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Natural Hazards and Earth System Sciences
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Discussions

# *Interactive comment on* "TITAN2F: a pseudo-3-D model of 2-phase debris flows" *by* G. Córdoba et al.

**Anonymous Referee #2**

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The manuscript describes a general solid-fluid shallow flow model based upon earlier work proposed by Pitman and Lee in 2005. Main features are the individual consideration of evolution equations for both fluid and solid phases, as well as modified constitutive and closure relations with respect to the Pitman 2005 model. The depth-averaging step is carried out in a similar manner to previous work within the TITAN group. Details on the numerical solution are omitted, but are mentioned to also follow the work of Pitman. The paper concludes with tests against an analytical 1d dam-break solution and validation runs against two sets of experimental data.



## 0.1 General impression

I recommend a major revision of the submitted publication due to the following reasons: Generally, the paper is a nice contribution to the field as it builds upon previous modeling efforts and tries to overcome their shortcomings by altering constitute and closure relations. The derivation of the depth-averaged model equations is complete and offers a new flavor to two-phase shallow flow theory. However, while vast parts of the model derivation (in particular the depth integration) closely follow depth-averaging strategies presented in previous publications, the really new aspects of the TITAN2F model remain unclear to the reader and could be exposed much more. In parts, the authors address differences between the chosen approach and previous work in a discussion of the differences to the Pitman Lee model, but in my opinion this discussion is quite weak. I regard this discussion as one of the most important sections of the paper as it pinpoints the value-add of the chosen approach. My major remark for the authors therefore is to state more clearly throughout the paper, which of the steps differs from existing theory and which one really is new and due to the authors. This also includes a discussion of the motivation for this work, maybe by commenting on specific shortcomings of the Pitman Lee model which the authors hope to overcome. Also, this includes a more rigorous summary of the implications of the model changes. Additionally, I have the following major objections:

- In all three sections, the abstract, the introduction and the preliminary paragraph of the model derivation, the authors write about concepts from geoscience and engineering incorporated to reflect a more realistic material behavior. Why not being more concrete even in the first part of the paper? What concepts do you mean? What is the fundamental idea of your work?
- Regarding the validation runs ... which parameter values have been used and why? The authors furthermore state, that they reduce the number of parameters

used in the Pitman Lee model, but in fact, they also introduce quite a number of parameters. Are the new parameters real physical values taken from the literature? If yes, what parameter values have been chosen in the numerical experiments and what are the sources?

- The derivation is in 2d, whereas all three test runs are 1d. Would it make sense to reduce the derivation to a depth-averaged 1d theory? Or if not, what additional difficulties are expected in the 2d solution? Are the DEM induced instabilities present in both 1d and 2d calculations?
- A nomenclature table would be helpful
- Generally the scientific language style can be improved substantially (use of articles, third person 's', tenses). Additionally, the style of section 2.1. Fundamental assumptions and section 2.2. Scaling or at various occasions throughout the depth averaging section seems odd, as it reads as an exercise instruction. Also, I really should mention that the number of spelling errors is unacceptable. Some of them (not all!) are listed later as minor objections. Please make sure to use a spell check software before submitting again!

## 0.2 Further minor objections

- P3790/L8: systems → is models or programs better?
- P3790/L11: geo-science → geoscience?
- P3790/L13: fraction → fractions
- P3790/L16: delete with (two times)
- P3791/L18: What are these order of magnitudes? Clay to boulder size, hence order of magnitudes in the length scales? Be specific!



- P3791/L18: develop → developed
- P3792/L12: use either three-dimensional or three dimensional consistently throughout the paper
- P3792/L23: employ → employs
- P3793/L1: visco-plastic → a visco-plastic
- P3793/L14: please comment on relation to pressure in fluid mechanics, as the audience might not be well familiar
- P3793/L25: What is the difference between component and phase (superscript and subscript)?
- P3794/L5+6: Why $v_i$ and not $\mathbf{v}$ in the mass conservation? Likewise for fluid component?
- P3794/L23+25: What is the range of empirical values suggested by the listed literature Wallis ... Lettieri? Are these values consistent with the empirical law stated in equation (6)?
- P3794/L23+25: For $\phi \to 1$ (dry flow) you will have problem using equation (6) as it tends to infinity. How do you deal with that (technically)?
- P3797/L1: momentum → momentum balance equations
- P3799/L16: One can also depth average a non-divergence free flow. I don't see why this should be a necessary condition for depth integration
- P3799/L20: It is not obvious to the audience, how equation (14) is deduced from the fact, that the upper free surface is a material surface. Either include an explanation, or a reference to another publication, in which this is discussed.

- P3799/L23: Similar comment as above: It is not obvious to the audience, how equation (15) is deduced from the properties of the basal surface. Include an explanation or a reference.
- P3800/L5+6: Though it seems to be correct through out the paper, it is quite confusing, that you introduce $h$ as the position of the upper free surface in the coordinate system and $\hat{h}$ as the height of the flow. Why not following other literature and have one variable for the upper surface, maybe $s$ and then $h$ as the difference between $s$ and $b$?
- P3800/L19+P3801/L2: This seems to be a bit of an unnecessary back and forth substitution. Can you put this into one eqaution, or at least avoid the second $=$ in P3801/L2?
- P3801/L2: In any case, the $f$ has to be a superscript, here.
- P3801/L9: albiet?!
- P3801/L13: inappropriate .
- P3801/L16: Reference to a literature (Pitman/Hutter?) in which error bounds for this are discussed.
- P3801/L19: One $x$ velocity component is missing in the unnumbered equation before equation (19). It should be $v_x$ squared.
- P3802/L5: This can concisely be stated as a fully saturated flow.
- P3802/L7: What are parameter values, that are typically used here? Or do you suggest to use this as a calibration parameter? In my opinion it is crucial here, to give the audience some idea of how the model will actually be used later.



- P3802/L15: This is not the $\alpha$ used in the empirical relation for $D$. Consider to use a different letter here to avoid confusion.
- P3803/L10: What are typical values for $C_f$?
- P3803/L11: coeficient → coefficient
- P3803/L13: can be approached? → approximated?
- P3805/L12: exhibit a shallow flow geometry? Do you mean: reduces to a shallow water flow as the solid volume fraction vanishes?
- P3805/L14: equation system → system of equations
- P3805/L15: Which variables are solved exactly? Do you also solve for the volume fractions? What are the initial conditions: Zero velocity (slab) or inflow conditions (hydrograph). It might be appropriate to spend another section 4 Numerical solution here. The numerical solution does not fit into the section on depth-averaging.
- P3806/L2: What is $v$ in the equation for the dynamic pressure in relation to $\mathbf{u}$ and $\mathbf{v}$. How do you compute it?
- P3806/L12: You should call the Courant like condition by its common name the CFL condition (Courant-Friedrichs-Levy). If the conditions differes from that one, please give details, as it is non-standard then.
- P3806/L15: As result, ... poor language quality
- P3806/L16: Is this what you mention here (numerical difficulties due to the DEMs) the same as in P3806/L7? If yes please combine. Otherwise explain the difference.
- P3807/L6: steep → step

- P3807/L10: need → needed
- P3807/L12: authomatically → automatically
- P3807/L14: at → are?
- P3807/L19: equation system → system of equations
- P3807/L19: First → First,
- P3807/L19: experiment → experimental
- P3808/L6: litereture → literature
- P3808/L9: delete the
- P3808/L17: paricle → particle
- **I stop listing spelling errors here, please use a spell check before submitting a manuscript!**
- Fig 1: Qualitatively, both analytical and numerical results show a reasonable fit. However, quantitatively there are still significant differences given that you solve shallow water flow here. There are a lot of numerical examples of very good agreement (e.g. CLAWPACK or other gravitational mass flow solvers). Like this, the results are not very convincing. Such a big error introduced solely by the numerics is not acceptable. Can you comment on this?
- Fig 2: Two-Phase-Titan = TITAN2F? Is this always the same? The meaning of circles, etc. should be explained in a legend.
- Fig 3: Include unit into the title. Can you interpret the difference between your model and the data just after the front arrival?



- Fig 4: Include unit into the title.
- Fig 5: Is the distance from lock really in km? It would be nice to have an overlay with height and velocity of the debris flow here together with an interpretation of the evolving solid volume fraction.

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 3789, 2015.