Response to the comments of reviewers for nhess-2020-289

Answers to Technical items for which revision is required --- ‘*Numerical investigation on the kinetic characteristics of the Yigong landslide in Tibet, China*’

The authors are grateful for the reviewers’ comments and suggestions. The manuscript has been revised and each point of the reviewers' comments has been incorporated and addressed. Your comments have greatly improved the quality of this manuscript and we hope the revised manuscript will be of suitable standard to be accepted for publication in your journal.

Reviewer #1:

1. Which is the novelty of this numerical code when compared with other SPH numerical codes? Moreover, this code does not simulate the bed-entrainment as that of Cuomo et al. (2016).

Answer: Thank you for this comment.

a) The novelty of this numerical code is using the Open Multiprocessing (OpenMP) API to conduct the parallel implementation and improve the computational efficiency. We add some explanation in the manuscript:

“*3.2.3 OpenMP parallelism*

To simulate the propagation of a rapid landslide across complex terrain, it is necessary to develop a three-dimensional numerical model. In the 3D SPH model, however, the computational efficiency is sharply reduced as the particle number increases. To improve the efficiency, it is necessary to parallelize the numerical code without suffering from a loss of precision.

The Open Multiprocessing (OpenMP) API for shared-memory programming enables loop-level parallelism by the insertion of pragmas within the source code. By adding special directives at the beginning and end of the loop, the OpenMP parallel implementation can be easily conducted. The cycles of the loop are then randomly assigned to the available threads. In the present work, the paralleled numerical code was written in FORTRAN 95 and the program was compiled using Microsoft Visual studio 2015 in a PC with the quad-core 8-thread CPU, Intel Core i7-7820HQ, and run at 2.90 GHz clock with 32 GB main memory under the Windows 10 Professional 64-bit operating system.” (Lines 189-199)

“*To verify the performance of parallel computation, the 3D SPH modelling was carried out using different thread numbers (1, 2, 4, 6, and 8). Figure 17 shows the relationship between the average program running time and the thread number. It is obvious that the computation efficiency of the presented SPH model increases with the thread number.*” (Lines 290-292)

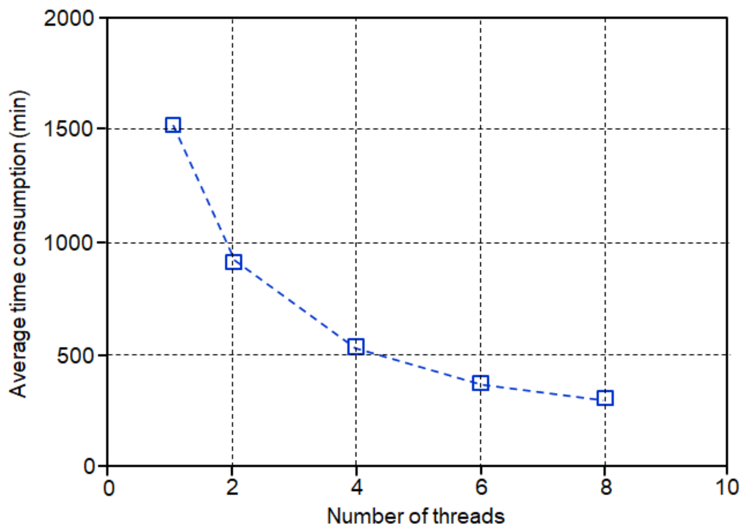

Figure 17: Relationship between average computing time and thread number in 3D SPH modelling.

b) The reason we don't simulate the bed-entrainment in this work is explained as follows:
"*Though several numerical models have been proposed to consider the entrainment effect (Cuomo et al., 2016; Li et al., 2019), it is still difficult to find an appropriate failure criterion to determine when the entrainment effect will occur. Moreover, it is also difficult to quantify the entrainment depth and volume in field investigation. Therefore, the bed entrainment effect during the propagation was not considered in the presented SPH model to simplify the simulation.*" (Lines 336-340)

2. what about the pre-event bathymetry? What about the Digital Elevation Model? Model results depends also on the data (LiDAR or photogrammetric points) by which the Digital Elevation Model is built (LiDAR, photogrammetry, see Degetto et al. 2015), the interpolation technique (Boreggio et al., 2018) and grid size (Stolz and Huggel (2008)).
Answer: Thank you for this comment. We agree that the digital elevation model (DEM) is the fundamental input to simulate the landslide propagation, which can influence the accuracy of the model results. A simple review on the DEM generation technique is provided in the manuscript. In this study, the two-dimensional SPH model is based on the topographic profile provided in Yin (2000), and the 3D digital topographical data used in the three-dimensional SPH modelling is digitized on the contour lines (provided in Zhang, 2013) using the linear triangulation interpolation method.
"*To simulate the propagation of the flow-like landslide, the fundamental input is the topographic data, usually in the form of Digital Elevation Models (DEMs). Stolz and Huggel (2008) revealed that DEM quality and grid resolution significantly influenced the accuracy of debris flow modelling. Degetto et al. (2015) analysed the differences between using RTM-based DEM and LiDAR-based DEM for hydrological modelling of debris flows and showed that LiDAR-based DEM had relatively higher accuracy. Boreggio et al. (2018) investigated the performance of several common interpolation methods in building DEMs with the complex topography, and revealed that the interpolation algorithm had little effect on the model outcomes. In this work, the topographic profile of the Yigong landslide used in the two-dimensional SPH modelling is from Yin (2000). The 3D digital topographical data used in the three-dimensional SPH modelling is digitized on the contour lines (Zhang, 2013) using linear triangulation interpolation method.*" (Lines 208-216)

Boreggio, M., Bernard, M., Gregoretti. C.: Evaluating the Differences of Gridding Techniques for Digital Elevation Models Generation and Their Influence on the Modeling of Stony Debris Flows Routing: A Case Study From Rovina di Cancia Basin (North-Eastern Italian Alps), Frontier in Earth Sciences, 6, 89, doi: 10.3389/feart.2018.00089, 2018.

Degetto, M., Gregoretti, C., Bernard, M.: Comparative analysis of the differences between using LiDAR and contour-based DEMs for hydrological modeling of runoff generating debris flows in the Dolomites, Frontiers in Earth Sciences, 3: 21, doi: 10.3389/feart.2015.00021, 2015.

Stolz, A., Huggel, C.: Debris flows in the Swiss National Park: the influence of different flow models and varying DEM grid size on modeling results, Landslide, 5, 311-319, doi: 10.1007/s10346-008-0125-4, 2008.

Zhang, Y.J.: Study on dynamic characteristics of typic rock avalanche on canyon area, Ph.D. thesis, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, 28 pp., 2013.

3. Information about the development of the phenomenon and post-event bathymetry are introduced without any explanations:

1) Who estimated the peak and average velocity of this rapid landslide? Which sensor was used for measuring them? Moreover, the peak and the average values of the velocity, 100 m/s and 40 m/s respectively, seem physically not acceptable.

Answer: The runout distance of the Yigong landslide was about 8,000 m. According to eyewitness' account, the propagation time of the landslide was about 3 min (Xu et al. 2012). Therefore, it can be estimated that the average velocity was about 40 m/s. Li et al. (2020) computed the velocity process of Yigong landslide by the Massflow software, and the results showed that the peak velocity was more than 100 m/s. According to the dynamic analysis conducted by Zhang (2013), the peak and average velocity of this rapid landslide were about 111 m/s and 55 m/s, respectively. Therefore, the velocity time history predicted by the SPH model in this work is reasonable. We add some explanation in the manuscript:

"*Velocity is one of the key kinetic characteristics during the landslide propagation, which is difficult to measure in field. According to eyewitness' account, the total sliding time of the Yigong landslide was about 3 min. The runout distance was about 8,000 m. Therefore, the average sliding velocity of the landslide was estimated to be about 40 m/s. According to the dynamic analyse results (Zhang, 2013; Li et al., 2020), the maximum velocity during the landslide propagation was more than 100 m/s. Therefore, the velocity time history predicted by the SPH model in this work fits the literature data well and is reasonable and reliable.*" (Lines 327-332)

Li, J., Chen, N.S., Zhao Y.D., Liu, M., Wang W.Y.: A catastrophic landslide triggered debris flow in China's Yigong: factors, dynamic processes, and tendency, Earth Sciences Research Journal, 24, 71-82, doi: 10.15446/esrj.v24n1.78094, 2020.

Xu, Q., Shang, Y., van Asch, T., Wang, S., Zhang, Z., Dong, X.: Observations from the large, rapid Yigong rock slide—debris avalanche, southeast Tibet, Canadian Geotechnical Journal, 49,589–606, doi: 10.1139/T2012-021, 2012.

Zhang, Y.J.: Study on dynamic characteristics of typic rock avalanche on canyon area, Ph.D. thesis, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, 28 pp., 2013.

2) How the post-event topography was measured?

Answer: The landslide dam broke down about two months after the landslide occurrence. Most of the landslide deposit was washed away by the flood. Therefore, we didn't measure the post-event topography by ourselves. We add some explanation in the manuscript:

"*About two months after the Yigong landslide occurrence, the landslide dam broke down, and most of the landslide deposit was washed away by the flood. Therefore, it is difficult to measure the post-event topography in field.*" (Lines 319-321)

4. Moreover, the reliability of a model depends on the its capability of reproducing the observed deposition pattern. The authors should compare the observed and simulated deposition depths not only the deposition area (Gregoretti et al., 2019).

Answer: We totally agree with this comment. In the two-dimensional SPH modelling, we compare the simulated deposition depths along the topographic profile with the measured results recorded in Yin (2000), as shown in Figure 14 in the manuscript. However, for the three-dimensional SPH modelling, we don't carry out the comparative analysis due to lack of measured data. We add some explanation in the manuscript as follows:

"*Figure 14 compares the simulated landslide deposition with the measured data recorded in Yin (2000). The predicted landslide deposition area is consistent with the measured data, and the simulated deposition depths along the topographic profile match the observed results well.*" (Lines 244-246)

"*Figure 16 shows the Yigong landslide deposition. The blue solid line represents the observed landslide deposition and the red dash line is the simulated results. It shows that the shape of the simulated deposition zone is basically in agreement with the observed one. The comparative analysis of deposition depths is not carried out in three-dimensional modelling due to lack of measured data, though it is important to verify the reliability of SPH model (Gregoretti et al., 2019).*" (Lines 285-289)

Gregoretti, C., Stancanelli, L. M., Bernard, M., Boreggio, M., Degetto, M., Lanzoni, S.: Relevance of erosion processes when modelling in-channel gravel debris flows for efficient hazard assessment, Journal of Hydrology, 568, 575-591, doi: 10.1016/j.jhydrol.2018.10.001, 2019.

5. Finally, some other general comments: it is strange that no erosion was observed along the flow path and that this rapid-landslide did not transform into a debris flow?

Answer: Thank you for this comment. Actually, during the propagation of the Yigong landslide, the sliding mass entrained the bed material and transformed into a debris flow. We describe the phenomenon in the manuscript as follows:

"*The high-speed sliding mass can entrain large volumes of sediments on the runout path and transform into a debris flow, which is an important feature of many rapid landslides (Gregoretti et al., 2019; Li et al., 2019). According to the field investigation conducted by Zhou et al. (2016), the bed entrainment effect during the propagation occurred at this landslide because of the high motion speed. Though several numerical models have been proposed to consider the entrainment effect (Cuomo et al., 2016; Li et al., 2019), it is still difficult to find an appropriate failure criterion to* *determine when the entrainment effect will occur. Moreover, it is also difficult to quantify the entrainment depth and volume in field investigation. Therefore, the bed entrainment effect during the propagation was not considered in the presented SPH model to simplify the simulation.*" (Lines 333-340)

6. Other specific comments are as follows:

1) Lines 17-18 "This approach can provide a new way to predict hazardous areas and estimate the hazard intensity of rapid landslides." This sentence is misleading: models are used to simulate scenarios and building hazard map. Therefore, where is the novelty of this approach?

Answer: Thank you for this comment. This sentence is modified as "*This approach can predict hazardous areas and estimate the hazard intensity of rapid landslides.*" (Lines 17-18)

2) Line 216 "The simulated runout distance is about 8,000 m, which can also match the measured result very well." This sentence is useless when observed and simulate deposition pattern are compared (see figure 16) The word "accumulation" is not appropriate: use the term deposition

Answer: We agree with this comment. The sentence "The simulated runout distance is about 8,000 m, which can also match the measured result very well." is deleted. The word "accumulation" is replaced by "deposition" in the manuscript.