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Discussions

Interactive comment on "Positive and negative human-modified droughts: a quantitative approach illustrated with two Iranian catchments" *by* Elham Kakaei et al.

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Interactive comment on "Positive and negative human-modified droughts: a quantitative approach illustrated with two Iranian catchments" by Elham Kakaei et al.

Anonymous Referee #2 Received and published: 11 July 2018

This paper proposes a new methodology to identify positive and negative human modified droughts and tests the methodology on two Iranian catchments. There certainly should be more studies investigating human-modified droughts and it is refreshing to see a case study application with data from catchments in Iran. However, there are a

number of key issues with the study that affect the robustness of the results and conclusions. While I agree with the authors that the methodology could enable quantification of positive and negative human modified drought in the Anthropocene - currently (1) the methods are not very clear which makes it difficult to understand exactly what was done in the study and (2) the methodology only works and attributes droughts correctly if the modelling simulations are robust. The model performance and large differences during the naturalized period do not provide confidence in the validity of the key results of the paper and instead I believe that the human-modified droughts identified are more due to hydrologic model uncertainty rather than human activities. The presentation of the figures also needs to be significantly improved. I encourage the authors to re-address the hydrological modeling they have done, to significantly revise the methods section and to improve the quality of the figures to support their key results.

- The authors appreciate the reviewer's constructive comments. The comments have been incorporated in the revised manuscript. Responses to the specific comments can be found below.

Response:

- In the paper, a step-wise methodology was proposed to make a distinction between different hydrological drought types in the Anthropocene e.g. climate-induced drought, human-induced drought and human-modified drought. We propose a methodology to distinguish and quantify positive and negative human-modified droughts to explore the impact of human interferences on river flow and groundwater. The methodology uses naturalized conditions obtained by simulation modeling as a reference to distinguish the droughts. So as the first step (Step 1), the non-parametric Mann–Kendall test and Pettitt's test were applied to characterize the trends and change point of hydrometeorological variables. Any other technique could also have been used, as long as these distinguish between the natural and disturbed periods. According to the Pettit's test results, the change point divided the study period into two periods: the "natural" and "disturbed" periods. Then at Step 2, hydrological modeling was performed and the model was calibrated and validated using the data from the natural period. By calibrating the model for the natural period and applying this calibrated model to the disturbed period, the discharge of the disturbed period was naturalized. The HBV light model with the DELAY response routine was selected as a hydrological model (more details about hydrological modeling are presented on P6, section 2.3.2). Clearly any other model could have been used that is able to naturalize disturbed time series. Next, as Step 3, the threshold for the drought analysis was defined for the natural period and applied to the disturbed period. Then, at Step 4, the natural drought (climate-induced drought) and the two human-affected droughts (human-induced drought and human-modified drought) types were distinguished by comparing the naturalized, observed and threshold. Finally, as a final step (Step 5), which is the innovative part of the approach, a distinction between positive and negative human-modified droughts has been made through an extended anomaly analysis. The methodology and each step are broadly described (P3, l7-23). In addition, each step was presented in more detail in Sections 2.2, 2.3, 2.4, and 2.5. We think that these descriptions together with the conceptual diagram (Fig. 3) and the equations in Section 2 adequately explain the proposed methodology. We have moved some text from Section 2 Methodology to Section 3 Results to make the description of the Methodology more clear (Section 3.1, P10 l5-l22 and Section 3.2, P10 l25-l31 and P11 l1-l11).

- The model's performance was evaluated by comparing simulated against observed discharge, especially considering low flow discharge by calculating the Nash-Sutcliff efficiency with logarithmic values of the observed and simulated discharge (lnNSE), which reacts less on peak flows and stronger on low flows than NSE (Krause et. al., 2005) (P7 l9-l21). The NSE$\geq$0.5 has been defined as an acceptable value for model performance (Christiansen, 2012; Moriasi et. al., 2007) (P7 l22-24). The lnNSE for both catchments was equal to 0.5 or higher (Table 1), which we think is acceptable considering the purpose of the study. Although, the model uncertainty will affect the numbers, and other model structures likely will result in other numbers, we believe that the portion of negative and positive human-modified droughts will not substantially

change, e.g. differences similar to what we obtained by using different thresholds (Table 5). Furthermore, we would like to stress that the focus of the paper is on the methodology rather than on the exact numbers for the two Iranian catchments. These are only in the study to demonstrate the methodology (P2, l30-33, P3, l28) Hence, we did not aim at finding a model structure with the best model performance. - In order to support the results of the current research most of the figures were also revised and presented in a better way.

Main Comments

Subdividing the time series into natural and disturbed

Better justification is needed to prove that these statistics are identifying change points. One way could be to gain qualitative data about human activity that is occurring in the catchment (i.e. was a dam built in the change-point year, or a significant new water abstraction implemented?). Figure 1 also needs improving- currently it is really difficult to see any evidence of a distinct change point. As low flows are of interest then discharge could be plotted on a log scale, you should remove the blue dots and I would also add precipitation data. I would also consider plotting a much shorter timeseries (perhaps years that have similar climatic characteristics for both the natural and disturbed period).

Response:

- A justification for change point in discharge time series has been presented in Section 3.1 (P10 l5-l22) for both the Eskandari and Kiakola catchments. Figure 1 (Annex 2) has been deleted and the change point in the discharge and rainfall time series are presented on a y-logarithmic scale (P37, Figure 1 and P38, Figure 2). In addition, the FDC of monthly discharge have been added for the natural and disturbed periods before and after of change point (P 39, Figure 3).

HBV Hydrological Modelling Set Up

a) Objective Function – It isn't clear from the paper whether you used logNSE or NSE. There also needs to be better justification for this use of objective function – there are lots of different metrics that evaluate low flows and you need to better justify your choice here and discuss how it might impact the results.

Response:

- The model performance is evaluated based on the lnNSE, which is appropriate objective function for low flow simulation (P7 l9-l21). It has been frequently used. Each of the statistical criteria has specific pros and cons, which have to be taken into account during model calibration and evaluation. The Nash-Sutcliffe efficiency (NSE) and the coefficient of determination are very sensitive to peak flows, at the expense of being less sensitive to low flow condition. They are based on the squared differences between observed and simulated values (Pushpalatha et. al., 2012; Krause et. al., 2005). Additionally, the coefficient of determination alone should not be used for model evaluation, because it can have still high values for very poor model results, because it is based on the correlation only. In order to reduce the problem of the squared differences and the resulting sensitivity to high extreme values the Nash-Sutcliff efficiency is often calculated with logarithmic values of observed and simulated values (lnNSE), in particular if drought is considered. Through the logarithmic transformation of the discharge values the peaks are flattened and low flows are kept more or less at the same level. As a result the influence of the low flow values is increased in comparison to the peaks values resulting in an increase in sensitivity of lnNSE to systematic model over- or underestimation. So, the lnNSE reacts less on peak flows and stronger on low flows than the NSE (Krause et. al., 2005). So, in the paper the lnNSE has been utilized as an appropriate objective function for low flow simulation.

b) Calibration – The calibration section needs to be much better explained. On Page7, L6 it states that 'The calibration procedure was done more than fifty times' and then on L9 it states 'each calibration was repeated 100'. It isn't particularly clear what the calibration procedure is (simply optimizing logNSE but then R2 is introduced?), how the

parameters ranges were chosen for each of the 14 parameters, how many samples were implemented (50 or 100?) etc. On L9 it also states that this 'resulted in 100 different parameterizations' but it isn't clear how these 100 different parameterizations were used in the rest of the study – I assume you just took the best one to use in the rest of the study but given the uncertainty in the hydrological model, your results would be much more robust if you calculated natural-human drought characteristics for all 100 parameterizations.

Response:

- For the Eskandari and Kiakola catchments the DELAY response routine was used as one of the options in the HBV model, and values of HBV parameters were determined by using the genetic calibration algorithm, which is described by Seibert (2000). Possible ranges of parameter values were defined based on previous studies (Seibert, 1999; Vis et al., 2015). With the genetic calibration algorithm (P6, l26), optimized parameter sets are found by an evolution of parameter sets using selection and recombination. An initial population of n parameter sets is generated randomly in the parameter space and the 'fitness' of each set is evaluated by the value of the defined objective function. From this population a new generation of parameters is produced by n times combining two of the parameter sets. The two sets are chosen randomly, but the chance of being picked is related to the fitness of the parameter set (i.e., the value of the objective function) giving the highest probability to the sets with the highest fitness. In the paper, the calibration procedure was done more than fifty times. Because of the random elements of the Genetic Algorithm and Powell optimization (GAP optimization) used for calibration (Vis et al.,2015), each calibration was repeated 100 times (number of model run for each parameter set), which resulted in 100 different parameterizations. The fitness of each set in the new population is evaluated and the new generation replaces the old one. However, the best set is retained if there is no better set in the proceeding generation. This evolutionary process has been repeated for a number of generations until the maximum number of model runs has been reached (100 times) (P6 l28-l32 and

P7 l1-l8). Finally, the HBV model with the best set of parameters based on the lnNSE was selected for the further analysis. We have decided not to calculate natural-human drought characteristics for all a large set of parameterizations because the focus of the study is on the methodology rather than on the outcome for the two catchments.

c) Calibration Results – It is very difficult to see from Figure 4 the comparison between the observed and simulated discharge. It would be useful to plot a comparison of the flow duration curves (on log scale)

Response:

- Thanks for the suggestion. Figure 4 has been replaced by the FDCs of observed and simulated discharge for the natural period (P29, Figure 4).

HBV Model Results

The attribution of positive and negative human-modified droughts rests entirely on the performance of the model and its ability to represent the naturalised flows. From Figure 5, the observed flows are plotted against the modelled naturalised flows for the period 1987-1988 for Eskandari and 1988 – 1989 for Kiakola. As I understand it from Section 2.2.2 both these periods lie in the 'natural' period (undisturbed period) for each catchment and so you would expect the naturalised model flow to (as much as possible) represent the observed flow and so climate-induced droughts to be identified at the same point in the time series. In this case, there are quite large discrepancies between the observed and modelled naturalised flows and climate-induced droughts are identified at completely different points. This is because the threshold is derived from the observed flows (which are very different to the naturalised flows produced by the model) and so casts doubts on the modelling results as they should be similar for the naturalised period. This has knock-on impacts for the attribution of positive and negative human modified droughts, which again I think are due to model simulation uncertainty rather than human influences. Consequently, it is difficult to have confidence in the results and key conclusions of the paper.

Response:

- Uncertainty is an intrinsic part of the any hydrological modeling. The quality and quantity of hydrometeorological data of arid and semi-arid regions have been the biggest concern of hydrological modeling. In the selected case studies, long time series of observed hydrometeorological data were not available and do not have a high quality. In addition, the spatial distribution of rain gauges in both catchments likely has impact on the hydrological modeling. Besides that, security issues and water conflicts that have occurred over the past years have led to reduction in the availability of information in many parts of Iran. In the paper, we tried to minimize the uncertainty to an accepted level by using a genetic calibration algorithm (GAP optimization) to find an optimal parameter set. Model performance was evaluated by using the lnNSE as an accepted measure by low flow researches. Model performance expressed as lnNSE was not high, but equal or just above the minimum ($\geq$0.5) in both catchments. Hence, we accepted the model for further analysis. We agree that the non-perfect model performance leads to uncertainty in the naturalized flow, which is reflected in differences (i.e. bias) between the observed flow and the naturalized flow for the undisturbed period. Yet, the identification of climate-induced drought is based upon the naturalized flow time series and the threshold derived from these series, which implies that we do not have to account for the bias. The human-modified droughts are more affected, because these are compared against the observed flow. It certainly will have influence on the portions of negative and positive human-modified droughts, similar as the selection of the threshold (Section 5, Table 5). However, the focus of the paper is on the methodology rather than on the actual portions of the negative and positive human-modified drought, which allows us to accept the outcome of the model as a mean to illustrate the potential of the methodology.

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Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2018-124/hess-2018-124-AC3-supplement.zip

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