Authors’ Response to Second 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 authors have improved the manuscript on most of the points raised. However, I think it would still benefit from discussing limitations of the proposed method more generally and therefore I suggest minor revisions before publication.***

AR: First of all, we would like to thank Reviewer #1 for accepting to review our article a second time, and for the very useful comments they provided each time. We will explain hereafter how we plan to adapt the manuscript according to their recommendations.

1.2. Main comments

RC: ***I suggest the authors to discuss the limitations of allocating gauges to coarse resolution gridded flow directions more generally, possibly in a separate section. The issue highlighted for method 2 also applies to method 1 and 3 and is inherent to coarse resolution grid based representation of river networks. Assigning gauges to multiple cells could limit the errors made, i.e. in the cases presented in Figure 3 and 9 the most correct result is obtained by either taking the sum of the upstream cells or difference of the downstream cells. However, errors will remain especially in cases where a coarse resolution representation of the river network is simply not possible (e.g. Figure 9). The authors are right to point out at the end of the conclusions that in these situations vector based model would circumvent issues introduced by coarse resolution gridded models.***

AR: We do agree that the limitations should appear more clearly and be a little bit more elaborated. To link up with a suggestion from Reviewer #3, we propose to introduce three subsections in the conclusion, and to change the text as follows:

> **5. Discussion and conclusions**
>
> This comparative study of methods allocating river points to coarse grid cells was driven by the shift in approach from area-based methods to contour-based methods. In this work, we compared these two categories of methods and introduced a new approach based on topological proximity.
>
> **5.1 Application domain of each method**

The study results revealed that contour-based methods were more relevant and satisfying from a hydrological point of view, although costly in terms of computing time. The introduced topology-based method is a good compromise because it leads to similar allocation quality than the contour-based method. However, it is inoperable when the fine and coarse resolutions river networks come from different data sources, since it requires the definition of "cells outlet points" as well as the vector-based description of the river network. Moreover, it cannot allocate an as many points as the contour-based method.

The area-based method generated numerous allocation errors, which the contour-based method was able to address for a significant portion of them. However, upon closer examination, it was observed that the performance gap between both methods was more pronounced for small catchments, while being less significant for larger catchments (with $S > 100km^2$). The area-based methods thus lead to satisfying results if we only consider river points with large UPAs compared to the grid cell resolution. Based on the results obtained, we would recommand a minimum factor of 100 between a river point's UPA and the resolution of the hydrological modelling grid for the application of an area-based method.

The transferability of the results outside the test area and to coarser resolutions (i.e. global hydrological models) is debatable, as there are many uncertainties and non-linearities in the representation of hydrological information at such larger scales and coarser resolutions. However, it is very likely that, with coarser resolution grids, allocation problems will increase and that errors related to area-based methods will impact larger catchments (i.e. larger than $100km^2$). Even if this needs to be verified, the "contour-based" method will certainly remain more effective at coarser resolutions than the "area-based" method.

5.2 Remaining limitations of allocating river points to coarse grid cells

Even if allocation errors are reduced, some low CSI scores remain with contour-based methods, due to the inherent difficulty of representing the boundaries of small basins at a 1km resolution. The situation illustrated in figure 9 is an example of configurations where different branches of the river system are crossing the same coarse grid cell, which makes it impossible to correctly represent the river network and basin contour with coarse flow directions. However, it is important to note that these inevitable errors resulting in low CSI scores are generally found on small catchments, and are less problematic than low CSI scores on larger catchments, because of the more limited variability of rainfall at smaller spatial scales.

A possible way to reduce these remaining errors could be to allocate river points to multiple grid cells, by either taking the sum of the upstream cells, or the difference of the downstream cells, even though it could complicate the hydrological modelling at a later stage. Another approach that could circumvent the challenges faced would be to use hydrological models structured based on vectorial objects instead of regular grids. These models preserve the topology of river networks and allow seamless integration of observational data. However, vector-based modeling also introduces its own challenges related to data and computational requirements and the need for accurate input data.

1.3. Minor comments

RC: ***Figure 2 and 4. The caption reads "In this situation, the river point is allocated to the [x,y] cell in the grid (zero-based numbering)." If possible I suggest to add row and column numbers or at least state row x and column y as the current notation is not clearly defined.***

AR: According to the recommendations of Reviewer #3, we have indicated the chosen cell with hatching on Figure

2, therefore removing the row/columns notation. On Figure 4, we suggest the following changes:

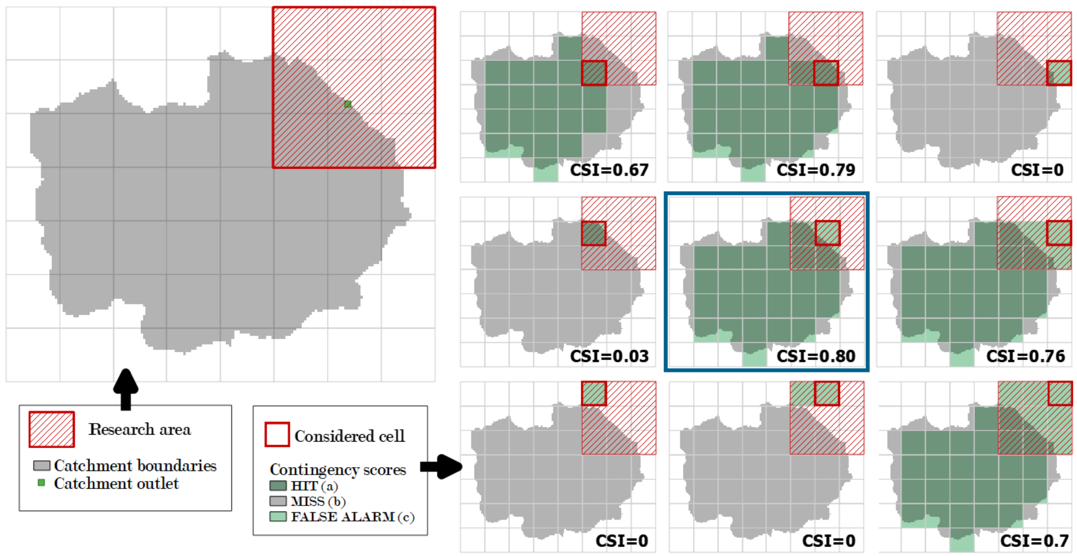

Figure 4: Illustration of Method 3: CSI calculations for the nine candidate cells. In this situation, the river point is allocated to the candidate cell of the blue box scenario, which maximises the CSI (CSI = 0.80).

RC: ***Figure 9. It seems that in this situation the flow directions on the coarse resolution cannot represent the full river network, as two rivers run parallel trough the a single cell (i.e. the cell on the upper right of the gauge). In this situation upscaled flow directions are basically inconsistent with the outlet locations. The most correct allocation would come from the difference between the two downstream cells. I suggest to add this to the discussion of this figure.***

AR: Thank you for noticing this. This issue with two rivers crossing the same cell are often at the roots of such situations, and it makes it impossible from the very start to find a correct grid cell for the allocation, though it is argued that Method 3 limits the damage in these rare situations. We propose to add the following text line 184:

> ... resulting in notable differences in UPAs. Figure 9 shows an example of these situations, which are often complex configurations where different branches of the network are in close proximity to each other, often within the same grid cell. As a consequence, the upscaled flow directions cannot represent faithfully the river network, and all candidate cells would give a mediocre allocation result. However we argue that Method 3 will give the most correct allocations in these situations.

2. Reviewer #3

2.1. General comments

RC: ***This technical note focuses on comparing three methods for allocating river points to coarser-resolution grids for hydrological modelling. The authors describe in detail the methods and evaluate them on a large area in South-eastern France. The work provides useful insights on a relevant question and therefore I believe it could be useful for the hydrological modelling community.***

AR: We would like to thank Reviewer #3 for accepting to review our manuscript and for their positive comments. We provide below detailed answers showing how we plan to adapt the manuscript according to their suggestions.

2.2. Minor comments

RC: ***Figure 2: Can you identify the coarse-grid cell in the drawing (e.g. with hatching)?***

AR: We agree that identifying the chosen coarse-grid cell in the figure would be better than in the legend. We adapt the figure as follows:

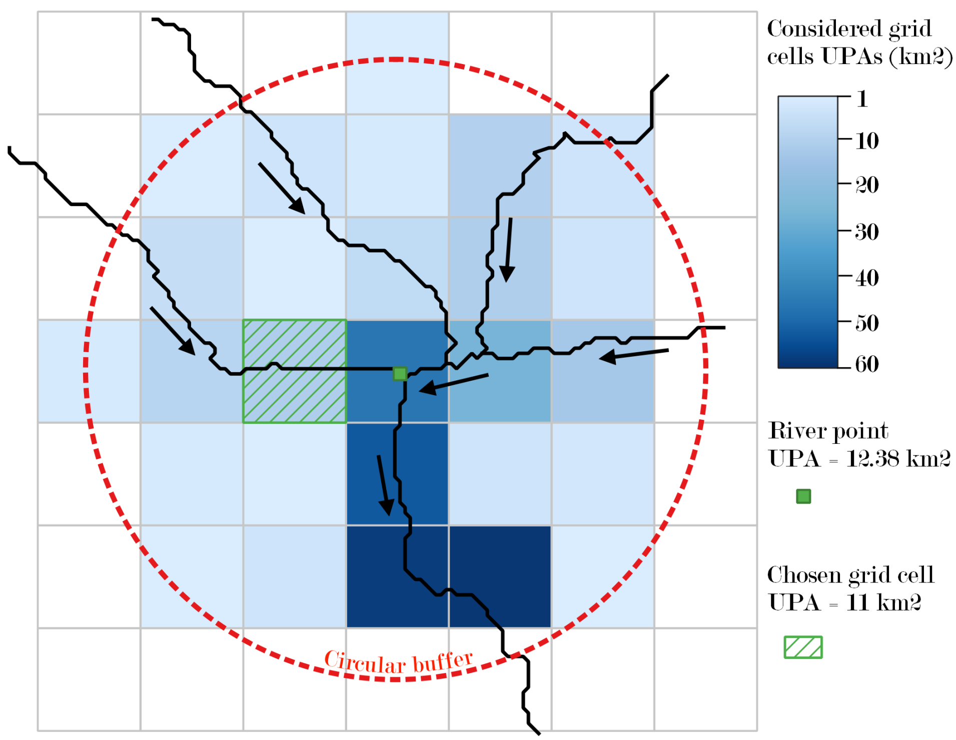

Figure 2: Illustration of Method 1: grid cells candidates for a specific river point. In this situation, the river point is allocated to the green-hatched grid cell.

RC: ***Lines 110-114: Wouldn't make sense to extend the search area first within 5x5=25 closest cells, and then within 7x7 cells?***

AR: That was our first idea too, however extending the research area from 9 to 25 cells did not correct most of the targeted cases, which had to be sought even further. That is why we directly extended to the 49 closest grid cells. We suggest to add the following sentence at line 108:

> ... is extended to the $7 \times 7 = 49$ closest grid cells. Tests carried out prior to this choice showed that extending the research area to the $5 \times 5 = 25$ closest grid cells did not allow most of the targeted cases to be corrected.

RC: ***Table 1: I assume that these computational times refer to the test area. Maybe the authors could say something about how run times could increase on larger areas. On this point, my opinion is that applying a method with long computational times might be acceptable if resulting accuracy is significantly higher than for other methods, given that river point allocation is not done routinely.***

AR: We agree. We suggest to change lines 150-151 as follows:

> Method 1 and 2 demonstrate superior performance in terms of computation times. The most time-consuming stage of Method 3 is the computation of the upstream catchment for each candidate cell, and its comparison with the reference catchment. The duration of these processes will naturally increase with the size of the considered case study and the number of points to be allocated. However, the computation times might not be considered as a crucial issue, since the allocation of river points to grid cells need do be performed only once, before hydrological modelling. Method replicability is probably a more important issue for this work. Method 2 is limited...

RC: ***Section 4.2: I am wondering how these results could change with a different coarse-grid resolution. Perhaps the authors could briefly elaborate on that***

AR: We argue in the conclusion that our results are valid for the tested resolutions, but we believe that with coarser resolution grids, allocation problems will increase and that errors related to area-based methods will probably impact larger catchments. We also believe, as it is written in the conclusion, that contour-based methods would remain more effective than area-based methods for coarser resolutions. These discussions might not be very visible, thus we have suggested, based on the recommendations of Reviewer #1, to put them in a separate section (see the answer to reviewer #1 here).