Authors' Response to Reviews of

Technical note: Comparing three different methods for allocating river points to coarse-resolution hydrological modelling grid cells

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RC: ***Reviewers' Comment***, AR: Authors' Response, ☐ Manuscript Text

1. Reviewer #1

1.1. General comments

RC: ***The paper investigates different method to allocate locations of stream gauges to the correct river cell in course resolution distributed hydrological models. Three different methods are investigated and compared for the French southeastern Mediterranean region. The methods are based on 1) upstream area and distance; 2) high-resolution river topology; and 3) catchment contour. The methods are compared based on the overlap between the high resolution catchment contour of the gauge and the low resolution catchment contour of the model upstream from the allocated river cell. The topic is relevant and often overlooked. The paper is also generally well written and the methods are mostly well described. However, I have some concerns about the methods and the results as outlined below. I therefore recommend major revisions of the paper.***

AR: First of all, we would like to thank Reviewer #1 for the careful read of our manuscript, and for the emphasis they have placed on understanding each method. We provide point to point answers below, including details about the corresponding modifications of the manuscript.

1.2. Main comments

RC: ***For gauges which are located between two confluences within one cell, see e.g. P3 in Figure 3, the authors state that these cannot be allocated to the correct river cell using method 2, but can be allocated using method 1 and 3. In my opinion, the only correct allocation would be to both upstream cells (e.g., cells C3 and C5), by comparing the sum of the model discharge against the observed discharge. With method 1 and 3, while the method does assign the gauge to a single cell, I think that is an incorrect allocation for these cases. This is not discussed in the paper. Also, with a small extension, method 2 would actually be able to correctly allocate the gauge to both cells.***

AR: We would rather speak of imperfect allocations than of incorrect allocations for all methods which is an inevitable consequence of the limited spatial resolution provided by the grid cells. In case of figure 3, methods 1 and 3 will probably allocate point P3 to one of the grid cells C3, C5 or C6 depending on the shape of the upstream river network which is not illustrated on the figure. The case of point P3 corresponds to 2% of all the river points to be allocated in the considered region. Method 2 was thought as a simple allocation method consisting in going up and down along the river network, and it did not appear necessary to look for cells outlet points upstream confluences. To discuss these choices in the paper, we suggest to add the following text in Section 4.1, after Table 1:

It is also important to note that river points similar to P3 in Figure 3, i.e. points located between two confluences within the same grid cell, are not allocated with Method 2. These points represent about 2% of the total number of points to be allocated in the considered region. One potential solution could consist in selecting, among the closest upstream or downstream outlets of grids, the one with the nearest usptream watershed area. Another solution would be to allocate P3 to both upstream cells (C3 and C5 in Figure 3), however in this paper we chose not to permit the allocation to several grid cells. In these cases, Method 2 detects that all allocations to a single grid cell will be imperfect, which is why it was not deemed essential to propose an allocation solution for these specific points, for the sake of comparison.

We also suggest to replace the second paragraph in section 4.2 with:

In its state, Method 2 cannot allocate 100% of the river outlets, even though it could with a small extension (see previous section). Method 3 was able to allocate the excluded outlets successfully, with a mean CSI of 0.7. Additionally, Figure 7 highlights that Method 3 consistently yields a minimum CSI of around 0.25, whereas Method 2 falls below 0.05 (with 12 river points having CSI < 0.25). Figure 8 provides a more detailed comparison of CSI scores between Method 2 and Method 3. It clearly demonstrates the consistent superiority of Method 3 over Method 2. ...

RC: ***The authors compare the different methods based on the CSI of overlapping catchment contours, which is also optimized in the allocation process of method 3. I find this single metric for benchmarking the different methods too limited. For a fair comparison, it would be better to use multiple metrics including difference in upstream area (which is also easier to understand). Or if possible, use manually allocated gauges as a reference, to understand the true errors made by each method.***

AR: The manual allocation would indeed serve as a good reference to understand the true errors made by each method, however it would be a very time-consuming for the 2580 river points of the study case and manual allocations are also deemed to errors... However, we argue that the difference in upstream areas (UPA) metric can be misleading, as explained on figure 1 (in the article), and should be considered with caution. We also maintain that, in this work, the addressed problem is the correct delineation of the basin contours, rather than the correct value of upstream watershed area.

We have nonetheless calculated the difference in UPA relative to each method, and the results are presented on figure 1.

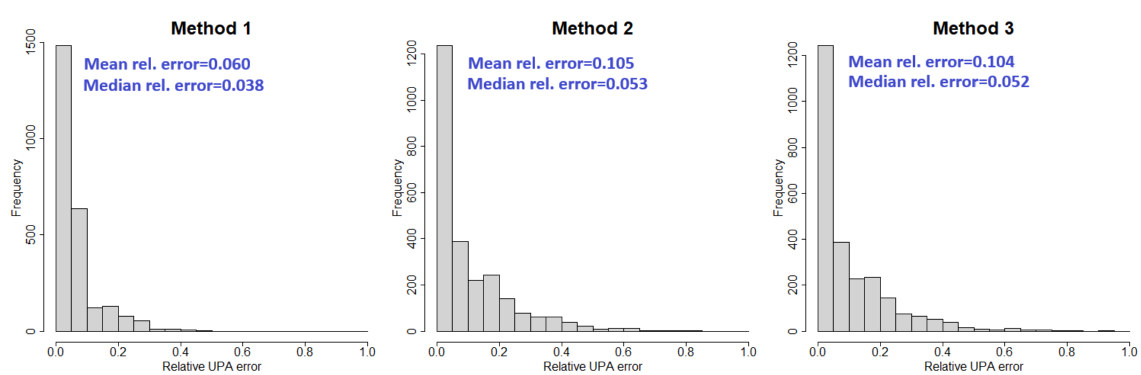

Figure 1: Results of the calculation of difference in UPAs

As expected, Method 1 provides the best results according to this metric. The problem is that it doesn't account for all the cases where a river point is allocated to a hydrological modelling cell describing a different upstream catchment, if they have similar UPAs. We suggest to add this figure in the manuscript to support the fact that an evaluation based on UPA comparison can be misleading. We therefore suggest to add the following text at the end of section 4.2:

> Finally, the difference in UPAs between each reference catchment and its corresponding coarse resolution catchment was also calculated, even though we decided not to use this metric for the comparison of the three methods, in agreement with the many hydrologists (e.g. Davies and Bell, 2008) who have pointed out that an evaluation based on UPA comparison is highly uncertain. This thesis is supported by the results presented on figure 7b, which show a slightly smaller difference in upstream area for Method 1 than for Methods 2 and 3. Thus, comparing the three allocation methods based on this criterion only would be misleading, because it would not account for all the cases where a river point is allocated to a hydrological modelling cell describing a different upstream catchment, if they have similar UPAs. However, these results show that the relative difference in UPAs remain limited (mostly lower than 15%) for all three methods.

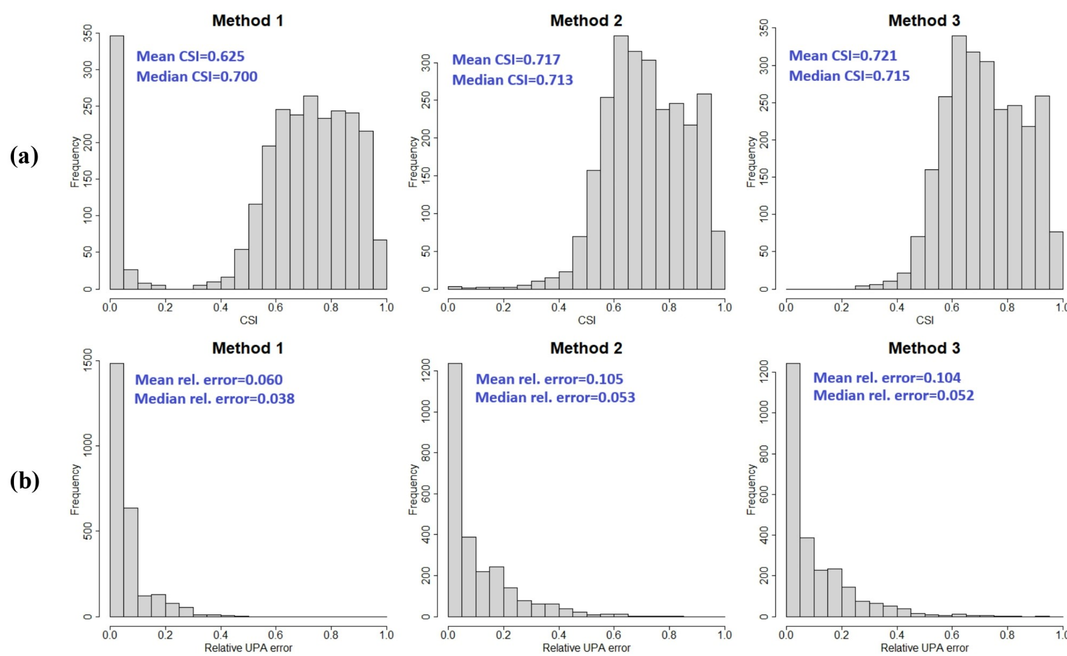

Figure 7: Histograms of (a) CSI values and (b) UPA relative error for the three allocation methods

1.3. Minor comments

RC: ***It would be helpful to illustrate in Figure 2-4 to which river cell the gauges are allocated.***

AR: This is already indicated in figure 3 (see Allocation process). However, in the revised manuscript, the allocated grid cells will be indicated in the captions of Figures 2 and 4.

RC: ***Line 89: Consider using a more commonly used notation for CSI (see e.g., Fleischmann et al., 2019). It is also not entirely clear to me how the CSI is calculated because of the different resolutions of the catchment contours. Is the CSI calculated based on the low resolution catchment contour of the model or the high resolution catchment contour of the gauge? This could make quite a difference for certain catchments.***

AR: As noted in line 94, the CSI is sometimes known as Figure of Merit, Intersection over Union Index, and is also referred as Fit metric as in Fleischmann et al., 2019 (this will be added in the text). All these scores are scrictly identical, and to our knowledge, the Critical Success Index remains the most generic term used in the litterature for this metric, which is widely used when dealing with contingency tables. We thus suggest to modify line 94 as following:

> It can be noted that the CSI has often been used with alternative denominations in previous studies, such as the Intersection over Union criterion (Munier and Decharme, 2022; Burek and Smilovic, 2022), the Figure of Merit (Li and Wong, 2010), or Fit Metric (Fleishcmann et al., 2019).

The CSI is calculated here based on the high resolution catchment contour of the river point. In order to clarify this point, we suggest to add the following text line 104:

> ... and will be used hereafter. The CSI is calculated based on the low resolution catchment contours (reference contours).

RC: ***Line 94: The inline formula is hard to read and the variables unclear as they refer to criteria used in other papers. Could the authors explain the variables shortly here to make interpretation easier?***

AR: We suggest to remove the formula, and only keep the text as written in the previous answer.

RC: ***Figure 9: Can you add the outflow points of all cells in Figure 9B to better understand why the cell just upstream from the gauge is not found?***

AR: We have added the outflow points of all cells in Figure 9B. We have also drawn small tributaries that did not initally appear because their upstream area is inferior to $5km^2$. However here they help understand why the cell just upstream from the gauge is not an option (its outlflow point represents the very small tributary, which has a smaller upstream area but occupies more space in the cell than the main river reach). We suggest to replace Figure 9 by the following:

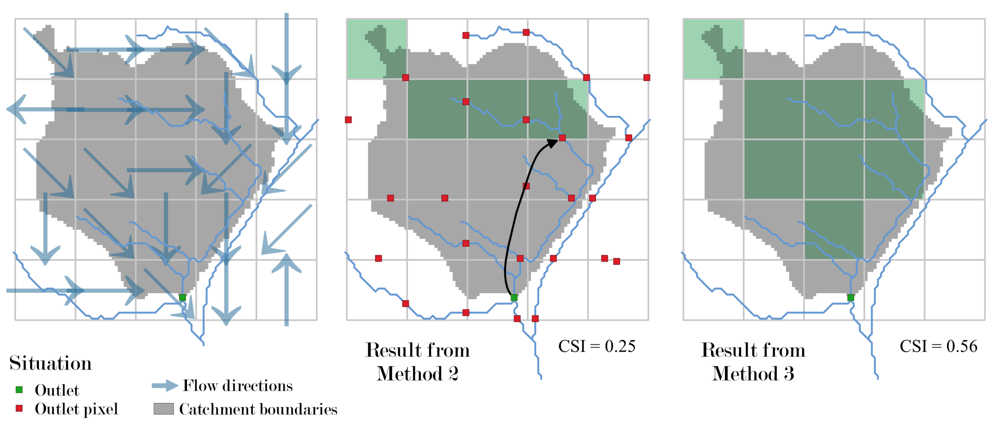

Figure 9: An example of high CSI differential between Methods 2 and 3 (basin area $12km^2$)

RC: ***Figure 10: the stacked histograms are difficult to read. Consider using a different histogram style.***

AR: We suggest to use boxplots instead of histograms, and to reduce the number of surface classes to make the figure less busy.

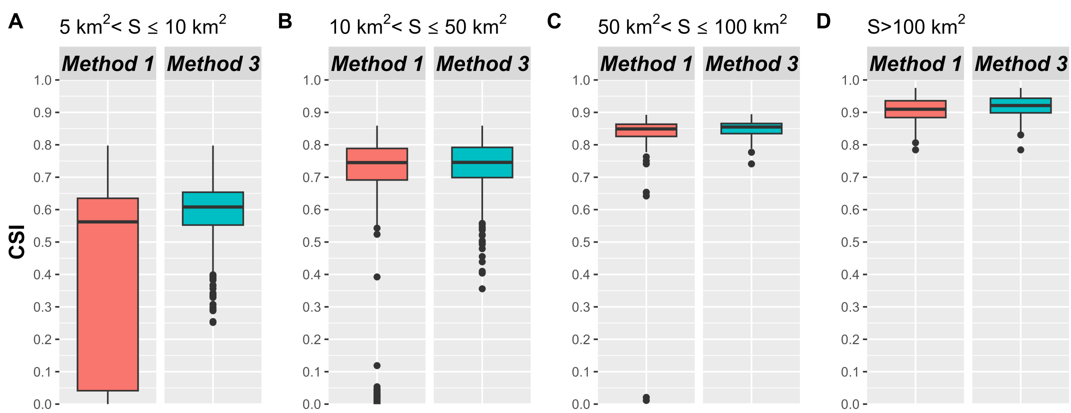

Figure 10: Boxplots of CSIs divided into classes of surfaces for Methods 1 and 3

RC: ***Line 211: It is stated that method 2 requires a vector-based description of the river network (which I guess is the same a the high resolution river topology / flow directions?). However, if I understand correctly, method 3, would require a vector-based description of the catchment contour which is not mentioned here.***

AR: Indeed, in both case, vectorial data (high resolution river topology or high resolution catchment contours) is needed. We thus suggest to remove "as well as the vector based description of the river network" from the text.

RC: ***Line 222: I suggest to mention vector-based models already in the introduction to emphasize that issue and proposed methods are specific to raster-based models.***

AR: We suggest to add the following text after the first sentence of the introduction:

> ...or evaluation purposes. Vector-based hydrological models are adequate to meet these objectives, because it is straightforward to locate a gauging station along the river network. However, when using gridded models...