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1, C606–C615, 2013

Interactive Comment

Interactive comment on “Shallow landslides stochastic risk modelling based on the precipitation event of August 2005 in Switzerland: results and implications” *by* P. Nicolet et al.

P. Nicolet et al.
pierrick.nicolet@unil.ch

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Thank you for your comments, a discussion for each point is given below. Questions or remarks are in italic, whereas answers are in bold.

Some scientific comments: Page 5, line 16: "Soils (regolith) and loose materials cover most of the time the bedrock. Most of these shallow and superficial formations have not been mapped, except for the cases where..." You may want to comment this in connection with the working scale. In the same way, it implies an additional limitation *of the lithological units used (to be mentioned in the discussion section).*

This is indeed a limitation coming from the working scale, but not only since geological maps are (at least in Switzerland), more common than soil maps. In geological maps (even at 1:25'000 scale), abstraction is generally made of the first meters: if colluvium covers a solid rock formation, the solid rock formation generally appears on the map. However, as mentioned in the article, the properties of the local soils strongly depend on the underlying bedrock. As a result, this simplification is considered as acceptable. Nevertheless, we'll discuss this limitation in the discussion section as it is not the case yet.

Page 6, line 17: "It is worth mentioning that the uncertainty of this estimation is quite important as an event of such intensity was never observed in the past at the considered weather stations." You should mention and discuss this issue within the discussion section.

We haven't included this point in the discussion section since the return period is not used in the model, but is given as a general information on the past event. However, we could mention this issue in the discussion when we speak of the potential for modeling precipitation events (p. 763 l. 17 ss.).

Page 10, line 9: "The highest accumulations are observed on the northern slope of the Alps, in particular along a line from the Berner Oberland to the mountain range of Saentis." If it is possible and easy, I suggest you to indicate those locations in figure 1.

This location should indeed be mentioned, we'll modify the figure to include this location or change the text.

"The spatial distribution of landslides closely follows the regions with the highest rainfall totals with some spatial heterogeneity due to the different geological settings." Could you provide a clearer and more extended explanation?

The general idea is that there is a correlation visible at first sight between precipitation amounts and landslides, but the correlation is not direct since other local factors control the landslides. We will change the sentence this way: "The spatial distribution of landslides is strongly correlated to the spatial distribution of rainfall amounts. The remaining unexplained spatial variability is due especially to the local geological and morphological settings, which control the sensitivity of the soil to the input rainfall.

Page 10, line 18: Can you provide any reference on the geotechnical map of Switzerland you have used?

The geotechnical map we used is based on the 2nd edition published by the Swiss Geotechnical Commission (de Quervain and Frey, 1965, 1967, 1963; de Quervain and Hofmänner, 1964). The legend has been simplified into 30 classes for the vectorized version we posses, but since this is difficult to find a source for this reclassification, we will use a newer version given by the Swiss Geotechnical Commission for which the documentation is more complete.

Page 11, line 3: "Cells that contain water (lake or glacier) or that are located on the Swiss border have a cumulative value below 1 (Fig. 4e). The model is run several times and assigns at each iteration a unique lithological unit following the probabilities given in the maps shown in Fig. 4." It is not clear to me how you obtained unique lithological units. I ask you to explain the procedure in a more detailed way." I think Fig. 4e should be 4E.

The value for each unit is given by the surface (in km^2), covered by the unit in the cell. Therefore, the sum should be 1 for each cell. Nevertheless, since lakes are displayed on the geotechnical map but not taken into account for the sum, some cells have a sum below 1. The effect appears also on the borders, since the polygons are cut at the border.

NHESSD
1, C606–C615, 2013

When it comes to the unit attribution, a random number between 0 and 1 is generated, and, depending on this number and the lithologies in the cell, the geology is attributed. For example, if a cell contains 20% of lithology A, 30% of lithology B, 25% of C and 25% of D, the cumulative values will be respectively 0.2, 0.5, 0.75, and 1. If the random number is 0.1, lithology A will be assigned to the cell. If it is 0.6, lithology C will be assigned, etc.
We will unify the letters type case for this figure, to be consistent with the text.

Next paragraph: "Landslides are transformed from point features to a raster displaying the landslide number in each cell (Fig. 1). This raster is then MULTIPLIED by the cumulative geological raster (Fig. 4e) to take into account the smaller land surface inside the cell. Indeed, cells with a total value below one for the geology (borders of Switzerland, lakeshores, etc.) are taken into account only at some iterations. Therefore, by DIVIDING them with the geology allows to maintain a..." Again, I can't understand well the procedure.
It should be written twice "divide-(ing)". The idea behind that is to express, for each cell, the number of landslides per km^2 of land. If this division was not done, the number of landslides taken into account to build the distributions would be below the actual numbers since these cells are not always considered. For example, if 50% of the cell is covered and the random number is 0.6, the cell will not be considered in the iteration, and, as a result, the landslides in this cell will be attributed to none of the lithologies. By doing this division, the number of landslide will be greater when the cell is taken into account (i.e. when the random number is below 0.5 in this example), which will allow to keep a mean number of landslides consistent with the observation.
Nevertheless, this section seems to be not clear, so we'll try to make more explicit figures and rewrite the text in order to make this section more understandable. "Dividing with the geology" is indeed ambiguous, so instead of geology, we

NHESSD
1, C606–C615, 2013

Interactive Comment

will use the term "total land surface" (or an other similar term), to insist more on the transformation into the unit "landslide per km^2 of land", instead of "number of landslides inside the cell".

Page 12, line 22: "Since, for a given surface, an elongated shape is more likely to intersect a building than a round one, the circle diameter is set to 200m in order to completely include 90% of the landslides (Fig. 2). This diameter results in an overestimation of the landslide surface, but takes indirectly into account the landslide geometry and provide a slightly pessimistic risk estimation in terms of number of affected buildings. Thus a 100m...". 200 m is the distance traveled by the 90% of the landslides but this is a very maximum diameter, since shallow landslides are normally very elongated features (rather than circular). Why have you applied a 100 m buffer and not 120/90 m for instance? Will you please explain and justify it?

This circular shapes comes from the approach used to model the intersection probability. If the landslide is assumed to be circular, the intersection is a function only of the position of the landslide center. As a result, it is possible to assess, for each location in the cell, if a randomly localised landslide will reach a house. Therefore, the intersection probability can be simplified as the proportion of the cell covered by the houses and a buffer around them of the same size as the landslide diameter. If the landslide is not circular, this procedure can't be used since the intersection does not depend only on the position of the center, but also on the orientation of the shape. It is, as far as we know, not possible to simply estimate the intersection probability with complicated shapes and it would therefore be necessary to make a simulation where landslides are actually generated together with their shapes, which would drastically increase the processing time and change completely the approach.

Also I ask you to explain better figure 9 (I do not understand: "Thus, if the center of a *circular landslide (in brown), ...").*

The idea is that the buffer corresponds to all the points that are located at a distance d_1 from the house. In the same time, a circle represent all the points located a at distance d_2 from its center. As a result, if we assume circular landslides, then we have to set d_1 equal to d_2 to obtain a buffer around the house which represent the limit distance for the centers position of a circular landslide reaching a house. As a result, a landslide which center is located farther from this buffer will not reach the house, whereas a landslides which center is located closer will reach the house. The implication of this statement is that the probability that a landslide reaches a house depends only on the position of its center. As a result, the probability that the center of the landslide is located in a zone where it reaches a house is given by the proportion of the cell covered by this zone. Therefore, this probability is only one number, which would not be the case if the shape was different.

Page 13, line 12: ". . ...The lack of knowledge on the precise landslide characteristics and location as well as the inherent variability of the elements at risk complicates even more the assessment of the vulnerability (Galli and Guzzetti, 2007)." This is true and particularly in the case of deep seated landslides. Shallow landslides are simpler. Additionally, the vulnerability of buildings to shallow landslides is normally very low (They rarely affect building foundations).

We agree with your comment, especially as the deep-seated landslides usually provoke progressive damage. Nevertheless, we haven't found usable vulnerability data for shallow landslides, but we know that some houses have been severely affected, although the estimated mean value is effectively low. However, although this is not the purpose of this article, shallow landslides often kill.

NHESSD

1, C606–C615, 2013

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Interactive Discussion

Discussion Paper

Page 13, line 18 and following paragraph. Again, it is not clear to me the procedure you used.

This procedure aims at characterising the uncertainty in the estimation of damage amounts. From the 2005 event, we are able to estimate a mean value, but as we said above, there have been a lot of small damage amounts and a few high amounts. This procedure aims then at reproducing this variability with a plausible distribution.

Page 14, line 20: "The probability to observe a given number of landslides in a given lithological group is a monotonically increasing function of the precipitation amount." This is an interesting result. Nevertheless, I think (theoretically speaking) that the function shouldn't be so monotonically increasing. For example, I am thinking in low precipitations (a rainfall threshold depending on the lithology would determine a nick-point in the function).

There might be a knick-point somewhere, but the number of landslide in low precipitation areas is too small to be generalized. This observation is more based on the 4-5 classes with the higher precipitation amounts. Moreover, it is monotonically increasing in the sense that there is not a quantity above which the probability decreases. There is probably a quantity above which the probability does not increase anymore, but it does not decrease.

Page 17, line 2: "However, other variables such as terrain slope, soil thickness and permeability contrast,..." At least you should add "etc" since some important conditioning factors are missing in the text. For instance, vegetation could play a relevant role in shallow landslide generation. I think that vegetation is simpler to model at your working scale than lithology. Similar comment can be done for other important factors. Therefore I suggest reinforcing this part of your discussion. I think one of the limitations of your contribution is the working resolution. Working in higher resolution (e.g. 100 *m x 100 m) would probably reveal that rainfall is not so significant and other missing variables become critical.*

The "such as" is expected to show this incompleteness, but to insist on it, we'll add "etc.". Vegetation is indeed something we haven't considered and that we could try to use (at least the presence or absence of the forest since it is the only information that we can obtain at this scale). We could try other resolutions , but since 1 km x 1 km is the resolution of the radar data and since the landslide location is not exact, this would add an artificial precision. Furthermore, precipitations will be important no matter the scale, although a higher resolution would increase the importance of other factors.

Table 1. I am not familiar with this type of data. Will you please comment on it ?

The gamma distribution function is a function of x and two constants, α and β. α corresponds to the scale parameter, whereas β correspond with the shape of the curve (this parameter has then a strong influence on the tail of the distribution). An interpretation of these parameters is given in page 761, lines 9–14, but, as suggested by referee #1, we'll add a description of the gamma distribution we used.

Figure 5. It is not clear to me. "A lithology is assigned at each model iteration by choosing a random number u." This sentence is quite ambiguous to me.

This is related to the 6th answer. We'll try to improve this explanation on the sampling process.

Figures 7 and 8 don't provide any additional clarification to what is indicated in the text. Perhaps, you could improve the figure/caption/text to make the methodology more comprehensible.

It aims at outlining what's already described in the text. We believe that it is

helpful to understand the succession of the steps, but we'll think about it.

Please use cell instead of "celle" in those figures.
Thanks for pointing it out

Figure 11. Colors in the legend are not clear (lowest value in red; highest values also in red tones)
We tried to use a maximum number of colors of the RGB wheel to distinguish the colors, but we can add a bigger gap between the first and last value. The idea is also that the colors are progressive and, since the curves are well ordered, it is easier to understand than with random colors.

Technical corrections: In several parts of the manuscript appears 1 km2 x 1 km2. Please, use 1 km x 1 km resolution instead (or 1 km2 cell).
That is correct. We changed the notation during the typesetting process from "1 km^2" to "1 km^2 x 1 km^2" instead of "1 km x 1 km". This last notation will be kept.

References

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1, C606–C615, 2013

Interactive Comment

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