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Hydrology and Earth System Sciences Discussions

Interactive comment on "Effect of DEM resolution on SWAT outputs of runoff, sediment and nutrients" *by* S. Lin et al.

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Dear Reviewer #2,

We are very grateful to have your comments/critics/suggestions on our work. All your inputs are very helpful for improving our paper. With the consideration of your advices, some revisions, including a review on resolution sensitivity of various topographic terrain parameters, more details of description of SWAT, and more discussion of the results, will be provided in the revised version. Following are our responses to your comments/critics/suggestions.

Sincerely,

The authors

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1) Inclusion of more relevant literature:

To me it seems that the authors don't rely much on literature in the field of digital terrain modeling and resolution sensitivity of various topographic terrain parameters. Maybe the authors focused their literature search and review too much on authors who specifically investigated SWAT rather than terrain parameters such as gradient in general. I definitely second point 10) raised by anonymous reviewer #1 regarding the literature.

RE:«««««««

The relevant literatures will be reviewed in the revised version.

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2) More detailed and concise description of SWAT:

Not knowing SWAT I found the description of the model structure and the inner workings should be more detailed. As of now, I also have the impression that the model's workings are touched upon from time to time in the text, so that it is difficult for the reader to assemble all these bits of information into a coherent understanding of the model. Ideally, the authors would strike a balance between giving enough information as to understand the model's workings and not giving too much detail which would not add to the reader's understanding. Having enough information on the model's functioning would ideally enable the readers (and the authors!) to understand how the different DEM resolutions affect the model's results. As of now this remains a black box. In this respect I seem to be supporting the discussion points 3) and 4) by anonymous reviewer #1.

RE:«««««««

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We agree that more details about the model description can help reader understand the results. Actually, that information was in the early version of this manuscript, but it was dropped out in our final version for submission with the consideration of the length limit of each paper. In the revised version, we will add some formulas directly related to the terrain topographic parameters, which are sensitive to the resolution.

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3) More in-depth analysis and discussion of the results:

I take from the text that SWAT is a semi-distributed model. However, the investigation of resolution-induced differences remains wholly a-spatial. I think that (if possible) mapping some of the probably a-spatially derived model properties back into space and looking at *spatial* distributions of parameters and model factors could be insightful. As the text stands now, I feel like only half of the story may be told; we get to know about statistical distributions of model results, but we don't know about their spatial distributions. Seeing the latter may, however, help in explaining the former.

RE:«««««««

Results illustrating the predictions in HUR and subbasin levels will be provided in the revised version to investigate WHY the DEM influenced the results.

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– In the following I will address certain points a bit more specifically.

– Starting from line 6, p. 4423 there is a citation error. Quote:

"Previous studies showed inconsistent results about the effects of original resolutions on SWAT predicted runoffs. Some found that runoff decreased with coarser original DEM resolutions (Wolock and Price, 1994; Cho and Lee, 2001; Di Luzio et al., 2005), some did not (Bosch et al., 2004; Dixon and Earls, 2009)."

In my impression, this paragraph implies that Wolock and Price researched resolution

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effects on SWAT model performance. However, this is demonstrably not true! The work by Wolock and Price was about TOPMODEL (http://dx.doi.org/10.1029/94WR01971), not about SWAT. (Of course some of the input parameters of these two models are identical)

RE:«««««««

This citation error has been corrected and the other references have been checked again.

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– Regarding literature I encourage the authors to look at for example the following:

Kienzle S. W.: The effect of DEM raster resolution on first order, second order and compound terrain derivatives. Transactions in GIS 8 (2004) 83-111

Zhang W., Montgomery D. R.: Digital elevation model grid size, landscape representation, and hydrologic simulations. Water Resources Research 30 (1994) 1019-1028

Bruneau P., Gascuel-Odoux C., Robin P., Merot Ph., Beven K. J.: Sensitivity to space and time resolution of a hydrological model using digital elevation data. Hydrological Processes 9 (1995) 69-81

Brasington J., Richards K.: Interactions between model predictions, parameters and DTM scales for TOPMODEL. Computers & Geosciences 24 (1998) 299-314

Vieux, B.E.: DEM aggregation and smoothing effects on surface runoff modeling. Journal of Computing in Civil Engineering 7 (1993) 310-338

Gao, J.: Resolution and accuracy of terrain representation by grid DEMs at a micro-scale. International Journal of Geographical Information Science 11 (1997) 199-212

Thompson J. A., Bell J. C., Butler C. A.: Digital elevation model resolution: effects on terrain attribute calculation and quantitative soil-landscape modeling. Geoderma 100

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(2001) 67–89

Wilson J. P., Repetto P. L., Snyder R. D.: Effect of data source, grid resolution and flow routing method on computed topographic attributes. In: Wilson J. P., Gallant J. C. (eds.): Terrain Analysis. Principles and Applications. John Wiley & Sons, New York (2000) 133–161

RE:«««««««

Indeed, there have been studies on effect of data source, grid resolution on terrain attribute calculation and environmental models, especially TOPMODEL (Kienzle, et al., 2004, Zhang, et al., 1994; Brasington, et al., 1998). The accuracy of different resolution of DEMs produced from contour lines was studies too (Gao, et al., 1997). We shall review these literatures in the revised version of this paper. Thank you very much for providing the literature list in details.

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– Regarding your interpolation scheme: Can you reason a bit more as to why exactly you chose this methodology? Why do you use a TIN-based interpolation for the contour line data? Does this have negative effects on the quality of the DEM? Did you try contour-specific interpolators such as ANUDEM?

RE:«««««««

With the innovation of drainage enforcement algorithm and aiding data such as lake polygons, cliff lines, and streamlines, ANUDEM has been proved to be an efficient tool for DEM generation from contour lines (http://fennerschool.anu.edu.au/publications/software/anudem.php, accessed on 7th August, 2010). Comparing the method of ANUDEM and TIN, we are aware that the ANUDEM method presents the relief with smoother and more continuous slopes and the TIN algorithm has a great difficulty dealing with the steep gullies and ridges (Yang et al., 2005). Though the TIN method is not the best for generating DEM, we still

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applied it in this study for the following reasons: a) The TIN method is widely used; b) The major objective of this study is the assessment of resolution sensitivity on SWAT rather than the accuracy of the DEM interpolation, although the accuracy of DEMs from different sources were discussed.

Reference:

Yang, Q.K., Van Niel, T.G., McVicar, T.R., Hutchinson, M.F. and Li, L.T. (2005) Developing a digital elevation model using ANUDEM for the Coarse Sandy Hilly Catchments of the Loess Plateau, China. CSIRO Land and Water Technical Report 7/05, Canberra, Australia, 74 pp.

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Is it sensible (or under what conditions is it sensible) to interpolate SRTM data at 3 arc seconds onto a 5m grid? What effects are to be expected?

RE:«««««««

It is not common to interpolate a 3 arc-second SRTM DEM onto a 5 m grid DEM. But it is possible in the small watershed study when the high resolution (e.g. 5 m) land use/cover or soil data are available while the SRTM is the only choice of DEM. By comparing the SWAT performances with the 5 m grid DLG DEM as input data and resampled 5 m grid DEM (from ASTER or SRTM), we expected to evaluate the SWAT sensitivity to different data sources at the same grid size.

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– What is the information content of your input DEMs? On that note I encourage you to have a look at the distinction between nominal and real resolution in Straumann and Purves (2007). Straumann R.K. and Purves R.S. (2007): Resolution sensitivity of a compound terrain derivative as computed from LiDAR-based elevation data. In: Fabrikant S.I., Wachowicz M. (eds.) Lecture Notes in Geoinformation and Cartography. Proceedings of AGILE 2007, 8.–11 May 2007, Aalborg, Denmark, 87-109.

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In conjunction with this I think there is already a growing body of literature which examined the quality and information content of ASTER GDEM in more depth than the manufacturer's specifications (e.g. "Is the resolution of ASTER GDEM really three times higher than that of SRTM90?"). It would be nice if you could incorporate some of that research into the paragraphs on page 4417.

The notion of nominal versus real resolution might be helpful in explaining or underpinning some of the findings of your study as well as some partly contradictive results you included from the literature towards the end of your article. Some examples where thinking about said notion may be helpful are: first paragraph on page 4422, line 6 and following on page 4423, second paragraph on page 4426.

RE:«««««««

It is important to identify the 'nominal' and 'real' resolutions of DEMs (Straumann and Purves, 2007)). Studies (e.g. Reuter et al, 2009) also have shown that the real resolution of ASTER GDEM is not really three times higher than that of SRTM. The main objective of this study was to find out a suitable data source and suitable resolution for SWAT model. Therefore, we directly measured the resolution impact on SWAT input parameters derived from DEM and predicted outputs, without consideration of DEM content. Your advice is very helpful for this study. We will evaluate the DEM content by indicators such as entropy (Shannon and Weaver, 1964) to get an assessment of the real resolution of DEM.

On the other hand, it is interesting to note from our results that there could be no 'real' resolution in specific circumstance. For example, the SWAT predicted runoff is not sensitive (RD <= 1.0%) to the DEM resampling resolution (from 5 m to 140 m) and to the data source (DLG5m, ASTER30m, and SRTM90m) either. Therefore, with a 1.0% RD margin, any resolution of any data source is efficient for the runoff prediction. In other words, with the respect of SWAT predicted runoff, any resolution could be the 'real' resolution.

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Reference:

Reuter et al, 2009, A FIRST ASSESSMENT OF ASTER GDEM TILES FOR ABSOLUTE ACCURACY, RELATIVE ACCURACY AND TERRAIN PARAMETERS, IEEE IGARSS 2009, Cape Town.

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– I definitely second comment 6) by Reviewer #1 ("differences" vs. "errors" as well as absolute values).

RE:«««««««

See the reply to Reviewer #1

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Regarding table 1 I suggest dropping the third to last column since it offers no information value at all. Think about including absolute values in this table and also about changing the order of columns (first REoriginal and then REmax-min, since the latter can be seen as a crude distributional parameter).

RE:«««««««

We will revise accordingly.

RE(max-min) indicates how significantly the variables varied with resolution, while RE(origina) indicated the performance of DEMs of different source of data at their own original resolutionsâĂŤthat is to say, the former provides the information of resample resolution effects, while the latter provides the comparison of data source effects. Both of them are discussed in the text.

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– Please work carefully through your manuscript to prune some more typos and poor English (some examples: "shaped terrains" line 2, p. 4418 / "did not sensitive to" line

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28, p. 4421 / "runoff would not affected" line 12, p. 4422 / "from SRTM90m, flowed by" line 18, p. 4422 / "Result justifications" chapter heading 4.1 / "how differently input data" line 26, p. 4425 / "forest, which domains the land use" line 27, p. 4426).

RE:«««««««

We will do our most to improve our English.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 4411, 2010.