To the Editor:

Thank you for considering our manuscript and the Hydrography90m dataset for publication in Earth System Science Data. Please find attached the reviewer comments along with the responses. We took all comments into account and updated the manuscript accordingly, and hope that this new version satisfies the requirements for publishing our dataset in the journal.

Best regards

Giuseppe Amatulli & article's authors.

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Reviewer #1:

This is a very well written paper, that describes the data science techniques to create a huge data set, as well as the characteristics of the many layers in the data set. It will be of interest to a huge number of users. My only qualm is that it is a feast of data, or perhaps trying to absorb the data through a fire hose, and the paper does not provide a lot of help on how to get started with the data for many potential users who will not be acquainted with the technical literature. I would hope the authors can create an introduction on how to get started using the data, and some practical suggestions on which versions to use (e.g. for all the different stream ordering algorithms).

- Is the article itself appropriate to support the publication of a data set? Yes, it describes a new data set.
- Is the data set significant – unique, useful, and complete? Yes, it includes just about everything you could want for drainage networks at 90 m scale, and they point to way to future improvements under way.
- Is the data set itself of high quality? Yes, based on an initial analysis.
- Is the data set publication, as submitted, of high quality? Yes
- By reading the article and downloading the data set, would you be able to understand and (re-)use the data set in the future? Yes, but I would like to see the authors make a "Hydrography90m for dummies" cheat sheet or cook book to help novice users get started on the data. It might not be appropriate for the journal, but could go on a web page, or at the data download site. While the U-Tube video is helpful, it is not what I would like to see.

We thank the reviewer for his/her very constructive comments. We have now added more details and explanations regarding data download and usage. We like the idea of the cheat sheet and have included one workflow example using GDAL and GRASS-GIS, and another one using R. We hope that this will help users to get started with the data.

There are three minor comments in the attached PDF:

Fig. 3: Many of the tile names are impossible to read. Make the colors of the basins pale so the labels stand out.

Thank you, we have addressed this issue by removing the blak-basins border. Now the tile labels are more readable.

In addition, and in line with the journal request to account for color blindness, we have adapted the palette “viridis” following the recommendations by Stoelzle & Stein (2021; https://hess.copernicus.org/articles/25/4549/2021/).

I went to the website to download, and the tiling scheme was not obvious.

We have now added a clickable map on the https://hydrography.org/ website such that users can click on a given tile and receive the download links immediately. The current repository was in place as long as the website was not online yet.

We have also facilitated the usage of the vector data by splitting the line segments and outlet points in separate gpkg files. The reduced file size is better manageable for standard GIS applications.

Table 2: Commas to make the numbers easier to read.

Done.

Line 463: add ")"

Done.

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Reviewer #2:

This is a well written paper and nicely conducted study on extracting vector river flowlines based on the MERIT-Hydro product, for people to use in global river-related applications. However, I have the following concerns which prohibits the immediate recommendation of this paper for publication in this round.

We thank the reviewer for his/her constructive comments. We addressed all comments and added text where necessary to clarify the text.

Major concerns:

On channelization threshold: 0.05 km2 does not always outline better hydrography. Because uncertainty remains in headwater channel initialization threshold, and if you read earlier HydroSHEDS documentations by Lehner's group, and you will find it says often times threshold smaller than 100 grid cells (100*90m*90m) will introduce a lot of uncertainty. So, can the authors provide more justification on why using 0.05km2? How about the uncertainty it provided? What if the 726M lines mean just "more" channels, but not "better" channels? (related to this, what does it mean by saying "we address the all-important issues of headwaters" in Line 70? Is it related to the 0.05 km2 threshold?)

Thank you for bringing up this question. We use the 0.05km² as the threshold to initiate the headwater channels. This is the lowest possible threshold at 90m (3-arc-sec) resolution, without creating artifacts in the river channels. In this contest, it is important to define "uncertainty" that can mean two things: i) uncertainty in the spatial location of the stream channel, and ii) uncertainty regarding the presence of water in the stream channel.

In our study, we have focused on assessing the "spatial location of the stream channel" (Figure 8), and are in a separate study focusing on the second item which is the presence of water and the volumetric flow rate. In the manuscript we now rephrased line 460 to "*In summary, we employed a low threshold of 0.05 km² in this paper, and in subsequent research, will shorten (prune) the network dynamically given the modelled discharge in the stream segments.*" The idea is that by having an estimated discharge per stream channel, we can remove those channels that carry no water (across a multi-decade time window). Hence, removing streams channels later is possible, but the opposite is not feasible (i.e., having initially shorter stream channels and then adding streams later). Therefore our Hydrography90m manuscript sets the basis by delineating many headwater streams, i.e. a high density of stream channels, and we are aware that (i) many of them carry water only during a short time frame, or (ii) no water at all. If our analysis shows that there is no water at any given time, we will remove these stream channels and update the Hydrography90 network.

The use of such high resolution headwater thresholds is also used to delineate the NHDPlus HR stream network in the United States, which is later pruned using a complex method of flow estimation, and provides a dynamic HeadwaterNodeDrainageAreaSqKm attribute (see also the *User's Guide for the National Hydrography Dataset Plus (NHDPlus) High Resolution*, available at https://pubs.er.usgs.gov/publication/ofr20191096).

In addition, we calculated flow direction and thus flow accumulation using the multi-flow (MD8) algorithm that represents flow contributing areas in headwater regions more accurately compared to D8 (such a statement is also reported by Yamazaki 2019). In contrast, MERIT-Hydro computes flow accumulation using D8, which is considered a possible constraint for stream networks derived using that dataset (see Lin et. al. 2021).

Overall, headwaters have not been addressed in detail in previous global hydrographical datasets. Yet, headwaters are extremely important given that they comprise ca. 70% of the overall stream length, are vital for ecosystem services for humans and harbor rich biodiversity. One obvious reason that headwaters have not been delineated in great detail can be attributed to the uncertainties regarding the location of small rivers, as correctly pointed out by the reviewer. Our validation, however, shows that our stream channels provide a high spatial accuracy when compared with the NHDPlus HR – the pan-United States dataset that contains both wet and dry regions. And as headwaters contribute most to the river network length, those Hydrography90m channels that overlap with NHDPlus HR can be considered accurate. Findings from Agren et al. (2015) also support our decision to use a low stream initiation threshold, as they needed a threshold of 0.02km² to depict all intermittent streams and the flood-flow network in their study catchment. We have now added an additional explanation and the Agren et al. (2015) reference to the Introduction.

Nevertheless, we agree that Hydrography90m may also contain stream channels that "are more" compared to the observed flowlines. Still, we believe that delineating these potentially seasonally dry or ephemeral streams is a valuable contribution to hydrological and ecological research on the global and regional scale.

Data format: I have some concerns of storing the data in 20-degree by 20-degree tiles. There's no problem with grid-based MERIT DEM or Hydro products of storing the data in tiles. However, when it comes to vectors, storing the data this way will artificially cut off the channels that crosses basin boundaries. If you look at other widely used vector-based hydrography dataset (e.g. Lehner et al 2008; Linke et al. 2019; Lin et al. 2019; Lin et al 2021), they have all stored data in terms of different watershed levels. Can the authors rethink their data supplying strategy? I think a user that accidently sits in a basin being cut by the tiles will have a frustration using the data. Isn't it?

We have indeed discussed this issue extensively in our group, and we thank the reviewer for bringing it up. Originally, we opted to store the data in basins, as these are the natural spatial units of the hydrography. However the size of larger basins leads to the fact that the data is very heavy to download and to manipulate, even when optimized and compressed. In contrast, downloading the data in tiles is faster, and a standard "merge" of tiles in QGIS works in a reasonable amount of time (e.g. merging two tiles, totalling 1GB and including all attributes takes less than a minute, and merging tiles totalling 20GB takes ca. 12min). The basins and streams in these merges tiles are again connected.

While raster data is preferable for large-scale analyses, we agree that we need to make the data usage as easy as possible. That is why we now also have a clickable map for data download, available on hydrography.org. It offers a direct download of the data without having to search for the correct file name. We have also included a cheat sheet for users to quickly access all necessary data ready for their analyses.

Please see www.hydrpgraphy.org for example scripting procedure examples, and we are in the process of developing additional helper functions in Python and R.

Figure 8: this is related to the earlier uncertainty question – how does this overlap percentage differ if considering wet/dry region differences? For example, smaller threshold is definitely

better for wet regions, but how about dry regions? I think this evaluation method can exaggerate the benefits of Hydrography90m. Can the authors provide more assessments here?

In the current Hydrography90m dataset, the delineated stream channels represent the maximum of possible streams, i.e. a high stream density. The underlying assumption is that the spatio-temporal climatic variability can theoretically lead to ephemeral streams at a given point in time. We note that we are currently in the process of modeling discharge for each of the 726M stream channels, and will then remove those channels that do not contain any water. In other words, we will assign a probability of water occurrence per stream-cell channel. This step however requires first delineating headwaters with the smallest possible threshold (0.05km²), a product which we have now provided to the scientific community. We now emphasize this in the Discussion, and also added the additional explanation and the Agren et al. (2015) reference who refer to the fact that a low threshold is needed to account for intermittent streams.

That said, the stream channels in Hydrography90m do not yet include this spatio-temporal water availability assessment. We therefore are currently limited to perform a stream network density comparison for the different regions for reasons amply explained above. We will however consider such analysis when defining a ‘dynamic’ threshold for wet and dry regions.

Minor ones:

I disagree with the statement “no such hydrographic study has been published to date” in the Abstract. Since the publication of MERIT Hydro in 2019, there has been many hydrographic work published based on MERIT Hydro. I think the authors should step back a bit in the very beginning of this paper.

Thank you for this comment. Indeed this statement was confusing. We refer to a *global* dataset that includes small headwater and intermittent streams and have changed the sentence to read:“However, no such global hydrographic study with high resolution headwater features has been published to date.”

Line 51 and thereafter is a mis-citation to Lin et al. (2019). That paper used a 25 km2 threshold for the sake of building a model. I think a later paper by Lin et al. (2021) was the one featuring variable drainage density.

Thank you for this comment. We changed the citation to Lin et al. (2021).

Figure 3: I appreciate this figure, but again related to my earlier comment on data supplying format – is it possible to supply data by using the basin outlined here? Otherwise readers will make additional efforts to merge the data themselves if being cut.

Please see the previous reply. We agree that basins should be preferred, however given the size of some basins the data handling of the vector data would be extremely difficult. Also, given the many basins, it would be difficult for users to download single, small basins and these would need to be lumped to allow an efficient workflow. We provide easy-to-use and efficient code and instructions to merge the tiles, and no border effects/artifacts remain after the merge.

We provide a first set of helper functions at www.hydrpgraphy.org and we will add more, especially for Python and R users.

In this regard we note that due to the size of the dataset, the usual graphical procedure of merging in ArcGIS/QGIS (i.e., standard GUI applications) works but is considerably slower than the command line options. This is not related to our dataset data itself but occurs in global, high resolution datasets.

We are in the process of creating Pfafstetter basins for the Hydrography90m and look forward to providing the data for the sub-basins of a given Pfafstetter level.

References:

Agren AM, Lidberg W, Ring E. 2015. Mapping Temporal Dynamics in a Forest Stream Network—Implications for Riparian Forest Management. Forests 6, 2982-3001; doi:10.3390/f6092982.

Lin, P., Pan, M., Wood, E.F., Yamazaki, D. & Allen, G.H. (2021) A new vector-based global river network datas

Yamazaki, D., Ikeshima, D., Sosa, J., Bates, P.D., Allen, G.H. & Pavelsky, T.M. (2019) MERIT Hydro: A High-Resolution Global Hydrography Map Based on Latest Topography Dataset. Water Resources Research, 55, 5053-5073.