Interactive comment on

“Optimal Design of Hydrometric Station Networks Based on Complex Network Analysis” by

Ankit Agarwal et al.

Anonymous Referee #2

We thank the reviewer for investing his/her valuable time in our manuscript. We understand that conciseness is particularly important for manuscripts like this which builds on emerging ideas in the very fast-evolving field of complex network theory, as well as on new ideas around similarity measures, such as event synchronization, which is rather new in hydrology.

We have responded (in black) to each reviewer comment (in red).

General comments

This manuscript introduced the use of complex network analyses for designing optimal hydrometric networks. I find the concept interesting, but the authors somewhat fail to explain what the advantage of this method is, and to make me really understand what the network analyses will mean in the case of hydrometeorological observations. *It is clear how a linear network can be defined, as in Figure 1, but I find it difficult to imagine the network that is built from the event synchronization.*

We thank the reviewer for a constructive summary of our manuscript and also for his/her critical and supportive suggestions. Your feedback is vitally important to increase the readability of the work.

We agree with the reviewer that network construction using ES is not that trivial, since complex networks and event synchronization have hardly been used in hydrology. Hence, we propose to insert the following schematic figure with modifications in a revised version to better explain the network construction using event synchronization. All the equations and symbols has been explained in the main text of manuscript.

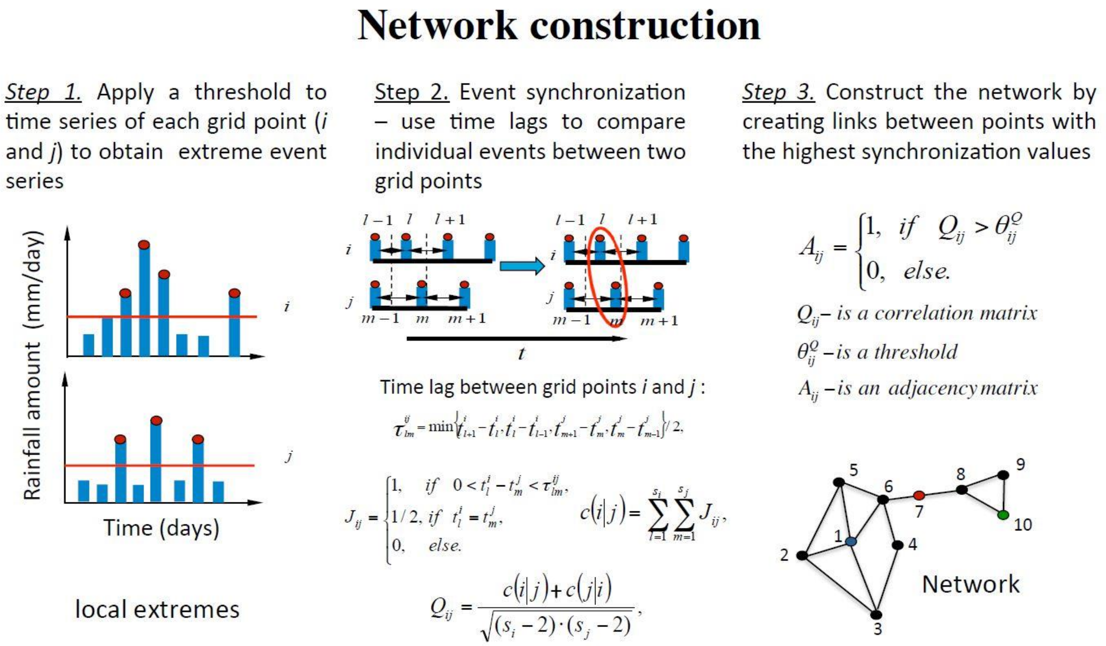

Figure 1: Schematic of network construction using event synchronization (ES). All the equations and symbols has been explained in the main text.

Major comments

Additional synthetic case study for expandable stations: Maybe the authors could show a small example where only a few (imaginary) stations are analyzed with the network methodology. *Then it can be shown how and why some stations are redundant and can be removed.* The real case example from Germany is interesting, but with such a high number of stations, it is challenging to understand what actually happens.

The specific application to use the WDB measure for ranking raingauges in Germany may indeed be difficult to understand. Reviewer #1 (in RC2) suggests that "… Some extracted maps from figure 4 showing on a limited size area, the topography along with the location and resulting ranks of the raingauges and maybe also the location of the 10% higher ranked removed gauges could improve a lot the presentation of the method. …" In the revised version we will attempt to incorporate this suggestion. We think that this suggestion helps understanding in detail what actually happens.

Threshold cutoff justification: I am not convinced by the use of a somewhat subjective cutoff value for the Qs to define the network, without at least a much deeper discussion around the effect. This will to a large degree ignore the level of similarity, it is just a yes/no transformation. Increasing or decreasing the threshold could drastically change the importance of the nodes in the network. Two stations with similarity just above the threshold will be treated the same way as two stations which are almost identical. On the other hand, two stations just under the threshold are treated completely different than the stations just above, even if their similarities are almost the same.

We thank the reviewer for raising the concern with the subjectivity of threshold. In the revised version we will provide a sensitivity analysis to quantify the effect of the cutoff values.

Global bridge node: The authors do several times mention the importance of global bridge nodes, and the possibilities these give in analyses of complex networks. For example*: "For i**nstance, in climate networks an** early warning signal could be generated by capturing the flow of information at such points."* This might be explained better in some of the references, but it should anyway be better explained what a local center and global bridge node really means in the climate network, and what kind of information we could particularly capture from this node.

In climate networks, local centers correspond to nodes which are important for local climate phenomena, while bridges correspond to nodes which connect different subsystems of climate (Jensen et al., 2016), such as the Asian monsoon and El Niño/Southern Oscillation, leading to teleconnections (Paluš, 2018). Bridge nodes spread a process to the entire spatial region globally whereas the effect of a local center is confined to a region (community) (Lawyer, 2015, refer Fig.2).

In temperature base climate networks it is the energy that is transported, and with this, some kind of information about the atmospheric state in a region (Hlinka et al., 2017). For rainfall networks in general, the links reflect the major propagation path ways of moisture, for extreme precipitation it is even more specific and reflects certain weather conditions, e.g. a specific "Großwetterlage" in central Europe. Ozturk et al., 2018 proposed a complex network based approach to estimate the tendency of extreme rainfall movement over Japan during typhoons. They iteratively approximated likely tracks of the extreme precipitation for each grid cell, many of which present redundant information, and hence the computation is time inefficient (several days). We suggest that by applying the same method only on global bridges and local centers, we can reduce the redundancy in such large climate networks; and deduce the likely track of extreme events because individual grid points do not represent distinct climatological processes.

Kriging: I noticed that also the other reviewers asked for some improvements regarding the relative kriging errors. In addition to what they wrote, I was not sure whether the variogram is recomputed when stations are removed. If this is done, then variogram fitting is a science in itself, whether done manually or automatically, and this can lead to changes in the kriging error, making small changes more a result of random changes. The kriging error should normally not decrease when you remove stations, so the reduction in table 4 for the mean is most likely because the variogram has been fitted differently. When kriging error is used to estimate network modifications, the variogram is therefore usually kept constant, to avoid having to also analyze the variogram fitting. The larger changes are still significant.

We thank the reviewer for highlighting this important piece of information which is essential for the replicability of the work. However, we confirm that the variogram has been kept constant during the network modification. We will better explain the Kriging application in the revised version.

Some smaller issues:

P2L25 the sentence is somewhat contradictory to the previous one, try to rephrase.

Yes, the statements were contradictory, which will be modified in the revised version.

P13 - Fig 6 Remove 10% from the x-label

Will be changed in the revision.

P16 Eq. A3 explain why the numbers are 1 and ½ in the equation.

This definition of J_{xy} prevents counting a synchronized event twice. When two synchronized events match exactly ($t_l^x = t_m^y$), we use a factor 1/2 since it double counts in $C(x|y)$ and $C(y|x)$. We will add this explanation in the revision.

$$J_{xy} = \begin{cases} 1 & if \quad 0 < t_l^x - t_m^y < \tau_{lm}^{xy} \\ \frac{1}{2} & if \quad t_l^x = t_m^y \\ 0 & else, \end{cases} \tag{A3}$$

References

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