Reply to the comments of Reviewer 2 (https://doi.org/10.5194/essd-2021-72-RC2) on the manuscript "LamaH | Large-Sample Data for Hydrology and Environmental Sciences for Central Europe" submitted to ESSD (https://doi.org/10.5194/essd-2021-72).

Dear Gemma Coxon,

thank you for your positive feedback as well as your valuable comments and suggestions. Please find our answers to your comments below. Your comments are displayed in italics and colored with a blue font. Our reply is written with black font, while text lines from our submitted manuscript are colored in orange-brown font (proposed text passages to delete are additionally crossed out) and suggested new text passages in green font.

Best,

Christoph in behalf of all authors

1. *Basin delineation and 'headwater' catchments. The delineation of the catchment boundaries is a key feature of the dataset but currently is not clear. I suggest the following:*

Thank you for your comment. We fully agree, that the delineation of catchment boundaries was not well described and the actual terminology can lead to misunderstandings.

1.1 *Terminology needs to be much clearer. What do you mean by 'orographic catchment' (is this a commonly used term? Do you mean topographic catchment?). I don't believe you are using the term 'headwater catchment' correctly - I interpret headwater catchments as low order catchments found in the upper reaches of river basins. In which case statements like 'In contrast, however, LamaH does not only consider headwater basins' on L18 are not correct as CAMELS datasets also do not only consider headwater basins.*

We replaced "orographic" by the term "topographic" and suggest to add a short explanation to the manuscript:

(delineated only considering terrain features and ignoring potential subsurface cross-basin flows)

The term "headwater catchment" was replaced by "independent catchments, covering the full upstream area".

1.2 *Data source of the catchment boundaries – why did you use catchment boundaries from two products? It is not clear how the catchment boundaries are combined. L114 'As aggregation areas….' This sentence doesn't make sense and needs rewriting.*

We propose to change the description of the sub-basin aggregation and hope that this makes it clearer and explains why we used two different products.

~~As aggregation areas are catchment boundaries (Fig. 2) from the Digital Hydrological Atlas of Austria (HAO, 2007) and from HydroATLAS (Linke et al., 2019) used. The sub-basins of both data sources were combined and, if necessary, adjusted to reflect the gauges catchment area at their downstream end. In a next step, all (smaller) sub-catchments, which belong to the~~

~~respective upstream catchment area of an individual gauge, were combined. Each gauge is therefore assigned an aggregation area representing the overall orographic catchment area.~~

Starting point for creating the aggregation polygons (catchments) were sub-basins from the datasets Digital Hydrological Atlas of Austria (HAO, 2007; full expansion) and HydroATLAS (Linke et al., 2019; level 12), which was used for areas not covered by HAO. The sub-basin outlets of HAO agree with the gauge locations. In contrast, the catchment boundaries of HydroATLAS were partially manually adjusted to guarantee that the basin outlets of the polygons agree with the gauging station locations. Since the sub-basin delineation in HAO and HydroATLAS were aggregated to represent the complete topographic catchment area upstream of a gauge, the different resolutions in the data sets did not matter.

1.3 *Figure 2. I find this figure a little unclear and the figure caption is currently very long. It may be worth simplifying the figure and thinking about moving some of the explanatory text in the figure caption to the main text in the paper.*

Thank you for the suggestion. We propose to add a legend to the figure and to shorten the figure caption. We also increased the brightness of the background and hope that these adjustments will make it easier to understand the plot. We hope that these adaptions allow for a good understanding of the sub-basin aggregation, the catchment delineations and gauge hierarchy.

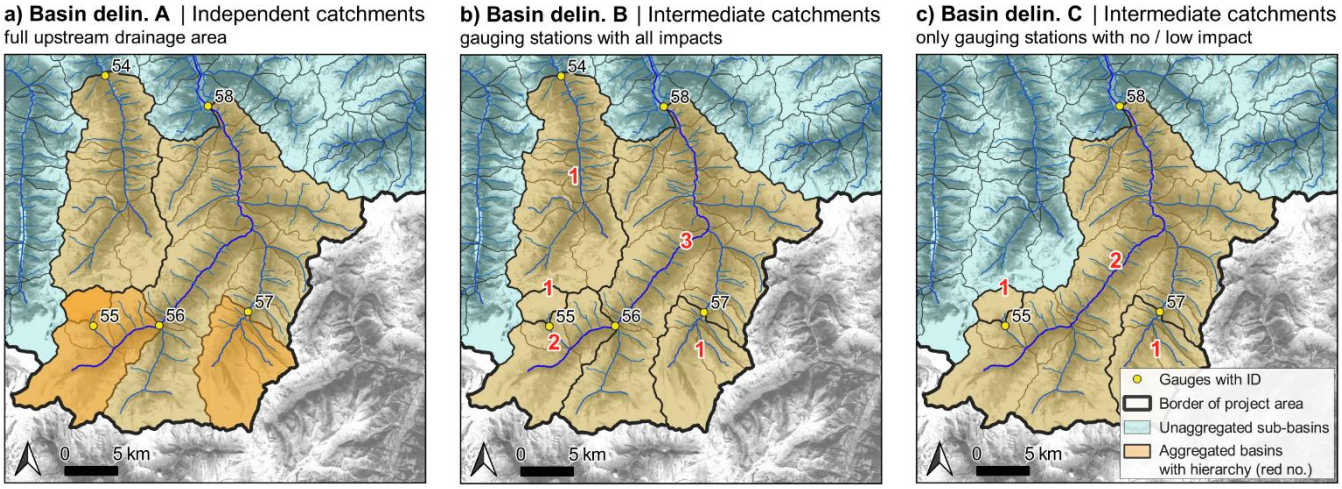

Fig. 2: Types of basin delineations in LamaH shown with an example. ~~Unaggregated sub-basins within the project area are marked with a blue tone and bordered with a thin black line. Aggregated basins are displayed with an orange/brown tone and are surrounded by a medium-thick black line. The thickest black line shows the border of the project area. The numbers in black font indicate the gauge ID, while the numbers in red show the gauge hierarchy (plot b and c).~~ Plot a) Basin delineation A (similar to the well-known CAMELS datasets): The aggregation area corresponds to the topographic catchment area of a gauge. In plot a), the aggregation area of gauges 56 and 57 overlaps with that of gauge 58, and the aggregation area of gauge 55 overlaps with that of gauges 56 and 58 (indicated by the different color tones). Plot b) Basin delineation B: The aggregation areas in this method considers the difference area (intermediate catchments) between the topographic catchment area of the respective gauge and the catchment area of the next upstream gauges. Consequently, there are no overlaps, but a gauge hierarchy is necessary. The hierarchy of the gauges 54, 55 and 57 is 1, because there is no upstream gauge. Gauge 56 has the hierarchy 2, because gauge 55 with hierarchy 1 is upstream. Hierarchy 3 is assigned to gauge 58, because there is at least one gauge with hierarchy 2 (gauge 56) in the upstream area. Plot c) Basin delineation C: Similar to basin delineation B, but only uninfluenced or low-influenced gauges / catchments (see chapter 5.8) are considered. In plot c), it is assumed that gauges 54 and 56 are strongly influenced. Consequently, these two gauges are excluded from the basin

delineation. The aggregation area of gauge 58 (now hierarchy 2) includes the intermediate catchment area of gauge 56. Source of background satellite image: Google © 2020 TerraMetrics, Kartendaten © 2020. Source of stream network: TYROL (2020).

2. *Potential evapotranspiration. The analysis in Section 4.2 is really interesting and an important addition to the paper. I understand the authors decision to not include the PET data of ERA-5, but given the importance of this variable as forcing data for a large amount of hydrological models (particularly conceptual lumped hydrological models), it seems a shame not to include it as a variable.*

Thank you for the appreciation of Section 4.2 and understanding of our decision not to include the ERA-5L PET data. We fully agree with your thoughts regarding the importance of PET as input for hydrological modelling. We of course discussed this deficit of LamaH internally when preparing the manuscript, but did not find an adequate alternative data product of PET to use. For the revised manuscript / updated LamaH-dataset we propose to provide daily time series of PET estimates (Thornthwaite's approach) from the hydrological model simulations, which will be included in LamaH (see our response to the comment CC1 of Daniel Klotz in the discussion).

It is not entirely clear how you would derive PET from the reference evapotranspiration provided. Were other global PET products considered?

It is not intended to derive PET from ET0 (available as static attribute calculated for the period 1970-2000). We provide therefore an attribute for long-term ET0 as a substitute for PET and propose to clarify this in the manuscript:

Potential evapotranspiration (PET) can be derived from ET0 using correction factors for vegetation and soil properties (Allen et al., 1998; Hargreaves, 1994), but was not realized in LamaH.

3. *Code availability. Reproducibility for these large-sample datasets is key. The authors should consider making their code available alongside the dataset. I would also recommend a code availability statement to make clear the code that was used in the paper. For example, I believe you used Nans' code to calculate the hydrologic and climatic catchment attributes and it would be good to make this clear at the end of the paper.*

Thank you for your suggestion. We have already cited the codes of Nans Addor (Addor, 2017b), but can of course also explicitly mention this in the end of the manuscript. Furthermore, we will add all relevant R and Python scripts for reproducing the dataset into the "G_appendix" folder of the dataset.

Code availability. We have used R-Codes from Nans Addor (Addor, 2017b) for reproducing the climatic (Table A4) and hydrological (Table A5) indices as well as for creating the Figures 3, 5 to 13a/c. The color schemes in the plots are based on ColorBrewer 2.0 (Brewer, 2021). Further relevant R- and Python-scripts for reproducing the dataset are available in the folder "G_appendix".

4. *Colour scales. Often diverging colour scales are used for sequential data (for example Figure 3a and 3b). I encourage the authors to change the colour scales on these plots to sequential colour scales as this is a more appropriate colour scale for*

sequential data values. There is a nice discussion of this issue in Section 3.2 of this preprint for HESS by Michael Stoelzle and Lina Stein: https://hess.copernicus.org/preprints/hess-2021-118/

Thank you for your suggestion. We have changed the color scales from diverging to sequential for the following plots and adapted the caption of Fig 3a according your suggestion:

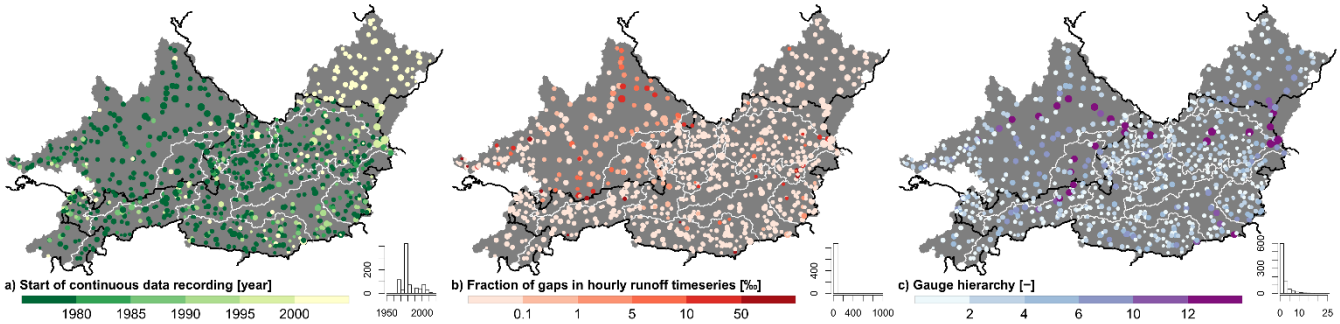

Fig. 3

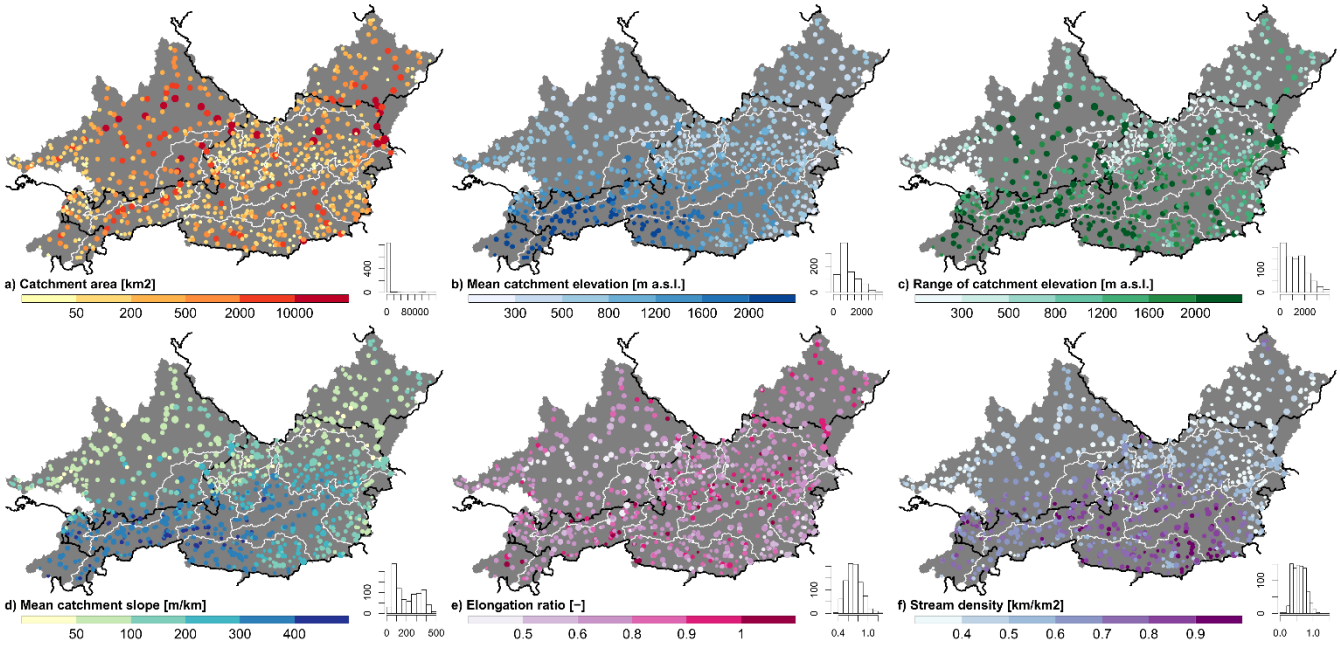

Fig. 5

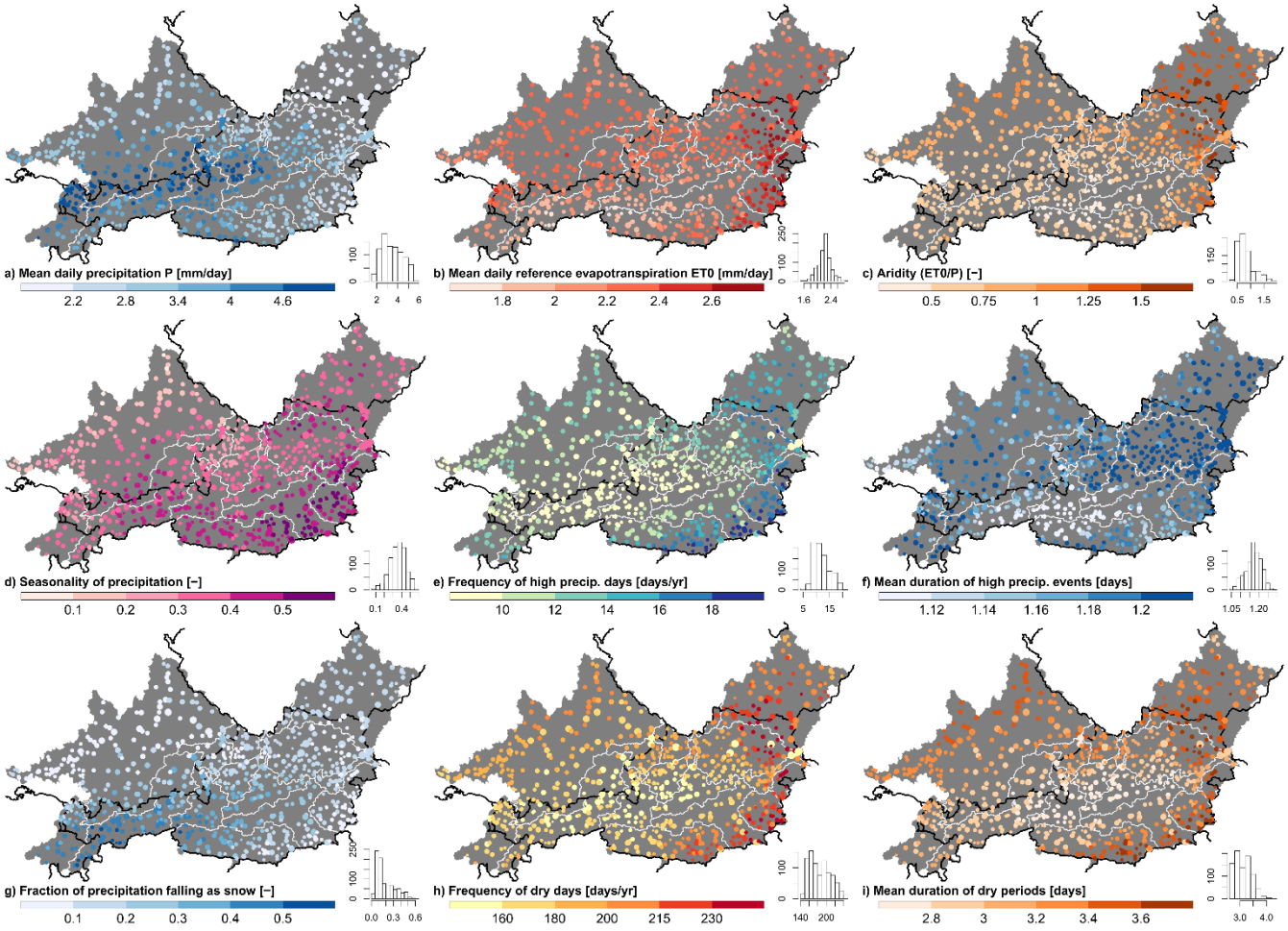
a) Mean daily precipitation P [mm/day]
2.2 2.8 3.4 4 4.6
b) Mean daily reference evapotranspiration ET0 [mm/day]
1.8 2 2.2 2.4 2.6
c) Aridity (ET0/P) [−]
0.5 0.75 1 1.25 1.5
d) Seasonality of precipitation [−]
0.1 0.2 0.3 0.4 0.5
e) Frequency of high precip. days [days/yr]
10 12 14 16 18
f) Mean duration of high precip. events [days]
1.12 1.14 1.16 1.18 1.2
g) Fraction of precipitation falling as snow [−]
0.1 0.2 0.3 0.4 0.5
h) Frequency of dry days [days/yr]
160 180 200 215 230
i) Mean duration of dry periods [days]
2.8 3 3.2 3.4 3.6

Fig. 6

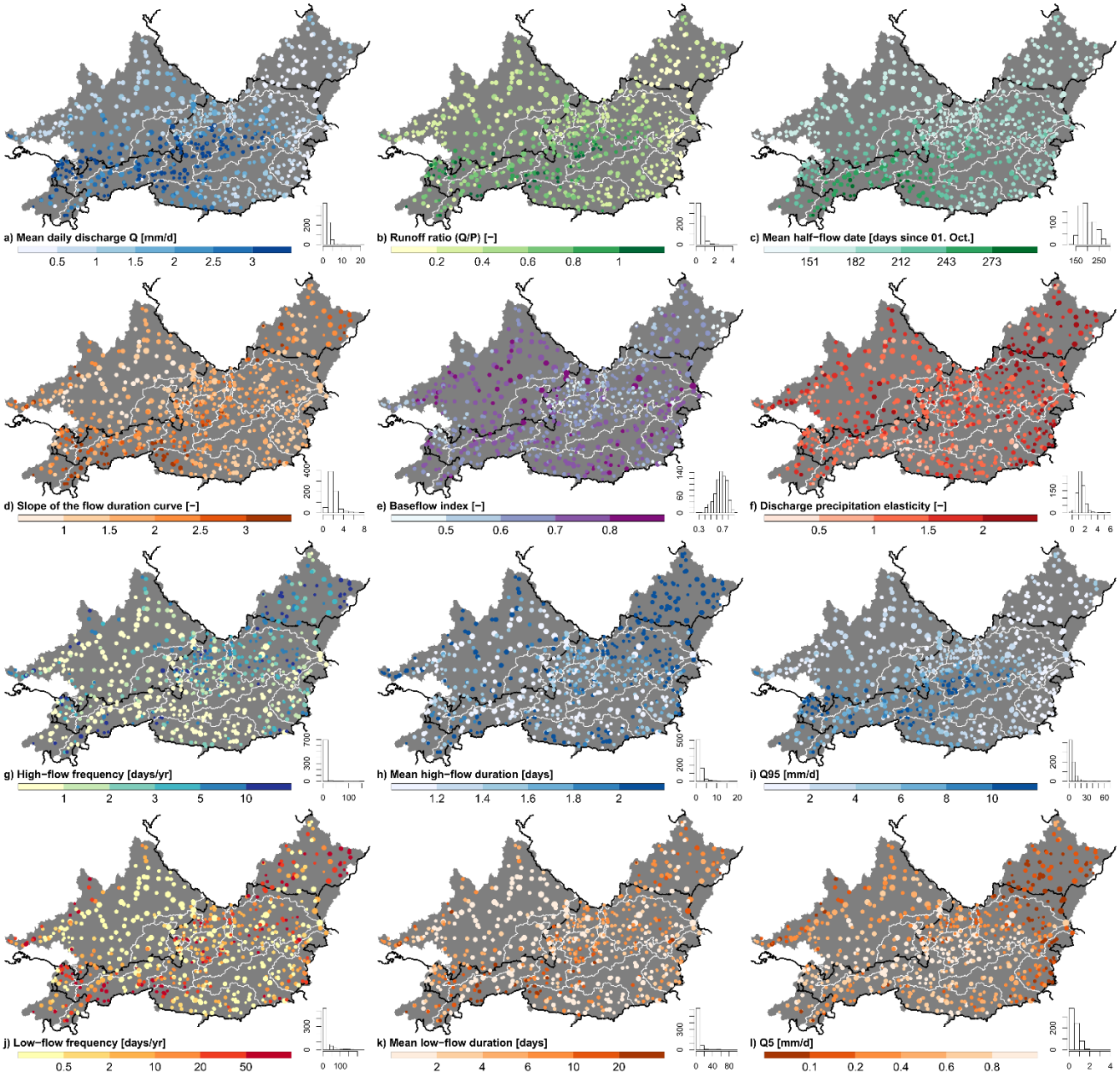
a) Mean daily discharge Q [mm/d]
0.5 1 1.5 2 2.5 3
b) Runoff ratio (Q/P) [−]
0.2 0.4 0.6 0.8 1
c) Mean half−flow date [days since 01. Oct.]
151 182 212 243 273
d) Slope of the flow duration curve [−]
1 1.5 2 2.5 3
e) Baseflow index [−]
0.5 0.6 0.7 0.8
f) Discharge precipitation elasticity [−]
0.5 1 1.5 2
g) High−flow frequency [days/yr]
1 2 3 5 10
h) Mean high−flow duration [days]
1.2 1.4 1.6 1.8 2
i) Q95 [mm/d]
2 4 6 8 10
j) Low−flow frequency [days/yr]
0.5 2 10 20 50
k) Mean low−flow duration [days]
2 4 6 10 20
l) Q5 [mm/d]
0.1 0.2 0.4 0.6 0.8

Fig. 7

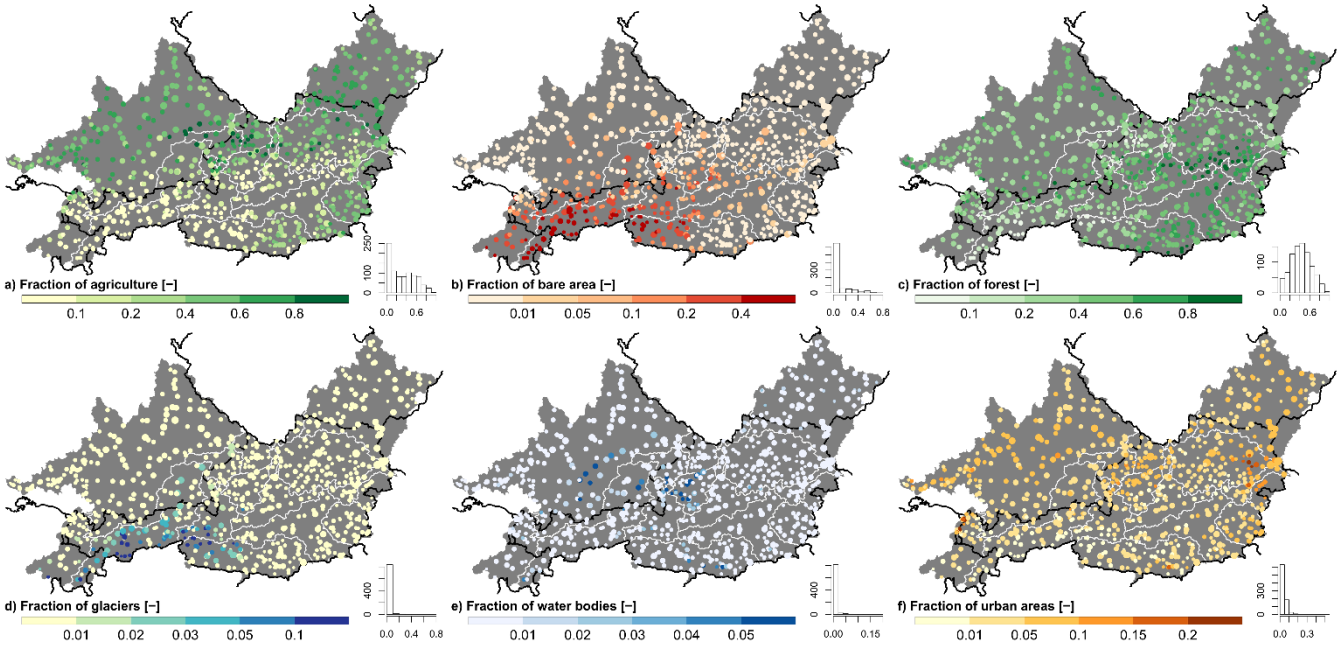
a) Fraction of agriculture [−]
0.1 0.2 0.4 0.6 0.8
b) Fraction of bare area [−]
0.01 0.05 0.1 0.2 0.4
c) Fraction of forest [−]
0.1 0.2 0.4 0.6 0.8
d) Fraction of glaciers [−]
0.01 0.02 0.03 0.05 0.1
e) Fraction of water bodies [−]
0.01 0.02 0.03 0.04 0.05
f) Fraction of urban areas [−]
0.01 0.05 0.1 0.15 0.2

Fig. 8

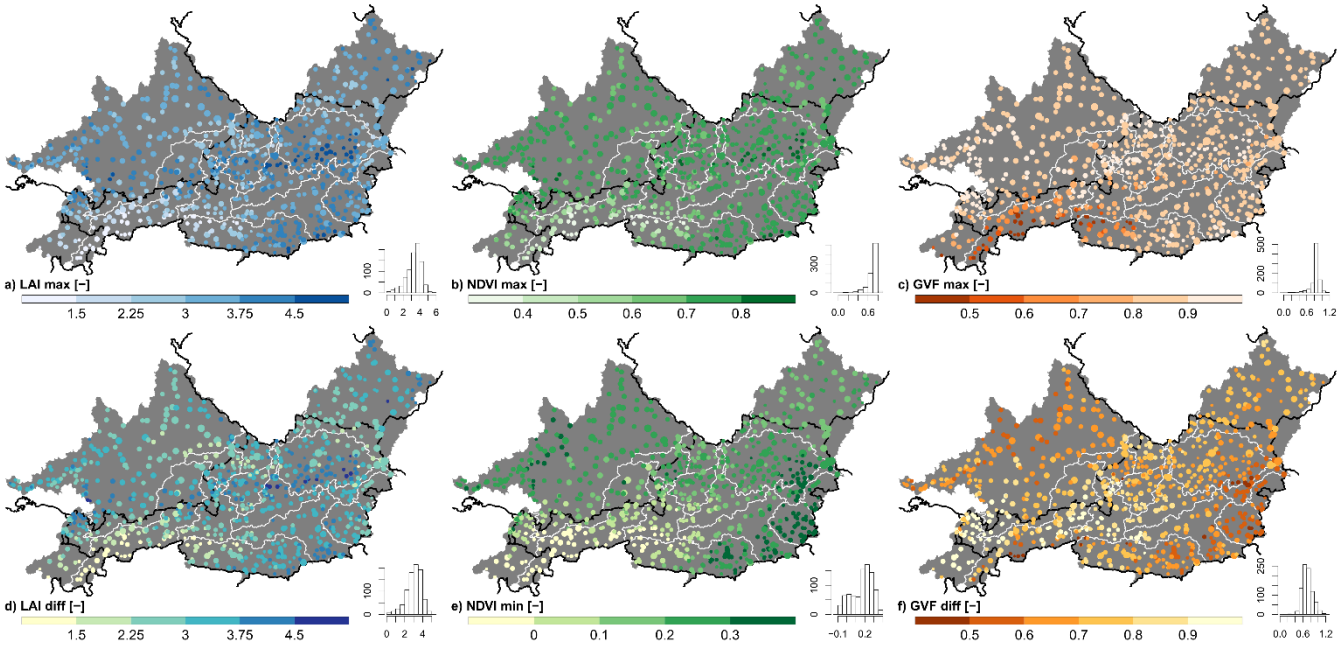
a) LAI max [−]
1.5 2.25 3 3.75 4.5
b) NDVI max [−]
0.4 0.5 0.6 0.7 0.8
c) GVF max [−]
0.5 0.6 0.7 0.8 0.9
d) LAI diff [−]
1.5 2.25 3 3.75 4.5
e) NDVI min [−]
0 0.1 0.2 0.3
f) GVF diff [−]
0.5 0.6 0.7 0.8 0.9

Fig. 9

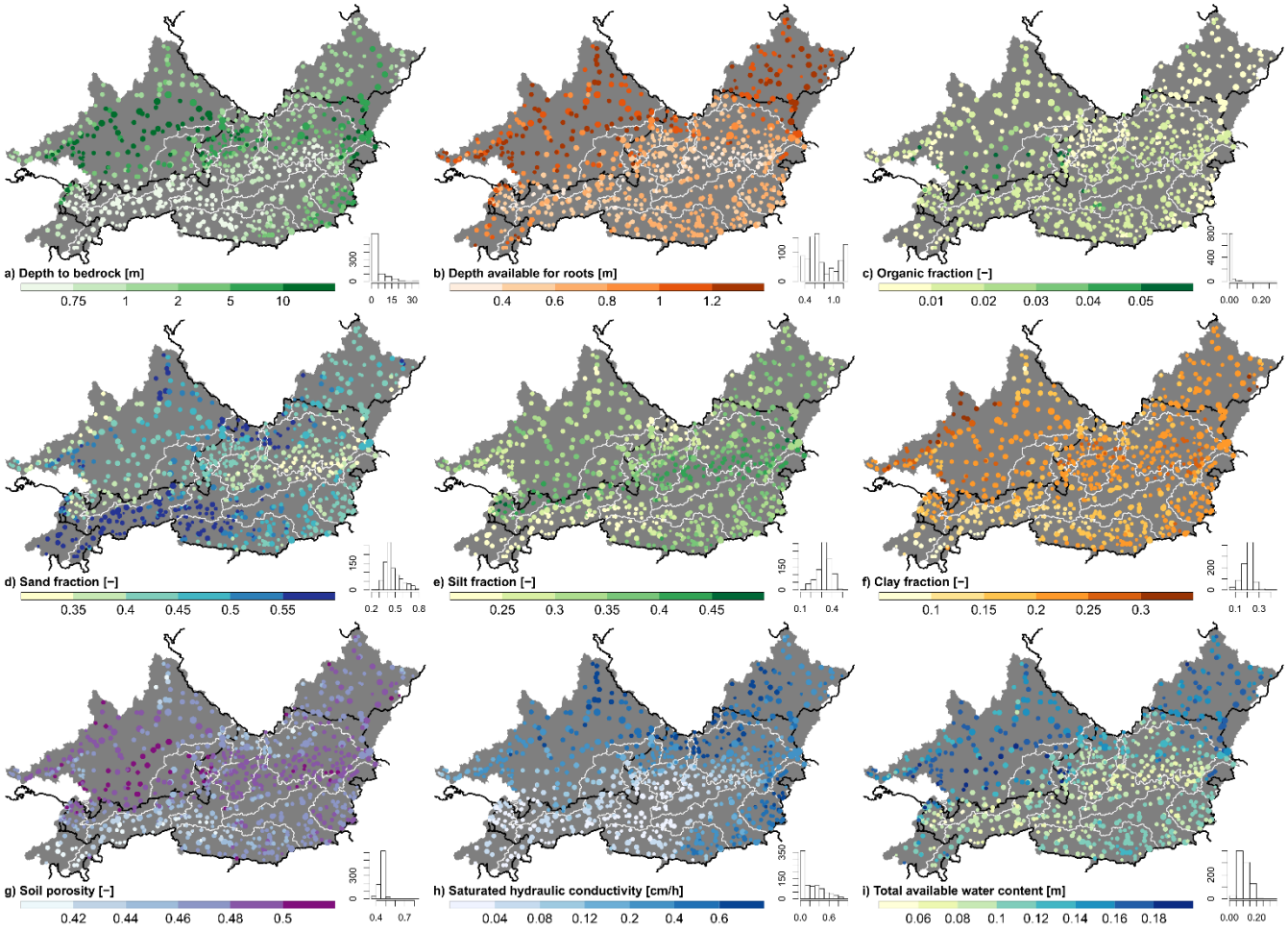
a) Depth to bedrock [m]
0.75 1 2 5 10
b) Depth available for roots [m]
0.4 0.6 0.8 1 1.2
c) Organic fraction [−]
0.01 0.02 0.03 0.04 0.05
d) Sand fraction [−]
0.35 0.4 0.45 0.5 0.55
e) Silt fraction [−]
0.25 0.3 0.35 0.4 0.45
f) Clay fraction [−]
0.1 0.15 0.2 0.25 0.3
g) Soil porosity [−]
0.42 0.44 0.46 0.48 0.5
h) Saturated hydraulic conductivity [cm/h]
0.04 0.08 0.12 0.2 0.4 0.6
i) Total available water content [m]
0.06 0.08 0.1 0.12 0.14 0.16 0.18

Fig. 10

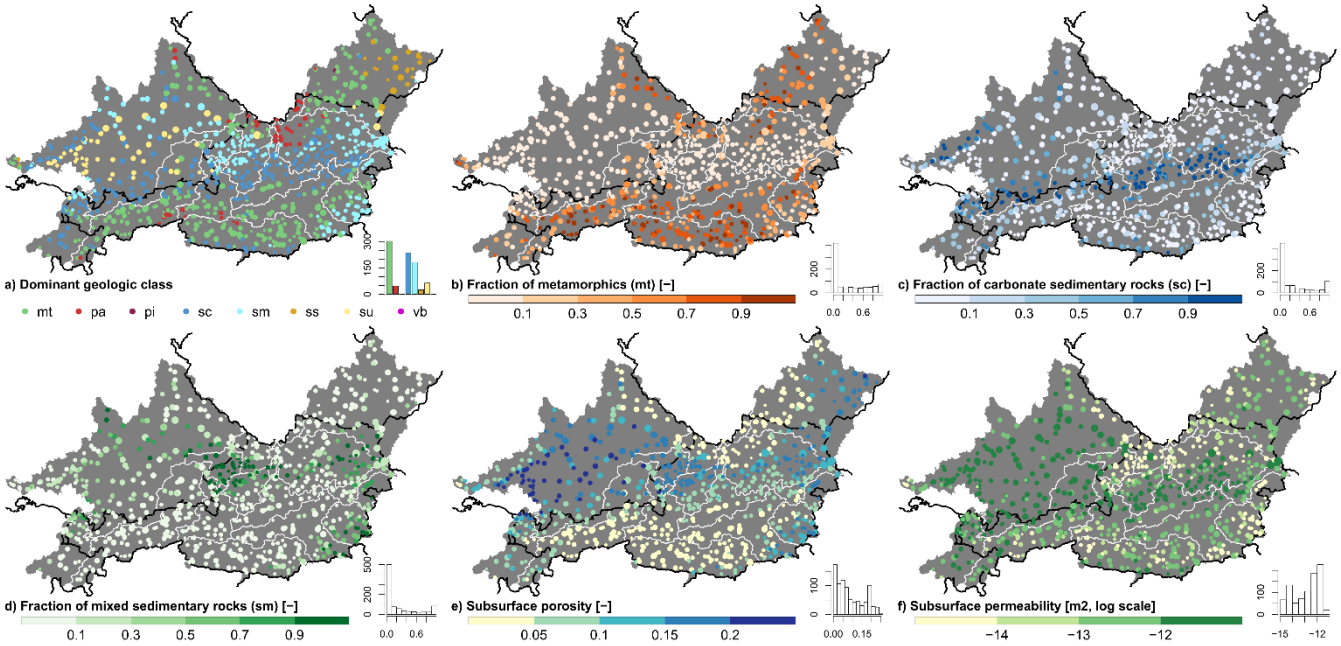

Fig. 11

5. *L20 and L57 'data basis' – unsure what is meant here. Can it be rewritten so it is clear?*

Thanks for the comment, in L20 we propose to rewrite the sentence and in L57 to use the term the term "dataset" instead.

~~We discuss not only the data basis and the methodology of data preparation, but also focus on possible limitations and uncertainties.~~

We describe not only the used basic datasets (e.g. for elevation) and methodology of data preparation, but also focus on possible limitations and uncertainties.

6. *L42 'are probably known to a broader audience' – can you make a more pertinent point here? What is significant about these particular missions?*

Sentinel, MODIS and Landsat are famous and popular remote sensing products. We propose to remove this sentence, because it doesn't really add valuable information to the manuscript.

~~The Sentinel (ESA, 2021; Malenovsky et al., 2012), Landsat (NASAa. 2021; Irons et al., 2012) and MODIS (NASAb, 2021; Barnes et al., 2003) missions are probably known to a broader public.~~

7. *L68 'and the United Kingdom' – this should be 'and Great Britain'*

You are of course right - we will change it according to your suggestion.

8. *L89 'in nine different countries' – I would remove the word 'different' here.*

Please see 17).

9. *Figure 1. Can you add the size of the circle to the legend in the plot making it clear how the circle size relates to catchment area?*

Thank you for your suggestion. We have added a legend to the figure. Reviewer 1 has suggested to highlight the macro- river region (i.e. Danube A, Danube B, Rhine and Elbe). Water from river regions declared with "Danube B" join the Danube outside Austria.

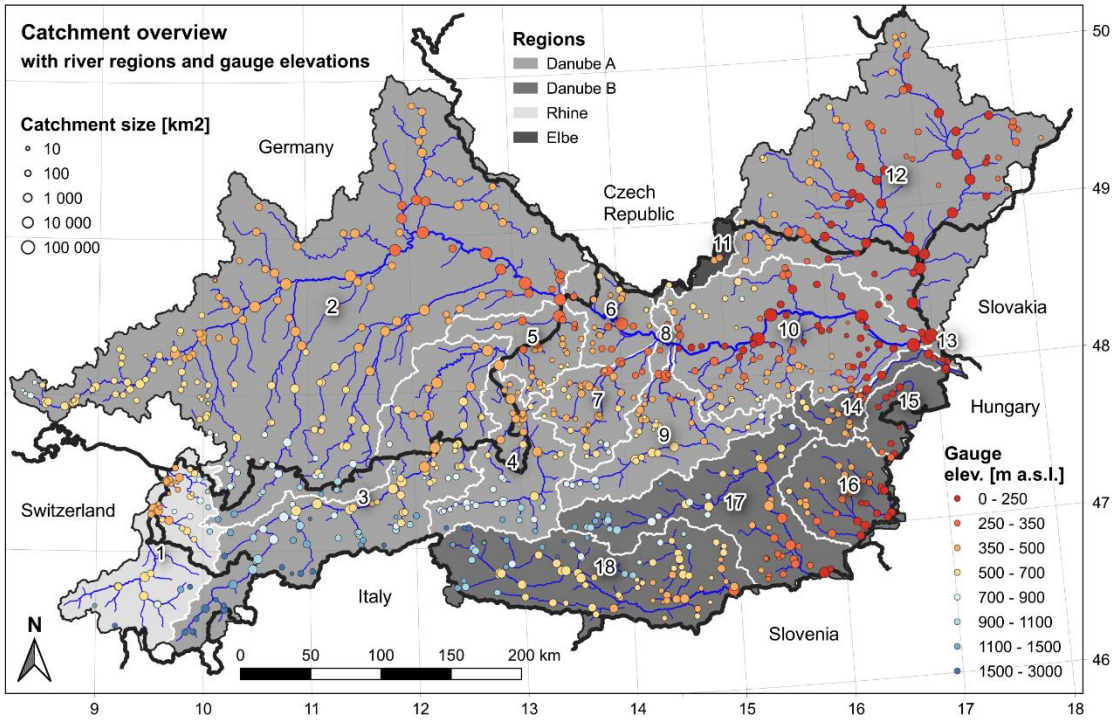

Fig. 1

10. *Table 1. I don't think Table 1 adds much to the paper and would move to supplementary information.*

We agree and propose to move Table 1 to Appendix B.

11. *L159 'respectively 61 runoff time series' – this doesn't make sense.*

Thank you for your comment. We have reformulated the sentence.

~~The hydrographical services of the German federal states Bavaria (GKD, 2020) and Baden Württemberg (LUBW, 2020) provided 125, respectively 61 runoff time series.~~

The hydrographical services of the German federal states Bavaria (GKD, 2020) and Baden-Württemberg (LUBW, 2020) provided 125 and 61 runoff time series, respectively.

12. *L165 It is not just changes in channel profile that lead to incorrect runoff calculation but also extrapolation of the rating curve, backwater effects etc. It may be worth expanding this a little and citing McMillan et al (2012) here (https://doi.org/10.1002/hyp.9384).*

We fully agree with your comment. Thank you for pointing to McMillan et al. (2012). We propose to extend the sentence as follows:

~~Changes in channel profile, e.g. after floods with strong bedload transport, can lead to an incorrect runoff calculation.~~

Changes in channel profile, e.g. after floods with strong bedload transport, extrapolation of the rating curve or backwater effects and transient runoff conditions (runoff hysteresis) can lead to an incorrect runoff determination (McMillan et al., 2012).

13. *L171. When you aggregated the hourly timeseries to daily – what time period do you use? For example, daily flow timeseries in the UK is the mean river flow in a water-day, (09.00 to 08.59 GMT, for example; 09.00 1st December to 08.59 2nd December).*

Thank you for this comment and it is a really important information. In Austria (7:00 to 6:59 CET of the following day) it is quite the same than in UK. We decided to aggregate from 0:00 to 23:59, as the timestamps are probably different in each country.

However, we normally requested only the time series with hourly resolution and derived the daily time series from them. Thereby the hourly values of the respective day were used for determining the daily values (as well as for the meteorological variables), e.g. for 01.01.1981: 01.01.1981 00:00 to 01.01.1981 23:59 GMT.

14. *L184. Personally I would not interpolate any timeseries and leave this up to the data user.*

Thank you for the comment. The interpolation is certainly not a big deal for scientific users. However, since the dataset is also intended for other users (e.g. consulting offices, ministries), we decided to interpolate 6 hours linearly and export the interpolated timesteps in an additional text file "LamaH\D_gauges\2_timeseries\gaps". We kindly hope for your understanding.

15. *Fig 3. Figure 3a legend title should be 'Start of continuous data record'. I also think the x-axis on the histogram in Figure 3b is incorrect – should go from 0 – 100%?*

Caption of Figure 3a was changed, see our answer at 4). The fraction of gaps in each runoff time series (Figure 3b) are plotted in [‰]. In Fig. 3b the last class is set to >50‰ because only few gauges have more than 50‰ gap fraction in their time series.

16. *L190. I am unclear what you mean by 'gauge hierarchies'?*

The gauge hierarchy indicates the order of the gauge within the interconnected river network. Please find more information in the caption of Fig. 2) in 1.3). We hope that our response can clarify the ambiguity.

17. *L270. 'for each of the 3 different basin delineations' – you don't need 'different' here and can be worded as 'for each of the 3 basin delineations'. Also L423, L601 and L602 – you don't need the word 'different' here.*

Thank you for your comment, we removed the term "different" in many cases.

18. *L310. What do you mean by 'large notches in catchment shape'?*

We meant irregular incisions in the shape of the catchment area. We propose to remove this sentence, because it doesn't add relevant information for the users.

~~But irregularities like large notches in catchment's shape may reduce the significance of this attribute.~~

19. *L555. What do you mean by 'herding'?*

We propose to change the term to "weed".

20. *L605. I disagree that 'These uncertainties have been addressed'. They have been considered and discussed but I wouldn't say they have been addressed as many are not quantified in the dataset.*

Thank you very much, we have definitely not described all sources of uncertainty. We propose to change the sentence as follows:

~~It is clear that LamaH also contains deficits and uncertainties, also due to the large number of data sources included. These uncertainties have been addressed.~~

It is clear that LamaH contains deficits and uncertainties due to the large number of data sources included. We however tried to consider and discuss most of these limitations.