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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Quantifying lahar damage using numerical modelling" *by* S. R. Mead et al.

Anonymous Referee #1

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General comments

Title: After having read the article, I do not think this study really quantifies the damage. Rather, it describes the conditions under which damage occurs, all the more that the authors consider either total damage or no damage, but no intermediate levels.

The building vulnerability part presents interesting results and could be interesting for the public of the journal but, in my opinion, some points could be explained better before considering the paper for publication. Moreover, I think that more warnings should be presented in the text each time where important assumptions are done and also the results, even though interesting, should be presented with more caution.

Overall, the article presents an interesting approach and tries to push forward research which in this topic is still very poor. However, this study relies on a patchwork of data

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taken from other studies and parameters extrapolated from other contexts. The authors themselves state that lahar modeling scenarios may not represent any specific event or plausible set of events likely to happen in the studied area (line 268). Many assumptions guide the choice of decisive parameters and also the interpretation of results. As mentioned above, these are not always clearly pointed out nor thoroughly discussed.

The structure of the article consists of several parts that are in my opinion not enough interconnected. This makes it sometimes difficult to follow as a lot of different aspects are treated (civil engineering aspects to lahar rheology and modeling) with in each section quite an amount in technical vocabulary that not all readers will be familiar with. Important and recurrent terms such as vulnerability, hydrostatic, dynamic pressure, Newtonian, non-Newtonian, pressure magnitude, etc. should be clearly defined as they are used in different contexts and sections. The number of presented equations might be reduced and/or their presentation simplified as these are not key aspects of your study.

If this manuscript is accepted for publication, I am recommending major revision. The revision should aim at rendering the manuscript easier to read, better interweave the different sections to clearly show the relationships between the different considered aspects and parameters. Add a section where you clearly state all the assumptions you make and how these influence the credibility of your results. Add a section on limits and perspectives of this work. Ideally, the approach should be applied elsewhere and results compared to this study.

Specific comments

Building vulnerability: A general confusion is created by the use of building types from other studies (Thouret et al., 2013, 2014) which are referred to as building vulnerabilities. Clearly define what you mean by vulnerability. In my understanding, the classes you use from Thouret et al. are not indicating a vulnerability per se but correspond to different building types. If this is not the case, you need to explain how you integrate

the vulnerability calculation realized by Thouret et al. in your calculation. Is your result then a cumulated vulnerability? What is the weight of the different vulnerability indicators etc. Also, a minimum of explanations concerning these building types is necessary and it would be interesting to have a performance curve associated for each building type at the end.

Building vs block: it is not always clear throughout the paper what you are taking into account for your modeling and how data is aggregated. Are you using individual buildings? If yes, how many per block, what is the composition of each block in terms of building types, number, exposition, etc. If you use blocks, how is the "block" data generated from individual building data? Statistically? Subjective choice? There is more explanation needed here.

Lahar rheology and modeling: A lot of detailed description is provided on lahar rheology with the result that the reader remains relatively confused facing a complex topic with lots of technical terms in a few paragraphs. It is not clear from the structure of the text, what objective this section serves. A reorganization of this section might help to outline more specifically why the SPH model has been chosen, what its differences are compared to more commonly used lahar modeling software and what interest the use of this model has in terms of creating the depth-pressure curves.

Structural failure model similar to those employed by Roos (2003): Roos (2003) made his classifications and his study (comparison of the loads on the structure with the strength of the structures) for masonry buildings in the Netherlands, so the transposition for Arequipa buildings should be argued.

Technical corrections

Title Better : lahar induced damage

Abstract

Line 13 : uncertainty in number and type of buildings – this parameter is in my opinion

not to put in relation with potential building damage and its quantification. This is a question of scale and your objectives. What you may be rather referring to is the varying number and types of buildings, but uncertainty is misleading.

Line 15: What is the “relative importance” of lahar hazard, etc.?

Introduction

Line 24/25: may add here Vallance (2000) as a reference

Line 28: again, careful with the word “uncertainty” here, I think it is not adequate.

Line 34: clarify “relative” – is this from a statistical point of view?

Line 75: “to identify strategies that may reduce building loss” – these strategies appear to be mentioned only in a short paragraph in the conclusion which appears quite disconnected from the rest. If this really is one of your objectives, this needs more argumentation and be put in relation in a more concrete way with your modeling results.

Case study

Line 86: watch the spelling – torrenteRAS, one R at the end

Line 93: cite also and in first place Martelli 2011

Line 109: “relative effects” – again, don’t understand the use of the word relative here. Be more precise.

Line 118: I don’t understand the use of “by” here before cross streets. Does this mean the cross streets and quebrada separate the buildings in a way that blocks are formed?

Line 119: the “general approach” needs to be explained at least in a few sentences for those who do not have the time to read Thouret et al (2014).

Developing building vulnerability relationships

Line 133 and 135: Need to give more detail on these models/approaches.

Line 134-135: this is a very important assumption “Stresses for buildings in Arequipa are calculated using the approach specified in Australian Standard (AS) 3700-2011” and some better explanations should be provided

Line 135-136: Reformulate the sentence; it is not clear what you mean here.

Line 136: “In these models” – are you referring to the structural failure models?

Line137: “While some specifications in the standard may not be relevant for Arequipa, the calculation method is still valid for the area provided construction material properties from Arequipa are used as inputs.” Yes, some specifications in the standard are not relevant for Arequipa, and the calculation method are not just related to the material properties, but also to the construction mode and the behavior, so “the methods are still valid” is not necessarily obvious, but should be argue in this way. Also important simplification or assumption “In these models, masonry walls are presumed to fail when the applied bending moment and shear forces are greater than the calculated ultimate bending moment and shear force the walls can withstand. We only consider the maximum bending moment here as preliminary investigations suggested the force required to overcome the ultimate moment was consistently lower than the force required overcoming the ultimate shear force”.

This should be justified by literature investigation, experimental test or numerical simulation. The behavior of masonry wall is quite complex and can be (or generally is) a mix of flexural and shear behavior, in this case, considering just the maximum bending moment is an important assumption that can affect the global results and conclusions. See macroelement masonnery behaviour software TREMURI paper S. Lagomarsino, A. Penna, A. Galasco, S. Cattari, TREMURI program: an equivalent frame model for the nonlinear seismic analysis of masonry buildings, Eng Struct, 56 (2013), pp. 1787–1799 Moreover, when we use “design capacity specified in actual standards” for the constructions that have certainly “no design” or, in the better case “low code design”, this affect the results and cannot be considered as representative for the studied area.

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Line 139: “preliminary investigations” – of what? Lab tests? Modeling? Field work?

Line 146: “should not be greater than this value” – Why? Explain for those not familiar with this context.

Line 150 and following: quite a lot of equations and parameters presented. Since you are basically using parameter values specified in the Australian Standard, it may not be absolutely necessary to detail all of these equations . . .

Line 169 and following: a little graphic illustration would be SO helpful here!

Critical depth-pressure curves

Line 186 and following: I am not able to follow here, there are too many classes from different sources, I got lost. Can you present this in an easier way than A0, 1A-2B etc.? Or at least provide an informative table describing what these mean? General remark: you are analyzing vulnerability of buildings so it is a little strange to use already defined vulnerability classes. It would sound more logical to refer to simple building types or categories for the Thouret et al classifications instead of calling these vulnerability classes.

For figure 4, you mean that the graphic represents the combination between the depth and the dynamic pressures for which you have failure of the building class? This could be assimilated as a limiting right under the line you do not have collapse and above the line you have collapse? In order to verify the results for one structure or one wall it will be interesting to perform a kind of push-over curve (curve displacement-shear base response).

Maybe a table with the description of the building types from 1A to 6C would be useful for self-understanding of the paper accompanied by the building damage threshold for each typology (these thresholds are a very important issue, that can modify completely the results, and in my opinion this issue is not sufficiently treated in the paper).

Line 195 and following: OK, but is this representative? Most hyperconcentrated flows

in Arequipa carry boulders given the environment there, and the impact of those is very important although not taken into account at all in your study . . .

Lahar rheology

General remark: This is a long overview but it is not clear why you expose all this to introduce finally the quadratic rheology model. Rewrite this section illustrating from the beginning the quadratic rheology model and how it compares to other existent models and explain your choice rather than the general information which is rather disconnected from the rest. Also, you are using a lot of technical vocabulary here concerning the rheology which some part of the readers may not be familiar with. So, simplify and rather concentrate on providing definitions of critical terms such as non-Newtonian, Newtonian, etc.

Implementation in smoothed particle hydrodynamics

Line 246: OK, but you need to describe at least a little bit what this model is and how it is different from classically used lahar modeling software such as Titan2D/3D, LaharZ, etc.

Line 257f: Again, I got lost here – what is your point?

Line 263: Where is m in the equation? How many validation simulations did you use and what data was chosen for it?

Line 268: "may not represent any specific event . . ." So what is the use of it? This is not at its place here. You may have a general discussion section where such issues should be discussed, but at this point, the reader may not think it is useful to continue the reading.

Line 269: 12.5 cm resolution? At this resolution, the identified building blocks and houses should be much more accurate than what appears in Figure 2 and Figure 5!

Line 281: Again, remind what these stand for and why you can take the experimental

values for Arequipa.

Line 286: Hyperconcentrated flows can have high viscosities, no?

Line 289: 45 seconds: why? Computational time and resulting cost? Maybe optimize this paragraph.

Line 290f: I do not agree here. Lahar surges do not always have higher depths than a steady lahar flow. First, a steady lahar flow is not necessarily the opposite of a lahar surge but a different flow type/phase. Second, the surge can be quite small and there can be several small surges before the major lahar flow front arrives. It depends a lot on the location and the environmental conditions triggering the lahar. So careful here to not make it sound as a general rule.

Flow behavior

Line 297ff: Not clear. What is your point here?

Line 300: This is not new . . .

Line 300ff: Decreasing velocity can also be due to friction effects and turbulence along the channel walls

Line 308: “buildings oriented parallel to the channel”: this depends how you define the long axis of the building. Looking at Figure 2, this is not very clear to me. What do you mean by “broad understanding of normal pressure”?

Line 313: illustrate this with a graphic illustration. “Higher EW pressures . . .” Not sure I understand what you mean. Flow looses velocity and depth when spreading in side-roads?

Line 316: Pressure magnitude: you need to define this term.

Line 323: normal pressure: need to define this term!

Line329: you were mentioning earlier that you consider only initial lahar surges, so this

is not really a conclusion of the modeling, is it?

Line 330: Why is this a consequence of the short timeframe?

Line 334: “higher pressures”: you mean higher dynamic pressure?

Line 335: If this indicates elevation differences, it would be helpful to have a map illustrating what elevation differences there are in this study area.

Line 336: acting on blocks: rather buildings?

Line 337ff: reformulate, this paragraph is not clear. Also, I am skeptical that higher density generally causes larger dynamic pressure. . .can you provide reference?

Line 338: near perpendicular walls: and not near, what happens?

Line 340: The dilatant component is lower for debris flows than for Newtonian and hyperconcentrated flows, so the latter decrease in velocity quite rapidly when diminishing in depth which also reduces the pressure for these flows. . .

Application of critical depth-pressure curves

Line 342: “along the block” – means what?

Line 348f: Not clear, “well above the critical curves for each block”. General remark: you switch between buildings and blocks and it is in the end not very clear for what you realize your modeling and how do you generate the curves for one block? Is it the mean value of all buildings contained in the block? In this case, we need to have more information on each block. . .

Line 353: fluid height – be consistent in the use of your terms to make it easier for the reader to follow. Either use fluid height or flow depth.

Line 354: Which means no damage to expect?

Line 357: lower depths? This is interesting: I would have thought that depth rises when flow impacts a perpendicular wall. At least this is what you see frequently with

floodmarks on house walls after flash floods or torrential floods in the Alps . . . it would be interesting to compare your methodology with another location and see if you find similar relationships.

Line 359: “effect of vulnerability”: this means what?

Line 371: explain in more detail what this means “reducing the size of the applied moment”.

Line 375: across scenarios: means that this can be observed in several scenarios? How many did you have in total? Other studies also indicate that distance from the channel plays a more important role than the building type itself. . .

Discussion

Line 380ff: Reformulate, this paragraph is not clear.

Line 389: “applied to ultimate moment and damage through other actions” – how are these defined?

Line 390: comprehensive data: like what?

Line 393: Repetition, see line 329

Line 395ff: depends on localization of the building respective to the channel: first row, second row, screening effect, etc.

Line 409: this is not new. . .

Line 410: “may be too complicated” – no, not necessarily, it just needs better assessments, more data and detailed field studies. . .

Conclusion

Line 416: not new . . .

Line 417ff: This paragraph comes somehow out of the blue and is quite disconnected

from the previous rather technical descriptions. The recommendations for retrofitting are not enough put in relation with the results of your modeling, it would maybe be a better option to add this into the discussion and link it more specifically to your results.

Line 425: here you say the approach can be generalized but given all the restrictions and constraints you have for Arequipa, this sounds rather unlikely. The best way would be to propose a section where you apply this approach to a different study area and shortly explain how you validate your approach. Or you need to explain more in detail why and how this approach can be generalized.

Line 429: Large-scale indicators: such as?

Line 430: In my opinion, you are not modeling vulnerability. You use building type data, do lahar modeling and cross this information to generate building performance curves . . .

Line 431: "refine the indices in order to focus": only if data is available as for now you use a lot of data extrapolated from other sources.

Figures

Figure 1: need to complete the legend indicating what the yellow and orange lines stand for as well as the orange areas (built area: extent of the city at present?); reduce the size of the North arrow. The NE end of the quebradas Venezuela, Huarangal and Andamayo are quite low and appear disconnected from the foothill of the volcano – is there a reason for this presentation?

Figure 2: I think you need to better define what you understand by building block. Since you refer a lot to the works of Thouret et al. 2013 and 2014, his definition of building blocks seems to be different from what you delineate here as a block. Clarify. Also, the delineation of your blocks is not easy to understand: for example in fig. 2B, bottom left, you distinguish three blocks dark green, light green and dark blue; on the opposite side of the road, the light violet block appears to be a single block although you might

also have distinguished at least two; same for the light green block further North on the right side . . . if so is your choice, at least explain how you determine.

Figure 3: title of legend "Design compressive stress" – means what? Is it the compressive stress? "Building Type" – no capital letter for type.

Figure 4: Maybe simplify where possible this group of graphics: no need to put the "depth" legend title everywhere; reduce the appearing scale numbers (no need to detail every 0.25, just indicate 0,5; 1 and leave the little markers for subunits). There is a lot of information presented, so simplify a maximum.

Figure 5: what do the arrows indicate on the lower left of each image? Images are quite small, text is a little too big. Might be helpful to have an image without any modeling result where you locate the channel limits, outline the buildings and indicate flow direction.

Figure 6: same remark as above; legend too big, no need to reproduce the same legend for all three image groups. The pressure value to the left is too isolated, difficult to understand what this means.

Figure 7: OK, very nice.

Figure 8: OK, very nice.

Figure 9, 10 and 11: Difficult to distinguish the individual curves: maybe fine lines of different colors would be easier to read here.

Figure 12 and 13: Legend title "loss fraction" is a little strange not associated with percentages . . . Flow rate needs a unit! For the rest: same remark as above: simplify.

Tables

Table 1: Associate table with a figure where these numbers can be seen.

Table 2: OK – I am not an expert in streamflow/lahar rheology, so I am not able to

evaluate the correctness of these parameters. However, I understand these parameters are not your own modeling results but used to model, so provide reference for the source of these values in this table.

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