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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 #1,

We greatly appreciate your time and thoughtful comments/critics/suggestions on our manuscript. In our revised version, we will provide 1) an HRU and subbasin scale analysis on SWAT outputs, 2) a sensitivity analysis of SWAT outputs to mean slope, 3) a more complete review of previous studies, and 4) some conclusions. Your inputs have been very helpful for improving our paper and our further study. Again, thank you very much.

The following are our specific responses to your comments/critics/suggestions.

Sincerely,

The authors

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1) A fundamental question is why a catchment has been chosen that is to 96% covered by forests (p4416, 8). Looking on the papers about the Taihu Lake Watershed the major non-source pollutions come from agriculture and also in general one would expect larger contributions from agricultural areas. Looking on a forested catchment does not seem to be most relevant.

RE:«««««««

SWAT is designed to predict the impact of management on water, sediment and agricultural chemical yields in large ungauged basins (Arnold et al., 1998). Ideally, the topic of the non-point source pollution in Taihu Lake watershed is interested by the public and an agricultural catchment should be selected. The main reasons for choosing the study area in this paper are:

a) This is a preliminary study of Tiaoxi Watershed modeling to tackle the question of what kind of DEM is suitable for the study. Therefore, a small subbasin is used to speed up the model running, which can take days for a single run of the whole Tiaoxi Watershed in high resolution (e.g. 5 m). Meanwhile, the Xiekengxi Watershed is the only watershed with long-term water quality monitoring data. In addition, in Tiaoxi Watershed, bamboo forest and nursery are very popular and cover about 20% area. These two types have high cash return. Farmers usually apply fertilizers intensively (up to five times as much as fertilizers as paddy rice). Unlike paddy field that is flat with field boundary encircled, these two types distribute in relatively hilly areas and subject to soil and water erosions. Therefore, they are major sources of non-point pollutions.

b) The DEM grid size influence the SWAT predicted output in three model run stages, which are (1) watershed delineation, (2) HRU definition, and (3) SWAT module runs.

It was found by Cotter et al. (2004) that relative distribution of agricultural, urban, and forest areas within a watershed could be affected by the DEM grid size. Therefore it is the stage (2) that is affected by the LULC. Cotter et al. (2004) also found that the SWAT predicted flow, sediment, NO3-N, and TP were slightly affected by the land use resample resolution. Taking into account that the LULC impact on SWAT runs with different resolutions DEM as inputs is minor, we do not transfer the study area to a typical agriculture catchment.

Reference:

Cotter, A. S., Chaubey, I., Costello, T. A., Soerens, T. S., & Nelson, M. A. (2004). WATER QUALITY MODEL OUTPUT UNCERTAINTY AS AFFECTED BY SPATIAL RESOLUTION OF INPUT DATA. JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION, 72701, 977-986.

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2) A major limitation is that the results are analyzed only in a lumped way with regard to both space and time. Interesting questions could be addressed by looking at smaller spatial scales (e.g., different sub-catchment) and/or shorter periods. This would allow investigating when and where differences occur and, thus, provide much more information than the lumped analysis of average values

3) This leads to another important point: what is currently missing is a more detailed investigation on WHY the DEM infiuences the results. This would include looking on why we see effects in the models and how this relates to the 'real' processes.

RE:«««««««

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

Studies showed that the SWAT performance can be varied in different weather conditions of different months (Bosch et al., 2004) or different years (Di Luzio et al., 2005).

Therefore, it can be expected that the DEM resolution impact on SWAT outputs could vary on time and time scale, but the general trend should be consistent (Bosch et al., 2004). That is why the accumulated one year result rather than the monthly or daily result was studied. To verify this assumption, we will look into a time series to investigate the variation over time.

References:

Bosch, D. D., Sheridan, J. M., Batten, H. L., & Arnold, J. G. (2004). EVALUATION OF THE SWAT MODEL ON A COASTAL WATERSHED. Transactions of the ASAE, 47(5), 1493-1506.

Di Luzio, M., Arnold, J. G., & Srinivasan, R. (2005). Effect of GIS data quality on small watershed stream flow and sediment simulations. Hydrological Processes, 19(3), 629-650. doi: 10.1002/hyp.5612.

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4) More information on the model application is needed (examples of information which I could not find: how many precip gauges, point sources, runoff observations, . . .).

RE:«««««««

The following paragraphs have been revised/added to the revised version.

Three years (2006-2008) of daily weather gauge data (precipitation, temperature, solar radiation, wind speed, and relative humidity) of one station were provided by Weather Service of Zhejiang Province, China.

The Xiekengxi River watershed is a forest (accounting for 96.0% of area) watershed without significant point source pollution, so there was no input data of point source pollution. Only 0.9% of the area is cover by arable land, and the crop practices were set as model default values, by which auto fertilization would be applied when the N or P concentrations of the soil were below the thresholds. Nutrition (TP and TN) concentration was observed once for each season in the watershed outlet.

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One question is how a particular model parameterization might infiuence the overall results. A full parameter sensitivity analysis might be beyond the scope of the study, but some tests of 'parameter effects on DEM effects' would be motivated. This would allow to say something on the generality of the results.

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A sensitivity analysis of the flow, sediment, TN and TP to mean slope will be added to the revised version.

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5) It also remains fully unknown how well the SWAT model reproduces observations of runoff and nutrients. The authors refer to three papers where the model has been 'found to be acceptable' (p 4420, 18ff), but in these applications the model has been applied to the much larger Taihu Lake Watershed (37 000 km2 compared to the 81 km2 sub-catchment used in the present paper).

RE:«««««««

Obviously, the model performance varies with different situations, especially in places outside USA where the model was developed and tested. Indeed, the acceptable performance in the Taihu Lake Watershed does not assure the same performance in the smaller sub-catchment. The objective of this study is to investigate the sensitivity of SWAT to DEM resolutions. Therefore, we assert that the default parameters, which are comparable in different circumstances, make sense for SWAT. Nonetheless, a calibrated run will be provided in the revised version to show how well the SWAT model works in the study area.

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6) The results are presented as 'relative errors'. While I do not like the term (it implies that the baseline simulation is true, I'd prefer 'relative difference'), using the relative differences makes sense. However, the absolute differences should also be provided. Without this information it is impossible for the reader to assess the importance of certain relative differences!

RE:«««««««

The 'relative error(s)' has been replaced by 'relative difference(s)' in the revised version.

The comparison between the real values and predicted ones can partition the total error into the error caused by the model itself and error caused by different DEM grid sizes. In this way, we may obtain a complete assessment. In the revised version, we will provide a calibrated run to illustrate the absolute differences.

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7) The results are based on only one year (p4419, 23). Please discuss at least how 2008 was compared to other years and how this might have influenced the results.

RE:«««««««

See our response to your Comment #3

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8) The DLG5m is taken as the 'truth'. One might argue that the highest resolution DEM not necessarily is the best for hydrological modeling. This could at least be discussed.

RE:«««««««

The following sentence has been added to the methodology:

It should be noted that the highest resolution might not always guarantee the best performance in a given SWAT run.

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9) I don't think a summary in the end is needed, I'd rather see some conclusions (i.e., what have we learnt from this study)

RE:«««««««

Conclusions have been provided in the revised version:

To decide which DEM is feasible for SWAT model, the interested output variables and the maximum acceptable error variation should be predefined. In this study area, we have the following conclusions:

The SWAT predicted runoff is not sensitive (RD <= 1.0%) to the DEM resample resolution (from 5 m to 140 m) and the data source (DLG5m, ASTER30m, and SRTM90m) either. Therefore, with a 1.0% RD permission, we can use coarse resolution DEM of any handy data source as SWAT input to accelerate the model computation.

If the sediment is the focus of study and 6.0% RD is permitted, we can use the lowest resolution (140 m) DEM of each data source as SWAT input to speed up the computation. Results from any sources of data (DLG5m, ASTER30m, and SRTM90m) are acceptable.

The TP and TN decreased linearly on resampled grid size, and it should be aware when replacing the original DEM resolution with the resampled one. The performances of SWAT predictions on TP and TN with ASTER30m and SRTM90m are close (RD < 2.0%). We can use any of them with a 2.0% RD. However, the predicted TP and TN by DLG5m were much higher (RD > 8.0%) than those by ASTER30m and SRTM90m.

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10) It might be valuable for the authors to better connect to previous work. Below I list some references on DEM-scale effects on topographic indices which the authors might want to consider. Some literature on the effects of DEM resolution:

Brasington, J. and Richards, K., 1998. Interactions between model predic-

tions, parameters and DTM scales for TOPMODEL, Comput.Geosci., 24, 299–314, doi:10.1016/S0098-3004(97)00081-2

Lassueur, T., Joost, S., Randin, C.F., 2006. Very high resolution digital elevation models: do they improve models of plant species distribution? Ecological Modelling 198 (1–2), 139–153. Sørensen, R. and Seibert, J., 2007. Effects of DEM resolution on the calculation of topographical indices: TWI and its components, Journal of Hydrology, 347: 79-89

Zhang, W.H., Montgomery, D.R., 1994. Digital elevation model grid size, landscape representation, and hydrologic simulations. Water Resources Research 30 (4), 1019–1028.

RE:«««««««

The literatures above are excellent references about DEM resolution impact on TOPMODEL (Zhang et al., 1994; Brasington et al., 1998; Sørensen, et al., 2007) and plant habitat model (Lassueur et al., 2006). Frequency distributions of slope (tan B), drainage area per unit contour length (a), and the topographic index (a/tan B) were calculated for each grid size model in the TOPMODEL studies. The sensitive grid size range (Brasington et al., 1998) and suggested grid size (Zhang et al., 1994) were provided in some studies. We shall review these previous studies and compare the results in the revised version.

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