27%', etc. in panels [remove from Caption]. If possible put measurement errors. Mention data source. Also mention at which channel positions.

experiments with water contents of 27% (top), 28.5% (center) and 30% (bottom) –> experiments with different water contents.

What is 'box-averaged'?

Fig. 5: Put legend for: - Exp. depo. margin; - Sim depo. margin.

Write water contents in panels and remove from caption. Put actual coordinates. For w = 28.5% sim. fits very well with exp. Probably explain how such a (almost) perfect fit could be obtained. What is the reason for lower and higher w values simulated inundation/deposition areas are globally wider than experiments? Does this mean there are some special/critical aspects in model and simulations such that it behaves in some typical/critical way with some particular choice of w and the simulation produces less and less accurate results as you deviate away from this value of w?

Fig. 6: A full 3D photo of the channel would be helpful. Put marks showing positions of measurements. This would help to have an idea on how the super-elevation or the normal load would develop that later effects the viscosity/flow.

Fig. 7: Indicate flow direction, inner-, outer-curvature.

Mention in appropriate place in text: Although only one set of comparison with experiment is shown, mainly with front position, given the complexity of the problem and its intrinsic consequences, such results are important to highlight the potential use of the simulation model to geometrically more complex flows as mostly in literature (except in Pudasaini et al., 2005; 2008) modeling/validations are limited to simple straight or curved and lower dimensional channels.

If possible, also put velocity and viscosity fields; put the flow in red-brown and material-free area in white.

Fig. 9: Fig. description and caption: not clear.

The simulation only covers a single surge runout with homogeneous (unsorted) material.: This would require real two-phase flow model with phase-separation mechanism.

Fig. 10; Fig. 11; Fig. 13: Remove, not needed! Also Fig. 9?

Fig. 14: Explain what generates ‘surface wave fronts’ and how?

Fig. 15: Why 5 lines 4 legends? Put 32 m, 66 m, etc., on panels. The reason for using SD is not clear. This fig. is not enough discussed in text.

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