

Interactive comment on “Geostatistical prediction of flow-duration curves” by A. Pugliese et al.

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Reply to Anonymous Referee # 2

We thankfully acknowledge Referee # 2's comments, which we find extremely useful for improving the presentation of the work, enhancing its accuracy and rigorousness. We report below our replies (the actual reply is denoted by “Response”, while “Action” briefly details the revisions to the manuscript) to all referee's comments (indicated by “Reviewer”).

GENERAL COMMENTS

Reviewer:

The paper presents a novel method for prediction of flow-duration curves in ungauged basins, which is of interest to the readers of HESS and which would make a valuable

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contribution to the literature. However, before publication the quality of the paper should be improved by addressing a number of methodological and technical issues, including a better discussion of the limitations and assumptions in the method as well as the language and structure of the paper. Many of the issues were brought up by the first reviewer and since these are already mentioned I will focus this review on other aspects of the paper.

The data from several of the gauging stations are not independent since they are coming from stations that are located upstream/downstream on the same river. This would likely make it easier to predict streamflow at a new location when part of the catchment is in fact gauged and these data are used in the prediction (especially when the method is based on spatial proximity), and this might therefore limit the predictive power in completely ungauged catchments. How similar are the upstream/downstream FDCs? How does the fact that upstream/downstream stations are included affect the evaluation of the method? Please also discuss how this relates to the assumptions implicit in the different regionalisation methods that are used: the top-kriging as well as the regression-based methods.

Response:

The Reviewer raises a good point, which is of particular interest for Top-kriging because the procedure incorporates in the hydrological predictions the nested structure of the stream network (see e.g. Skøien et al., 2006), and probably less interesting for the previous regionalization studies that were used in our study only for benchmarking the results of TNDTK.

Action:

The additional analysis suggested by Referee D. Ganora (relationship between λ and δ values) will be performed by considering all catchment pairs in the study area, and also by referring at nested or unnested catchment pairs separately. This first analysis will shed some light on the relationship between the stream-network structure and similarity/dissimilarity between empirical FDCs. Also, a new analysis will be performed.

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TNDTK will be applied in cross-validation by neglecting all information collected for the site of interest, but also upstream or downstream the site of interest, and the performance of the procedure will be compared with the performances obtained through the leave one out cross validation (LOO). A discussion of the results of these two additional analysis and additional diagram will be included in the revised manuscript.

SPECIFIC COMMENTS

Reviewer:

Abstract. There is a lot of information about the method in the abstract but very little information about the results (only one sentence), more information about the findings of the study should be given.

Response:

We thank the referee for the suggestion.

Action:

We will add some more lines about the results in the revised abstract.

Reviewer:

Page 13058, line 4. The aim, part (iii) could be better formulated to rather be about “to evaluate” the method in comparison to other regionalisation methods instead of “to use”.

Response:

We agree with the Referee.

Action:

We will replace “use” with “evaluate”.

Reviewer:

Since data from some of the basins in the study region are used in Fig 1 it would make more sense to describe the study region and data as the second section after the introduction, otherwise it is not clear what the basin numbers in Fig 1 refer to.

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Response:

We understand Reviewer point, but we prefer to have a classical structure for our manuscript, i.e. theoretical concepts presented before the study area and practical application. Action:

We will include a reference to Section 4 – Study Area in the manuscript body when Fig. 1 is recalled, and we will also refer to Section 4 in Fig. 1 caption.

Reviewer:

Page 13066, line 14. “Rather dense raingauge network” specify this in terms of numbers of gauges per km^2 .

RESPONSE:

Agreed.

Action:

The revised manuscript will report an indication of the raingauge network density (i.e. 1 raingauge per $\simeq 50km^2$)

Reviewer:

Page 13068, Line 6-9. The cross-validation is described as “comprehensive”, but ideally (if there are more catchments than in this case) one would set aside a whole set of catchments in a separate validation set, which would then constitute a stronger test than a cross-validation. Also, what does “As anticipated” refer to here?

Response:

Split-sample validation is a powerful validation procedure, which is routinely used in some hydrological studies, but it is seldom adopted for testing regional models. LOOCV is a standard validation approach for evaluating the accuracy of regional models as, once the model structure is set, it simulates the ungauged conditions at each and every site in the study region (this is why we used the term “comprehensive”). Therefore it provides very valuable information on how the proposed model is supposed to perform when applied to ungauged sites in the study area. There is a vast hydrological literature

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on statistical regionalization in which LOOCV is used (these are only a few recent examples: Kroll and Song, 2013; Laaha et al., 2013; Salinas et al., 2013; Srinivas et al. 2008; Wan Jaafar et al., 2011)

Action:

The sentence will be reformulated as follows: "As mentioned in Section 1, a leave-one-out cross-validation ..." will replace "As anticipated, a comprehensive leave-one-out cross-validation ...".

Reviewer:

Page 13068, line 10-20. It is not clear if the gauging station for the ungauged station is removed before the estimation of the variograms. If not, why is this not done? If it is included then some of the information from the ungauged basin is used in the method and it is not truly a prediction for an ungauged basin. Please clarify this.

Response:

We run set of preliminary investigations to assess the sensitivity of empirical semivariogram to the LOOCV, and the results pointed out negligible variations.

Action:

The preliminary analyses will be explicitly mentioned in the revised manuscript.

Reviewer:

Page 13068, line 16. The choice of $n=6$ neighbouring stations needs to be better motivated. This could be done by presenting a figure of cross-validation results plotted against the number of surrounding stations used.

Response:

We thank the referee for the suggestion and we will add that figure in the revised manuscript. We invite the referee to read the answer we give to Referee D. Ganora , were we also explain how we want to modify the manuscript.

Reviewer:

Page 13068, Line 23 to Page 13069, Line 4. This information is quite general and

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vague, and the steps i-iv in cross-validation methods are probably obvious to most readers, so this could be excluded.

Response:

Agreed.

Action:

The steps will be omitted by dropping the text that follows ", but the rationale is the same."

Reviewer:

Page 13074, Line 10 "More accurate predictions for 10 out of 18 catchments", this is still just about half of the cases and does not distinctly "confirm good performance". Please write this in a more nuanced way.

Response and Action:

Agreed. We will take into account this advise in the revised manuscript.

Reviewer:

Page 13075, Line 11-12 and Page 13078, Line 14-16. It is highlighted as an advantage that the method only relies on spatial proximity, however this may also be an important limitation of the method in other regions where e.g. geology have a larger impact on streamflow such that the hydrological behaviour of nearby catchments may be quite different. In the study, there was also poorer performance for the 3701 catchment that had a different behaviour. This limitation and the general applicability of the method in other areas should be better discussed.

Response:

Point taken.

Action:

The sentence indicated by the Reviewer in the Conclusions (p. 13078) will be integrated with a brief discussion of the sensible point raised by the Reviewer.

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Reviewer:

The Conclusions section is too long, it is about as long as the discussion section. In its present form it is written as an extended abstract describing the whole study. It would be better to just shortly (e.g. with a few bullet points) describe the main findings/conclusions that can be drawn from the paper, the rest of the information does not need to be repeated here.

Response:

The referee is right.

Action:

We will reduce the length of the Conclusions by removing redundant lines and focusing on the study outcomes.

Reviewer:

Table 1. This table should show the characteristics for each basin instead of the statistics for the whole dataset to make it possible to interpret the results for the different basins. It should also give the number of years with data for each catchment.

Response:

Agreed.

Action:

The complete set of catchment attributes will be illustrated in annexed diagrams (e.g., PNG images accessible via "Supplement link"). Unfortunately, some of the data cannot be freely distributed, but their graphical representation can.

TECHNICAL COMMENTS

Reviewer:

Table 1. Too many significant digits are given for MAP.

Figure 1. should be "thick line" instead of "tick line"

Figure 3. Show maps of MAP and MAF as well.

Figure 6 and Figure 8. No units are given on the axes.

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Page 13058, line 8. The abbreviation MAP for Mean Annual Precipitation should be introduced here and used consistently for the remainder of the paper. The English language needs to be checked throughout the paper since the text is full of minor grammatical errors (e.g. using "then" instead of "than" in many places, "reminder" instead of "remainder" on p 13067, line 11, "routinely" should be "repeatedly" on p 13060, line 2, etc). I also recommend avoiding the use of emphasis words such as "very", "excellent", "extremely", "scrupulously", "superior", etc. Grammatically it would be more consistent to also write the steps 1-6 in the cross-validation on Page 13068 in the past tense instead of present. The paper could also benefit from a revision of the text to reduce repetition, e.g. Page 13074, Line 2-5 is repeated information and could be excluded.

Response and Action:

We agree with the Referee. We will take all of his suggestions (thanks!) into account while revising our manuscript.

REFERENCES

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