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Hydrology and Earth System Sciences Discussions
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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.

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We would like to thank review referee #1 for the constructive comments on the manuscript. In this document we will clarify and respond to the comments. If we agree with a comment, we will not explicitly answer here, but adapt the text accordingly in the revised manuscript.

A major comment is on the horizontal transport in the GHM. There is no lateral redistribution of water between grid cells in both resolutions of the GHM W3RA. It is also not common to have a groundwater flow component in a global-scale model, although it has been implemented in some (de Graaf et al., 2015). Nevertheless, we will include in



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the experimental set-up that lateral groundwater flow is not implemented, whereby we refer to the documentation of W3RA for a more detailed description of this assumption (Van Dijk, 2010). In the discussion, we mention that lateral groundwater becomes more and more important at higher resolutions, starting from 1 km (van Dijk, 2010; Bierkens et al., 2015; Wood et al., 2012). This sentence was meant as an outlook for future experiments but does not corresponds with our simulations, which we should clarify. In addition, there is horizontal transport of runoff via the routing module which is run after the hydrological model run. This routing scheme is run at different resolutions for the different resolutions GHM, namely: for the low resolution GHM (0.5 degree) we perform the routing on a resolution of 0.5 degree, for the high resolution GHM (0.05 degree) we perform the routing on a resolution of 0.0833 degree. This means that for the high resolution run we apply closest distance interpolation to remap runoff to the routing resolution.

Detailed comments:

* Reviewer: Page 2, L10: could you expand this sentence to specify which parameters are unknown or not easily quantifiable? Also in Page 5 L3 and L4: which parameters are remapped? Which method is used to remap them?

Response: On page2, line10 we could include an example of an unknown and not easily quantifiable variable but at this point in the introduction we think it is too specific to mention a whole list of parameters. In the experimental set-up we will include a reference to the model documentation (page 73-74) where one can find all the parameters which are included in W3RA and therefore will be remapped from the low to the high resolution (except for orography and vegetation). We remap the parameters from the low to the high resolution using the resample statement in PCRaster (Karssenberg et al., 2010).

* Reviewer: Page 5, L14-15: is one year enough for spin-up? Is soil moisture in equilibrium? How deep are the soil layers?

Response: For each member we performed a spin-up of five years (total length of member). Thereafter we perform the five year simulation, from which we leave out the first year for analysis. So in the end we have 6 years of spin-up, which we assume is long enough for soil moisture to be in equilibrium. Figure 1 shows a simulation of member 3 with the initial states of member 3 and member 4. From the figure we can see that in general, and especially after one year, the discharge signal is almost equal. This indicates that the discharge is hardly influenced by the initial states. The depth of the three soil layers are 0.15, 0.85 and 4 m (i.e. 0-0.15,0.15-1, 1-5 m).

* Reviewer: Section 3.4: The authors use the term ‘coupling’ between the GCM and GHM but the right term should be forcing/driving, as there is no interactions/feedbacks involved.

Response: We agree with the referee that ‘coupling’ of the GCM and GHM is not the appropriate term in this study. Therefore we will replace coupling with forcing or driving in the revised manuscript.

* Reviewer: Page 6, L3: GHM forced with ERAI data: how long is the simulation? Is it 1 simulation of 30 years, or 6 simulations of 5 years?

Response: We will clarify in the experimental set-up that for verification we force W3RA with 30 years of ERA-Interim data from 1984 until 2014. For all the simulations with forcing from ERA-Interim we have performed a spin-up from 1979-1990.

* Reviewer: Page8, L14-15: Is it really an improvement due to the storm track? Could it be also that the high-resolution GCM simulates precipitation over orography more accurately, as well as the dry shadow at the lee of the mountains (as shown on Fig 4)? It would be good also to add the convective part on this panel to determine if the peak in June is mostly convective.

Response: We agree with the reviewer that the improvements in precipitation over the Rhine basin in the high-resolution GCM are likely a combination of an improved storm-track, general circulation and a more detailed topography. The improvements related to topography are mentioned in L6-7, and not repeated in L14-15. We will mention topography again as a likely reason for improvement in L14-15. Figure 2 shows the contribution of convective precipitation to the total precipitation over the Rhine basin, peaking in June. This will also be shown in the revised manuscript.

* Reviewer: evaporation panels: are solid lines GCM only, and dashed lines GHM at 0.5d forced by low and high-resolution GCM? If so, this needs to be made clearer in the caption.

Response: This is correct, we will clarify the caption.

* Reviewer: Page 11, section 4.1.2: why is the high-resolution GCM worse than the low-resolution for the most extreme precipitation events in SON, while the discharge is better? Moreover, the high-resolution model shows much higher precipitation extremes but Fig 5 shows a similar mean seasonal cycle between low- and high-resolution models. So what is the contribution of extreme precipitation to the mean over the Mississippi?

Response: For the precipitation extremes in the Mississippi in SON, we do not see that the high-resolution GCM is worse than the low-resolution GCM in the most extreme precipitation cases. We think it is the other way around. Which than corresponds with higher extreme discharges with forcing from the high-resolution GCM. In SON we see much higher precipitation extremes in the high-resolution GCM (Fig. 8g). In these SON months we also find a higher monthly mean of precipitation over the catchment (Fig. 5b). We indeed see that the mean in DJF T799 and T159 are similar, although the extreme precipitation values are higher for the T799. We would like to mention that for the extreme precipitation plots we use 10-day precipitation sums. We can conclude here that the extremes in DJF do not influence the precipitation mean in this season.

* Reviewer: Fig. 7: it is hard to see any difference. Do instead a difference plot. CPC, low-res minus CPC, high-res minus low-res. It could even be more informative to split

it into seasonal means.

Response: We agree that it is hard to see the differences between the high-res, low-res and CPC data, therefore we will adapt the colour scheme as can be seen in Fig. 2. Now the differences between the simulations appear more clearly. We do not change the colour scheme for the Rhine, as the current colour scheme shows clearly the differences for the Rhine. We agree that seasonal means will provide more information, nevertheless this also will increase the amount of figures. Therefore we will include the seasonal means in this review (Figure 3) and in the appendix.

* Reviewer: Difficult to jump back and forth between Rhine and Mississippi.

Response: We understand your comment on jumping back and forth between the Mississippi and Rhine. At first hand, we decided this set-up as want to compare the two different basins. Nevertheless, as the anonymous referee #2 also suggests to first discuss the Rhine and then the Mississippi we will do so if we get the opportunity to revise the manuscript.

*Reviewer: Fig 10: how do the models compare with observations? Is the distribution at high resolution closer to observations?

Response: We added the correlations between observed 10-day precipitation sums and observed discharge. We are still working on making this plot more clear.

*Reviewer: Page 20, L15-16: high-resolution is needed for such an extreme event, but is it realistic compared to observations? Adding observations would be useful here.

Response: The simulations of EC-Earth are not constrained by observations (except for the configuration of the model and the boundary conditions: sea surface temperature, greenhouse gases, aerosols and land use). Due to the chaotic nature of atmospheric flow it is not possible to make a one-to-one comparison of specific events between the simulations and observations (i.e. we can only compare the simulations and observations in a statistical sense).

References

Karssenberg, D., Schmitz, O., Salamon, P., de Jong, K., and Bierkens, M. F. P.: A software framework for construction of process-based stochastic spatio-temporal models and data assimilation, Environmental Modelling & Software 25(4), 489-502, 2010. doi: 10.1016/j.envsoft.2009.10.004

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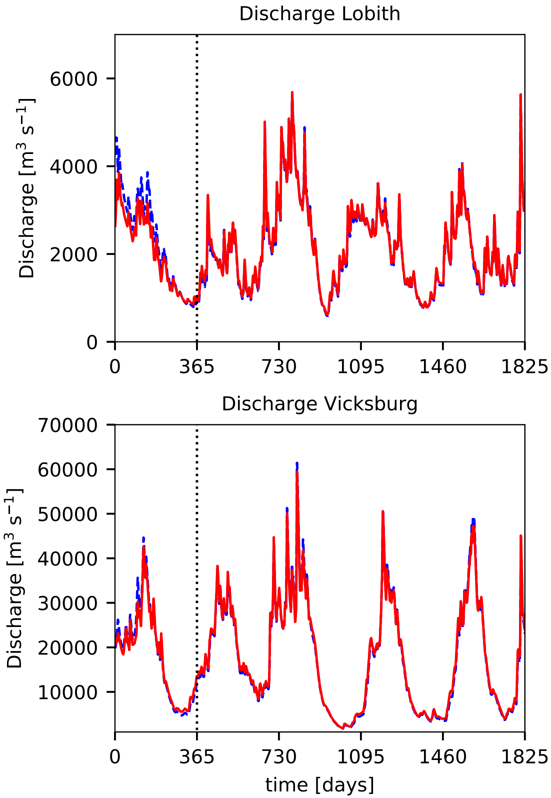


**Fig. 1.** Discharge at Lobith and Vicksburg from member3 of the EC-Earth T159 data initialized with spin-up states from member4 (blue) and member3 (red line). The right plots are a zoom in of the left figures.



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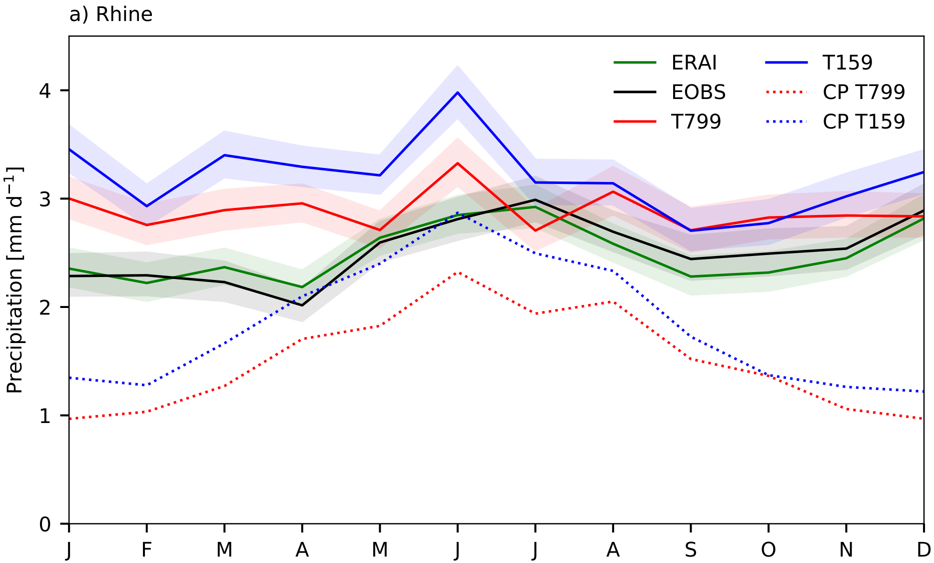


**Fig. 2.** Monthly averages of daily total precipitation (straight lines) and convective precipitation (dotted lines) over the Rhine basin for ERAI (green), EOBS (black), EC-Earth T799 (red) and T159 (blue).

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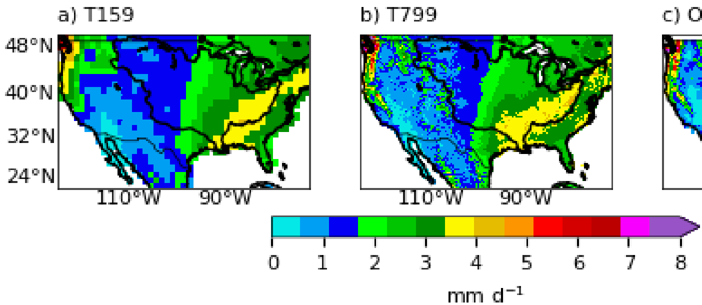


**Fig. 3.** 30-year average of daily precipitation sums (mm d-1) over the Mississippi basin for the low resolution EC-Earth simulations (T159), the high resolution EC-Earth simulations (T799) and the CPC dataset



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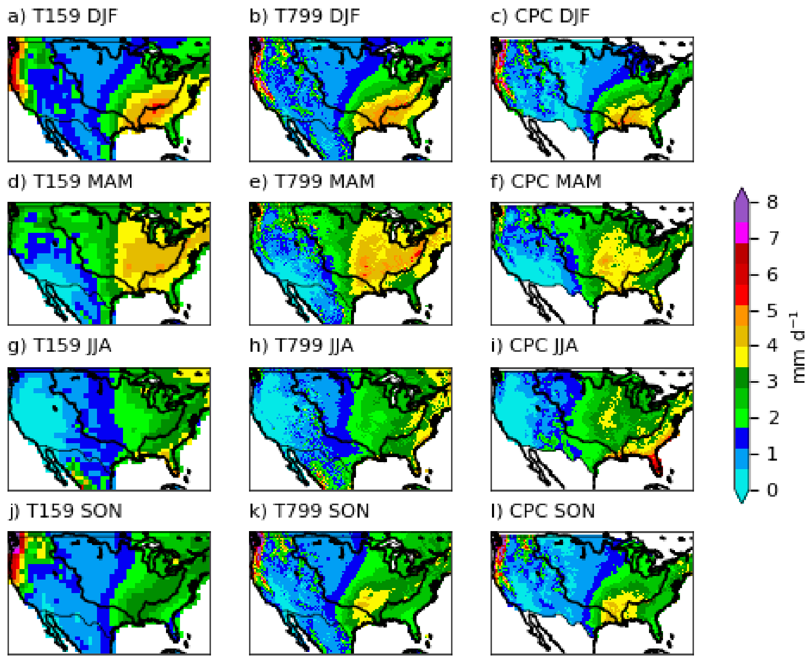


**Fig. 4.** Seasonal means (DJF, MAM, JJA and SON) of daily precipitation in mm d-1 from the low resolution GCM (T799, left) the high resolution GCM (T159, middle) and the observations (CPC, right)

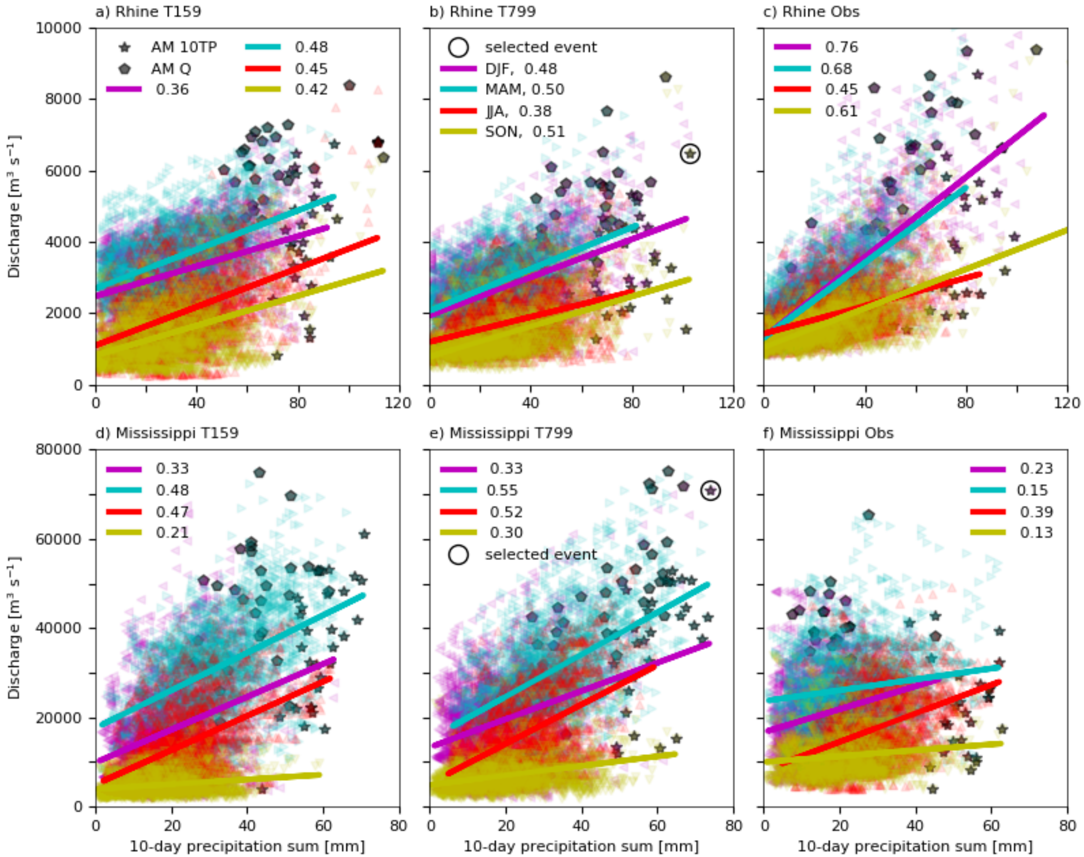


**Fig. 5.** The original scatterplots of simulated 10-day precipitation sums and simulated discharge, where we now added the left plots with the correlation between the observational data.