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Hydrology and Earth System Sciences Discussions

Interactive comment on "Sensitivity of point scale runoff predictions to rainfall resolution" *by* A. J. Hearman and C. Hinz

A. J. Hearman and C. Hinz

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General

All three reviewers felt that the results of the paper were potentially useful and addressed relevant scientific questions within the scope of the journal.

Major issues raised by the reviewers were that the limitations of the one dimensional model were not addressed in detail, in particular with respect to saturation excess as this process involves two and three dimensional processes at the hillslope scale and macropore flow (Reviewer 1). It was further pointed out that the paper lacked detail on advantages of the model and applicability of the results (Reviewer 2). The authors agree with these comments and have subsequently highlighted the limitations of this approach throughout the paper but still believe that the inclusion of the storage element (given by the saturation excess mechanism) in the model is important in investigating the effects of rainfall resolution on processes which are buffered by soil storage and drainage and dependent on the differences in soil infiltration created from the interaction of the different rainfall resolutions and the infiltration capacity threshold. A number of new references were added to the paper and discussed in detail to further justify and to illustrate the usefulness of the simple approach used in this paper (see below). Furthermore, the authors have addressed the issue of applicability by including another section to the paper specific to the application of the approach to different rainfall regions within Western Australia. The authors feel that this extra section adds another dimension to the paper, making it more applicable and usable.

Reviewer 3 rightly pointed out that there were errors in the equations and that it was important to verify that these errors were not embedded into the code. These errors were not embedded into the code, the results and the conclusions of the paper do not change and the equations have been subsequently modified to reflect exactly what was modeled. Reviewer 1 highlighted that where the authors' spoke of "runoff generation" they really referred to "surface runoff generation." This was subsequently changed throughout the manuscript including the title.

Overall the authors agree with the reviewers' comments and have found them to be very constructive. We have attempted to change the manuscript where suggested as will be outlined below. The following response to reviewers' comments goes through each reviewers' response one by one detailing the changes. A new manuscript will be submitted and for this reason where the reviewers have referred to page and line numbers we note that appropriate changes have been made but have not given a new page and line number as we anticipate this will change once the manuscript has been formatted.

Reviewer 1

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Interactive Comment

General Comments:

The reviewer points out that where we speak of runoff we really should be using surface runoff. The authors agree and have subsequently changed this throughout the paper and included it in the title.

The reviewer asks the authors to acknowledge and briefly discuss the possibly effects of macropores. The authors acknowledge this in the last paragraph of section 3.2: “Although this analysis looks at different soil textures and does not specifically address different soil structures and macropores, if the infiltration capacity of different soil structures or macropores can be predicted then they can be incorporated into the sensitivity curve by adjusting the infiltration capacity”. The reader is then referred to the previous work done on this by Struthers et al., (in press b) who "showed that with a similar focus on soil and storm properties the fraction of storms that trigger macropore flow could be estimated from average storm and soil properties and did not require simulations.”

The reviewer points out the limitations of applications of the saturation excess predictions as the paper only models 1D vertical processes and saturation excess is influenced by two and three dimensional processes such as subsurface flow and groundwater interactions. The authors agree and have subsequently highlighted the limitations of the saturation excess predictions in the introduction, methods and results and discussion. For example: “Although these point scale saturation excess predictions have limited application as the model does not account for two and three dimensional aspects, the authors believe the inclusion of this storage element in the model is important in investigating the effects of rainfall resolution on processes which are buffered by soil storage and drainage and dependent on the differences in soil infiltration created from the interaction of the different rainfall resolutions and the infiltration capacity threshold” (the last sentence in the 7th paragraph of the introduction).

The reviewer cautions the authors on their interpretation of the saturation excess results and points out that if 100 mm of sand was investigated then the lower boundary must be controlling the system. In response to this the authors have highlighted the assumption that the lower boundary is assumed to be highly permeable and also point out that this was the purpose of adding the layered soil into our investigation. The layered soil investigates a soil with a high infiltration capacity but much slower draining coefficient to represent a less permeable lower boundary.

The reviewer feels that the presentation of the results is a bit lengthy, especially sections 3.2.2 and 3.3.1. The authors have attempted to shorten these sections. Section 3.2.2 has been removed and joined with section 3.3.2 to make section 3.5 on dynamics of both infiltration excess and saturation excess. The explanation of the dynamics of both sections has been reduced and the reader is referred to the figure (now combined) for qualitative results. An attempt to reduce section 3.3.1 (now 3.3) has been made, a figure has been removed and the explanation of scaling results reduced.

The authors would like to acknowledge that whilst this reviewer suggested shortening these sections and cautioned on wider implications of the saturation excess results, reviewer 2 asked for further elaboration on the wider implications of the results. For this reason the authors have added implications to these sections but are cautious not to be too speculative considering the limitations of the 1D vertical assumptions of the saturation excess results.

The reviewer suggests adding some return periods for the storm depth and intensities used. In the methods section the authors now acknowledge that in regards to range of rainfall intensities modeled that these: "were chosen to allow for a wide range of scaled parameters (to be described later in section 2.4) rather than to reflect the predominant rainfall intensities in Australia". The authors have also added another section to the paper which investigates the effect of within storm patterns of rainfall generated from different regions on the scaled sensitivity analysis of rainfall resolution to point scale infiltration excess predictions and also the likelihood of the occurrence of events where using temporally averaged rainfall data will influence point scale infiltration excess predictions. The authors feel that the addition of this section adds another dimension to

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the paper and illustrates how this sensitivity analysis can be used to investigate how rainfall from different locations impacts the likelihood of these events occurring. Whilst the authors have not added the return periods as the reviewer has suggested we feel the addition of this section addresses the issue of the likelihood of these events occurring and illustrates how the method can be applied to different locations and different soils.

Specific remarks:

p. 3520 l28 - sentence has been removed.

Point scale was already in the title.

Elaboration of deriving the drainage coefficient from the soil data - the reader has been referred to the work of Struthers et al. (2006) who "showed that the drainage parameters of a lumped parameter bucket model are related to the drainage recession response based on the unsaturated hydraulic conductivity function of Brooks and Corey (1964)."

Wolfram Research Inc., 2005 has now been added to the reference list.

The likelihood of event occurring has been added in a new section.

p. 3527 l19/20 sentence has been changed.

An attempt has been made to shorten pages 3528-3534 as outlined above.

The journal volume has been included.

We have included reference to the earlier works of Woolhiser and Goodrich (1988) in the second paragraph of the introduction.

Reviewer 2

General Comments:

The reviewer's general comments suggest that some of the limitations of the modelling

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approach, together with applications of the findings, could be clarified for the reader in the text. The authors believe we have improved these aspects of the paper with the limitations of the modelling approach, especially in regards to saturation excess predictions being highlighted in several sections of the paper (introduction, methods and discussion) and a more detailed, yet cautious applications of the findings in regards to implications to current modelling approaches and possible over predictions and under predictions throughout the results and discussion, as well as the inclusion of a whole new section dedicated to the application to different rainfall types.

Specific comments:

The reviewer comments that the authors concentrate on the rainfall aspects of the research with little explanation of the soil conditions. The authors have changed the introduction. There is only one paragraph solely dedicated to rainfall modelling. There are two paragraphs dedicated to the conceptual rainfall partitioning model and the other paragraphs refer to both rainfall and soil properties. The authors believe this is an appropriate balance of rainfall and soil properties and would also like to note that the emphasis as per the title is on the rainfall resolution.

The reviewer suggests that the authors could highlight in the methods section to what extent there are limitations to the soils dataset. The authors have referred the readers to the work of Struthers et al. (2006) who "showed that the drainage parameters of a lumped parameter bucket model are related to the drainage recession response based on the unsaturated hydraulic conductivity function of Brooks and Corey (1964)." and in the introduction have notes that the bucket model allows us to scale the few soil parameters with storm properties.

The reviewer asks the authors to comment on the effects of macropores. Reference to macropores has been added in the last paragraph of section 3.2 the reader is also referred to the works of Struthers et al. (in press b) in relating soil-storm properties to the hydrological impact of macropore flow.

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The reviewer asks the authors to refer to alternative approaches to the model they have used. This has been done in the introduction. The authors refer to the work of Yu et al. (1997) and Yu (1999) that compares a simple infiltration capacity to the commonly used Green and Ampt approach. In regards to the saturation excess predictions we refer to the more complicated Richards equation and note the advantage of using a simple bucket model in terms of fewer parameters that are able to be scaled with storm properties. The limitations of the saturation excess predictions are highlighted in regards to neglecting two and three dimensional processes but the use of this model justified in terms of investigating the impacts of rainfall resolution on processes which are buffered by soil storage and drainage and dependent on the differences in soil infiltration created from the interaction of the different rainfall resolutions and the infiltration capacity threshold.

In response to the reviewers comments the authors have included a statement on the advantage of using a dimensionless (scaled) analysis in the introduction and the beginning of section 2.4.

The reviewer suggests that each section be concluded with a brief outline of why the findings are important for other hydrological research. The authors have attempted to do this but are also aware of reviewer 1's comments to reduce these sections and the limitations of the applications when two and three dimensions are included. As well as including another whole section on the application of the results to other rainfall types (section 3.6) the authors have included comments such as: "These results also highlight the differences in water able to enter the soil depending on the rainfall resolution. Our results show that for high average intensity storms using low resolution rainfall over predicts the amount of water entering the soil and may result in an over prediction of processes affected by soil water storage such as drainage and subsurface flow predictions, the leaching of agri-chemicals and our understanding of the ecology of plant species and their adaptation to certain soil-water conditions" (section 3.3).

"It also demonstrates that at lower average intensity storms the rate at which water en-

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ters the soil may be under predicted with the use of low resolution rainfall and therefore result in an under prediction of drainage and the potential for the leaching of agri-chemicals"(section 3.3).

"These differences in point scale dynamics may influence the dynamics of runoff further down the hillslope. Puigdefabregas (1999) explains that pauses in rainfall allow over-land flows to infiltrate and thus constrains overland flow lengths. In contrast, long last-ing saturation excess overland flow covers greater distances (Puigdefabregas, 1999). This illustrates the need to accurately represent the processes at the point scale so that discrepancies from rainfall resolution at the point scale are not further compounded when slope dynamics are also taken into consideration" (section 3.5).

The reviewer found some of the results to be quite wordy. As per the first reviewers comments we have attempted to shorten the results with shorter explanations of each figure.

The reviewer found the explanation of Fig. 6 to be particularly confusing. This figure has been edited and combined with Fig. 9 (as a response to a later comment of this reviewer). The labels should now match the text and the explanations of this figure in the text have been reviewed and reduced.

The ln k* values should have read greater than 1.5 rather than 2.5. This has been changed.

The reviewer suggests P3536 line 5 was difficult to follow. This paragraph has been changed and shortened.

As per the reviewers suggestion the authors now state up front in section 3.3 that "Unless stipulated, the following results show simulations where the initial soil water content was at field capacity". Comments on the initial soil moisture come later in this section.

As per the reviewers comments the conclusion has been changed so that the summary

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of the conditions affected by rainfall resolution has been shortened and the application of the results and implications expanded. There is now a section in the paper on the application to other rainfall regions and the application to other soil structures such as macropores addressed earlier on in the paper. Note that in the earlier manuscript the authors alluded to implications for erosion and hillslope stability. In this manuscript the authors are careful not to be too speculative considering the limitations of the point scale model to larger scale processes.

Minor Errors

"inturn" has been split into two words. "soil, storm relationships has been changed to soil-storm relationships. Equation 2 has been changed so that psoil(t) has been replaced with prain(t). The italics in equation 3 have been changed. The 'if' statement has been added to equation four. Page 3523 line 4. This sentence has been moved to after the cascade approach has been introduced. Figure 1 has been altered so that the fluxes are written in capitals and the thresholds in lower case. Lateral fluxes have been given a horizontal arrow. Figure 9 has been combined with Figure 6 as per recommendation and as a consequence the figure caption changed. Figure numbers have changed.

Reviewer 3

General comments:

The third reviewer has found errors in the model equations and suggests that they be corrected and checked to see if they change the results. The authors agree with the reviewer that these equations were incorrect and would like to note that they were not the equations that were modeled. The equations have been changed and now describe exactly what was modeled.

Specific Comments: Equations three and four have been changed. The units now match and the equations now reflect what has been modeled.

The use of the drainage coefficient is explained and the reader is referred to the work of Struthers et al. (in press a) who also used this approach and Struthers et al. (2006) who "showed that the drainage parameters of a lumped parameter bucket model are related to the drainage recession response based on the unsaturated hydraulic conductivity function of Brooks and Corey (1964)."

Page 3523 lines 27-28 this statement on the cascading rainfall has now been placed after the bounded random cascade model has been explained.

The breakdown coefficients, u, have now been defined properly.

The explanation for the bounded random cascade model has been modified so that the beta distribution is defined along with the beta function (see section 2.2).

Figure 2 has been removed and the authors believe all the parameters have been defined. The authors do not want to regurgitate someone else's method and refer the reader to the original source (Menabde and Sivapalan, 2000).

Page 3525 lines 13-14. The reviewer comments that these seem to be in mm/h not mm as stated. The authors have changed this statement to the following (they were referring to amounts but have attempted to make it clearer that these amounts were calculated at the end of each simulation). "At the end of each simulation the total amount of infiltration excess, saturation excess, deep drainage and runoff were calculated (mm). The first, second and third moments of the distributions of these amounts as well as the time each process was active throughout the storm event (min), frequency it was initiated and the maximum intensities (mm min-1)".

Minor Errors

Page 3530, line 3: This sentence has been changed to: "To quantify this we can look at plots of the way the mean maximum intensities, the frequencies each process was triggered and the time each process was active throughout a storm event changed with our scaling parameters, k* and g* (Fig. 9)".

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Page 3531, line: 8 sentence was changed.

Page 3538, line 8: sentence was changed.

The caption of figure 9 has been changed.

theta_satr was a typo. The r has been removed.

References

Brooks, R. H. and A. T. Corey., 1964, Hydraulic properties of porous media. Hydrology Paper 3, Colorado State University, Fort Collins, CO, 27ň110.

Menabde M. and Sivapalan M., 2000, Modeling of rainfall time series and extremes using bounded random cascades and Levy-stable distributions, Water Resources Research, 36(11): 3293-3300.

Struthers, I., Sivapalan, M., Hinz, C., 2006, A multiple wetting front gravitational infiltration and redistribution model for water balance applications, Water Resources Research, 42: doi:10.1029/2005WR004645

Struthers, I., Sivapalan, M., Hinz, C., in press a, Conceptual examination of climate-soil controls upon rainfall partitioning in an open-fractured soil I: Single storm response. Advances in Water Resources [online]: doi:10.1016/j.advwatres.2006.04.006

Struthers, I., Hinz, C. Sivapalan, M., in press b, Conceptual examination of climate-soil controls upon rainfall partitioning in an open-fractured soil II: Response to a population of storms. Advances in Water Resources [online]: doi:10.1016/j.advwatres.2006.04.005

Woolhiser D.A. and Goodrich D.C., 1988, Effect of storm rainfall intensity patterns on surface runoff, Journal of Hydrology, 102: 335-354.

Yu B., 1999, A comparison of the Green-Ampt and a spatially variable infiltration model for natural storm events, Transactions of the ASAE, 42(2):89-97.

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Yu B., Rose C.W., Coughlan K.J. and Fentie B., 1997, Plot-scale rainfall-runoff characteristics and modelling at six sites in Australia and southeast Asia, Transactions of the ASAE, 40(5): 1295-1303.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 3, 3517, 2006.

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