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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

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Dear Anonymous Referee #2

We appreciate your criticism because it helped us to improve our manuscript. We agree that the advantages of our method over the existing method was unclear in the first version of the manuscript (also criticized by Referee #1). Addressing the comment from Referee #3, we have included and described a schematic diagram (Figure 1) in the further extensively revised manuscript (available as a supplement to this post) to expand on the advantages of our method over the existing method as well as their

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methodological differences. We have also included pooled within-time series (PTS) variogram estimation by averaging empirical variograms and weighted averaging empirical variogram methods in the R script (also provided as a supplement to this post), so that users can estimate PTS variograms by the three methods and directly compare them. We believe that they will clarify the advantages of our method over the existing method. Below we provide a point-by-point reply to your comments.

Best Regards

Avit Kumar Bhowmik and Pedro Cabral

Reply to referee's comments:

RC 1:

This manuscript describes a method for estimating temporally pooled variograms. Whereas the authors claim that their method gives some improvement to what they refer to as existing methods, I struggle hard to see the advantage of their method. Actually I would normally have rejected this manuscript, but seeing that Reviewer#1 had similar concerns, which the authors claim to have addressed well in a revised version, I will give them the benefit of the doubt and give them a second chance and recommend major revision. I have not seen the revised version though, so my comments will only refer to the current version.

My main concern is that I do not see the reason for introducing a rather complex idea of spatially shifting the points when the method just seems to estimate the 0 time lag bin for a spatio-temporal variogram. The authors claim in the answer to Reviewer#1 that averaging the fitted daily variogram parameters (as suggested by Gräler et al., 2011, but seems to be d) rather than c)) is the only way for estimating pooled variograms. My intuitive thought for creating a pooled variogram, however, would rather be to compute the weighted average of all empirical semivariances for each spatial lag. This is also how I understand method c) of Gräler et al., 2011, although it is unclear if they do

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a weighting according to the number of pairs for each time step. If I understand the method of the authors correct, this should give the same result, just without the added complexity of a random spatial shift. Using the data and the script from the supplement, the averaged variogram can then be computed as in section 2.2 of the vignette of the spacetime package in R: http://cran.r-project.org/web/packages/gstat/vignettes/st.pdf:

spacedata = spacedata[,c("PRCPTOTWet", "years")]

spacetime.dir = variogram(PRCPTOTWet $\sim$ 1, allSpPoints, alpha=41.90442, width=27.51, cutoff=550, dX = 0)

This variogram seems to be exactly equal to PRCPTOTWet.dir.SSTP, just achieved in an easier and less counterintuitive way. For a possible publication, the authors therefore have to explain if I have completely misunderstood something here, or if there are some additional advantages of their method.

AC 1:

We agree that a pooled within-time series variogram (PTS) is theoretically a spatiotemporal variogram with 0 time lag. Hence, an aggregation of the empirical variograms computed for individual time lags is essential to achieve the 0 time lag bin. This can be done in two different ways: (i) averaging, as done by the existing averaging empirical variogram (AEV) method that has been further extended to a more robust weighted averaging empirical variogram (WAEV) method, and (ii) comparing data point values for all time lags simultaneously and computing an empirical variogram, as done by our spatially shifting temporal points (SSTP) method. Hence, the main advantage of SSTP over the existing AEV as well as the modified WAEV methods is that it computes empirical variograms by simultaneous comparisons of point pairs from all time steps instead of averaging empirical variograms computed by comparisons in individual time steps. As a result, the empirical variograms computed by SSTP exhibited much lower noise than the AEV and WAEV computed empirical variograms and in turn showed higher precision for variogram model estimation. The WAEV method increased robustness

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and thus precision when compared to AEV, but SSTP also showed higher precision than WAEV because of the advantage of simultaneous comparison. Further advantages of our method over AEV and WAEV have been described in P 16 L 23-30, P 17 L 1-4, P 19 L 10-31 and P 20 L 1-2. We have also expanded on the methodological differences of our method with the existing AEV and the modified WAEV methods in a schematic diagram (Figure 1) and in P 7-10.

We also agree that the conceptualization of SSTP may be complex. However, we claim that conceptualization of SSTP is much more intuitive than AEV and WAEV, as it interactively pools data points from time on space and employs a spatial variogram estimation technique to arrive at the PTS variograms.

Method d in Gräler et al. (2011) refers to the mean variogram, i.e. averaging non-singular variogram parameters estimated for individual time steps (explained in P 4 L 1-10) and hence does not refer to pooled variograms. The only existing method of pooled variogram computation refers to the method c in Gräler et al. (2011), i.e. AEV, which is supported by Pebesma and Gräler (2014) (vignette of the spacetime package you provided) and hence does not corresponds to WAEV.

Neither AEV nor WAEV provides identical results with SSTP. You have obtained the exactly same variograms as ours because of syntax errors in your code. First, the "dX" argument in the "variogram" function of "gstat" package does not work without a regressors, and hence "PRCPTOTWet $\sim$ 1" cannot be provided with a "dX". Second, time steps should be provided as a regressor when "dX" is provided for AEV variogram computation, i.e. "PRCPTOTWet $\sim$ years" should replace "PRCPTOTWet $\sim$ 1". Finally, you have called the variable values and locations from "allSpPoints" object, which is the spatial object containing SSTP points computed by the SSTP method in the previous lines of codes. Overall, your code is actually identical to our code for SSTP variogram computation (see the R script) and hence, gave you the exactly same results. The correct code for AEV variogram computation is:

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spacetime.dir = variogram(PRCPTOTWet ∼ years, spacedata, alpha=41.90442, width=27.51, cutoff=550, dX = 0),

which provides identical results with our AEV variograms. We have included the AEV and WAEV variogram estimations using our data in the R script (supplementary materials) that enables users to directly compare SSTP variograms with AEV and WAEV variograms.

RC 2:

Minor issues: A method for variograms in data scarce regions can be just as useful in developed countries, so please remove the limitation to development countries.

AC 2:

We agree, however, data scarce regions mostly correspond to the resource constraint developing countries. Hence, we removed the limitation to only developing countries but stated that this can particularly be the case for a developing country (P2 L 8, P 3 L 3 and P 24 L 12-13).

RC 3:

The authors recommend temporal pooling of variograms as this can overcome the issues of few data points. However, they should then also discuss the issue of how temporal correlation affects the effective number of observations, and that long time series from a few locations with the same temporal pattern will only give minor improvements to the individual variograms.

AC 3:

We agree, however, this is highly unlikely that all data points in a region or separable by a spatial-lag exhibit identical temporal patterns for a variable. We discussed this in P 21 L 32 and P 22 L 1-2.

RC 4:

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P2246, L2 As far as I can see Schuurmans et al. (2007) refer to an experiment where a few rain gauges were put out with very small distance between them. This is independent of the use of pooled variograms

AC 4:

Schuurmans et al. (2007) states in page 5, section 3.a.2 Pooled variograms: "...these networks do not give insight into the spatial variability of rainfall at distances smaller than approximately 10 km. To be able to make high-resolution predictions of rainfall in spite of that, we computed a single pooled variogram for each extent based on all the 74 selected events ...". Hence, we referred to Schuurmans et al. (2007) to support our claim that PTS variograms reduce uncertainty for short distant variability modelling by incorporating spatial variability from time steps where point pairs are separable by smaller spatial-lags (P 3 L 30-32, P 22 L 31 and P 23 L 1-4).

RC 5:

P2249, Eq 1. What are n and N? This matrix could well be better explained.

AC 5:

N corresponds to natural numbers and n belongs to N. This has been clarified in P 7 L 22-23.

RC 6:

The description of the variogram on P2250 looks a bit strange. Is the spatial lag a distance or a vector?

AC 6:

We agree and corrected them throughout P 7-9, spatial-lag is a distance.

RC 7:

The i's and j's around Eq 5 does not seem to be the related to the 1, : : :, n of Eq.

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5. Does the first part of Eq. 5 really reduce the uncertainty of short distance spatial variability?

AC 7:

We agree and corrected Eq. (5) in P 9 L 25. We also expanded on how the first part of Eq. (5) reduces the uncertainty for short distant spatial variability in P 17 L 6-12, P 22 13-31 and P 23 L 1-4.

RC 8:

P2251 L16 I do not think a was replaced with the anisotropy parameter, rewrite.

AC 8:

We agree and have rewritten it in P 11 L 24-28.

RC 9:

P2252 L23 I guess it should be 1948-1975?

AC 9:

L 23 corresponds to the entire series and hence refers to 1948-2007.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C2507/2015/hessd-12-C2507-2015-supplement.zip

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