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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Spatially shifting temporal points: estimating pooled within-time series variograms for scarce hydrological data" *by* A. K. Bhowmik and P. Cabral

Anonymous Referee #1

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In this manuscript, Bhowmik and Cabral tackle an incredibly relevant problem confronting the use of geostatistical tools in the hydrologic sciences. Namely, they seek to improve the representation of spatial structure in time series of climatic phenomenon. Their tool, spatially shifting temporal points (SSTP), allows for a representation of spatially distributed time series, which are inherently three-dimensional at least, in a single two-dimensional space. This allows for a fitting of a single variogram across both space and time. As it is, this technique is shown to be superior to the simplest technique of spatio-temporal variogram modeling, an averaging of temporally-independent

variograms. The authors conclude by arguing that their technique, by expanding the number of data points in a single space, may be applicable for data-scarce regions.

Having reviewed this manuscript, I feel that it should be reconsidered pending major revision. It is a significant contribution to the development of geostatistical tools in hydrologic sciences, but I was confronted with a few significant methodological questions that should be addressed before final publication. As I will explain, my major concern is that the authors have presented their method as more convoluted than it need be. I do not dispute its effectiveness, only its conceptualization. Beyond this, there a few claims that I would ask the authors to further substantiate. I will conclude with a brief, though non-exhaustive list of technical corrections.

In presenting their method as a technique that shifts temporal points in space, the authors inadvertently over-complicate their method. It appears to me that this approach is nothing more than a pooled variogram model. Because the authors restrict the averaging in equation (4) to spatial-lags within the limits of the maximum and minimum across time series and the spatial shift (d) is beyond twice the largest spatial lag, none of the semivariances used to construct the empirical variogram cross between clusters in figure 2. This is, of course, as it should be. Effectively, this can be explained without the complication of spatial shifts. All that has been done is that the semivariances at each time step have been pooled together, binned and averaged to produce a single empirical variogram. If all the time series of are the same length, than SSTP and AEV would be more than just "similar", as noted in line 9 of page 2255, rather they would be identical. By another view, if the empirical averaging of AEV were weighting by the number of points in each bin at each time step, then SSTP and AEV, I believe, would be identical. The AEV, by averaging empirical variograms rather than pooling the semivariances, simply assumes that each empirical variogram should be equally weighted. This is not the case for data sets of vary size, which the authors' method corrects. If there is some other advantage to spatial shifting, the authors have not made it clear.

In identifying this over-complication I, in no way, intend to detract from the value of this technique. I feel that it presents as a viable tool for estimating pooled variograms. It is a relevant competitor to the methods presented by Gräler et al. (2011), and especially useful in the case of time series of different lengths. I strongly encourage the authors to reconsider their technique in this new light, revise the manuscript and resubmit. In the hopes of improving the future manuscript, I will now provide some additional, lesser concerns.

The authors claim that AEV is the only alternative for estimating pooled variances across time, citing the work of Gräler et al. (2011) [lines 12-15, page 2246]. Firstly, Gräler et al. (2011) provide a large number of methods for variogram prediction, but it is unclear why Bhowmik and Cabral have rejected these other methods. Furthermore, it is unclear which method AEV corresponds to in Gräler et al. (2011). From the description, it seems that the authors applied the pooled variogram model (model c in section 2.4) from Gräler et al. (2011). This is surprising as it is not the best method identified by Gräler et al. (2011). (If this is not the case, I encourage the authors to clarify which technique was applied. My discussion above assumes that AEV is Gräler et al.'s (2011) model c in section 2.4.) How does SSTP compare to something like the mean variogram (model d of section 2.4)?

The authors claim that SSTP improves estimates in data-scarce regions, regions with only a few small-lag or large-lag sites, but this claim is unsubstantiated. Their method only improves extreme-lag estimates when the time series are not of equal length. The technique, as it is, does not increase the information content at extreme lags and therefore does not seem to improve the predictability at small lags. If all of the time series were of equal length, the method would still be limited to the most extreme lags available. With this in mind, I do not think that it can be claimed that SSTP, in of itself, improves extreme-lag estimates. Consider a "data-scarce" region where all stations, with varying record lengths, are 100s of kilometer away from each other. Would SSTP really improve the small-lag estimates in this data-scarce region?

Finally, I would ask the authors to briefly consider the issue of temporal dependence or autocorrelation. This point is less a critique on the present manuscript, and more of a consideration for future work. To my eye, the current methods (SSTP and AEV) do nothing to preserve the temporal structure of the data set. Would an estimated time-series at an ungaged site represent the correct autocorrelation structure? Surely this is of some importance in time series modeling.

Having presented these thoughts for your consideration, I will present a list of minor, technical corrections. Before doing so, I wish to thank the authors for a stimulating and encouraging manuscript. I sincerely look forward to their revisions or rebuttal.

Suggestions for technical corrections: p. 2244, l. 03: "... spatial[ly] data-scarce regions..."

p. 2244, l. 04: Remove the phrase "conditional that time series are available"

p. 2244, l. 26: "..., i.e. [the] spatial variogram[,]..."

p. 2245, l. 01: strike the word "estimation" and end the sentence after the Webster citation.

p. 2245, l. 02: strike the word "while" and start a new sentence at "[T]he precision of [the estimated] variogram strongly dependes..."

p. 2245, l. 03: Insert a comma after "data points"

p. 2245, l. 07: Remove "(reliable)"

p. 2245, l. 14: Remove hyphen and insert a comma after "smallest spatial-lag". Note, it is unclear how SSTP fixes a limitation from small lags.

p. 2245, l. 20: Insert a comma after the parenthetical and strike the word "spatial"

p. 2245, l. 21: Remove the entire ending clause "conditional that a time series of hydrological data is available"

p. 2245, l. 25: The sentence starting on this line and proceeding to (p. 2246, l. 2) should be revised. One example might be "The advantages of PTS variograms over individual variograms are: (i) The number of point pairs is considerably increased, reducing the noise in in empirical semivariograms and increasing the precision with which variograms can be estimated. (ii) The smallest spatial-lag is considerably decreased by including multiple time steps. Because of the stations being operable over different periods, different time steps may possess smaller spatial lags. Pooling allows these shorter distances to play a more significant role in the fitting of a stable variogram (Schuurmans et al., 2007)." Note that this second point is the one that I contest earlier. The shorter records are handled better here, but they do not improve uncertainty in short-lags.

p. 2246, l. 09: Replace "numbers of data points within a" with "lengths of"

p. 2246, l. 10: Replace "while" with "and, as previously discussed, the"

p. 2246, l. 22: ". . . spatial[ly] data-scarce. . ."

p. 2246, l. 23: "sufficient", not "insufficient", right?

p. 2246, l. 24: "outline", not "outlined"

p. 2246, l. 25: ". . .them[. We call this] "spatially. . ."

p. 2246, l. 28: ". . . spatial[ly] data-scarce. . ."

p. 2247, l. 05: Where is this data from? Please describe the source in addition to providing a citation.

p. 2247, l. 06: Remove "(data points)", revise to ". . .Bangladesh, classifying the. . ."

p. 2247, l. 07: Remove "because the number does not meet the threshold for satisfactorily precise variogram estimation"

p. 2247, l. 09: ". . .in 2007[, indicating variably] imprecise spatial variograms for individ-

ual . . ."

p. 2247, l. 14: Remove the two commas.

p. 2247, l. 20: "in" not "on". Combine to a single sentence ". . .'gstat' (. . .), 'intamap' (. . .) and 'spacetime' (. . .) packages."

p. 2248, l. 07: Remove "Hereafter," revise to ". . .was [then] applied [to] the correlation. . ."

p. 2248, l. 09: Remove the "in" at the last sentence

p. 2248, l. 16: "check [to ensure that] the numbers of pooled. . ."

p. 2249, l. 01: Please wrap the coordinate x,y in paraenthesis. The same can be said of s,s. As it is, the terminology is very unclear.

p. 2249, l. 08: N remains undefined.

p. 2249, l. 20: Insert a comma before "and shifts"

p. 2249, l. 25: It is unclear how the shift represent a spatially rescaled temporal distance. Please compare this to the spatially rescaled temporal distance of Gräler et al. (2011) to clarify.

p. 2251, l. 25: "The [SSEs of] previously fitted variogram models were compared and the best-fit. . ."

p. 2252, l. 02: "model [form] was" Was the full "best-fit model" used or was the model form recalibrated using a CV routine before providing an estimate?

p. 2253, l. 18: "Consequently, the PTS variograms [estimated] by SSTP. . ."

p. 2253, l. 20: ". . . in cross-validation, [showing] higher. . ."

p. 2253, l. 25: Insert a comma after 2007.

p. 2253, l. 26: Note that you cannot compare SSEs between these periods, because

they a sums of different numbers. Instead, you should present mean squared error.

p. 2253, l. 28: The number of points is not the only difference here. As you noted earlier, the spatial structure is inherently different. It could be that one structure is more easily modeled than another, regardless of the number of points. I do not feel this claim is substantiated by SSE. It is substantiated, I believe, by MSE.

p. 2254, l. 17: Remove the entire parenthetical phrase.

p. 2255, l. 14: Cannot compare SSE, show MSE.

p. 2256, l. 25: “in” not “on”

p. 2257, l. 05: Insert a comma before “will increase. . .”

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 2243, 2015.