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An evaluation of the importance of horizontal resolution in global climate and hydrological models based on the Rhine and Mississippi delta

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We assess the benefits of exceptionally high horizontal resolution global climate- and hydrological models by analysing precipitation and discharge of two well-known basins: the Mississippi and Rhine delta. By increasing the resolution, we expect that large-scale meteorological processes will be better simulated and small-scale extremes will be more pronounced. In addition, river delineation and land-use will be better represented. Coarse and high resolution simulations of a state-of-the-art climate and hydrological model are compared for two very distinct river basins: the large Mississippi basin is strongly influenced by moisture input from the Pacific and the Caribbean, and the moderately sized Rhine basin receives most of its precipitation from mid-latitude cyclones.

With increased horizontal resolution (∼25 by 25 km), the representation of precipitation over the Rhine improves significantly, caused by the better represented large-scale circulation patterns. This improvement could not have been achieved by regional downscaling from coarse resolution climate models, which emphasizes the need for high resolution global models for the Rhine basin. On the contrary, the precipitation budget over the Mississippi does not change with increased horizontal resolution, most likely because it is strongly dependent on the representation of even smaller scale convective processes. Therefore, the Mississippi basin is more appropriate for downscaling. Besides, there is a large bias between the simulated and observed precipitation over the Mississippi.

By forcing the global hydrological model with the climate model output, we find that the precipitation signals are clearly reflected in the discharge and evaporation budget of the two basins. Changing towards a higher horizontal resolution in a hydrological model (∼5 by 5 km) is a complex task, as it strongly depends on the availability of necessary input parameters. Such a higher resolution model requires a significant amount of tuning, before any improvement in the hydrology can be found.

To conclude, our study shows that increasing the horizontal resolution of the global climate model can lead to better precipitation results, depending on the climatic drivers of the precipitation. Improving hydrological models by increasing the resolution is, however, far less trivial and depends strongly on the availability of high quality land-use data and discharge measurements.