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Interactive comment on "An evaluation of the importance of spatial resolution in a global climate and hydrological model based on the Rhine and Mississippi basin" *by* Imme Benedict et al.

Anonymous Referee #2

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This study compares the benefits of increasing the spatial resolution of a global climate model (from 120 to 25km) and of a global hydrological model (from 50 to 5km). The comparison is performed in Rhine and Mississippi basin. The benefits are variable and illustrate that an increase in resolution does not automatically lead to an increase in simulation realism. The study is interesting and the simulations performed are quite unique. However, it is not always clear how the models were adapted to be run at higher resolution, and the experimental setup has some flaws, which prevent the isolation of the benefits of the resolution increase. My major comments are on the spatial scale of the simulations (A), the benefits of increasing the resolution of the climate model (B) and of the hydrological model (C).

Major comments

A. Spatial scale: The authors take a GCM all the way to the regional scale, which is uncommon in hydrological studies and hence makes their study particularly interesting. They essentially skip the RCM step by running their GCM at a 25km resolution. I recognize this has advantages, in particular since RCMs typically cannot correct for errors in large-scale fields (P2 L16-17).

There are however two essential steps that require further discussion:

A1. It is debatable whether the resolutions the authors run the GCM at are high enough to capture the hydrological processes they are interested in. For instance, it is unclear whether the influence of elevation on snow can be correctly captured in mountainous areas. Snow processes are essential in the studied catchments, as the authors recognize: "[s]now melt, in combination with frozen soils, can occasionally lead to extreme flood events as well (Hegnauer et al., 2014)", and similarly in the Mississipppi basin, "[m]ost flood events occur in winter and spring due to heavy precipitation, snowmelt and rain-on-snow events." I understand that to bridge the resolution gap between the climate model and the hydrological model, the climate variables are "remapped" (P5 L9-10). I ask the authors to explain in more details how this is done, and in particular to discuss if this step provides climate simulations at a resolution high enough to enable them to capture the hydrological processes relevant for their study.

A2. Bias-correction is now routinely applied to climate model simulations before they are used for hydrological modelling. This allows for the adaption of the simulations to local conditions, and is usually necessary to produce realistic hydrological simulations. The authors might want to explicitly acknowledge that they skip this step.

Now, let us assess whether higher GCM resolution leads to better simulations:

B1. In Figure 4b) precipitation is overestimated in specific locations, in particular on the Italian side of the Alps. I am not convinced by the authors' explanation that this is caused by the “underestimation of precipitation in the E-OBS dataset, which is based on a sparse gauge network in mountainous areas” (P8 L9-10). Those high precipitation locations are in unexpected places and I cannot think of atmospheric processes that could cause them and explain their highly localized pattern. It is my impression that those red/orange grid cells reflect errors in the model simulations at high resolution, and illustrate that increasing model resolution does not immediately lead to improved simulations.

B2. Increasing the resolution from T159 to T799 slightly improves the precipitation in the Rhine basin, but not in the Mississippi basin (Figures 5 a) and b)). The authors argue that this is partially explained by the imperfect “representation of small-scale convective processes” and “recommend to use convection permitting models, to more explicitly resolve tropical storms and moist convective processes” (P23 L5-7). I suggest that they provide evidence from other studies that further reducing the resolution will provide the better precipitation simulations in the Mississippi basin or similar areas. It is an expensive solution, hence it is important to better assess its chances of success based on literature already published.

B3. More details are needed to explain how the GCM was adapted to run at higher resolution. In particular, the authors state that “the land-use products are similar for the two resolutions, where the high-resolution information is used for the high-resolution runs”, but it is unclear what the “products” are and in which respects they are “similar”.

B4. Although I recognize the importance of getting large-scale processes right, is it necessary to run a climate model over the entire planet on a 25km grid to capture them adequately? As a follow-up to point A2, an alternative would be to run the GCM model at standard resolution (say 120km) and then use a convection permitting model over the area of interest. Because computational resources are scarce, I think this article would be more useful for the design of future experiments if those points were discussed, even though they go slightly beyond the scope of this paper.

Now, does higher GHM resolution leads to better simulations?

C1. “we remapped the parameters from the 0.5 to the 0.05 resolution” (P5 L5). It is essential to explain how the remapping was done, as it can significantly influence the perceived benefits of the increased resolution. Please dedicate a paragraph to it, explain how your design differ from Melsen et al. (2016) and discuss whether their results are truly transferable to your study. This is similar to my comments A1 and B3.

C2. Horizontal transport was switched off in the GHMs. I agree with reviewer 1 that this makes it difficult to truly assess the gains of the increased resolution. This aspect of the experimental setup should be made much more explicit and the implications for the results should be better discussed.

C3. I find Tables 3 and 4 useful to disentangle the effects of resolution increase in the GCM vs. in the GHM, but the results would be easier to interpret if they were represented graphically, for instance using barplots.

C4. I wonder how close GHMs are to replace calibrated catchment-scale hydrological models. To be able compare their performance, it would be useful to compute the NSE for hydrological simulations driven by ERA-interim. I recognize that it would not be a completely fair comparison, since the calibration of the catchment-scale model usually relies on observed discharge data, but it would be interesting to assess how well an uncalibrated GHM does in comparison.

Minor comments

“Increasing the resolution of a GHM also requires to increase the number of unknown, and often not easily quantifiable, model parameters” (P2 L9-10). This is also true for climate models, which also involve parameterizations whose parameters cannot be determined using measurements or physics, and hence have to be tuned.

“The representation of these processes is resolution dependent” (P2 L30-31). The representation of all processes is resolution dependent, I suggest removing this sentence.

“For both resolutions, six members of five years (2002-2006) are created, resulting in 30 years of data representing present climate” (P4 L14-15) Please explain why six simulations of five years were run instead of a single simulation of 30 years. Please also explain how the six members differ.

“For each member, we perform a spin-up of five years (length of timeserie per member). We leave out the first year for analysis due to the influence of spin-up, which results in 24 years of discharge simulations to analyse.” (P5 L13-15) These two sentences apparently contradict each other: was the spin-up (i.e. the period not used in the validation phase) of 1 or 5 years?

I agree with the first reviewer that going back and forth between the Mississippi and the Rhine makes the text difficult to follow, and that it would be better to entirely describe the simulations in one catchment and then move on to the other one.

Figures 5, 6, 8, 10: Those Figures would be easier to understand if the authors took the legends out of the panels, synthesised them in a single legend and added it at the bottom of the Figure.

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