

Interactive comment on “Cost-effective rain gauge deployment and rainfall heterogeneity effect on hydrograph simulation in mountainous watersheds” by Jr-Chuan Huang et al.

Anonymous Referee #1

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General comments:

The paper describes the effect of subsampling from a radar rainfall image on the quality of streamflow predictions by a hydrological model based on the TOPMODEL subsurface runoff principles.

I am not sure about the value of the paper. There are quite a lot of assumptions that are not necessary valid. They also make the results quite uncertain, and difficult to interpret and extrapolate. At this point it is difficult to see what the reader can really learn from the paper. My main points of critique are:

- the paper assumes that radar rainfall represents the true rainfall, and that rain gauges can be simulated by sampling from the radar map. This is of course a very strong assumption. Radar represents a kind of average over a certain pixel size (in this case 1.3 km²) which may be very different from the scale at which a raingauge works. Furthermore, raingauges are influenced by wind, topography (especially in mountainous areas!), vegetation, and other local conditions that are very differently picked up by radar. Although it is possible that the high intensity of torrential rains results in less errors between rain gauges and radar (e.g., no effect of drizzle and "horizontal" rain), still the extrapolation is a very tricky one that needs more attention in the paper.

- As the other reviewer notes, extrapolation with Thiessen polygons is a strange choice for a mountainous area. It is quite likely that some spatial patterns are present, e.g., from the influence of topography, which may be incorporated in the interpolation. This may drastically increase the performance of the "rain gauges".

- I have some specific questions about the hydrological model, which are given in the section below. However, also the use of the model is not entirely clear to me. As the authors observe in the paper, hydrological models may act as a smoothing filters, which means that errors in precipitation may get smoothed out in the discharge prediction. But this is highly dependent on the model, and may introduce other errors. The authors seem to be most interested in the water balance, and the shape of the recession curve. For the first, why not compare directly between the precipitation input given by the subsampling, and by the radar grid itself? This reveals direct information on the sampling density that is required to get a certain quality of model input. In a second step, the model can be used to see whether input errors decrease when putting them through a model. But the latter conclusions will be conditional on the model that is used, as well as the characteristics of the rainfall event. This suggests that maybe more than two events will be needed to really characterize the impact of rainfall measurement errors on streamflow.

I also wonder why the authors compare with the model results from the "true" model,

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i.e., the model forced with the radar data, rather than the measured streamflow data. In the end, it is the streamflow you want to predict, not some artificial benchmark.

These remarks, together with the specific remarks given below, and a strong need to improve the clarity of the formulation and the language, make me recommend at least major revision. I can see value in the data and a large part of the work that is done. Therefore I suggest the following approaches to improve the paper:

- Either the authors focus on the conceptual side of the paper, using the setup as a "virtual catchment" to test sampling and interpolation techniques. Now, they used only the simplest of these approaches, a random sampling and a nearest neighbour interpolation. As noted above, the value of these techniques is questionable. However, it would be interesting to see how a targeted sampling (e.g., covering different topographic elements) or a more complex interpolation method (e.g., kriging with external variables such as elevation) may improve the model performance. This will yield very useful information, not only about the number of rain gauges that are required, but also about their optimal location and the type of covariables that may help in improving the interpolation. As a suggestion, here are a few papers that might be of interest on the impact of rain gauge density and interpolation:

A. Bárdossy and T. Das. Influence of rainfall observation network on model calibration and application. *Hydrology and Earth System Sciences*, 12:77-89, 2007.

P. Goovaerts. Geostatistical approaches for incorporating elevation into the spatial interpolation of rainfall. *Journal of Hydrology*, 228:113-129, 2000.

R. E. Chandler and H. S. Wheeler. Analysis of rainfall variability using generalized linear models: A case study from the west of Ireland. *Water Resources Research*, 38:1192-2002, 2002.

- Another approach can be taken by looking more at the processes in the catchments. As noted by the other reviewer, extrapolation of the results is very questionable, given

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the low number of events. However, a more detailed study of the nature of the events may help understanding the processes. For instance, it is likely that the number of required raingauges for good prediction depend on the (spatial) size of the storm. Also, the torrential nature of the typhoon events may result in less discrepancy between rain gauge readings and radar. Or how does the catchment land cover influence infiltration and routing? This is important, because the precipitation error will be smoothed out more for subsurface runoff than for surface runoff, and this may be related to the intensity of the event. Currently there is very little information in the paper to interpret the results in this light, which I think is necessary for interpolation.

Specific comments:

- 2171/10: The paper by Celleri et al. (2007) is not about radar measurements (although it is a good example of how analysis of the spatial variability found in mountainous catchments can help to understand the processes that take place!)

- 2174/11-15: this part is not clear. Does this mean that the evapotranspiration mechanism of TOPMODEL is replaced by something else in order to avoid the need for reference evapotranspiration data?

- 2174/6: I guess this refers to the fact that TOPMODEL is based on the assumption that surface runoff is the result of saturation excess (hence the importance of the topographic index). Given the torrential nature of the typhoons I would expect infiltration excess overland flow to be an important process too. Is this represented in the model?

- 2174/19: This sentence is not clear. It suggests that RC in formula 1 is used to represent surface runoff at plot scale (i.e. an infiltration excess mechanism) rather than at catchment scale (where it would represent evapotranspiration and deep infiltration losses)?

2175/6: what does "accordingly" refer to? There are quite a few of such transitions between sentences that are not really clear and highlight the need for a thorough revision

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of the language.

2175/10-11: I am wondering whether this is a distributed model or not. It seems that surface routing is done in a distributed way (taking into account spatial variability in channel roughness for instance) but subsurface routing is not. Is this correct and what is the justification?

2176 equation 5: Obviously this estimator does not take into account any spatial dependence between the samples, which certainly will be present. You may want to have a look at this paper (among others) for more advanced methods of comparing spatially correlated fields:

M. Fuentes, P. Guttorp, and P. Challenor. Statistical assessment of numerical models. *International Statistical Review*, 71:201-221, 2003.

2177/14-20: This is a quite confusingly written paragraph. I understand it is a random sampling from the radar map, but as noted above, I am not sure this is the best sampling procedure.

2178/13: redundant sentence

2178: it should be "classes"

- 2191 caption figure 3: "Some dots outside the axes were not shown." Does this mean there are (large) outliers? Why is this?

- 2197 caption figure 9: Reformulate as: "(a) relation between rainfall amount ratio and covering area; (b) relation between...". Please also explain R_s and R_r . What exactly is the rainfall amount ratio?

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