List of Responses to the Reviewers' Comments

Journal: Hydrology and Earth System Sciences

Title: Drought Risk Assessments of Water Resources Systems under Climate Change: A Case Study in Southern Taiwan

Author: T. C. Yang, C. Chen, C. M. Kuo, H. W. Tseng, P. S. Yu

Dear Editor and Reviewers:

Thank you very much for your important comments and constructive suggestions. We have addressed the reviewers' comments in the revised manuscript. Each suggestion or comment is shown below in **Bold** followed with our action to modify the manuscript accordingly. All the page and line numbers correspond to locations in the revised manuscript except as otherwise specified. Moreover, according to the suggestion in the supplement, the authors have made necessary corrections in the revised manuscript. The revised contents in the revised manuscript are highlighted in red.

Reviewer #2:

[1] **The paper requires careful attention to issues of language. Some examples: Page 12396, line 16: "…which makes a big challenge on water supply and allocation…"; Page 12396, line 20: "…climate change causes that the atmospheric temperature and sea surface temperature increase."; Page 12397, line 8: "may increase obviously in the future, which let Southern Taiwan have to face the possible water shortage and make a big challenge to the authorities of reservoir on water supply and allocation."; Page 12397, line 13: "…which makes the wet and dry seasons obviously distinct in the area."**

Response: According to this comment, the authors have made necessary corrections according to the supplement provided by the reviewer. The revised manuscript has also been carefully checked and edited again.

[2] **Page 12403, line 10-14: The term "discount" is not explained nor are the values of A1-B2 given. It can be assumed that these terms mean "reduction factor" of the value of the demand when the reservoir level is in certain zones. But: are these substantial reduction factors, which would be**

anticipatory and reduce the demands before a shortfall occurs?

Response: Thank you for this comment. The authors have added the explanation for the term "rates of discount" **[Page 8, Line 13 of the revised manuscript]** and the values of A1-B2 are also given **[Page 8, Line 16 of the revised manuscript]** in the revised manuscript. Following is the added statement: These rates of discount are used to reduce the amount of water supply for more water reservation when the reservoir storage is below the limit of operation rule curve. Referring to "Operation Directions for Tsengwen Reservoir", the values of A1, A2, B1 and B2 are 1.00, 0.75, 0.80 and 0.50, respectively.

[3] Tsengwen watershed and reservoir are used as a case study: capacity 7,800 MCM, "the reservoir encloses" 481 km2 (is this the reservoir area or the watershed area?), precipitation 2740 mm/year.

Response: In the study, the watershed area is 481 km^2. For more readability, the authors have provided a more clear statement **[Page 4, Line 6 of the revised manuscript]**. The unit of annual precipitation has been corrected to mm/year. **[Page 4, Line 9 of the revised manuscript]** Moreover, all the units in the revised manuscript have been carefully checked again.

[4] It is stated that there are also considerations of flood control and hydropower (Section 2), but these do not appear at all in the rest of the paper (so why mention them?). - Total supply is 1,047 million tons (1,047 mcm using tons is unusual). Is this the average demand or an actual average supply to meet the demands? Figure 5 shows the demands but the actual supply is now shown.

Response: (1) According to the reviewer's comment on considerations of flood control and hydropower in the simulation model, the authors added the following description in the revised manuscript. **[Page 7, Line 6 of the revised manuscript]** "While the hydropower generation uses and releases water instantaneously but does not consume water, only water supply and flood control are considered in reservoir operation. The equation includes the inflow, draft (water supply), evaporation, spill (flood control) and storage of reservoir in each time period".

(2) The following description has been added into the revised manuscript. **[Page 4, Line 1 of the revised manuscript]** "Tsengwen Reservoir,

completed in 1973 with a storage capacity of about 780 MCM, is the largest reservoir in Taiwan and has multifunction of water supplies for agricultural water use, industrial water use, public water use, flood control and hydropower generation. The reservoir has to provide an amount of water about 1,047 MCM per year (i.e., the average demand) for satisfying all water uses."

(3) The analysis of monotonic behavior is executed through inspecting the monotonic response of selected index to explanatory variables. In this study, the four variables (i.e., evaporation loss, storage volume, demand and inflow) in the continuity equation, Eq(4), are used to detect the monotonic behavior of index in **Figure 5**. The actual supply, therefore, is excluded in the figure.

[5] The paper uses units that are either not common or not internally consistent in the paper: tons of water; 10-day periods (Figures 3, 8, 12); monthly volumes (Figures 4, 9, 10, 11). This makes the reading difficult, as the reader must adjust to these different units in order to compare results.

Response: (1) All the units in the revised manuscript have been carefully checked and expressed in a common form suggested by the reviewer. For example, instead of million tons and million m^3, the unit of volume is expressed in million cubic meters (MCM).

(2) Due to the operation rule curves of Tsengwen Reservoir is based on a 10-day period, the authors measured the demands (**Figure 3**), shortfalls (**Figures 8** and **12**) and other variables by 10-day period.

(3) In **Figures 4**, the time scale of plotted data is daily scale, however, the label of time-axis is expressed in month for brevity.

(4) In **Figures 9**, **10** and **11**, the values of daily variable (e.g., rainfall, storage and water supply amount) were summed up to monthly values but temperature and inflow are expressed in monthly mean.

[6] The inflow "adjustment" in section 4.4 and especially 4.4.2 seem completely artificial, motivated to generate a desired result, justified only by the ratio of forecasted future precipitation relative to the historical value (page 12410).

Response: (1) Thank you for this valuable comment. The inflow "adjustment" is not completely artificial, motivated to generate a desired result. The adjustment proposed in the study is mainly for (a) removing the system errors derived from the weather generator and the hydrological model, and preserving the change rate of mean monthly inflow and (b) keeping the generated inflow temporal pattern close to the observed inflow temporal pattern;

(2) For removing the system errors derived from the weather generator and the hydrological model, and preserving the change rate of mean monthly inflow (i.e., adjusting factor), the adjusting factor for each month in Eq(20) is defined as the ratio of generated future mean monthly flow divided by generated baseline mean monthly flow. For keeping the generated inflow temporal pattern close to the observed inflow temporal pattern, the adjusted daily inflows during the future period were obtained by using the observed daily inflows multiplied by the adjusting factor in Eq(21).

[7] The justification for selecting MSUI as the most appropriate index is not fully convincing. Using a monotonic response of the index to explanatory variables must be justified (a) Why select these particular explanatory variables: evaporation, storage volume, demand, inflow? (b) Why, for example, not combine inflow and evaporation into "net water input to the reservoir"? They act in the same sense (Figure 5, for DRI and especially MSUI) namely more inflow and less evaporation (the reverse of the top graph) produce the same form of the response of the index? (c) Isn't it obvious that indexes that define drought must increase with demand and decrease with storage and inflow?

Response: (1) Our paper uses a monotonic response of the index to explanatory variables based on the previous studies (Jain, 2010; Kjeldsen and Rosbjerg, 2004) which suggested that suitable water resource indexes should have monotonic behaviors (i.e., the value of index will monotonically increase or decrease when an explanatory variable increases or decreases). Since the water supply process is modeled by the continuity equation in Eq(4), this implies that all the variables in the continuity equation will affect the water supply and subsequent water shortage. Therefore, the authors used evaporation loss, storage volume, demand and inflow to examine the monotonic behavior of index. In the process of monotonic examination, only one of the former variables can be changed and the other variables should be kept constant.

(2) In the paper, the aforementioned four variables are independent and used for monotonic examination individually. Therefore, combining inflow and evaporation of reservoir as a variable is not considered presently, but considering this combination is interesting in the future work.

(3) In **Figure 5**, although it is obvious that indexes that define drought have the increasing tendency with demand and the decreasing tendency with storage and inflow, <u>not all the indexes have monotonic responses to explanatory variables</u> (e.g., the response of DRI to evaporation in **Figure 5(a)** and the responses of SUI to the four variables in **Figure 5(b)**).

Jain, S. K.: Investigating the behavior of statistical indices for performance assessment of a reservoir, Journal of Hydrology, 391, 90-96, 2010.

Kjeldsen, T. R. and Rosbjerg, D.: Choice of reliability, resilience and vulnerability estimators for risk assessments of water resources systems, Hydrolog. Sci. J., 49, 755–767, 2004.

[8] The reservoir is operated with fixed rule curves, i.e. there is no optimization that would/could be anticipatory and change the supply in view of forecasted future inflows and/or reservoir state. This task (of anticipating shortage) seems to be provided by the coefficients A1-B2 (page 12403), but there is no information that would explain how "clever" and "influential" these operational coefficients are. The drought indexes obviously depend on these coefficients and the supply is curtailed by them. But this does not appear in the results nor in the explanations. - This operation with fixed rule curves plus (unspecified) discount (reduction) factors is particularly deficient when one has a hydrological forecasting mechanism built into the system.

Response: (1) Because the study aims at assessing the "climate change impacts" on water supply and subsequent drought risk, the assumption of no change in operation modes during both the baseline period and the future period has been made. Therefore, the study let the reservoir be operated with fixed rule curves and fixed reduction factors for this assumption.

For reducing the impacts under climate change, optimization for reservoir operation is an efficient approach and will be considered as the future work. The authors have added the related statement in the section “Conclusions”. **[Page 19, Line 23 of the revised manuscript]**

(2) Referring to “Operation Directions for Tsengwen Reservoir”, the coefficients (i.e., reduction factors) used in this study are determined and fixed during both the baseline and future periods. The authors have added the values of coefficients A1-B2 and related description in the revised manuscript. **[Page 8, Line 13 of the revised manuscript]**.