Hydrol. Earth Syst. Sci. Discuss., 6, C799–C804, 2009
www.hydrol-earth-syst-sci-discuss.net/6/C799/2009/

Hydrology and Earth System Sciences Discussions

Interactive comment on "A modeling study of heterogeneity and surface water-groundwater interactions in the Thomas Brook catchment, Annapolis Valley (Nova Scotia, Canada)" *by* M. J. Gauthier et al.

Anonymous Referee #1

Received and published: 20 May 2009

Introduction

This paper focuses on the relationships between the quality of soil heterogeneity description (geometry and properties) and the soundness of the predicted surface water and groundwater flows at the catchment scale through modeling. Nine scenarios of increasing complexity were run using a distributed, physically based hydrological model, CATHY, integrating land surface and subsurface flow processes. Originality of the work lies in the fact that models coupling surface water flow (Saint Venant equations) and groundwater flow (Richards equation) have merely been applied to real catchments

because they came up against grave difficulties including convergence issues, and requirements of large computing power and time. One of the issues needed to be tackled is also the requirement in high quality description of soil properties, that is precisely the main topic of the paper.

General comments:

1) This paper was found to tackle original and important issues and to be well written. It is certainly of interest to the readers of the journal but would benefit of some revisions.

2) The structure of the article is acceptable, nevertheless, an overhaul of the structure of the article to emphasize the genericity of your study/results would be recommended:

- The article lacks of an explicit "material and method" section, with sound descriptions of the model, the modeling strategy and the catchment, the later being treated as a "study case". By beginning the introduction with the description of "The Thomas Brook catchment" the authors induce the reader to treat the paper as a"site specific" study. In the introduction the study should be replaced in a more general context, and include a review of other works dealing with the effect on soil heterogeneity modeling on water flow at various scale or the way soil heterogeneity is mainly treated in water flow catchment scale modelling studies.

- The "Results and discussion" section should be reorganized in order to better illustrate the effect of soil heterogeneity modeling.

3) It is unclear in what matter the scenario including snow cover modeling (scenario 9) represents an add value to the issue of heterogeneity modelling and so, unless the authors could discuss it, it should be deleted. Nevertheless, if snow accumulation and melting modeling is a critical issue in yearly water flow modeling, all the scenarios should include these processes. Finally, the conclusion of the study would be clearer and stronger if the authors focus their attention on the effect of soil heterogeneity on water flow modeling.

4) Scenarios 4 to 6 are not enough discussed. Some variables seem to be better simulated for high level of soil heterogeneity scenarios but the improvement is less clear for other variables. Could the authors discuss this point?

5) Recommendation on the “minimal description” of soil heterogeneity sufficient to assess water flow at the catchment scale would be of great significance and this point should be discussed in the conclusion.

Specific comments:

- part 2 and part 3 should be put together : the “description of the study area” includes the geological context.

- p 2755, lines 13-16 : It could be informative to indicate the number of year of surface flow data monitoring.

- p 2755, lines 26-27. For how many year is this average? Could the authors indicate whether the year 2005 is representative of the mean climatic and/or hydrological behavior of the study zone?

- p 2758 Please indicate the resolution method of the Richards equation : finite difference? Finite element ?

- p 2759: lines 1-3 : Could the authors justify your choice?

- p 2759 lines 5-9: figure 5 should be introduce and comment in part 3 (geological context)

- p 2759 lines 18 – 28. I believe the authors chose a flat base for the bottom of the flow domain to limit mesh complexity. How was assigned the thickness of 50m at the outlet of the catchment? Could the authors discuss these choices and indicate the possible consequences? Wasn’t it possible to decrease the total thickness and decrease the mean thickness of the vertical layers? The bottom layer is the only one to have a non-unique thickness. Therefore the maximal thickness of this layer may reach 200m. Is

this thickness not too high to support the assumptions of classical Richards equation resolution scheme? In particular it seems from fig 15 that this layer is not completely saturated near the North Mountain cuesta (between latitude 4.9955 and 4.995 106 m). More generally, the quality of the mesh should be evaluated with for example an aspect ratio (delta(x)/delta(z), Calver and Wood (1989), Paniconi and Wood (1993)).

- p 2760, lines 11-13: It means that surface catchment and ground catchment have the same limit and the same outlet. Is this hypothesis supported by experimental data or observations?

- p 2760, lines 13-22 : To my opinion, Fig 6 and its comments should be include in the description of the study site, as an illustration of the hydrological behavior of the catchment.

- p 2760, line 24 to p 2761 line 29: These are mostly general information concerning the model CATHY and not specific information relative to your study. Those general informations should be included in a 4.1- model description and only specific information (flow domain geometry and discretization, boundary and conditions, material properties...) should be kept in a 4.2- model implementation.

- p 2762, lines 2-6: Is it “response parameters” or “response variables”. To my mind, soil properties such as porosity or conductivity are parameters whereas discharge , saturation dynamics, ... are variables since they are calculated from state variables such as pressure head or soil moisture content.

- p 2762, lines 13-17 and Figure 7: It is not necessary to include conductivity and porosity value in the text. It would be clearer to report those values in a table than to indicate it on figure 7. In Figure 7, soil number should be reported and the boundaries between soils better marked (by black line?).

- p 2764 §1 and 2: These 2 paragraphs (and part of the following paragraph p2764-2765) mainly present the method of model initialization and calibration and should

therefore be included in the 4th part of the article (4.3. Model calibration).

-part result and discussion : The last paragraphs of 5.1 and section 5.2 should be rearrange in order to better illustrate the effect of heterogeneity on surface and groundwater flow (the title “effects of heterogeneity and other factors” is not appropriate). The authors should better described the results of all the scenarios. In particular, scenarios 4 – 5 -6 simulate better the mean outlet streamflow than scenario 8. It could be interesting to plot in a graph the stream-flow simulated by all the scenarios.

The section “Catchment behavior for different response variables” is interesting but does not lead to new informations/ideas about the effect of heterogeneity on flow modeling. This section should be removed OR you should compare the difference in “saturation zone” location for the 8 scenarios.

- p 2765 lines 14-16 / 23-25 : How many wells measurements were used? In particular were all the data for well 1 and well 2 used ? If not, why?

- p 2766 lines 6-8: How fluctuate the groundwater level for scenarios 1 to 7? It would be interesting to examine “groundwater variables” especially for scenarios 4 to 6 for which the mean outlet streamflow was well reproduce.

- p 2766 lines 22 – 26: the sentence is difficult to understand and need to be clarified.

- p 2767 lines 25-27: Did the authors include recharge value for January in the annual value reported in table 3. If simulated value January recharge are too high because of initial conditions, January should be included in the “initialization period” and the comparison between simulated and observed data should be made from February to December.

- p 2768 lines 1 – 10: This part of your paper should be enhance (since it was mentioned in the introduction results in terms of numerical performance.)

- Table 3 : correct the number of “*” for the first note and in the formula.

- figures 2 to 4: roads should be removed. Figure 2 is not clear: what was drawn : altitudes of soil surface as indicated in the text or potentiometric map as indicated in fig 2 caption?

- figure 9 : it would be informative to plot daily net atmospheric forcing and/or outlet streamflow above this graph.

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