Interactive comment on "Variability of low flow magnitudes in the Upper Colorado River Basin: identifying trends and relative role of large-scale climate dynamics" *by* M. Pournasiri Poshtiri and I. Pal

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[Authors' Response] Thank you for the third review. We are glad to respond to and address all the allegations raised about the paper. Largely speaking, after reading and re-reading the third reviewer's comments, we started to wonder that perhaps there is a lack in understanding the original focus of the paper. This paper is not presenting a physical modeling study of low flows, neither is it addressing the regionalization challenge but the paper presents the question of the connections between the large-

scale ocean-atmospheric patterns (monotonic trends, non-stationarity, multi decadal patterns etc) and their connections to low flow indices of Upper Colorado River Basin, which can potentially be important to serve as empirical predictors of low flow indices. We urge the reviewer to check the manuscript from the latter point of view, and not from the earlier perspective, which we acknowledge are related, but our contribution here is to reach at the consensus scientific understanding of low flow variability of Upper Colorado River Basin from large-scale climate point of view, and climate non-stationarity, which could largely be connected to meteorological drought studies. Our response to each comment is written below and we incorporated them in the manuscript wherever appropriate, as track changes. Please check the supplementary materials.

[Reviewer comment] A. General comments: This paper aims to explore cross-correlations, trends and correlations to climate variables (total precipitation, global surface temperature anomalies and mean sea level pressure anomalies) at the Colorado river basin. The analysis are based on 17 stream gauges, and are conducted on a monthly and seasonal basis. Although the topic is indeed interesting, I feel that the paper has several weaknesses. First, it uses rather simple, descriptive methods, and presents rather superficial, descriptive analyses. Second, it is also weak in the interpretations of the results. The impression I got is that there are hardly new findings deducted from thorough interpretations of analyses. Rather, commonly known statements about low flow drivers are concluded, from rather simple analyses. My overall impression is that the paper lacks the necessary depth concerning both, study design and style of presentation that would be necessary for being published. I therefore cannot recommend it for publication.

[Authors' Response] Following previous 2 reviews we received back in September we spent considerable amount of time to do several new analyses, and re-wrote many parts of the manuscript, which now reflects better the major science questions addressed within the paper. Regarding Referee #3's comment on "rather simple, descriptive methods, and presents rather superficial, descriptive analyses", we are unable to

understand how the reviewer would like us to address this allegation. We request the reviewer to check the revised manuscript that meaningfully addresses the research questions that are articulated based on knowledge gaps identified for the study region in the literature. To summarize our approaches, (1) we analyzed monotonic trends in location specific low flow indices using non-parametric Mann-Kendall technique. (2) We determined periodic signatures (indicating "sub-decadal to multi-decadal" variability) of low flow using Wavelet Power Spectrum analysis. (3) We determined the common variability of low flow patterns over the Upper Colorado River Basin using Principal Component Analysis and checked the associations between the Principal Components and large-scale atmospheric patterns using Pearson Correlation Analysis, which beautifully contributes to the scientific consensus on droughts but from the perspectives of the variability of low flow and connections with large-scale ocean-atmospheric patterns. The main findings we have are: eastern and western sides of Upper Colorado River Basin (UCRB) indicate opposite trending patterns of low flows, the west (east) showing drier (wetter) conditions, and the low flow magnitudes were specifically found to be having multi-decadal variability revealing the close associations with Interdecadal Pacific Oscillation or Pacific Decadal Oscillation (PDO) patterns. Although there were studies relating droughts in the Southwest versus large scale ocean-atmospheric patterns, which we do refer in the paper, we didn't find established relationships between the low flows and climatic patterns. In fact, The National Weather Service's Advance Hydrologic Prediction Service (AHPS) has identified that a system is urgently needed for low flow forecasting, similar to flood forecasting, for several river basins in the U.S. and also to include information on current and potential future impacts of low flows on a variety of sectors (Woudenberg, 2008). Hence, there is urgent need of direct low flow forecasting that can simply be done using the variance explained by ocean-atmospheric patterns. Hence, the methods used in this research, although seem "rather simple", does answer the research questions we proposed. If the reviewer would like to suggest other statistical ways to do the above analyses, we are happy to hear about it. Regarding the comment "the paper lacks the necessary depth concerning both, study

design and style of presentation": Further to our response above, we do not agree with this comment, unfortunately this is also in stark contrast to other reviewers' comments. There is a huge gap in understanding the purpose of this paper and the reviewer's perspective of understanding and writing the paper. However, we will appreciate if the reviewer could help us to detect why there is "lack in necessary depth" and how we can improve the "study design and style of presentation" in the updated manuscript. We refer the reviewer back to the annotated manuscript, in supplementary material.

[Reviewer comment] B Specific comments: Abstract: The abstract is not very informative. Shorten the existing to less than the half, and add description of exact methods used, and the main results (as quantitative as possible).

[Authors' Response] We have re-written the abstract.

[Reviewer comment] Introduction: Lengthy, and not at the point what the reader would need to understand local hydrological setting. P 8782, second paragraph: "There is complexity and heterogeneity of low flow dynamics in a river basin..." The reader will know about low flow processes in general, so will hardly find any new information in this paragraph. However, the specific processes of the Colorado River should be presented here. I learned that between 85 and 90 percent of the Colorado River's discharge originates in snowmelt, so we have a very specific hydrologic situation. Snow accumulation and delay of discharge will be important processes, which determine the low flow regime and this should be explicitly assessed. For instance, by analysing the effect of previous winter precipitation on the summer low flows. Or the influence of summer drought in combination with precedent winter conditions...

[Authors' Response] In the first paragraph of Introduction section we convey general information about any river basin low flow but in the second and third paragraphs, also in the Data section we specifically present information pertaining to Colorado River flow (low flow). The focus of the paper is the sensitivity of low flows to fluctuations in large-scale atmospheric circulation patterns. Precipitation/snow in the previous season

is important but addressing seasonal snow relationships with the annual q7âĂŤwhich is the major focus here that forms the major index for water management decisions for the US regions during low flowsâĂŤis a challenge. Therefore, northern seasonal climatic conditions, which has a longer memory to detect the associations is more pertinent, which has been done here.

[Reviewer comment] Same paragraph: "Therefore, we conjecture that climate is linked with low flow characteristics and those links vary for different locations because of variable physiographic parameters." This has already been shown in a number of studies, for a summary statement of low flow driving processes see Chapter 8 of the PUB report, or Tallaksen & van Lanen (2004). REF: Runoff Prediction in Ungauged Basins: Synthesis across Processes, Places and Scale, edited by G. Bloeschl et al., pp. 163–189, Cambridge Univ. Press, New York.

[Authors' Response] We did refer to Chapter 8 of Tallaksen & van Lanen (2004). Again, the reviewer mis-understood our focus, which is NOT the prediction of flow in an ungauged basin, but to detect statistical relationships between "large-scale climate" and the "local scale natural low flow variability". This chapter is mainly focused on physical hydrological aspects of ungauged basin flow, which is not our focus.

[Reviewer comment] Next line: "This leads to the science questions: How heterogeneous are the variability of low flow conditions in the headwater basin of Colorado River? . . ." This is not a consequence of what is said before.

[Authors' Response] We are not sure what the reviewer specifically means by "This is not a consequence of what is said before".

[Reviewer comment] Introduction – last paragraph: You show the paper outline, but reference to a Methods Section is missing.

[Authors' Response] We have updated the paper outline paragraph.

[Reviewer comment] Section 3: Is not informative at all. Why only about low flow char-

acteristics – the complete methods could be presented here. Last sentence, stating that analysing q7 low flows in seasons is largely non-existent in the literature is not true. There are numer- ous examples, e.g. Haslinger et al. 2014. REF: Haslinger, K., Koffler, D., Schöner, W. and Laaha, G.: Exploring the link between meteorological drought and stream- flow: Effects of climate-catchment interaction, Water Resour. Res., 50(3), 2468–2487, doi:10.1002/2013WR015051, 2014.

[Authors' Response] We didn't clearly understand what the reviewer means by "the complete methods could be presented here". Analysis of seasonal natural q7 of Upper Colorado River Basin and its large-scale climatic connections is the focus of this study, is indeed largely non-existent in the literature. This reference study is done for Austrian data, not for Colorado River Basin. Also the referred study focuses on meteorological drought indices (SPEI/PDSI etc) vs q7, which is related but not exactly the large-scale ocean-atmospheric patterns.

[Reviewer comment] Section 4: Section 4.1. Here I learn the first time about the methods, what is too late in the paper.

[Authors' Response] Thank you. Methods relevant to the results are presented in the respective sections.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/11/C5295/2014/hessd-11-C5295-2014-supplement.pdf

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