Nat. Hazards Earth Syst. Sci. Discuss.,
doi:10.5194/nhess-2016-372-AC3, 2017

Natural Hazards and Earth System Sciences
Open Access
Discussions

Interactive comment on "Empirical prediction for travel distance of channelized rock avalanches in the Wenchuan earthquake area" *by* Weiwei Zhan et al.

Weiwei Zhan et al.

18202308@qq.com

Received and published: 17 March 2017

Dear Prof. van Asch,

We acknowledge your time and helpful comments, which are valuable for improving the quality of our manuscript. We have revised the manuscript carefully according to your and other reviewers' comments. The revised manuscript will be submitted after the reply to reviewers' comments stage. Your comments are reproduced below, followed by our responses and/or a summary of revisions to the manuscript.

With my kindest regards, Sincerely, on behalf of my co-authors, Xuanmei Fan

Comments in general:

Q1: This is an interesting paper showing that with a limited amount of factors one is able to predict the travel distance of rock avalanches provided that they occur in the same area, are of the same type and have the same triggering conditions. This was already shown in this paper where the validation with landslides with other triggering conditions and lying in another area gave sometimes poor results. I am wondering why the authors did not mention in the introduction explicitly the use of the energy concept for runout modelling, which gives a simple transparent insight in the most important factors (relief and friction) influencing run-out distance. Interesting question arises also from the introduction about advantages and disadvantages of the use of deterministic physical models and statistical models.

R1: Thanks for your comments. We have added one chapter 4.1 to analyze the application of energy line model on the channelized landslides (see the revised text).

Comments tied to sections: Q2: In the introduction, the authors mention examples of important fast landslides but they must more precisely describe triggering condition and type.

R2: Thanks for your comment. We added a table summary of some commonly used empirical-statistical models for landslide motion prediction in Table S1 (please see the attachment 1).

Q3: I have great difficulty in presenting the total height (H) as an important factor for the run out distance since it is highly correlated with run-out distance (L) Therefore Equation 2 and 3 are really not useful predictive equations because you need the travel distance L which you have to predict? May be a trial an error procedure for L is a solution when using this equation? It would be nice to test this.

R3: We agree that travel distance (L) is highly correlated with total relief (H) partly due to the geomorphologic similarity in same area. Yet we suggest there are potential benefits of Eq(2) and Eq(3). As the Eq(2) is developed through a stepwise linear multivariate regression technique to get the best-fit multivariate regression model for travel distance prediction, H is attracted to the equation when taking account of H, Hs, V, beta as input variables. On the physical base, total relief indicates the potential energy difference of the failure mass which control the motion of rock debris. Eq(2) can give a clue to the compare the influence of two important factors, volume and potential energy difference on the travel distance. From the point of practical use of Eq(2), the estimated results using Eq(2) can be a benchmark of the results obtained through other models especially while H can be estimated to close to elevation difference between source area and valley floor for cases with high possibility to reach the valley floor.

Q4: The authors solved the problem by making a correlation of Hs with H (Eq4) which is a practical solution but has of course no physical meaning and it has to be questioned whether it works in other areas. I want to see comments on this in the discussion paragraph.

R4: The positive correlation between Hs and L can be explained to be the increasing tendency of Hs with the volume.

Q5: The energy approach to model run-out (not used in this paper) shows that volume does not play a role. But in that case it is assumed that friction is not influenced by volume, which in practice seems to be the case due to all kinds of physical processes in the mass. Therefore in order to show this, I asked the authors to make also a correlation between H/L (mean friction during run-out) and volume.

R5: Thanks for your suggestion. We have added one chapter “4.1 Apparent coefficient of friction” to discuss the influence of several factors such volume, effective drop height, slope angle, channel angle on the H/L” (please check the attachment 2).

Q6: The effect of slope angle beta is a bit strange In Eq, 2 and 3 it is negative while in Eq 4 it is a positive factor. The authors should comment on this.

R6: Thanks for your comment. We suggest the positive maybe caused by the introduce of source area height and slope angle alfa to the regression model

Q7: The authors give sometimes unclear and peculiar explanations of their findings regarding the effect of volume on travel distance and the effect of total height and channel angle on run-out distance.

R7: We have clarified this in the revised version, which will be submitted before 20 April.

Q8: A lack of clarity for me sometimes occurred in the text where the authors give no definitions of some terms like flow capacity, projectile motion etc., (see my annotations and comments).

R8: Thanks for your comment. We explained these definitions in the relevant detailed comments tied to lines, see R32.

Detailed comments tied to lines:

Q9: The grammar, terms and other similar details in lines 40, 68, 76, 80, 85, 86, 138, 183, 184, 238, 241, 279, 317

R9: We have corrected the above lines.

Q10: Line 28: What is the role of water in these rock avalanches?

R10: The term "rock avalanche" has developed naturally in the literature, as a simplification of the complex "rock slide-debris avalanche", proposed by Varnes (1998). Hungr et al.,2001, suggested that the term "rock avalanche" be reserved for flow-like movements of fragmented rock resulting from major extremely rapid rock slides. This contrasts with the term "debris avalanche", which should be reserved for landslides originating in unconsolidated material. Therefore, the role of water on the motion of rock avalanches is omitted in this study.

Q11: Line 49: Make it more general: The statistical empirical models enveloped in one region cannot be applied in another region with different geomorphological and geological surroundings. And to be honest: the same holds nearly always for physical models: due to the lag of parametric input data the parametric values have to be back calculated with passed events in a particular area and it has even to be seen whether these parametric values are valid for a next event in the same area

R11: We fully agree with the reviewer. We have added this in the discussion part of the revised version.

Q12: Three major sub-parallel faults were not marked in the map under this title.

R12: We are sorry about these mismatches of the sub-parallel faults. We have corrected the fault names in the text as “the Maoxian- Wenchuan fault, the Yingxiu-Beichuan fault and the Jiangyou-Guanxian fault”.

Q13: Line 62: what are highly developed stream systems?

R13: We agree that the highly developed stream systems is not explicit. We have rephrased this sentence to ‘With long-term endogenic and exogenic geological process, this region is characterized by high mountains and deep gorges and extreme rates of erosion’.

Q14: give an idea of the size of the fragments of these rock avalanche deposits.

R14: These rock avalanches deposits are mainly made up of debris with tens of centimeters as average particle size.

Q15: Rephrase the sentence ‘When the source mass was detached from the slide bedrock, it may directly move into the channel down slope (see Figure 2b), or access the channel with enter it at some impact transition angle of movement direction (see Figure 2a)’.

R15: Thanks for this comment. We rephrase this paragraph to “The influence of the local geomorphology on the topography of the rock avalanche depositions can be recognized from remote-sensing images after the earthquake. The source area and the transition area of channelized rock avalanches in the study area were somehow easy

to be differentiated, as the source area are normally located at the top or upper part of slope, while the flow path (flow or transition area) is partially or fully confined by channels.”

Q16: Line 88-112: Delete!! Repetition ! These section are a copy of what was printed above.

R16: We are sorry about this mistake. This page has been deleted.

Q17: Line 119: Vague! What means Geography in this case: ‘Another well-known model is the statistical α–β model in which the maximum runout distance is solely a function of geography’.

R17: We replaced “geography” with “topography”.

Q18: In the first paragraph after chapter title 3.1 General consideration, namely line 116-127, indicate in the type of landslide which was investigated.

R18: Thanks for this comment. We added a table of published empirical relations related to landslide travel distance prediction, which summaries the keywords, model formula, type and trigger of landslide samples of different models (please check the attachment 1, Table S1).

Q19: Line 144-146: Altitude difference determines with mass the potential energy difference. The difference in potential energy is of course related to the travel distance but is not a deterministic factor. What surprises me is that in the fore going no attention was given explicitly to the energy method with the use of a friction lines to predict runout distances. That brings me to the question why the authors did not consider material type as a surrogate for friction.

R19: Thanks for your comment. We have added section 4.1 to analyze the apparent coefficient of friction of channelized rock avalanches and also done some comparison in the discussion, please check the attachment 2 for the new section 4.1.

Q20: Line 153-155: This is unclear: what is inclination of slope section and valley section. Why they are obtained. In the next sentence you talk about Slope angle (alpha) and Channel angle (beta) Is that the same as the inclinations mentioned in this highlighted sentence?

R20: Thanks for this comment. We aimed to explain the same thing with different expression. We agree that sentence is not clear and rephrase it to 'The average inclination of sectional slopes and channels are obtained respectively, while the gradient of valley section is neglected as it has very little variation.' The angles of slope and channel section are obtained and considered respectively to analyze the influences of different topographic conditions on the travel distance of rock avalanches.

Q21: Line 164: From a theoretical point of view the empirical link between area and volume is very tricky because rock strength of a failing block, and slope angle plays an important role in the depth of sliding and hence the volume. R21: We agree that the sliding depth and the volume are affected by the geological structure (like weak zone), topographic condition (like slope angle, location on the slope), groundwater level, ground motion intensity and so on. But there are several publication confirming that power-law equations indeed exists between the area and volume of landslides. Considering the difficulty of obtaining the volume of every rock avalanches due to the lack of pre-quake topographic data, we still regarded as a practical measure the relationship build with accordance to a popular volume-area relationship adapt by Guzzetti et al. (2009), Larsen et al. (2010) and calibrated with the field dataset in the Wenchuan earthquake area by Parker et al. (2011).

Larsen, I.J., Montgomery, D.R. and Korup, O., 2010. Landslide erosion controlled by hillslope material. Nature Geoscience, 3(4), pp.247-251.

Guzzetti, F., Ardizzone, F., Cardinali, M., Rossi, M. and Valigi, D., 2009. Landslide volumes and landslide mobilization rates in Umbria, central Italy. Earth and Planetary Science Letters, 279(3), pp.222-229.

Q22: Line 164-165: Unclear No idea what you mean: 'Volume of some rock avalanches with detailed field investigation are replaced by the data from published literature.'

R22: Thanks for the comment. We rephrased this sentence to 'The data of some rock avalanches with detailed field investigation are attained through the literature review.'

Q23: Line 173: But in that case the empirical-statistical methods may miss important factors when one does not knowing the physical processes of the mobility.

R23: We agree that some fundamental physical processes and principles should be considered during the empirical-statistical method construction. But as there are many unknowns related to the hypermobility of the rock avalanches, using empirical-statistical methods can considerably simplify the travel distance prediction. We rephrased this sentence to 'Empirical-statistical methods have long been used as tools to study the mobility of rock avalanche since they are easy to develop and apply, and not dependent on knowing the complex physical processes involved in the hypermobility of rock avalanches.'

Q24: Line 193: H is not independent of L.

R24: We agree with you about H is relevant with L and think it can be a basis of the regression model considering H as a variable at least from statistical view.

Q25: Line 198: The differences must have something to do with the difference in type of landslides. The here investigated landslides are all? rockslides triggered by the Earthquake fragmented into a rock avalanche

R25: We will find different datasets considering the landslide classification and then make more specific compare to analyze the influence of landslide types and topographic confinement on the motion ability of landslides. We have analyzed the influence of landslide types on the landslide mobility in the revised discussion part (see the attached new added section 5.2, attachment 3).

Q26: Line 209: It appears that in a basic energy approach for run out, volume is canceled out and does not play a role if we assume that volume has no influence on the friction. But volume does have an influence on friction. Friction is lower at larger volumes which can be explained by all kind of physical processes. So it is nice to make a correlation between volume and H/L.

R26: We thank for your suggestion. We have made a new figure (Figure S7 in the attachment 3) to compare our dataset with the dataset of Legros et al. 2002. According this figure, the tendency that apparent friction angle (H/L) decreases with the increase of volume is still steady for channelized rock avalanches in our study. However, more scatters occur when the volume of channelized rock avalanches are less than approximately 4.0x106m3, which indicates topographic confinement may play a more important role than volume in determining the travel distance of landslides when the scale of landslide are relatively small.

Q27: Line 214 and 218: As the Eq.(2) and Eq.(3) show, if beta increases L decreases ?? R27: According to the results of best-fit regression and correlation analysis in Section 4.1, the L decreases with the increases of beta. Q28: Line 224: It looks to me also difficult to predict the area of rock mass which will fail?

R28: In our opinion, with adequate deformation premonition and detailed investigation, it is possible to reduce the uncertainty related to the scale estimation of potential slope failures.

Q29: Line 226: The correlation coefficient between H and alpha is not so high. Why do you want to introduce here alpha? In the foregoing you said that it is not a good correlator. Does it give a slighly better result with alpha in the equation?

R29: Yes it gives slightly better result.

Q30: Line 229: Compared with Eq 2 and 3 beta is now positive correlated with L in Eq 4??

R30: We will check this in the revised version.

Q31: Line 247: The Wenjia gully is of course a very complex one with among others a platform with a main deposition area half way.

R31: We agree with you. We want to take the Wenjia gully as an example to illustrate the influence of micro topography on the mobility of rock avalanches, especially of the broad depression at the upper end of channels.

Q32: Line 249: what is meaning of ‘projectile motion’ ?

R32: The projection process was a special type of failure mode of earthquake-triggered landslides that was first proposed by Huang et al. (2011). They defined that “ejection” (projection process here) as “Because of the landform enlargement effect of the earthquake wave, the slope close to earthquake fault or earthquake epicenter is pulled up from upper part or midupper part, and is thrown out, and forms projectile motion of the slope mass”. Several features of the Wenchuan Earthquake had quite different characteristics from those produced under general gravity force. Projectile motion here mean the drop under the action of gravity only that the failure mass experienced when a steep and high slope is under the toe of source areas. The Donghekou landslide is a good example.

Huang, R.Q., Xu, Q., Huo, J.J, 2011. Mechanism and Geo-mechanics Models of Landslides Triggered by 5.12 Wenchuan Earthquake. J.Mt.Sci 8:200-210

Q33: Line 260: Are these validation landslides all rock slides transforming into debris avalanches?

R33: No, they are rock avalanches. Even though the last two avalanches were triggered by heavy rainfall, their motion did not have strong relations with water.

Q34: Line 265: With equation 4 we get large errors especially with the Lushan earthquake and when triggered by rain. Do we get an explanation?

R34: The significant underestimate of travel distance of rock avalanches triggered by the Lushan earthquake and heavy rainfall was supposed to be related to the decrease of rock strength due to the Wenchaun earthquake.

Q35: Line 266: I find a 40 % error with Eq (4) a bit cumbersome. Maybe it have something to do with the trigger mechanism (rain) and another area (Lushan area more to the south).

R35: Yes, we have added some discussion on the effects of triggers on the landslide mobility. But in order to address this issue, further datasets are required.

Q36: Line 267: As for the best-fit regression model, But I am not so happy with the best fit regression model because it requires indirect knowledge of the predicted value (L) in order to obtain H.

R36: H could be considered as the vertical relief from the landslide source area to the nearest gully floor, which then could be obtained easily in the field or from the topography map.

Q37: Line 272: Was there an influence during the Wenchuan earthquake on rock weakening in the Lushan area?

R37: It is possible but we can not find enough evidence now. The influence of rock type (strength) is analyzed in the revised chapter 5.2.

Q38: Line 277: In Eq 2 and 3 beta is negatively correlated with L while in Eq 4 beta is positively correlated with L. I should expect that beta is always positively correlated with L.

R38: We will check this in the revised version.

Q39: Line 281-282: I do not see the logic of this. May be you can explain a bit more. It may have also something to do with a decrease in friction of larger volumes.

R39: 'Such a high correlation between landslide volume and travel distance implies that the travel distance of channelized rock avalanche is dominated by the spreading of the slide mass (Davies, 1982; Staron,2009).'

Q40: Line 283-284: The kinetic energy varies along the track starting with zero to a maximum and ending with zero. The positive relation between H and L is determined by the friction line and the slope profile. The friction line start in the source area and crosses the slope in the lower part where the mass comes at rest A variation of slope profiles and a constant friction line will give a linear positive correlation between H and L The llinear correlation between H and L in Figure 3 shows that the friction is more or less constant around a mean value.

R40: We agree with the reviewer and will check this in the revised version.

Q41: Line 285: Unclear, need more explanation.

R41: We will check this in the revised version.

Q42: Line 287: the medium negative correlation between travel distance and channel angle was referred in chapter 4.1, but Eq 4 shows a positive correlation!

R42:The same as aforementioned comment. We will check this in the revised version.

Q43: Line 290: the sentence 'the channel could not stop the rock avalanche until it lost fragment flow discharge' is not clear.

R43: We have rewritten this discussion.

Q44: Line 291-292: If discharge and flow velocity are the same the crossectional flow area is the same . Width and depth of the crossection can change but what has that to do with a decreasing slope angle leading to a larger run-out distance? More explanation here. What do you mean by flow capacity?

R44: Thanks for your comment. We have rewritten this discussion.

Q45: Line 305: I am not so happy with the factor total relief because it is highly dependent on the run-out distance L. ' As the total relief and channel angle act as external factors for the motion of rock avalanche, it seems like it is in essence landslide volume that control the rock avalanche movement.'

R45: Thanks for your comment. We have rewritten this discussion.

Q46: Line 312: ‘entrainment volume’ is not considered in this paper Can be very important!

R46: Thanks for your comment. We have rewritten this discussion.

Q47: Line 312: you mean in our case Beta Because apart from volume and H nothing was considered in the equation 2 and 3 and in 4 Alpha and Hs. A bit confusing to introduce here the term flow capicity as a factor.

R47: Thanks for your comment. We have rewritten this discussion.

Q48: Line 318: ‘leading to that the distal deposition appeared in the channel instead of the valley.’other (finer) half went into the valley.

R48: Thanks for your comment. We have rewritten this discussion. Comments on figures:

Q49: Fig 6, 7: the lateral axis titles are both log(L).

R49: Thanks for your comment. We have revised these two figures in the revised version.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2016-372/nhess-2016-372-AC3-supplement.pdf

---

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2016-372, 2016.