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Comment

## ***Interactive comment on “Estimation of flow velocity for a debris flow via the two-phase fluid model” by S. Guo et al.***

**Anonymous Referee #2**

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This manuscript considers a two-phase debris flow modelling frame, reduces it into a steady-state, one-dimensional flow. Then, by closing the solid and the fluid phases by the Bagnold and Bingham rheology, the model is reduced to two simply first order ordinary differential equations. This is the main attraction of the MS as these equations can readily be solved. Then, the authors construct analytical solutions for the solid and fluid velocities. Results are plotted for the mild variations with the lower values of the solid volume fraction parameter, and the particle diameter to show the model performance. There are certainly some important contributions in this MS that could be of value to the audiences of NPG.

The model is exclusively based on the definition of the solid and fluid pressure, both are defined as the impact/dynamic pressures, the validity of such uses as rheological

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closures can however be questioned! Except for the (constant) parameterization of the viscoplastic fluid parameters, other forces are ultimately ignored. So, the quality of the model is all based on the difference between the solid and the fluid impact pressures. These are strong assumptions. This must be justified! Another concern is the use of the Bagnold and the Bingham rheology for the solid particles and the fluid. It must be justified how these bulk rheological models can be used for the distinct phases. Although the authors mentioned that the results have been compared with observation, no such meaningful comparison can be found. Several assertions are made very weakly but without justification, and support. Several terminologies are improperly used. The values of the parameters used in the simulations are not strongly connected with the real physics of the flow, i.e., the values are weakly selected. The results could be better presented and described. The MS lacks several recent/relevant references. The MS must be enhanced and re-written thoroughly, e.g., by following the Detailed Suggestions given below. The manuscript requires a Major Revision.

Detailed Suggestions:

Abstract: “The comparison of those velocities obtained by the proposed method with the observed velocities of two real-world debris flows shows that the proposed method can estimate accurately the velocity for a debris flow.”: I don’t see how this can be done accurately!

R: Replace with,

I: Insert,

Ref.: Reference,

MC: Make clear,

IE: Improve English,

D: Remove.

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P2:

L10: and/or: R: and

L17: Himalaya-Karakorum

L10-26: Support with Ref.

P3:

L3: two-phase fluid model: R: two-phase model;

Pudasaini, 2005, 2012: R: Pudasaini et al., 2005, Pudasaini, 2012

L4-6: However, the two-phase fluid model describing a debris flow is still very difficult to explain via theoretical methods and to simulate accurately via numerical methods.: R: However, the two-phase models describing debris flows are still in development stages. Although, recently there have been substantial advances in simulating real two-phase debris flows [Pudasaini, 2012, 2014 (Acta Mech.)], construction of exact solutions are still very challenging [K. B. Khattri, 2014: ‘Sub-diffusive and Sub-advective Viscous Fluid Flows in Debris and Porous Media.’ M. Phil. Dissertation, Kathmandu University, School of Science, Kavre, Dhulikhel, Nepal, 2014.].

L7-9: To understand the dynamics of the debris flow, including its initiation, runout and deposition, finding out the velocity of the debris flow is important, which would be helpful to analyze and forecast the dynamics of the debris flow and then prevent its hazards.: MC!

L10: soils or rocks involved in a debris flow: R: soils or rocks, and fluid involved in a debris flow

L12: between the solid particles and the fluid: R: between the solid particles and the fluid [Pudasaini, 2012].

L16: I: “Pudasaini (2011) presented exact solutions for debris flow velocity for a fully

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two-dimensional channel flows in which the velocity field through the flow depth and also along the channel have been derived analytically.”

L16: Several models: R: Several other models

L22-23: Few theoretical results have been obtained to estimate the solid- and liquid-phase velocities for a two-phase debris flow.: Which? Mention!

L24-28: IE.

P4:

L1: the two-phase flow model: Which?

L6-9: Not clear how the obtained velocity would help estimating flow arrival time, and deposition area, etc. This can only be done by considering the full dynamical model and simulation that provides us with the temporal-spatial evolution of the flow depth and the velocities of the phases. So, improve writing!

L10-12: I do not fully agree, see comments above.

L20: I: “However, recently, by developing a general two-phase debris flow model, Pudasaini [2012] included several important physical aspects of the real two-phase debris mass flows with strong phase-interactions, including the generalized drag, virtual mass force, Newtonian, and solid particle concentration gradient enhanced non-Newtonian viscous stresses. These model equations have also been put in well structured and conservative form. Numerical simulations and possible applications of these models can be found in Pudasaini [2014], Pudasaini and Miller, 2012.”

P5:

L1-10: These three points can be written simply as [see, e.g., Pudasaini and Hutter (2007), *Avalanche Dynamics*, Springer, New York]:

1. One-dimensional, depth-averaged model (however, this contradicts with your state-

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ment in equations (18)-(22) where  $dv/dy$  is used!).

2. Finite mass.

3. Homogeneous and steady-state flow.

L11: Under the above assumptions and following the two-phase flow theory: R: Under the above assumptions and following the two-phase flow theory (see, e.g., Pudasaini, 2012 for more detail)

L16: Check the 'dot' operator (in equation (2)).

L22: In this study; R: For detailed model derivation, and how different types of forces and interactions can arise and should be introduced in a real two-phase mass flow model, we refer to Pudasaini (2012). However, In this study,

L22: Also mention the meaning of each term, variable, and parameter (e.g.,  $v_s$ ,  $v_f$ ,  $\phi$ ,  $\rho_s$ , ... ..) at place where they appear first. This will help the reader to follow the text.

P6:

L6: pressures are also the surface forces. So, either say surfaces for both or (better), say, viscous (shear) forces ( $f$ ) and pressure forces ( $P$ ), etc.

L5-25: These assumptions must be supported by physics of flow and references. - One of the major concerns in the MS is the definition of the pressure, which here is introduced as the impact pressure, which generally is a derived quantity but not a closure, or a rheological relation in fluid mechanics, mainly in the geophysical mass flows. Another problem with the definition (7) is the parameter  $k$ , which cannot be well constrained, but can only be a fit parameter. Further problem is that, the same parameter  $k$  can not realistically model the fluid and solid (impact/dynamic) pressures. Moreover, in geophysical mass flows, the pressure, e.g., for solid is modelled as hydrostatic, and rate-independent relation (the solid normal load). So, pressures are field variables, but here these are used as derived quantities. This consistency and validity of these

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pressure definitions must be justified!

The mixture density (8) and mixture velocity (11) are only defined but not used.

L25: after equation (12): I: “which is the buoyancy reduced normal load, see, e.g., Pitman and Le (2005), Pudasaini (2012).”

P7:

L4-9: IE, Ref.

L10-14: Provide Refs. for these definitions. It seems that these quantities are not consistent with dimensions!

P8:

L2: Bagnolds grain-inertial rheology is used to model the solid-granular-phase, which however, assumes more dilute, collisional flows.

L7:  $\lambda$ : Ref. and provide expressions.

L9-10: should there be  $\cos\alpha_i$ ?

L15: The fluid-phase assumes Bingham viscoplastic law.

L18: On the RHS: the second term should be with ‘+’!

Another major concern here is the use of the rheological equations and their validity! Bagnold and Bingham laws are used for the solid and the fluid, respectively. Now the question is: Bagnold and Bingham relations are used to model the rheological behavior of the bulk mixture as a whole other than to model the solid and the fluid phases separately. Usually, the solid and fluid phases in real two-phase debris flow mixture are, respectively, modelled by applying the Coulomb-type frictional model and rate-dependent viscous flow model (Pudasaini, 2012). Which means that the use of the rheological models can be questioned. So, justify their use, and mention that: “However, a physically more meaningful and consistent would be the use of the Coulomb-

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type frictional model for the solid and the non-Newtonian viscous flow rheology for fluid as in Pudasaini (2012)".

P9:

L3: and  $y$  is the internal depth of the debris flow body: this should have been introduced earlier!

L10-15: Mention that: "There are several model parameters in the proposed model including  $a, b, c, \tau, d_0, k$ , etc. Constraining these parameters could be challenging. Such parameters, which could also be used as fit parameters, however, do not appear in a real two-phase debris flow model such as that presented by Pudasaini (2012)".

L15-20: A principle question is that: pressures are included in (22) and (23). Then why do you need extra pressure terms (the last terms on the RHS of (5) and (6))? There is a redundancy!

P10:

L1-2: To simplify the calculation, the velocity of the solid phase in the  $y$  direction and the effect of turbulence in slurry are ignored.: This is not consistent, or at least not justified!

L3:  $d_0$  is usually small enough: which value  $d_0$  would take in practice? This is difficult, or not possible to say!

L6-12: As mentioned earlier, the last terms on the RHS of (26)-(27) are redundant! If not, explain!

P11-12:

Equations (34)-(35): The approach used in the model development and the physical correctness of final model equations must be justified and discussed! So, it would be better to mention here that: "Although the model solutions (34) and (35) providing the velocity estimates for the solid and fluid phases in a debris flow only utilize and

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retain the impact pressure difference between the solid and the fluid, and the Bingham viscoplastic parameter, they can only provide very basic qualitative picture of the solid and the fluid velocities. Also these solutions do not include any information about the volume of the debris material. Nevertheless, to develop velocity solutions for the solid and the fluid phases in a more consistent and physically more meaningful way, one must use a real and general two-phase debris mass flow model, such as the one developed by Pudasaini (2012), that includes strong phase interactions through the generalized drag, virtual mass force, non-Newtonian enhanced viscous stress, and the evolving volume fraction of the solid-phase.”

There are some strange effects: E.g., for  $\phi = 0.5$  (which may be a possible scenario), the second terms on the RHS of (34) and (35) associated with fluid disappears! Check, and discuss it!

P12-13:

L5(P12)-L13(P13): D: Because this does not add anything in the analysis! Also, there are inconsistency in the descriptions of, e.g.,  $M_2$ , because with increasing  $\tau_B$  and  $\mu$  the KE must decrease, but here it increases!

P13:

L14-25: IE. Improve the discussion with mechanically more appropriate statements. E.g., as the equivalent diameter of solid particles increases, the solid-phase velocity of a debris flow decreases very slowly whereas the liquid-phase velocity increases very slowly.: ‘the liquid-phase velocity increases very slowly’: this is not consistent with the physics of flow! Otherwise provide data! So discuss and mention that: “Such discrepancies may have been emerged do to the very simplified model consideration, or some possible inconsistencies in the use of the rheological models considered here. These problems could have been avoided by using more complete and real two-phase debris flow model (Pudasaini, 2012) which includes strong phase interactions.”

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P14:

L2: the K631 debris: what it is?: Ref.

L5-11: These comparisons are not so meaningful. Because: you must compare (with respect to the involved):

- the flow volume,
- travel distance, etc.

Discuss on this!

Again, you have not proven how 'the estimation method for the velocities of a debris flow can be widely used for a real-world debris flow'! You used very strong statement with relatively weak results. Otherwise, justify!

Tables:

P19:

equivalent radius of control volume: R: equivalent height or length of control volume

Also improve other items.

Figures:

P20:

Caption: R: Debris flow configuration, and definition of variables and parameters.

Also, make a debris flow profile and include the equivalent volume in it!

P21:

Mention (in the main text) that: "Such exact solutions have also been presented previously by Pudasaini (2011) for avalanche and debris flows."

- Fig. 2: Caption: put parameter's dimensions.  $\rho_f = 1500$  is too big,  $\phi = 0.1$  is too

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small,  $(\tau_B + \mu b)d_0 = 100$ : explain why this value is chosen.

- As you explained in the text,  $d_e$  must be larger than 0.2 m. This also applies to other figures!

- At the model solution says, at  $x = 0$ , both  $v_s$  and  $v_f$  must be zero, but here they are not! Check this!

- To check the model performances, results must also be plotted for more dense flows (i.e., for  $\phi = 0.65$ ).

- For which volume these results are plotted. It seems that your model solution does not include this information. This is a problem here!

- Mention in the main text that: “For such a large velocity difference, at least the drag and the virtual mass force must have been included in the model as in Pitman and Le (2005) and Pudasaini (2012). However, here the model does not consider such effects.”

P22:

Fig. 3: Caption: Mention in the text that: “However, 10% increase in the solid volume fraction resulted only in very slight decrease in the solid and fluid velocities.”

P23:

Fig. 4: Caption: Mention in the text that: “However, 10% increase in the particle diameter (as a parameter) resulted in almost no change in the solid and fluid velocities.”

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Interactive comment on Nonlin. Processes Geophys. Discuss., 1, 999, 2014.

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