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Hydrology and Earth System Sciences Discussions

Interactive comment on "A conceptual model of the hydrological influence of fissures on landslide activity" *by* D. M. Krzeminska et al.

Anonymous Referee #1

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Please also note part 1 of this comment.

Specific comments

It is stated that the STARWARS model considers unsaturated transient flow in vertical direction due to gravitation (page 11047, line 18), assuming freely drainable water (page 11045, lines14-15). This implies that capillary forces are neglected in the calculation, and soil saturation cannot go below field capacity. If that is the case, the fact should be added to the description of the model, together with a short description which state variables and governing flow equations are used in the calculations, and how retention is handled (e.g., in Fig. 3(b) a "soil water retention curve" shape factor is displayed).

It appears that in the "connected fissures" scenario, the toe of the hillslope is always saturated (Fig. 5) due to groundwater accumulation from uphill. The fissures are also discussed to act as lateral drains, resulting not in an accumulation but merely faster flow of water. The latter I would also have expected for the "connected fissures" scenario if the fissures extend over the model boundary. What kind of boundary condition was specified for the sides and the hillslope toe?

Is it correct that the number and aperture of fissures are only used to determine the mean distance for calculation of the gradient? Would the aperture not also be useful for assessing the hydraulic conductivity of open fractures?

It is stated that the infiltration capacity of the fissures is potentially unlimited (page 11048, lines 1-2). Would not the storage capacity or the conductivity of the fissure filling mark an upper limit to infiltration?

What impact has the filling of the fissure? Apparently, there is a filling considered for all fissures; otherwise the hydraulic conductivity of fissures with apertures between 5 and 20 cm would be much higher.

What is $F_{fis,max}$ (page 11051, line 24)? Is the fissure fraction varying over the model run, or why is an initial fissure fraction to be chosen for the "dynamic" scenario (page 11052, line 2)?

How is the vertical connectivity between the different soil layers handled in the model? From Fig. 2 it appears as if there are fissures that extend from top to bottom, while others terminate in the first layer.

Page 11049, line 5-8: Eq. (4): As fissures and matrix may maintain different water levels, the calculation of resulting pore pressure for one cell needs more explanation. The calculation of the weight of fissure and matrix fraction should also be explained; were these based on moist, saturated and buoyant bulk densities as described in Van Beek [2002]? Perhaps the values used can be given as a table or mentioned in the

text.

Does the outflow include overland flow? It would be interesting to know if there was more overland flow in the scenarios without fissures compared to the scenarios with fissures.

Are the gaps in the water balance (calculated from Table 1 as: initial storage + rain – final storage – outflow - evaporation), which are also a little different between the scenarios, due to numerical accuracy or some modelled processes that are not included in the table?

The amount of evaporation (two-third of total rainfall) appears to be rather high for a mountainous area at a first glance. As vegetation is not mentioned in the manuscript, this would be soil evaporation only, or were there any open water surfaces in the model? Based on the described geometry of the hillslope, the rainfall would be between 990 and 1200 mm, the evaporation thus around 660 – 800 mm. It would be helpful to have rainfall input and evaporation in mm, and information about the climate that was considered.

Discussion

The major part of the "Results and Discussion" section is presenting results; the discussion part is rather narrow. It would be helpful for the reader if the authors could come up with a critical discussion that evaluates the results obtained in the light of the underlying assumptions of the model. Furthermore, they should compare their approach to the "simplistic" representation of fissure flow already implemented in STARWARS, and discuss in which aspects their treatment of fissure flow within a zone of higher conductivity is beneficial or more realistic. It would be excellent if they would also discuss their findings in comparison to the more general literature on preferential flow modelling in hillslope hydrology and modelling using dual-permeability approaches.

References

A comprehensive discussion on "double-porosity" vs. "dual-permeability" approaches is, of course, beyond the scope of the paper. But as it this issue is raised in the introduction (page 11041, lines 16-22), and it is not so clear from the literature, how the terms are exactly defined, appropriate citations should be inserted to clearly point out which definitions are referred to [e.g., Gerke, 2006; Jarvis, 2007; Simunek et al., 2003]. The theoretical considerations of Barenblatt et al. are not necessarily limited to flow in fissures, they also derive the equations for both fissures and porous blocks [Barenblatt et al., 1960]. I think the important point to make is that two overlapping continua are considered, which requires the formulation of an exchange term. As an additional suggestion, consider skipping the entire part from page 11041, line 9: "This creates ...", to line 22: "... both domains (matrix and fissures).", and move it into an introductory section on "Preferential flow modelling" (see comments on section 1.3 below).

Page 11049, line 9: The cited reference (EGU abstract) seems not appropriate as a general reference for the infinite slope model. Besides the original work [Skempton and DeLory, 1957], many better references from recent applications can be found in the published literature.

Structure

Section 1.3: Page 11044, line 1: It is not quite clear why the authors choose to phrase this section "Hydrological modelling of rainfall induced landslide" (which probably should be "landslides"). In the introduction (page 11040, line 25, and page 11041, lines 1-3) it is emphasized that rainfall is a poor predictor for slow-moving landslides, now the focus is on "rainfall-induced landslides", which is rather confusing. Additionally, most of this section (page 11044, lines 11-27) is on preferential flow modelling and would thus also fit into section 1.2. I thus would suggest dedicating section 1.2 to a general overview on preferential fissure flow and its relevance for landslides, and

section 1.3 to an overview on modelling issues.

Section 1.4, section 2, section 3.2: The description of the STARWARS model and its modifications should be collocated in subsequent paragraphs, and could be made a bit more concise. It appears that section 1.4 could be moved or split. The part describing the model generally and treatment of fissures specifically should be combined with the description of the model in a section 2 on "STARWARS". In my opinion it would be beneficial to rearrange section 2 such that first the general aspects of the model are described (page 11045, lines 2-22; page 11048, lines 25-29), followed by the parts pertaining to the treatment of fissures, including section 3.2, and the assessment of slope stability. The part of section 1.4 describing the application of the STARWARS model in landslide research would also fit well into section 1.3 if this remains as an overview on hydrological modelling in landslide research.

Page 11049, lines 3 – 14: Perhaps the statement that infinite slope assumptions were used is better placed at the beginning of the paragraph, before it is explained in more detail.

General Writing Style

It appears as if quite a few typos, missing words and awkward sentence structures have escaped the proofreading by the author and coauthors of the manuscript. For example, page 11045, lines 2-3 should read (capitalization intended to emphasize letters added): "In 1999, Van Beek and Van Asch proposed A conceptual hillslope model that accountS for fissure-induced infiltration." The next sentence (lines 3-5) maybe should read: "This is A spatially distributed physically based model coupling hydrological and stability dynamics in the PCRaster environmental modelling software package.", but could perhaps even read better if divided in a main clause and two subordinate clauses. The heading of section 1.2 should read perhaps: "Preferential fissure flow in landslideS". Many more examples can be found throughout the text. As these small mistakes sum up, they deteriorate the overall impression of the paper. This kind of proofreading can-

not be the task of the referees (and I am also not a native English speaker); therefore, I strongly recommend taking advantage of a professional proofreading-service before handing in a revised version of the manuscript.

Technical questions

Equation 1: For parallel fissures, the number per cell would calculate as

$N_{fis} = F_{fis} * dx * dy/(a_{fis} * l_{fis})$, where l_{fis} is the length of the fissure

For square elements where fissures extend over whole length ($dx = dy = l_{fis}$) this would simplify to

$N_{fis} = F_{fis} * dx/a_{fis}$

So, where does the square root comes from in equations 1-2?

Equation 3: The notation $\overline{\frac{1}{2}L_{mat}}$ is misleading. It would be better to denote the mean distance from fissure centre to the centre of each matrix block by a symbol of its own. And would that not simply correspond to $\frac{1}{2}(L_{mat} + a_{fis})$?

Page 11041, line 8 "constant movement": as the movement rate of a slow-moving landslide does not necessarily have to be constant, perhaps "continuous" would fit better

Page 11042, line 5-6 "minimum": wording is misleading, 3 m diameter surely is not a minimum

Page 11042, line 6 "laminar water flow": Water flow in open structures with 3 m diameter is surely not necessarily laminar

Page 11048, line 25 "model run": probably should be "model time step"?

Page 11052, lines 6 – 9: The "sensitivity analysis" is not mentioned here?

Page 11059, lines 6-7: http://mountain-risks.eu/ is not working (26. January 2012)

Fig 3: Please label the contour lines; the coding by line width is not really clear. Please add the observation points from Fig. 8; maybe you could also add a profile of the hillslope showing these points along with surface and bedrock topography.

Fig. 4: Figure quality needs to be improved, and the horizontal bar between the panels should be deleted.

Fig. 5: Please indicate the direction of the slope.

Fig. 6: The table should be included as table, not as part of a figure. The figure quality needs to be improved.

Fig. 7(b) – caption: How does connectivity relate to storage capacity?

Fig. 8: Figure quality needs to be improved. The timescale on top is probably not labelled correctly (1/01, 2/01, 3/01, 1/04, 1/05,...).

Fig. 9: What is shown in this figure? The title of the legend is missing, and the figure caption should be revised to describe comprehensively the content of the figure.

Fig. 10: Figure quality needs to be improved; the figure also needs to be enlarged. The third row/top of panel (c) is not absolutely necessary – it is not really instructive as the fissure connectivity of C_{fis} = 50 % is not shown in other figures, and the effect of varying K_s is better demonstrated with the results for C_{fis} = 90%.

References cited in parts 1 and 2 of this comment

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Skempton, A. W., and F. A. DeLory (1957), Stability of natural slopes in London clay, paper presented at 4th International Conference on Soil Mechanics and Foundation Engineering, Butterworths Scientific Publ., London, London, UK, 12-24 Aug. 1957.

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