Hydrology and Earth System Sciences Discussions

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Reply on RC5

Damien Delforge et al.

Author comment on "Detecting hydrological connectivity using causal inference from time-series: synthetic and real karstic study cases" by Damien Delforge et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-445-AC4, 2021

1. General Response

Dear reviewer, we would like to thank you for your attention to the preprint manuscript and the helpful comments you made. Below are detailed responses to each of your major and minor comments. We hope they will answer your questions and expectations.

To improve the preprint based on the comments made by all the reviewers, our revised manuscript contains minor revisions throughout the document, a revision of the methodology section where some details of supplementary materials about the methods and their tests are included to make it more clear and self-explanatory, and a rewriting of the discussion section. Regarding the discussion, based on your remarks and those of the other reviewers, we will rewrite the section with improved references and comparisons to the literature on the following topics:

- a summary and appreciation of our results (in terms of type of connectivity as well);
- a particular focus on the estimation of Conditional Mutual Information (CMI) concerning missing values, record length, dimensionality, the nature of the dependencies, or noise;
- and practical recommendations for the uses of causal inference methods and future research perspectives.

Concerning point 2 and the virtual experiment, the other reviewers encourage us to extend the virtual experiment to study the effect of the sample size and/or the number of variables. This was not your request. For your information, we have decided not to comply with this request for multiple reasons that will be reflected in the revised discussion (point 2), as any reader may have the same concerns. You will find the motivations in our answers to the other reviewers.

Thank you again for your contribution to this discussion,

Damien Delforge

2. Major Comments

2.1 Major Comment 1

I was confused about the difference between the original dataset and the differenced dataset when comparing the outcomes of the methods. I am not sure what was differenced to produce such different results within the method. Further clarification on this would be great.

Other reviewers have also asked for clarification. The first-order difference is the time-series obtained by subtracting the values at the previous time step, i.e., Y_t-Y_(t-1). The differenced dataset is the first-order difference of the time series of the original dataset. This is now mentioned explicitly with a better motivation of the underlying reasons, as requested by other reviewers as well.

2.2 Major Comment 2

When you find contemporaneous links, could this be due to shorter term processes that could be resolved with a shorter time step? So an instant link means that the data are already synchronized and presumably there exists a measurable scale that could capture the actual lag of that information flow. Is that possible for the karstic data?

Indeed, contemporaneous relationships can be interpreted as a lack of temporal resolution. In our case, the ERT dataset is daily and we cannot get a finer time-resolution. Pursuing a finer scale is an option, and we briefly mention it in the perspective of the revised manuscript. However, one can expect cases of synchronization at all scales. Moreover, assuming that one wants to keep the same time horizon with the maximum delay d_max, finer resolution increases the dimension of the causal analysis. This is for these two reasons that we mention perspectives about causal inference method working on the frequency-domain to cover broader time-horizon (perspective 1, L365) and those aiming at solving contemporaneous dependencies (perspective 3, L375).

2.3 Major Comment 3

Discussion section: The discussion section could be improved by highlighting the results in terms of the connectivities described in the introduction, especially for the real case study. Also, greater connections between these results and previous studies on CIMs would add better context to the contributions of this study.

The revised manuscript includes a discussion better addressing the elements highlighted by the reviewers (see general response). In the introduction, the definition of effective connectivity is improved, and the first point of the discussion on the appreciation of the result now focuses on the question: "can we interpret our results in terms of effective connections?" For bivariate methods, the answer is no, because by definition they measure direct statistical dependencies and are to be associated with the definition of functional connectivity. We insist on this point for CCM because, contrary to cross-correlation which is implicitly used to make causal inference, CCM is explicitly put forward as a causal inference method. Bivariate methods remain interesting because multivariate methods provide results whose accuracy is difficult to judge. Insofar as we have identified a series of problems with multivariate methods, even if by definition they can reveal effective connections, we think it is more prudent to consider them as potential connections and thus as attached to functional connectivity. Regarding their use in general, these methods are one of many tools for exploration and analysis in science and are best combined with other tools given the uncertainties.

3. Minor Comments

3.1 Minor Comment 1

L66: You state the abbreviation of the method before stating the actual name. Please correct.

Corrected.

3.2 Minor Comment 2

L70: The phrase "obtained from" is repeated twice.

Corrected.

3.3 Minor Comment 3

L99: Change "not" to "no"

Corrected

3.4 Minor Comment 4

Figure 1 caption: It is unclear what the red areas are showing in the figure based on the description. Is it the overlapping timespans for all data? Or just the portion that can be analyzed using a 5-day lag? Please clarify.

Clarified in the manuscript and caption. When P1, P2, P3 are included individually, the red areas show the overlapping timespans for all data and their lags up to two d_max. Concurrently, this is the portion analyzed using a d_max lag of 5 days.

3.5 Minor Comment 5

L210: What is QB'?

L210: "*For comparison, we consider a case where QA and QB' are effectively connected as if they were contributing to the same drainage network, with QA upstream of QB' "*

Modified: *[…] we consider another case where QA is effectively connected to an adapted variable QB' […]*

3.6 Minor Comment 6

L218: Move the phrase "with R either A or B" earlier, when you first introduce HR.

Corrected

3.7 Minor Comment 7

L225, that paragraph: What is the length of the dataset? How did you set your length to ensure sufficient data for applying the CIMs?

The length is 365 days (L230). We did not ensure this but did not notice any particular unstable behavior, the performance was satisfactory and fully detailed in Table 2. Possibly, we would have obtained better results with a longer dataset. In the revised perspective and recommendation, we recommend using a virtual case mimicking the signal properties to answer this type of case-specific question.

3.8 Minor Comment 8

L233: Formatting issue for variable HAB.

Corrected.

3.9 Minor Comment 9

L238, that paragraph: It would help to reference specific parts of Figure 3 in the paragraph

The specific parts are now referenced in the main text as well.

3.10 Minor Comment 10

L271: Are the patterns shown in the figure or just stated here? It is difficult to know which relationships you are showing. I am also confused by what you mean by the time dependencies flipping as you can't have a negative delay? Please clarify.

L271: *"A typical pattern is that the sign of time-dependencies tends to flip after a few delays due to RF's forcing and the fact that dry periods come after the rain***."**

We now illustrate the pattern we mention with the R5-P2 relationship. At low lag, the relationship is negative as expected between resistivity and drainage, i.e., low resistivity implies high water content and drainage. After a few lag, the relationship becomes positive.

3.11 Minor Comment 11

L297: Phrase "P2 is be removed" is awkward. Please revise.

"be" has been removed.

3.12 Minor Comment 12

L317: You state the instability of the CMI may be due to the interdependence of the ERT data. Could this be considered a strength? Since this means it can detect that these data were already inter-related and therefore do not function well as independent nodes in the network?

We are not sure to understand how this can be a strength. We prefer to keep this as an

explanatory hypothesis that could deserve further consideration. Perhaps, beyond the ERT inversion model, the instability also depends on the used clustering method and the number of clusters selected.

3.13 Minor Comment 13

L329: Change “compare” to “compared”

Corrected

3.14 Minor Comment 14

Thank you for pointing the issue. We will make sure to check again the whole supplementary materials carefully.

3.15 Minor Comment 15

The source of confusion is that CCM forecast direction is opposite to the causal direction. We will clarify and make sure that the description matches the legend.