Responses to the comments from Reviewer #2

We are very grateful to the Reviewer for the positive and careful review. The thoughtful comments have helped improve the manuscript. The reviewer's comments are italicized and our responses immediately follow.

The paper presents a fairly interesting study on an important topic with substantial results and insights. The research therein is a good fit for HESS. The main focus is on the impact of human water use/regulation activities on drought. The authors also carried out a number of seasonal meteorological/hydrological forecast experiments and I find them very carefully designed and carried out. The results/discussions are clearly presented too. My major concerns are on the analysis methodology and the adequacy of supporting information. The study area is one large river basin in China while a quite minimum level of specific information on the local water management is provided. Usually, more information on the surface water use practices will be very useful in helping readers understand the findings and their implications across similar areas in other parts of the world. I recommend its publication in HESS with improvements on the analysis method and additional discussion on local water management and how that leads to what is seen in the results.

Response: We would like to thank the reviewer for the positive comments. We have added two new figures and the corresponding text to provide the water management information in details, and have revised the interpretation of the relation between meteorological and hydrological drought. Please see our responses below.

Specific Remarks

The paper (circa P. 5, L. 3-18) interprets the peak correlation time scale as the "optimal response time of streamflow to sub-basin averaged precipitation", while offering no supporting evidence (e.g. citation of previous research, data results). The 6-12 months (and later 8-16 months) "response time" seems incredibly long and beyond what a hydrologist can reasonably expect. Given the size of the Yellow River basin, it shouldn't take more than a month or two for water to travel from rain-falling hillslopes down to river gauging stations. And the local soil water stores or snowpack won't be able to defer the release of precipitated water for that long either. SPI/SSI does time averaging to the underlying parameters and this essentially smooths out noises at shorter time scales. A true "response time" is usually calculated from time lagged correlation analysis, e.g., between SPI-1 and SSI-1. Either the "response time" needs to be calculated differently or the same calculations need to be interpreted differently. Note that the change in the relationship between meteorology and hydrology is one of the major points in the paper as summarized in the abstract.

Response: We greatly appreciate the positive comment. We calculated the response time as suggested by the reviewer and found that the most significant lag correlations occur at lag-1 month both for naturalized and observed streamflow along the mainstream of Yellow River, although the lag-correlations are again lower for the observed streamflow.

Actually in the last version of the manuscript, we followed the work done by Vicente-Serrano and López-Moreno (2005), and thought the time scale with the maximum correlation is considered as the time scale of SPI that streamflow responds to, i.e., the SPI time scale that has the most similar variations to the SSI. However, we have realized using "response time" in the manuscript would be very confusing. So, we have removed all "response time" throughout the paper, and have re-written the corresponding text as follows:

Abstract—"It is found that human interventions decrease the correlation between hydrological and meteorological droughts, and make the hydrological drought respond to longer time scale of meteorological drought especially during rainy seasons."

Section 3.1—"Similar to Vicente-Serrano and López-Moreno (2005), the time scale with the maximum correlation is considered as the time scale of SPI that streamflow responds to. For the naturalized streamflow, it responds to 6-12 months SPI over the upper and middle reaches of Yellow River, and about 4 months SPI over the lower reaches … Except for the Tangnaihai gauge in headwater region, the SPI time scales with the maximum correlation are longer for the observed streamflow, suggesting that human interventions basically make the hydrological drought respond to longer time scale of meteorological drought … It is found that streamflow responds to shorter time scale of SPI in wet and warm seasons and longer time scale in dry and cold seasons. "

Concluding Remarks—"Comparison between naturalized and observed SSI at 12 hydrological gauges along the mainstream of the Yellow River basin (the second largest river basin in China with a drainage area of 7.52×105 km2) shows that human interventions decrease the correlation between hydrological and meteorological droughts, and make the hydrological drought respond to longer time scale of meteorological drought especially during rainy seasons."

Further, the notion of "nonlinear response" of hydrological drought to meteorological drought is a bit vague in the discussions. The rainfall-runoff process is by itself "nonlinear" and lagged in time, at least at short time scales. If the word "response" refers to the rainfall-runoff process (at any time scale), the research here should try to find out what exactly human interventions did to that process. Reduction in streamflow volume (i.e. significant amount of consumptive use)? Longer lag times (delayed release for flood control)? If the lag times become longer, should this be considered in the forecast post-processing procedure? (For example, a time series based procedure that looks at a prior history instead of just the current month.)

Response: We have also removed "nonlinear response" in the revised manuscript given that the focus of this work is not to investigate the lag-correlation for forecasting. We have plotted the annual cycle of naturalized and observed streamflow in Figure 3 to show the effect of human interventions, and revised the section "2.1 study domain and hydroclimate observation data" as follows:

“In general, human interventions decrease streamflow over upper and middle reaches of Yellow River during rainy season while increase it during dry season (Figs. 3b-3h). This suggests that reservoirs in the upper and middle reaches store rain water in wet season and distribute it in the remaining time of the year according to the need, which is similar to regulations in other parts of the world (Wada et al., 2014). Actually, Figure 4a shows that the annual mean observed streamflow at upper reaches can be higher than the naturalized streamflow during dry years due to the reservoir water release (e.g., years 2000, 2002, 2006 and 2010 for Lanzhou gauge). Over the lower reaches, the observed streamflow is significantly lower than the naturalized streamflow during wet season due to heavy water consumption (Figs. 3i-3l), but the former is close to the latter during dry season because of no significant water consumption or reservoir management.”

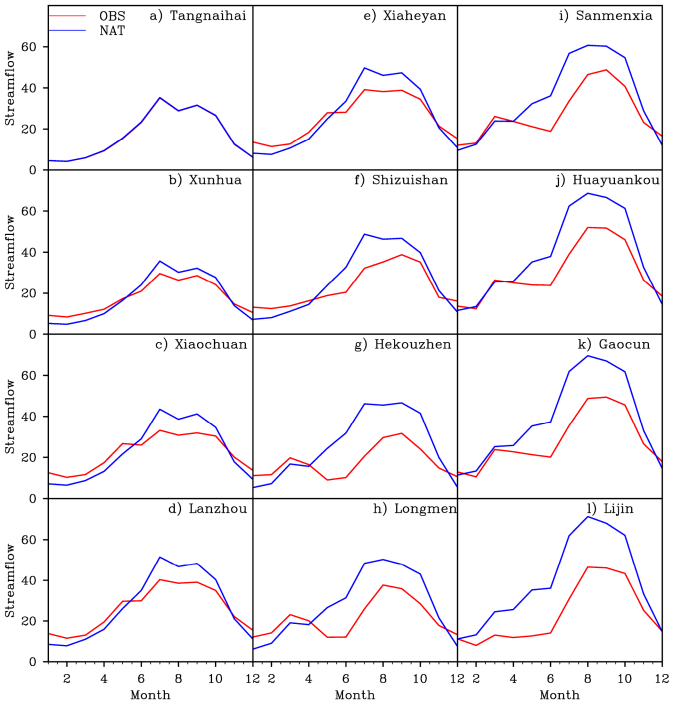

Figure 3. Monthly mean naturalized (blue) and observed (red) streamflow (10^8 m^3) averaged over 1961-2010 for 12 hydrological gauges located from upper to lower mainstream of the Yellow River.

For the same reasons, more information on the water regulation practices in the study area is needed for a (much) better understanding of the impacts and differences found in the results. For example, reservoirs may store rain water from wet season and distribute it in the remaining time of the year according to the need. How much of the streamflow water is being regulated in the Yellow River basin (e.g. reservoir capacity relative to the annual total inflow) and for what purposes? How much of the streamflow is being modified (in both absolute and relative senses)?

Response: We thank for the comment. We have now collected annual statistics for the reservoir storage change during 1998-2010, but failed to obtain the monthly data. Based on the data available, we have added Figure 4 to show the interannual variations of naturalized and observed streamflow and the reservoir storage change, and we have revised the manuscript as follows: "Figure 4 also shows that the magnitudes of reservoir storage changes are quite small as compared with streamflow. In fact, the mean absolute changes of reservoir storage during 1998-2010 are about 14%-38% and 12%-14% of observed and naturalized streamflow, respectively. This suggests that other human interventions, such as direct withdrawal of surface water for agricultural, industrial and civil consumptions, account for a large part of streamflow variations over Yellow River."

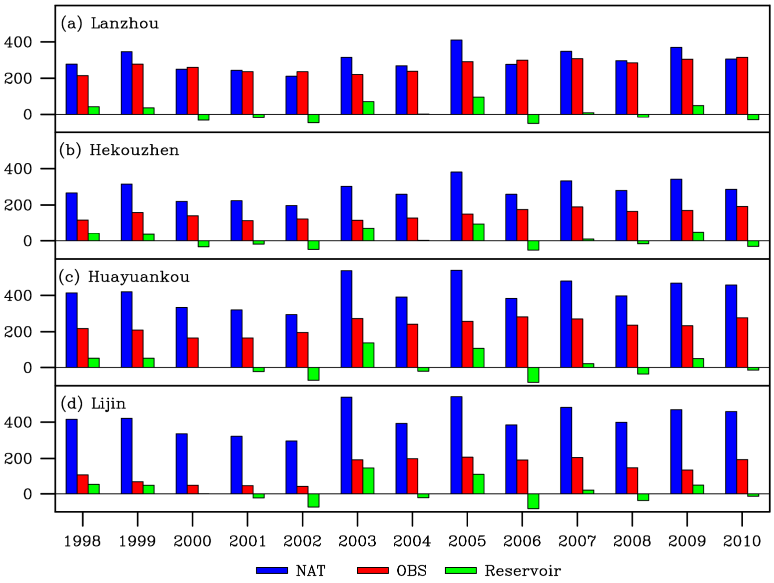

Figure 4. Annual mean naturalized (blue) and observed (red) streamflow (10^8 m^3), and reservoir storage change (10^8 m^3, negative green values represent reservoir water distribution) within four selected sub-basins during 1998-2010.

Fig. 4 helps to understand the scenario but direct comparisons between observations and naturalized values (in seasonal cycles and annual totals) can help explain what happened in Fig. 4 in a much better way. I guess the observed SSI in Fig. 4 is calculated against observed flow climatology and naturalized SSI against naturalized flow, right? (Please clarify.) If so, the comparisons between the two do not reveal the difference between the observed and naturalized climatologies, e.g. reduced total flow volumes or lagged peak times.

Response: Observed SSI in Fig.4 is not calculated against observed flow climatology. Actually both naturalized and observed SSI are calculated against the naturalized flow climatology, so they can be compared to detect the effect of human interventions on hydrological drought. Seasonal cycle of original values are now shown in Figure 3 (please see our response above) to support the SSI analysis.

Specific information on the local water management and water use practices is always helpful in understanding the findings and their implications across similar areas in other parts of the world (Wada et al., 2014). The study could be significantly stronger if more specific water management information is provided and related to the research findings.
Response: Thanks for the comment. Two figures regarding the seasonal cycle of monthly naturalized and observed streamflow, and the annual mean streamflow and reservoir storage change have been added into the revised manuscript. Please see our responses above.

P. 5, L. 13: nonlinearly -> nonlinear
Response: Revised as suggested.

Fig. 1: The map needs to show at least the Yellow River and its main tributaries (thicker lines for the main stream) under this study. Replace the political boundaries with sub-basin boundaries (keep the coast lines).
Response: We have revised Figure 1 as suggested.

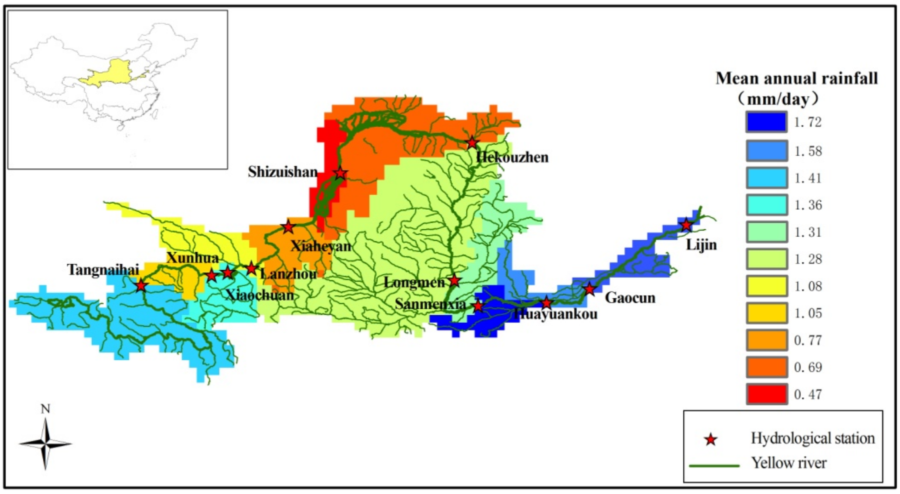

Figure 1. Locations of hydrological stations over the Yellow River basin. Shaded areas are regional mean annual rainfall (mm/day) averaged during 1961-2010.

Fig. 4: SSI at what time scale? 1-month? Subplots are too small and better if they are rearranged into multiple columns.
Response: Fig. 4 (Fig. 7 in the revised manuscript) has been replotted to show the panels in two columns. The SSI is at 1-month time scale, and it has been clarified in the revised figure caption:

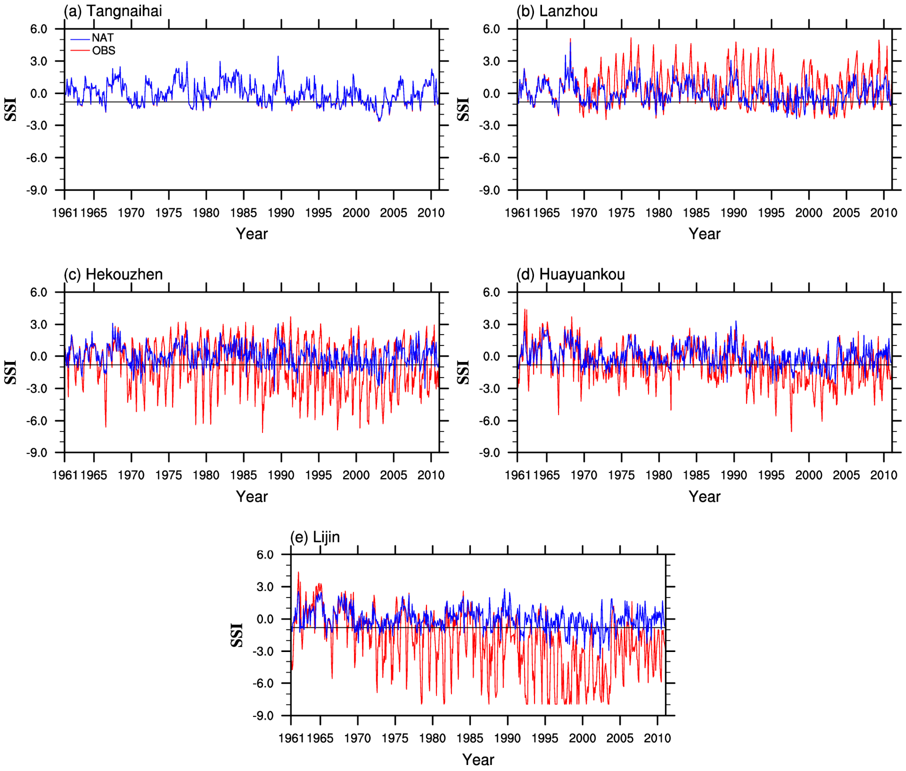

Figure 7. Time series of naturalized (blue) and observed (red) 1-month Standardized Streamflow Index (SSI) for five selected hydrological gauges. The horizontal black lines represent the threshold of -0.8 for drought conditions.

References:

Vicente-Serrano, S. M. and López-Moreno, J. I.: Hydrological response to different time scales of climatological drought: an evaluation of the Standardized Precipitation Index in a mountainous Mediterranean basin, Hydrol. Earth Syst. Sci., 9, 523–533, doi:10.5194/hess-9-523-2005, 2005.

Wada, Y., Wisser, D., and Bierkens, M. F. P.: Global modeling of withdrawal, allocation and consumptive use of surface water and groundwater resources, Earth Syst. Dynam., 5, 15-40, doi:10.5194/esd-5-15-2014, 2014.