River network and hydro-geomorphological parameters at 1/12° resolution for global hydrological and climate studies

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Reviewer comments are in italic and blue font.

Author response to reviewer #3

The authors have substantially improved the manuscript. But for the validation and data quality (one of my major concerns), in the revised version, the authors did not critically evaluate the improvement or differences from previous products (e.g., GRDC, DRT as shown in Table S1). The authors stated that 'only a few basins show a relative difference greater than 10 %' (L216). This is actually not the case. For example, for the GRDC, the difference is 13%, and it is even 23% for the DRT. For some rivers, the difference could be as high as 95%.... I believe the authors should be able to address these large differences in the revised version.

A lot of information are gathered in Table S1 on the differences between basin delineation from the different river networks. We highlighted the basins showing the largest differences and tried to identify the causes of all these differences. We then rewrote some parts of section 2.3 (Quality assessment) and added a more comprehensive analysis of Table S1 in the text (see bellow). We also added some statistics (median and mean) in Table S1. We think that now, all the major differences are addressed, and we thank again the reviewer for his/her valuable comment.

New text in section 2.3 Quality assessment:

Over the 69 largest basins, the overall agreement between MERIT-Hydro and the 12D river network is very good, with a median relative area difference of 0.3 %, which demonstrates the robustness of the upscaling algorithm. Among the main differences, a large part can be attributed to basins crossing arid regions. When neglecting such basins, the mean relative difference drops from 5.8 % to 3.7 %. This cause of differences is discussed thereafter.
Only two other basins are significantly different in the HR and 12D networks: the Nelson River and the Churchill River (Canada). Both river basins are connected via the South Indian Lake. The natural outlet of this lake flows into the Churchill River but the lake is anthropized and a part of the lake volume is diverted to the Nelson River basin for management purposes. The developer of MERIT-Hydro chose the Nelson River to be the major outlet of the South Indian Lake, considering the existing diversion project. We decided to disconnect this outlet, preferring to preserve the natural river network. Fig. 7 zooms over the region surrounding the South Indian Lake. Yellow circles denote cells where the flow direction has been inverted to reconnect the lake to the Churchill River. Another noticeable difference can be shown in the Amur River basin (Asia) in which the Kherlen River appears disconnected to the Argun River, a tributary of the Amur River, while both are connected at Lake Hulun in the GRDC database. Lake Hulun is usually an inland lake without outlet, but in wet periods it may overflow and then join the Argun River (Brutsaert and Sugita , 2008). As for the South Indian Lake, the developer of MERIT-Hydro preferred to keep them separated, which is reflected in the 12D river network (Fig. S2).

When comparing to GRDC and DRT, the averaged relative area difference equals 5.6 % and 8.4 %, respectively. The median reaches 0.8 % in the comparison with DRT. This shows that except for a few basins, the 12D river network and the original DRT are quite close. In Table S1, cells showing a relative area difference higher than 0.10 (10 %) are highlighted, and the potential cause of the difference is indicated by the background colour. Three main causes have been identified.

Most of the differences with GRDC and DRT come from arid conditions characterizing parts of some basins (with a red background in Table S1). In such regions, the terrain is generally quite flat and often disconnected to the river network (endoreic). It is thus quite difficult to extract river networks, which explains the differences between the datasets (as for example within the basins of Yellow River, Tigris-Euphrates, Senegal, Xi and Rufiji). Nevertheless, the small amount of precipitation that can fall in such regions is partly infiltrated and mostly evaporated. This volume of water never reaches the river network, so differences between river networks over arid regions can be neglected. This can be accounted for in the IoU index by removing arid regions from basin masks, arid regions being defined as regions where the mean annual runoff is below a threshold fixed to 1 mm/yr. Fig. 8 shows that the new 12D river network differs from GRDC in the Southern part of the Tigris-Euphrates river system. Note that DRT is quite similar to GRDC in terms of basin delineation. This major difference can be neglected since it is within the arid region of the Arabian Peninsula. In most of the cases, the IoU significantly decreases (down to less than 10 %) when removing arid regions from the masks for basins showing large differences due to arid regions.

Another source of differences is related to some missing tributaries (green background in Table S1). This is the case for many river deltas, including in the Tocantins, the Xi, the Ural, the Dvina and the Chao Phrava basins. With a D8 convention, models cannot simulate river divergence (a cell can flow into only one other cell). Fig. 9 shows the case of the Red River that joins the Delta of Mississippi, but not in the main branch. This results in different river mouths in MERIT-Hydro and thus in the new 12D network. The last noticeable difference is in the Neva river basin. It appears that in GRDC and DRT, Lake Saimaa (Finland) is disconnected from the Vuoksi river that flows into Lake Ladoga (Russia). As for the South Indian Lake, a significant part of water is derivated from Lake Saimaa to feed canals used for anthropogenic purposes (hydroelectricity, fluvial transport), which may reliably explain the disconnection of this sub-basin.

Finally, the upscaling algorithm produced a reliable and consistent global river network at 12D, very close to the GRDC database in terms of basin delineation for the 69 largest basins of the world. Since MERIT-DEM improved the HydroSHEDS high resolution river network (Yamazaki et al. , 2017), it is expected that the newly developed network improved the original DRT network.

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Author response to reviewer #4

The authors have mostly satisfactorily addressed my comments. One minor comment remained, which should not influence the decision: in the Conclusions section, it should be helpful for authors briefly mention the difference between vector-based and grid-based RRMs (as authors have already done in the Intro), and that these 1/12-degree river network datasets are the most helpful to high-resolution grid-based models (and make a few examples on which grid-based models can benefit from this the most). This way readers can fully appreciate the wider applicability of their data contribution, and also clear the confusion on why not directly supplying readers with vectors.

We would like to thank the reviewer for this remaining comment. We rewrote the last sentence of the conclusion as follows.

In grid-based approaches, the river network is discretized on a regular Cartesian grid, so that unit-catchments are rectangular pixels with their own hydrogeomorphological characteristics. The complete dataset described here is particularly well suited to a number of large-scale RRMs using a gridded structure for global hydrological studies (see Table 2 in Kauffeldt et al. , 2016). Not all of them are currently running at 12D resolution, while, on the other hand, the current tendency suggests that 5 arcmin could become the next standard resolution for global scale climate studies, namely via the release of the last global meteorological dataset for impact models in phase 3a of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP3a, Dirk et al. , 2022). With the entire dataset described here (flow direction, river length, river slope, river bank-full depth, river roughness, floodplains roughness, major groundwater basins boundaries, aquifer transmissivity, and aquifer effective porosity), many hydrological models could improve their river routing module by increasing the spatial resolution. Moreover, this consistent and comprehensive dataset can help modellers to integrate some important processes (such as inundation and groundwater) that are still neglected in some models.

Dirk N. Karger, Stefan Lange, Chantal Hari, Christopher P. O. Reyer, Niklaus E. Zimmermann (2022): CHELSA-W5E5 v1.0: W5E5 v1.0 downscaled with CHELSA v2.0. ISIMIP Repository. https://doi.org/10.48364/ISIMIP.836809.3