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Discussions

Interactive comment on "Using variograms to detect and attribute hydrological change" *by* A. Chiverton et al.

Anonymous Referee #3

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This paper introduce the temporal variogram as a tool to detect changes in streamflow variability. This is achieved by analyzing the changes in specific characteristics of the temporal variogram applied to moving windows.

I think the paper could be improved by (i) citing more literature to give wider background; and (ii) clarify the motivation and the aims for the paper. The cited literature on detecting trends and changes in environmental time series is too limited. It is not enough to state that in most studies Mann-Kendall test is used. Other trend tests that are less sensitive to start and end points are used (e.g. Stahl et al, 2010). Detection of one or several change points in mean and/or variance is studied in many papers (e.g. Raje, 2014; Sefidmazgi, 2014; Jandhyala, et al, 2013; Beaulieu et al 2012; Toreti et al, 2012). Also the links between changes in meteorological characteristics and

streamflow response is studied (e.g. Kumar and Duffy, 2009). I therefor think the authors should include more relevant literature and show how the proposed method fits into a wider background than what is currently in the paper. Since the paper already has a link to geostatistics, you might also refer to literature on detecting spatial non-homogeneities (e.g. Darbeheshti and Featherstone, 2014; Atkinsona and Lloyd 2007).

Concerning the motivation of the paper, I feel that there is a limited coherence between the suggested limitations of traditional methods (e.g. not able to tell when a change takes place, to sensitive to period of data, only indices are analyzed), the proposed methodology, and the final results. It would be useful if you demonstrate more explicitly how the proposed methods meet these challenges. I also think that the argument that "the method is based on raw daily flows and requires no pre-calculated indicators (e.g. annual or seasonal averages, minimum or maximum flow" is misleading since the paper actually analyze changes in "variogram parameters" that also might be used as indicators. Any kind of statistics and/or indicators, also Q95, could be calculated within sliding windows, not only variogram statistics. It would also be useful to more explicitly write out which changes it is important to detect (in this paper), and how they are detected based on the proposed methodology. Like reviewer II, I am not convinced that the variogram parameters are the best tool to detect these changes. Then more specific statistical tests for changes i trends and/or variability, changes in seasonality, might be more useful. Any kind of statistics could be calculated within sliding windows, not only variogram statistics.

Variogram estimation does not necessarily depend on the data to be normally distributed. However, if you want to interpolate, the normality of data becomes important. Log-transformation will also help to reduce the effects of high outliers. In many studies, i.e. on rainfall, variograms are estimated directly fro raw data (e.g. Leblois and Creutin; 2013). The tranformation of data will affect the shape of the variogram, the nugget and sill, but not (or maybe less) the range. E.g. Leblois and Creutin (2013) show how an "anamorphosis function" for the variogram might be estimated when the transformation is known. In this study the log-transformation will most likely increase the covariance for the shortest time lags.

Then over to some details.

Please state explicitly the time resolution of data used in the study.

Page 11767, line 10: It is written: "In terms of change detection, the key advantages of variograms are: the method is based on raw daily flows" This is confusing since "raw daily flows" are not used in the paper.

Page 11767: It is written: "In terms of change detection, the key advantages of variograms are: the method is based on raw daily flows and requires no pre-calculated indicators (e.g. annual or seasonal averages, minimum or maximum flow); both linear and nonlinear changes can be detected; the identified change is in relation to expected flow dynamics which represent the whole time period, not just the start and end of a given period; and the dynamics of the river flow time-series can be analysed as changes in variogram parameters relate to changes in different aspects of the river flow regime" I am a bit confused if this is a statement, conclusion, or a hypothesis. If it is a statement, I would like to see more arguments and maybe references, if it is a conclusion it should not be here, and if it a working hypothesis, it need to be reformulated.

Page 11770 First lines: Exactly which frequencies were removed?

Page 11770 line 13: I suggest to write: "Based on the transformed, de-seasonalized standardized flow data".

Page 11770, line 23: Does actually any nugget-effects appear using this data set? If you have daily data, no uncertainty included, I would guess that the empirical nugget is zero.

Page 11772 line 5-10: How large is the time shifts between the moving windows (1 day or 1 year?)

Page 11773 The paragraph starting on line 24 is not easy to capture.

Page 11780: Could temperature be a meteorological factor that is not accounted for? If snow accumulation and snow melt occurs in some of these catchments, it could be very important.

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