Review to the manuscript 'Three-dimensional hydrodynamic lake simulations of avalanche-generated impulse wave dynamics for potential GLOF scenarios at Lake Palcacocha, Peru' submitted by Rachel E. Chisolm and Daene C. McKinney to NHESS

General comments:

Lake Palcacocha – an emblematic case in GLOF studies – has been attracting attention of scientists as well as local authorities and practitioners since catastrophical outburst in 1941 (e.g., Oppenheim, 1946), resulting in implementation of remedial works (open cut and two artificial dams) in 1970s (Zapata, 2002; Emmer et al., accepted). Since that time, the lake has increased its volume from ca 0.5 Mm^3 to about 17 Mm^3 nowadays (UGRH, 2016), due to the glacier retreat, making these mitigation measures insufficient. Recently, Emmer et al. (2016) did lake inventory of lakes of the Cordillera Blanca (882 lakes identified, classified and described by the set of qualitative and quantitative characteristics) and assessment of susceptibility to outburst floods of all large lakes (A>100,000 m^2; n=64), revealing that Lake Palcacocha is among those lakes ranked as "highly susceptible" to produce GLOF, moreover located upstrem regional capital Huaráz. This study on the level of mountain range identified fast slope movements into the lake as likely trigger of GLOF from Lake Palcacocha, but does not provide more detailed information on them – apparent research gap which needs to be addressed. From this point of view is research on potential slope movements entering the Lake Palcacochca undoubtedly desirable.

The authors of the presented manuscript apply known methods and software in geographically relatively new contex of Lake Palcacocha, focusing on ucertainities in modelling displacement wave dynamics (formation, propagation and dam overtopping). Comparison of results obtained from different methods / models is presented, however, with no validation against real GLOF event. This I found to be the major drawback of presented study – no real baseline is used, therefore models are compared to each others, but the overall value of obtained results and implications is, thus, somewhat uncertain.

Additionally, I'm convinced, that uncertainity of scenarios, methods and software used in entire process chain should be somehow balanced. Presented manuscript is, however, very much concerned about the uncertainities of methods and software used to simulate displacement wave dynamics, without considering factuality (uncertainity) of avalanche scenarios used. Why 0.5, 1.0 and 3.0 Mm^3 ?? Why not e.g., 0.2, 2.0 and 5.0 Mm^3 ?? Are there any field / remote sensing-based observations suggesting these volumes ?? This is major issue which needs to be addressed, otherwise all hazard mitigation implications and conclusions are rather speculative.

Moreover, Somos-Valenzuela et al. (2016) recently published modelling of entire process chain of outburst flood from Lake Palcacocha in HESS, considering the same ice avalanche and lake level lowering scenarios and using the same methods and software (Heller and Hager, 2010; FLOW3D, Flow Science, 2012). Releasing of this publication and submission of presented manuscript seems to me chronologically in reverse order, in other words, presented manuscript seems bit redundant now, when paper of Somos-Valenzuela et al. (2016) is published, despite the fact that presented manuscript provides "improved understanding of the dynamics of avalanche-generated waves". In conclusions, would presented results change the results of Somos-Valenzuela et al. (2016) in a significant way ?? Some of results presented are actually overlapping with Somos-Valenzuela et al. (2016), without mentioning it (the results presented in the first paragraph in section 3.4 are identical to results in the last paragraph in section 4.2.1 of Somos-Valenzuela et al. (2016)).

Novelty and additional value of presented manuscript compared to previous studies, therefore, need to be clearly shown, not only in terms of modelling (comparison of different approaches) but also in context of ongoing mitigation activities and research at Lake Palcacocha and realistic (observation-based) potential GLOF triggers.

Specific comments and technical notes (key ones in **bold**):

P01L13: consider using the term “displacement wave“ in the manuscript

P02L11-16: see also recent lake inventory and GLOF susceptibility assessment for the Cordillera Blanca of Emmer et al. (2016)

P02L23: “... failure of lake-damming moraine.“

P02L24: see the work of Shiva Pudasaini and r.avaflow project (http://www.avaflow.org)

P03L04: “... may overtop or breach moraine dams.“

P03L28: replace “potential“ by “future“

P03L35-36: this needs to be specified in more detail; this has already been done as a part of Somos-Valenzuela et al. (2016)

P04L07: replace “mostly destroyed“ by “breached“

P04L09: replace “a smaller“ by “basal“

P04L09: replace “back“ by “upstream“; for people who don’t know this area, **field-based figure for better imagination** on that would be nice

P04L12: lake growth (glacier retreat) 200 m retreat since 2009 ?? please check

P04L17: replace “terminal“ by “damming“

P04L19-32: here, I miss two recent works focusing on Lake Palcacocha: Emmer et al. (2016) identifying Lake Palcacocha as highly susceptible and Klimeš et al. (2016) elaborating impact of potential landslides in moraines on the Lake Palcacocha (sorry, I contributed to both)

P04L01-P05L15: see also Westoby et al. (2014, 2015), Pudasaini & Hutter (2007); Mergili et al. (2016), r.avaflow project (r.avaflow.org) and others

P05L32-33: if it is true that the glacier retreated 200 m since 2009 (see P04L12), 2016 lake bathymetry should be used in order to obtain meaningful results

P06L05: how do you know these are “likely avalanche sizes“ ?? Why 0.5, 1.0 and 3.0 Mm^3 ?? Why not e.g., 0.2, 2.0 and 5.0 Mm^3 ?? Are there any field / remote sensing-based observations suggesting that ?? please explain and elaborate in detail

P06L07: why this baseline ?? this explanation (“appropriate mixing length was unknown“) is not clear to me

P07L17-L24: see also Westoby et al. (2014, 2015), Pudasaini & Hutter (2007); Mergili et al. (2016), r.avaflow project (r.avaflow.org) and others

P07L35-P08L02: this implication is not clear to me, please explain in more detail

P08L25: replace “terminal moraine“ by “dam“

P08L29: why not to use 2003 GLOF for the validation ?? yes, it was not ice avalanche-triggered GLOF (landslide in lateral moraine), but formation, propagation of displacement wave and dam overtopping occurred; please comment on that

P09L18-L20: is that what is actually being done currently ?? if hazard mitigation implications are elaborated, more info on ongoing works should be provided

P13L08-L16: similar to last paragraph in section 4.2.1 of Somos-Valenzuela et al. (2016)

P14L01: replace “damming moraine“ by “dam“

P14L18-P17L11: this is hard to follow; I strongly recommend to **structure discussion into the sub-sections reflecting individual issues discussed**

P14L31-L33: see also avaflow.org

P15L02-L07: comparing different models between each others with no comparison to reality seems slightly purposeless to me

P16L19: from my point of view, the greatest uncertainity arises from not knowing realistic (field investigation-based) scenarios of potential ice avalanches entering Lake Palcacocha, making all hazard mitigation implications and conclusions rather speculative; please discuss that

P17L06-L08: please add reference

P17L13-L14: improving the understanding of lake dynamics during GLOFs does not necessary require the use of 3D non-hydrostatic models only, this is just an option; please reformulate

P17L16-L17: this is very apparent

P17L22-L24: hazard level for Huaráz is not the subject of the manuscript, this conclusion is more based on work of Somos-Vlaenzuela et al. (2016); please rerformulate or avoid

Simulation vs. modelling – is there any difference ?? please explain and unify in manuscript

Tab 2: if the wave height is defined as “height above the moraine crest as the wave overtops the damming moraine“ (P13L10) it is not clear to me, why is increasing with decreasing lake level (volume, peak discharge) ?? please elaborate in more detail

Based on above mentioned I suggest major revisions of the manuscript. I’ll be happy to review revised version. Please, do not hesitate to contact me in case of questions (aemmer@seznam.cz).

Kind regards

Adam Emmer

References (style not unified, sorry):

Emmer A, Vilímek V, Zapata ML (2016, online first). Hazard mitigation of glacial lake outburst floods in the Cordillera Blanca (Peru): the effectiveness of remedial works. Journal of flood risk management. doi: 10.1111/jfr3.12241.

Emmer A, Klimeš J, Mergili M, Vilímek V, Cochachin A (2016). 882 lakes of the Cordillera Blanca: an inventory, classification and assessment of susceptibility to outburst flood. Catena 147: 269–279.

Flow Science. FLOW-3D Documentation: Release 10.1.0, Flow Science, Inc. Santa Fe, NM, 2012.

Heller, V., Hager, W. H. Impulse Product Parameter in Landslide Generated Impulse Waves. J. Waterw. Port CASCE, 136, 145-155, 2010.

Klimeš, J., Novotný, J., Novotná, I., Jordán de Urries, B., Vilímek, V., Emmer, A., Strozzi, T., Kusák, M., Cochachin Rapre, A., Hartvich, F., Frey, H. (2016): Landslides in moraines as triggers of glacial lake outburst floods: example from Palcacocha Lake (Cordillera Blanca, Peru). Landslides, 13(6): 1461-1477, doi: 10.1007/s10346-016-0724-4.

Mergili M, Fischer J-T, Krenn J, Pudasaini SP 2016. r.avaflow v1, an advanced open source computational framework for the propagation and interaction of two-phase mass flows, Geo-scientific Model Development 10: 553–569.

Oppenheim, V., 1946. Sobre las Lagunas de Huaraz. Boletin de la Sociedad Geologica del Peru 19, 68–80.

Pudasaini SP, Hutter K 2007. Avalanche Dynamics: Dynamics of rapid flows of dense granular avalanches. Springer.

Somos-Valenzuela, M. A., Chisolm, R. E., Rivas, D. S., Portocarrero, C., McKinney, D. C.: Modeling glacial lake outburst flood process chain: the case of Lake Palcacocha and Huaraz, Peru, Hydrol. Earth Syst. Sci., 20, 2519–2543, 2016. doi: 10.5194/hess-20-2519-2016

UGRH – Unidad de Glaciologia y Recursos Hídricos. Bathymetric survey of Lake Palcacocha. Autoridad Nacional de Agua (ANA) de Peru, Huaraz, Perú, 2016.

Westoby, M.J., Glasser, N.F., Brasington, J., Hambrey, M.J., Quincey, D.J., Reynolds, J.M., 2014. Modelling outburst floods from moraine-dammed glacial lakes. Earth Sci. Rev. 134, 137–159. http://dx.doi.org/10.1016/j.earscirev.2014.03.009.

Westoby, M.J., Brasington, J., Glasser, N.F., Hambrey, M.J., Reynolds, J.M., Hassan, M.A.A.M., Lowe, A., 2015. Numerical modelling of glacial lake outburst floods using physically based dam-breach models. Earth Surface Dynamics 3 (1), 171–199. http://dx.doi.org/10.5194/esurf-3-171-2015.

Zapata ML 2002. La dinamica glaciar en lagunas de la Cordillera Blanca, Acta Montana (ser. A Geodynamics) 19: 37–60.