

We thank reviewer for their comments and insight into this manuscript. We have addressed every point that they have made, with our responses below in blue italics.

Anonymous Referee #1

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This paper studies the anthropogenic effect of the Santa Juana dam on drought in the Huasco basin in Chile. The Standardized Indices (SI) and Threshold Level (TL) method with different thresholds are applied to observed and modelled data. The study illustrates the effect of the Santa Juana dam on different characteristics of the drought, including duration and intensity. Also, the performance of the SI and TL method on the observed and simulated data is compared. The topic of this manuscript is interesting, as reviewer found the study was more like to investigate the reservoir operation and reservoir's capability on mitigating drought conditions instead of drought monitoring and prediction. The current manuscript suffers from some major issues as reviewer listed below. Major comments:

1. Motivation: Reservoirs are able to change the patterns and magnitudes of streamflow. This is an unknown fact. Reviewer is unclear about the experiment design of this study. If both observed and simulated results shown reservoir was able to delay the timing, frequency or magnitude of drought events, then this again is a restate of known fact. Therefore, how this study can be used for more efficient reservoir operation or planning for droughts events still have questions. Authors are suggested to summarize more about recent published paper in WRR and GRL to better formulate the motivation of this study. (search key words: reservoir operation, water allocation, drought conditions).

We agree that the motivation behind the paper could be clearer, and we propose changes to the paper to address this, including changing the title, refining the abstract and the introduction, as well as minor changes to the methods section, major changes to the results section, and the inclusion of a discussion section.

The focus of the paper is: Finding the best method for quantifying the human influence on hydrological drought using observation data, by 1) comparing the threshold level method and standardised indices; and 2) testing the upstream-downstream approach to quantify the human influence from discharge data (in which we refer to in the paper – using discharge stations upstream and downstream of a human activity).

The specific reservoir is not the focus, but rather how these methods can be applied to quantify the impact of a human activity. By reorientation of the focus from Chile and the reservoir and those results, we consider now the methodological aspect of quantifying the human influence, and the sensitivity analysis of it. The new title reflects this re-focus:

“Evaluating observation-based methods to quantify human influences on hydrological droughts”

Suggested keywords: drought, analysis methods, quantification, anthropogenic activities

Proposed revised manuscript headings and subheadings:

1 Introduction

2 Methods

2.1 Observation data

2.2 Drought analysis approaches

2.2.1 Threshold level

2.2.2 Standardised Indices

2.3 Sensitivity analysis

2.4 Estimation of the human impact on drought characteristics

2.4.1 Percentage change due to human influence in observation data

3 Results

3.1 Results of human influence on drought characteristics downstream

3.2 Sensitivity analysis of drought analysis methods (SI vs TL)

4 Discussion

4.1 ST vs TL

4.2 Comparison between observed data and modelled data

4.3 Quantifying human influence on droughts: ways forward

5 Conclusions

2. Motivation and Organization: The introduction has described why drought is important and previous studies focusing on the relationship between human activities and drought conditions. However, reviewer find it difficult to understand the contribution of this study with respect to those mentioned studies in this manuscript. What is the scientific problem that this study is trying to solve and **how this study will contribute to those existing findings about human activities amplified or alleviated drought condition?** Reviewer believes this study is not targeting on methodology advances rather than application of certain existing analytical methods to a case study in Chile. Then, the question becomes how this application is unique and novel as compared to the uses of similar techniques to analyze the functionality of reservoirs on droughts.

We stress that this study contributes significantly to the problems outlined in the introduction of this paper by looking at the best method for quantifying the human influence on hydrological droughts through the use of Chilean data as an exemplar. Tools are of crucial importance for increasing the understanding of droughts in the Anthropocene. The major findings from this study are twofold:

1) Identifying the most appropriate drought analysis method for quantifying the human influence using observation data. This is something which is novel from an observation based approach;

2) A sensitivity analysis between two commonly applied drought analysis methods, standardised indices and threshold level, enabling recommendations on the best method to use to identify the anthropogenic influences on hydrological droughts.

3. Justification of results: In results section (line 337-338), authors also quoted that “This temporal difference between observed droughts upstream and downstream reflects the impact of human activities, also observed in other studies (Assani et al., 2013; Liu et al., 2106).” Then, the explanation is needed to justify in what aspects this study will differ from others?

We have stated that our results show that timing of droughts have been affected by human activities, which we have managed to find in limited studies elsewhere. But we would like to

emphasize (and this will be done in the revised version of the paper) that here we are actually producing quantification for the changes caused by an anthropogenic activity. It is this quantification aspect which is especially novel for the research area.

Furthermore, this paper itself is testing the application of the upstream-downstream approach for this research area and purpose, which is different to the existing observation-modelling framework and simulated naturalised discharge approaches because it only uses observation data. The quantification of the human influence through the upstream-downstream approach is explained in the paper (with the equations) so that this proposed methodology can be replicated with other case studies.

4. Justification of results: The “human-influenced” results only reached NSE=0.454, which is a rather poor performance. Considering the temporal resolution (monthly) and the length of analysis (over decade), this NSE value lacks proper accuracy to represent any simulation of human activities. This critically undermines the main motivation of analyzing the functionalities of reservoirs in alleviating drought conditions.

We agree that the human-influenced WEAP model scenario NSE results are low, as stated in the paper. However, we mention an important reason as to why this might be the case in the paper: because the model may not be accurately modelling human responses to drought situations (e.g. increase in water use, decrease in water use due to restrictions etc).

With our changes, we are proposing to take the focus away from the modelling aspect of this paper, by removing the modelling data part, refine the focus, and helping us to address a number of comments made by both reviewers.

5. Justification of results: line 15, “A delay in timing of drought events has been observed also with the presence of the dam” how is this being illustrated in the results and conclusion as this is one of the main concluding remarks in the end?

This is already show visually by the figures in the results section. However, in the revised version we have analysed and added a summary of the seasonal distribution of droughts into the results section (3.1 Results of human influence on drought characteristics downstream), as suggested by Reviewer 2. These results illustrate the importance of dam impoundment and reservoir management (human influences) on the timing of hydrological droughts downstream.

6. Experiment Design: Reviewer also found it is confusing about the experimental design. For instance, in Figure 4, both daily data from 1965-2013 for upstream discharge (this becomes reservoir’s inflow) and downstream discharge (reservoir’s outflow) were used in the “pre-dam versus post-dam” scenario. The results for the first scenario was compared with a “naturalized versus Human-influenced” scenario as shown on the right panel, in which the resolution of data become monthly and coverage of data starts from 1960 to 2010. It is confusing, or lack of explanation why different resolution and lengths of data were used and compared. Isn’t that Pre-dam the same as Naturalized, and Post-dam is human-influenced?

It is important to highlight that the time periods between the observation and modelled data used in the paper do not align directly because it is based on using available data, which can be especially limiting in an arid, developing country. The observation data runs 1965 – 2013 due to missing data before 1965. The WEAP model was already set up for the basin and had data from 1960 – 2010. However, with the emphasis now away from the WEAP model, this difference in time periods should be less problematic as all the observation data compared in the revised version is now consistent: 1965 – 2013.

We would also like to stress that for the sensitivity analysis we have kept everything consistent— such as the time period, the temporal resolution (monthly), the threshold (TL using variable 80th percentile and SI using -0.8) and using the whole time period for the threshold in both SI and TL. The sensitivity analysis discussion also highlights the potential difference for using daily and monthly data. This sensitivity analysis has now been moved forward in the paper to being one of the key results (section 3.2).

With the new changes, we now just look at the pre-dam upstream and downstream to establish the relationship in the undisturbed period, and we use the post-dam upstream as the “natural situation” and the post-dam downstream as the “human-influenced situation” to enable a comparison in the same time to ensure the same external factors (e.g. meteorological).

7. Experiment Design: Reviewer noticed that the length of the observed data and simulated data are different (Figure 5, 6, and 7). Any comments on some drought events happened after 2010 as many figures are showing a significant decreasing trend during the recent years?

Please see our response to the point above in regards to the different time periods. We comment on the change in drought frequencies between the upstream and the downstream stations, with a decrease in events observed downstream during the recent years in comparison to upstream, due to the reservoir.

8. Clarity and Presentation: A general overview of the WEAP model (inputs, output, general structure. . .) can give better understanding of the result section, as the author mentioned variation in water use as the reason for the performance of the model.

We propose to remove the information and results from the WEAP model element and focus on the observation data and the two methods (ST and TL).

9. Support of Conclusion: Line 575-592. This section again states some already known facts of reservoir operation, and the functionality of reservoir in mitigating droughts. One argument authors have drawn was on reservoir has capability of mitigating short-term drought, and has limited capability for multi-year droughts. This is not a surprise and it is due to the sizing of reservoir and local hydrology. None of the reservoir in the world will have unlimited resiliency for extreme water supply conditions. What is the uniqueness of the selected reservoir in Chile? And what the novelty of using author proposed methods to identify something already known?

The paper is not about the reservoir itself, but the method and idea of quantifying the human influence. Therefore, the method is not only applicable to the Santa Juana reservoir in Chile, but to other reservoirs and other human activities across the world.

10. Support of Conclusion: Last but most importantly, authors started the manuscript with a very new terminology of “anthropogenic drought”. This is true for deforestation, urbanization, and ground water over drawing or human activities induced temperature/CO₂ increases. However, this manuscript focuses on analyzing the modelled and observed data prior and after a single reservoir built in Chile. The scope of work falls better into reservoir operation, and drought mitigation by reservoir releasing strategies, instead of anthropogenic activity induced drought conditions.

We do not use the term “anthropogenic drought” in the paper, we refer to anthropogenic activities and how they influence drought. These influences could be negative (drought aggravation) or positive (drought alleviation, e.g. like the reservoir analysed here). We argue that the human actions of building and managing a reservoir is very much a direct anthropogenic activity that changes the severity and timing of drought compared to the normal, as seen here. In our study the reservoir had an alleviating effect on drought conditions, but different types of reservoirs can have negative impacts (aggravating), e.g. reservoirs built and managed for the purpose of supplying drinking water rather than providing water security downstream.

We disagree with the reviewers comment about the scope of the work and put this down to a misinterpretation of our aims, which we have now clarified (see aims). Furthermore, in changing the title and adding in sentences in the introduction, we believe that we have framed the scope of the work better.

11. Some English grammar issues such as: Line 12: which basin? Line 76, “It is currently unclear on what is the . . .”, the word “on” seems to be extra. Line 389, “including a having of average duration and deficit volumes with the presence of the dam” is not clear and need to be restructured. Line 500, “in which it they have”, the word “it” seems to be extra.

Thank you for highlighting these grammar errors, we made changes.