Review for Natural Hazards and Earth System Sciences

"3-D-numerical approach to simulate an avalanche impact into a reservoir"

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Specific comments:

The numerical results based on individual tests are compared with results based on Heller et al. (2009), a statistical approach (equations represent best fit to a point cloud with an under-laying scatter of at least ±30%). The manuscript would benefit from a 1:1 comparison of a numerical and experimental test, thereby comparing the wave profiles etc., before using the empirical equations (1) to (7). This is very much in line with the comment about the "black box" of Referee #1.

P4131/L17: The Authors reduce the snow avalanche to a "water" avalanche with identical mass, such that the impulse remains constant between the snow avalanche and the "water" avalanche. Therefore, both the first and the third parameter in Eq. (1) remain constant. However, if the volume is reduced, the slide thickness *s* is reduced and thus the second term in Eq. (1) changes having an effect on all wave parameters? In other words, some of the dimensionless slide parameters change even though the impulse remains constant. This point needs to be highlighted in the manuscript.

P4138/L14: Did the Authors use the slide front velocity to compute Eq. (1)? This would be incorrect as Heller et al. (2009) used the slide centroid impact velocity. The differences between the front and centroid impact velocities may be small for a water body, but can sometimes be relevant (e.g. 30%).

P4139/L5: This discrepancy between the results of the numerical simulation and the Excel-Tool may be explained with the reduced slide thickness *s* due to a reduction of the snow avalanche to a water avalanche. See comment P4132/L17.

Fig. 6: It is not fully clear what was varied here and under which conditions? E.g. the freeboard was reduced, was it reduced on the cost of the water depth or was the dam height decreased? If the water depth was reduced, were the input parameters in Table 1 re-calculated? (The slide velocity and thickness are expected to change as the slide travels a longer distance on the slope before it reaches the water surface). This all may explain the deviation in Fig. 6 between the numerical results and the observations based on Heller et al. (2009).

Fig. 8: This shows again a very nice agreement between numerical results and the results based on Heller et al. (2009). I am not sure if this is fully clear for the general reader, i.e. that the transition between 2D and 3D values in Fig. 8 with increasing B/b is expected. This should be better highlighted in the text.

Technical corrections:

Title: Consider adding the word "impulse waves" to the title, as 70% of the article addresses impulse waves.

Abstract: An abstract should also include the main conclusions; you may add a sentence at the very end of the abstract, e.g. "An overall good agreement between the numerical simulations and the…"

P4122/L21: "European" may be dropped.

P4123/L16: The point (c) is unclear. Frequency dispersion is clearly a feature of phase (b). So maybe write "…(c) wave run-up on the (opposite) shore."

P4126/L10/18: Write references in chronological order, and again on P4137/L20.

P4131/L17: The meaning of the sentence “The water depth should be adjusted in relation to the snow heights as good as possible.” remains unclear. Why should the water depth be adjusted? If it is adjusted, this has a large effect on all dimensionless parameters in Eq. (1) and the results?

P4134/L5: Write “…based on VOF, the…” rather than “based on the volume of fluid, the…” (the abbreviation was just introduced some lines further up.

P4135/L14: It is not fully clear what the difference between x and x “tilde” is?

P4137/L8: The impact crater can strictly speaking not directly be compared with the results of Fritz et al. (2003) as e.g. the slide density is very different (affecting the impact crater).

P4138/L5: The sentence “…a section…” is unclear, please revise.

P4138/L20: It is unclear when time starts ($t = 0$). At the moment when the slide is released or, as in Heller et al. (2009), when the slide front reaches the still water surface? The latter would be more related to the underlying physics of the problem.

Table 1: Clearly state that these parameters represent the water slide, e.g. add “…geometry based on the water slide.” In addition, the unit of the bulk slide density should read [kg^3s^{-1}].

Fig. 2/3/5/6/7/8: The symbols should be written in italic and it should read e.g. “b = 80 m” rather than “b: 80 m”

Fig. 3: Use a minus rather than a hyphen, e.g. write “– 680” rather than “-680.” Why are such strange numbers used, e.g. 602 (also in Fig. 4)? Further, the numbers on the x-axis are not aligned with the coordinate system in Fig. 2.

Caption Fig. 3: It is unclear from the text which moment in time $t = 0$ corresponds to (see point P4138/L20 above). In addition, should the unit not be [ms^{-1}] rather than [m]?

Fig. 5/6/8: Use a capital letter for e.g. “Overtopping” on the y-axis (currently the term Outflow is used, but I would use the word Overtopping).

Suggested grammatical corrections:

P4122/L2: Write ”…induces impulse waves, which pose a…” rather than “…induces an impulse wave, which poses…”

P4122/L4: I recommend replacing the word “outflow” with “overtopping” in the entre manuscript. Overtopping is the correct technical term, outflow is rather associated with the bottom outlet of a dam.

P4122/L9: Replace “The…” with “This…”

P4122/L11: Replace “real” with “actual”.

P4122/L14: Replace “at the ETH” with “at ETH”, here and in the entire manuscript.

P4122/L23: Write “rockfalls” in plural to be consistent with other causes.

P4123/L3: You may replace “compilation” with “collection” in order to avoid repetition of a similar word in the same sentence.

P4123/L5: Replace “At the moment, when the…” with “Once the…”

P4123/L7: Replace “spreading” with “propagation” as spreading is an uncommon word in this context.

P4123/L19: You may drop the word “usually”.

P4124/L13 and in the entire manuscript: The word “therewith” is very old fashion and may be replaced e.g. with “thereby” or just dropped at some passages.

P4124/L15: Write “…which are based on…” rather than “…which base on…”

P4124/L16: Replace the current sentence with “The latter approach will be addressed in Sect. 2.4”.

P4124/L23: Write “…on scaling laws…” rather than “…on the scaling laws”.

P4124/L24: Write “…be used to obtain the…” rather than “…be used to reach the…”

P4124/L26: Write “…or granulates have been…” rather than “…or an amount of particles have been…”

P4125/L2: Write “…of field data…” rather than “…of natural data…”

P4125/L4: Write “…carried out at ETH…” rather than “…carried out by the ETH…”

P4125/L5: Write “…different granulates and…” rather than “…different gravel granulates and…”

P4125/L10: Write “…tests focused on…” rather than “…tests are focused on…”

P4125/L11: Write “The run-up and overtopping were…” rather than “…The accumulation and spillover were…” (accumulation is an uncommon word in this context).

P4125/L13: Write “…of run-up, mass-included impulse…” rather than “…of accumulation, mass included impulse…”

P4125/L24: Write “…slide density smaller…” rather than “…slide density less…”

P4125/L25: Write “…characteristic for…” rather than “…decisive for…”

P4125/L27: Write “…at slide densities smaller than the water density. In case of a lager slide density…” rather than “…at lower slip densities than water density. In case of a higher slip density…”

P4125/L28/9: Write “…the slide thickness. At low densities the slide volume…” rather than “…the slip thickness. At low densities the slip volume…”

P4126/L3: Write “…diameter. The…” rather than “…diameter.The…”

P4126/L10: Write “…ramp, with variable steepness.” Rather than “…ramp, which can be varied in its steepness.”

P4126/L13: Write “…Alaska in 1958 at scale…” rather than “…Alaska from 1958 on a scale…”

P4126/L15: Write “…model at scale…” rather than “…model on a scale…”

P4126/L17: Write “…to investigate impulse waves can…” rather than “…to investigate impulse can…”

P4126/L19: Write “…(1995) and Panizzo…” rather than “…(1995); Panizzo…”

P4127/L7: Write “…g [ms^{-2}] are also considered.” Rather than “…g [ms^{-2}].”

P4127/L7: Write “Based on P,…” rather than “…Based on this parameter P,…”

P4127/L14: Write “…the run-up height R [m] and the overtopping volume…” rather than “…the overflow height R [m] (equal to the run-up height at the dam) and the outflow volume…”

P4128/L7: Write “…carried out with an Excel…” rather than “…carried out by means of with an Excel…”

P4128/L11: Write “…The formulas are based on…” rather than “…The formulas base on…”

P4128/L12: Write “…on a complex bathymetry or…” rather than “…on a complex terrain or..”

P4129/L24: Write “…hard to achieve…” rather than “…hard to realise.”

P4130/L8: Write “…limited to a specific…” rather than “…limited to specific…”

P4130/L10: Write “…simple solid slide is…” rather than “…simple solid is…”

P4130/L12: Write “…using gravel granulate…” rather than “…using granulates…”

P4130/L14: “liquid” should be dropped.

P4130/L16: Write “…which allows for a fast…” rather than “…which is the fast…”

P4130/L23: Write “…reproduce an existing…” rather than “…reproduce at the best and existing…”

P4131/L6: Write “…and further…” rather than “…and the further…”

P4131/L8: Write “…section is defined.” Rather than “…section is set.”

P4132/L5: Write “…starting point of the water…” rather than “…starting water…”

P4132/L13: Again, the word “therewith” seems to be very old fashion, I have never seen it, maybe replace with “Therefore”. Also on P4132/L22: Maybe replace there “therewith” with “thereby”.

P4133/L3: Write “…can reproduce the…” rather than “…can reproduced the…”

P4133/L6: Write “…has thereby to be neglected…” rather than “…has to be therewith neglected…”

P4133/L20: Write “…with a free surface…” rather than “…with free surface…”

P4134/L20: Write “…uses a more complex natural…” rather than “…uses a natural…”

P4134/L21: Write “Therefore, the…” rather than “Therewith, the…”

P4134/L24: Write “The hereafter presented…” rather than “The afterwards presented…”

P4135/L1: Write “…are investigated…” rather than “…are assembled…”

P4135/L12: Write “…of the coordinate system…” rather than “…of coordinate system…”

P4135/L26: Write “…FLOW-3D are based on…” rather than “…FLOW-3D base on…”

P4136/L11: Write “…the water is…” rather than “…the substitutional water is…”

P4136/L12: Write “…at the impact…” rather than “…before the impact…”

P4136/L19: Write “…and orthogonal to…” rather than “…and therewith orthogonal to…”

P4136/L21: Write “…or essentially no…” rather than “…or mainly no…”

P4136/L22: Write “…2-D-problem. To qualify the mixing process…” rather than “…2-D-problem and the symmetry plane of the channel is representative for the investigation. To qualify the mixture process…”

P4137/L2: Write “…of the mixing.” Rather than “…of the mixture.”

P4137/L9: Write “…first interaction of the model avalanche with the…” rather than “…first touch of the model avalanche into the…”

P4137/L17: Write “…no wave trough and…” rather than “…no wave hollow and…”

P4137/L23: Write “Overtopping at the dam” rather than “Overflowing of the dam”

P4137/L25: Write “…of a wave running over…” rather than “…of a wave run over…”

P4137/L26: Write “…complexity, a vertical…” rather than “…complexity, only a vertical…”

P4137/L28: Write “…the water distribution and potentially dangerous velocities downstream…” rather than “…the further water distribution and potential by dangerous velocity downstream...”

P4138/L3: Write “…of the overtopping of the primary wave at the dam…” rather than “…of the first overtopping of the dam…”

P4138/L6: Write “…first wave overtops at this section and the …” rather than “…first water flows through this control section on the dam and the…”

P4138/L9: Write “…slide thickness *s* are based on…” rather than “…slide thickness *s* base on…”

P4138/L12: Write “…at the time-step just before…” rather than “…at the time-step nearly before…”

P4138/L14: Write “To find *s*, the…” rather than “For *s* the…”

P4138/L22: The meaning of “first wetting of the control section or reaching the maximum” is unclear, please revise.

P4138/L25: Write “…is only 13% larger than the calculated value based on Heller….” Rather than “…is approximately 13% higher than the calculated value by Heller…”

P4138/L27: Write “A larger run-up height *R* is observed in FLOW-3D with 15.7 m (equal to a maximum overtopping height of 13.7 m at…” rather than “A higher overflow height *R* can be analysed in numerics with 15.7 m (equal to a maximum flow depth of 13.7 m on…”

P4139/L8: Write “…in general most critical, further…” rather than “…in general the maximum load, further…”

P4139/L25: Write “…water depth *h*…” rather than “…water height *h*…”

P4139/L27: Write “…of the 2-D to a 3-D-case is…” rather than “…of the 2-D-assumption to a 3-D-case is…”

P4140/L16: Write “…or a smaller water…” rather than “…or a shallower water…”

P4140/L17: Write “…the values based on the formula…” rather than “…the formula…”

P4140/L24: Write “…simulate impulse waves propagating in 3-D.” rather than “…simulate radial symmetric impulse waves.” (Impulse waves are not radial symmetric).

P4140/L26: Write “…study is conducted, which focused…” rather than “…study is added, which is focused…”

P4141/L1: Write “…the widest of the…” rather than “…the maximum of the…”

P4141/L10: Write “…far smaller overtopping volume, as expected.” Rather than “…far smaller outflow volume.”

P4141/L11: Write “…$B > b$…” rather than “…*B* is bigger than *b*…”

P4141/L14: Write “…simulation correspond to an expanded…” rather than “…simulation corresponding to a expanded…”

P4141/L15: Write “…width $B = b = 80$ m…” rather than “…width B equal to the slide width b of 80 m…”

P4141/L23: Write “…(Fig. 8) confirming the statements in Sec. ?.?...” rather than “…(Fig. 8).”

P4141/L24: Write “…the results of Heller et al. (2009) can therefore be reproduced with the avalanche modelled with water.” Rather than “…the assumption of Heller et al. (2009) can therewith be reproduced with the inflowing water as an avalanche model.”

P4142/L4: Write “The volume of the used water is identical to the…” rather than “The volume of the therewith used water is similar to the…”

P4142/L7: Write “…the velocities with which the water reaches…” rather than “…the velocities before the impacting water reaches…”

P4142/L12: Write “…an impact as well as the…” rather than “…an impact and as well the…”

P4142/L20: Write “…and supported by an Excel-Tool.”… rather than “…and are accessible via a provided Excel-Tool.”

P4142/L25: Write “…reach a slightly higher value…” rather than “…reach a higher value…”

P4145/L11: Write “…Anregungen…” rather than “Anregugngen…”

Caption Fig. 7: Write “…walls are coloured…” rather than “…walls coloured…”