

Interactive comment on “The Spatial Extent of Hydrological and Landscape Changes across the Mountains and Prairies of the Saskatchewan and Mackenzie Basins” by Paul H. Whitfield et al.

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Interactive comment on “The Spatial Extent of Hydrological and Landscape Changes across the Mountains and Prairies of the Saskatchewan and Mackenzie Basins” by Paul H. Whitfield et al.

Anonymous Referee #2 Received and published: 2 March 2020

General comments: Paper The Spatial Extent of Hydrological and Landscape Changes across the Mountains and Prairies of the Saskatchewan and Mackenzie Basins examines spatial distribution of streamflow regime types, trend patterns and satellite indices

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(NDVI, NDWI, NDSI) based on large number of streamflow and satellite data sets covering large area of continental Canada, east of Continental divide. Main contributions of the paper are: (1) applications of methodology such as dynamic time-warping which enabled alignment of stream flow hydrographs according to the point of inflection and K-means clustering enabled classification of seasonal streamflow regimes; (2) large spatially distributed data sets offering insights into changes in hydrological regimes and trend in large area covering several climate and topographical zones; (3) increasing number of available datasets with applied methodology. Overall this is very ambitious study done with the large data set covering large portion of continental Canada which offers new insights on hydrological changes in (especially) streamflow regimes and opens new research questions and deserves to be published in HESS. However, information and ideas presented in the paper are very difficult to follow so I recommend restructuring the text and adding some additional clarification to the questions presented in the next section. I recommend this article for final publication after the MAJOR revision, mainly regarding the paper structure and more concise communication of (very interesting and valuable) results.

Specific comments: Remarks that should be addressed in order to make paper more concise are listed below. Three main open questions/remarks that need to be addressed are: 1) Different concepts are presented and used in the text: e.g. landscape and ecozones are used throughout text interchangeably. What is the difference between them? This comment is also related to the title – landscape is stressed in the title and in the paper, but analysis is done related to the ecozones maps. What was the main motivation for the introduction of ecozones and what additional information does it offer in the explanation of e.g. streamflow regime types and trend patterns? Although ecozones are connected with the climate and topography (and with analysed satellite indices), from the aspect of hydrological processes and streamflow regimes, watershed level is the most important unit that would offer additional insights (this is also stated by the authors in the paper Pg. 13 L 300-303, Pg. 21 L 580-581). Also, maps that give information about climate zones and topography of researched part

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of Canada would be more useful for analysis of results, especially about streamflow regime types and trend patterns, but also satellite indices. Authors should decide what would be the main goal and main information that they would like to convey in the paper and then should choose appropriate spatial representations of the data. Question is again raised regarding landscape change and its influence on hydrological change on Pg. 30 L841 but answer or explanation is not given.

Authors' response: We chose to use ecozones as opposed to climate zones as reflective of the Canadian landscape. Climate zones are indeed intimately linked into the ecozones. We believe that ecozones are the appropriate context to examine these changes at this scale as that is where the changes are taking place. For example, Whitfield et al (2020) examined ecoregions and hydrological change in the Canadian Prairies; however, ecoregions would be too fine a scale to consider for ~400 watersheds. We have included topography in a new figure that shows the locations of seasonal and continuous station, river basin boundaries, and names of major rivers. In revising the manuscript, we have paid specific attention to making linkages between hydrological change and changes in basins. —

2) In the Pg. 6, L 140 it is stated that only time window between 19th April to 31st October for the streamflow data is used, and that satellite indices (NDVI, NDWI, NDSI) are extracted from the Landsat composite images for every sixteen days between 1980 and 2013 for the entire year (if I understood correctly). Although different time period is used for the hydrological storage (satellite) indices than for the streamflow regime and trend patterns, the reason why the same warm season time window of the data (between 19th April to 31st October) for the satellite indices is not used should be addressed. This would reduce the size of available data sets, but methodologically seasonal data would be comparable. Maybe this important methodological aspect of the paper, i.e. spatial analysis during the warm season, should be stressed and added to the title of the paper?

Authors' response: We have added a comment regarding the choice of a different

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seasonal window for satellite imagery than hydrological data. Satellite imagery is a different data type with images only available every eight days at best and adjusting to the time window of the hydrological data. The title has been modified to include 'warm season time window' —

3) Methodology regarding dynamic time-warping and trend pattern analysis need additional clarification or at least more clear explanation of the idea and of the conducted steps. Remaining questions / remarks:

Authors' response: Additional text and an additional panel in Figure 4 were added to provide the clarification. —

4) After the introduction, I recommend adding one (sub)chapter named "Data" where more specific information would be given about used dataset and (sub)basins, before any processing of the data. After that (sub)chapter, chapter about used methods for processing and selection of the data could follow. Readers would especially benefit if the map with Saskatchewan and Mackenzie Basins location in Canada and location of analysed stations would be provided. Also, table with summary statistics of streamflow data collected from 395 basins would offer additionally information important for understanding of the analysed streamflow and watersheds (e.g. min, max, mean of analysed streamflow, dataset lengths, (area and mean elevation of analysed watersheds, etc.).

Authors' response: We have separated the material describing the data from the analysis within the Methods section. An additional Figure was added to the main text showing the location of stations, the major river basins and the names of major rivers. An additional figure was added to the supplementary material showing the missingness/availability of data from continuous and seasonal sites and the overall annual data density. These address the comment about data lengths. Table 1 has been expanded to provide more details about the numbers of stations in the different major river basins. Some text was added to indicate the range of basin areas and station elevations. It is our opinion that the min, max, and mean of streamflow could be easy

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to misinterpret and as we use z-scores the sites can be compared based upon those, since this provides a mean of zero and a range in standard deviations. A note to this effect has been inserted in the main text. —

5) In Pg6, L144 - it is not clear for the reader what does “periods 23 to 61 (of 73)” represent. Also, these periods need to be marked appropriately in related figures (Fig 1-5,7,8, 11, S1-12, S14-20) and information about months or dates in the year (is it from 19th April to 31st October?) would be more useful. Especially since these are main figures for the understanding of the results presented in the paper.

Authors' response: All figures showing the five-day periods now have a secondary month axis included. Thank you for noticing that the lines showing periods differed between some simple plots and raster figures. These are now consistent. —

6) Overall, information and ideas presented in the paper are difficult to follow so I recommend restructuring the text and careful reviewing of naming used: e.g. main spatial areas of change introduced in the discussion are [i] North of 60° ; [ii] Boreal [iii] Prairies [iv] Mountains and in the conclusion are: [i] The Mackenzie Basin, [ii] The western Boreal Plains, [iii] the western Prairies, [iv] The Cordillera. Naming of the areas are different, and are also different from the three areas mentioned in the abstract: [i] north of 60° , [ii] in the western Boreal Plains, [iii] across the Prairie. Also, these areas should be mentioned and explained earlier in the discussion, not just to start section with this naming.

Authors' response: We have addressed this by changing the text to use the same names throughout the manuscript. We now use North of 60°, The Boreal Plains, the Prairies, and the Mountains in the same sense throughout the manuscript. —

7) Abstract should be more concise, shortened and connected more with the main conclusions (one example just mentioned in the previous section). Questions opened in the abstract are very general (Pg. 5 L 103-108) and have not been answered in the discussion nor in the conclusion. Information about the data used in this study are

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presented in different sections of the text and it is difficult to follow what was available (e.g. in chapter 2.1. Data streamflow data and satellite data is introduced and 3 pages later in 2.3 Landscape and hydrological storage trends satellite data is introduced).

Authors' response: The description of the satellite data was moved to the section on data. —

8) Pg. 6 L155-159 – it is not explained clearly enough why Figure 2 is important.

Authors' response: This is a useful suggestion and additional text has been incorporated to explain this. —

9) Pg. 7 L 175-176 “Only the data in the periods between the two vertical dashed lines in Figure 3 were used in the clustering”. These lines are not marked consistently in the remaining Figures (both in text and supplemental S1-S12) and they are important for the understanding of the analysed period.

Authors' response: Corrected as suggested. —

10) Results presented in Tables 5-7 show that fraction of stations showing a trend at $p \leq 0.05$ is decreasing with the number of stations increasing. This would be interesting to comment in the text.

Authors' response: A comment has been added to better explain this. —

11) Introduction of the analysis of the recession limb of streamflow regime hydrographs is made for the first time in the discussion (Pg. 22 L601). This makes no sense because it has not been mentioned earlier as one of the goals of this research. Although this analysis offers new interesting insights, it should be introduced and explained earlier in the introduction and in the methodology.

Authors' response: This has been addressed by introducing it in the methods. Thanks for pointing this out. But, the goals of the research did state “how are the hydrological types and processes distributed” and this material addresses that goal. —

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12) It is not clear why would authors want to introduce questions regarding PDO and AO (Pg. 29 L829-836) and how is that connected and important with the results that they presented in their paper. What would be methodology used to incorporate these signals in their future work?

Authors' response: We felt that it was important to acknowledge that we did not consider the effects of PDO, ENSO, or AMO which others have identified to affect streamflow in the section of the discussion dealing with limitations. We have considered how to express this differently and incorporate it into the paper. [Another option was to simply remove any mention of them and be criticized for not covering them.] —

Technical corrections: Figure 4 – 6 trend patterns (clusters) should be marked on vertical axis?

Authors' response: Figure 4 shows an example of dynamic time warping where the y axis is labelled as discharge as z-score. We think the reviewer may mean Figure 8 to which we will add numbers to indicate the groups. —

Figure S2 - description of the figure should be cluster number 2, not 3?

Authors' response: This typographical error has been fixed. —

Figure S4 / S5 – it is not clear where does description of the Figure belong

Authors' response: A “new page” was inserted before Figure S5 so all four occur on the same page. —

Interactive comment on Hydrol. Earth Syst. Sci. Discuss.,
<https://doi.org/10.5194/hess-2019-671>, 2020.

Authors comments:

Other changes made in revision

Tables:

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Table 1 was extensively revised to provide more detail about the distribution of stations between major watersheds.

Figures:

New Figure 1 was added to indicate locations of seasonal and continuous stations, the major river basin boundaries, the names of major rivers and the topography.

Figure 1 – a second axis showing months has been added.

Figure 2 – a second axis showing months has been added.

Figure 3 – a second axis showing months has been added.

Figure 4 - has been modified to include a figure showing the dtw alignment step.

Figure 7 – a second axis showing months has been added.

Figure 8 – a second axis showing months has been added, the separation between clusters has been made clearer and the cluster (Trend Pattern) shown in italics.

Figure 11 – labels added to axes

Supplementary Figures:

Captions of all supplementary figures were edited for clarity and consistency.

A New Figure S1 was inserted. The four panels show the missingness and the annual density of available station data for continuous and seasonal stations.

Figures S1-S12 – a second axis showing months has been added to each panel.

Figure S14 - a second axis showing months has been added.

Figures S15 to S20– a second axis showing months has been added to the raster portion and the layout of the figure elements were changed.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2019->

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671, 2020.

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