Reviewer 1

Thank you for the opportunity to revise this manuscript. Our responses that appear below will follow the format described below:

- black = reviewer comments
- blue = our responses to reviewers
- green = new text additions to the manuscript (as part of the revision)

We are sincerely thankful to the reviewers for their insightful comments and constructive suggestions. We have thoroughly addressed each point raised by the reviewers in the form of detailed explanations in this response document and modifications throughout the manuscript and the SI.

R1.1. The authors Zhao et al submitted a manuscript to GMD entitled with "GCAM-GLORY v1.0: Representing Global Reservoir Water Storage in a Multisector Human-Earth System Model". They intend to improve the representation of GCAM by developing GLObal Reservoir Yield (GLORY) and coupling to GCAM to enable inclusion of a feedback loop and update of the mechanisms of the reservoir module, specifically the water supply potential of reservoirs for satisfying water use demand. The manuscript is logically structured (esp. in Sect. 2) and well written. The authors clearly describe the rationale of the many decisions that have to be made for developing and running GLORY and coupling it with GCAM. Sometimes this reads by nature a bit lengthy but in fact, this level of detailed description is necessary to understand the structure of the model components. The authors demonstrate the application of the model with 4 scenarios to show the effect of the described model development. Those results are also well described, both by figures (e.g. Fig. 7) and the related text (e.g. around L720). The results show the difference to the original, static reservoir representation. Interpretation and scientific evaluation of the results (e.g. relation to other models) is not focus of the manuscript which is fine for the given manuscript type in GMD that focus on model description. So, I think the authors did a very good job and I have only a few remarks which could make the manuscript even more readable / broaden readership.

Thank you for your supportive comments and suggestions, which we agree will help to enhance the readability of the paper for a broader audience. Also, we agree that the paper is highly detailed, and thus can read a bit long. We have thus tried to eliminate unnecessary detail, but we think that the currently remaining content is required to fully understand the contribution.

R1.2. Congratulations to the provided meta-repository on GitHub which I enjoyed exploring.

Thank you for exploring our Github meta-repository. We are committed to supporting open science and we built our meta-repository to share data and codes we developed in this study and provide instructions to guide readers to reproduce our experiment and results.

R1.3. L 96 Agree, but for readers of communities that are not so familiar with MSD models, it would be really good to read a broad review about the principles and mechanisms of MSD in general, and also the difference to other approaches like GHMs. The authors relate to a nice tabular overview in the Supplement when it comes to the reservoir representation but I have the impression that such a table alone is not too informative and I would wish to see some additional explanatory text. I think both (overview and differences) could be very valuable to embed your work and broaden up readership. It can certainly be a paragraph in the Supplement, if text space in the main manuscript is the limiting point.

Thank you for your suggestions—we agree. First, we have added clarifying text to the Introduction section to describe what MSD models are, and under that MSD umbrella, what "global MSD models" are. This modified text reads as follows:

The emerging transdisciplinary field of Multi-sector Dynamics (MSD) is well positioned to explore these interactions given its focus on modeling complex systems of systems that deliver services, amenities, and products to society (Reed et al., 2022). Under the MSD umbrella, a sub-class of models simulate the integrated human-Earth system with global coverage by representing the integrated interactions among energy-water-land-climate-socioeconomic systems. While global MSD models are well-positioned in theory to explore multi-system interactions, their representation of reservoirs (especially future reservoir storage expansion) have remained limited (Bell et al., 2014) (See our review of reservoir representation in global MSD models in Table S1). Here we enhance the representation of reservoir storage in a global multi-sector model, the Global Change Analysis Model (GCAM) (Calvin et al., 2019), and demonstrate the scientific insights that can emerge as a result of this addition.

We have also expanded the SI to include commentary on Table S1. We think it is better to keep this text in the SI rather than the main manuscript. This is because we wish to streamline our manuscript (which, as the reviewer noted is already rather long). We also wish to make it clear that the focus of the paper is on advancing GCAM's capabilities, rather than serving as a comprehensive review of all global MSD model capabilities. One reason we do not wish to provide such a comprehensive summary is that there is a large and diverse group of models in this category, and they vary widely in quality and consistency of their water sector documentation, so we do not want to misrepresent the current state of capabilities from those modeling teams. Our new SI text now reads as:

Table S1 provides an overview of the representation of reservoir storage across a representative sample of global multi-sector dynamic (MSD) models designed to explore the interactions among climate, land, energy, water, and socioeconomic (CLEWS) systems from regional to global scales. MSD is an emerging transdisciplinary field that models complex systems of systems that deliver services, amenities, and products to society (Reed et al., 2022). A small subset of MSD models maintain full global coverage (i.e., model the entire world), and contain a diverse set of multi-sectoral CLEWS interactions that differ across models. The GCAM model is the focus of this paper. Table S1 is a representative, rather than exhaustive, list of models intended only to provide a broader context regarding the class of global MSD models that GCAM resides within. While we classify all of the models in Table S1 as global MSD models, a separate but long-standing body of literature also refers to many of these models as "Integrated Assessment Models" (or IAMs; Weyant 2017; Fisher-Vanden and Weyant, 2020). We use the label "global MSD model" here for multiple reasons, including to denote that models such as GCAM have substantially evolved with regard to spatiotemporal and sectoral process resolution, and have placed increasing focus on impacts, adaptation and vulnerability, and have thus evolved substantially enough from the original simple climate-energy “IAMs” to warrant a new clarifying label (global MSD model). It is also worth noting that each “model” may actually include a whole suite of models designed to interact with one another.

As shown in Table S1, the models share similarities along the “water availability” and “water supply” dimension (see definitions below Table 1). Reservoirs appear most prominently in the water supply category. The models are similar in the sense that they all include (often as part of a broader multi-model framework) a hydrology model (e.g., LPJmL), which in turn may (or may not) represent reservoir storage. While the hydrology models may represent reservoir storage, we find that they often do not represent “reservoir storage expansion”, including GCAM. Thus, we believe the current study is a novel contribution to considering global reservoir storage expansion. While not the focus here, the global MSD models differ significantly along the water demand dimension, including whether the process is handled exogenously or endogenously to the core global MSD model, as well as with regard to the approaches (e.g., economic versus physical) for allocating scarce water resources to different demand sectors.

R1.4. Sometimes (e.g. the overview section within Sect. 2.1) I read several aspects of review, motivation and application possibilities which I would not necessarily see well fitting in a methods section. Therefore, I would suggest to concentrate to methodological description in the methods section and put other aspects to other parts of the manuscript. Specificly, I was a bit surprised to read in around L 150 two (additional) research questions; would have loved to read those in the Intro section. That could help to streamline the manuscript and avoid repetition. On the other hand, I really enjoy reading Sect. 2.2.1. So, it is a bit a question of the right amount of overview (nicely done in 2.2.1) or going sometimes a bit beyond (e.g. 2.1.1) and of course it is subjective to find the right balance. I nevertheless would suggest to go through and try to improve the balance of the components.

We thank the reviewer for their valuable suggestion. In response, we have revised both the introduction and methodology sections to improve the balance between methodological details and introductory context. Specifically, we have refined section 2.1.1 and enhanced the concluding paragraph of the Introduction section to ensure a comprehensive coverage of the respective sectional topics.

R1.5. In some sections, e.g. 2.3.4 it is not always clear which time period is meant. E.g. Fig 4 vaguely expresses “historical SEDI levels” – but it would be good to have a statement in the figure caption which time period is meant. Also, as some of the input data are depending on Xanthos input it would be good to read which climate input the GHM is using (specifically to generate the diagrams in Fig. 4). This certainly would help the reader to digest such diagrams.

Thank you for bringing this to our attention. We have provided clearer explanations regarding the historical period used for calculating the average historical SEDI levels, spanning from 2005 to 2010, both within the manuscript text and in the caption of Figure 4. Additionally, we have enhanced the clarity surrounding the datasets used to drive Xanthos, including the historical climate dataset (WATCH) and the future climate dataset (MIROC-ESM-CHEM under RCP 6.0). The modified caption reads as follows:

Figure 1. Average surplus and deficit between water supply and demand during historical 2005 – 2010 period in six selected basins. The historical demand is from Huang et al. (2018) and the historical inflow is derived from Xanthos runoff driven by WATCH climate forcing (Weedon et al., 2011).

The modified text reads as follows:

Figure 4 shows the average historical (i.e., 2005 - 2010) SEDI levels globally with examples of average monthly water deficit and surplus for six basins.

R1.6. L 46 Text in brackets should be within the previous sentence

Thank you. We have relocated the sentence enclosed in brackets to be within the preceding sentence.

R1.7. L510 GranD should be read as GRanD

Thank you for spotting this. We have thoroughly reviewed the entire manuscript and corrected instances of the "GranD" to "GRanD."

R1.8. L 256 I cannot find the two references (with the indicated year) in the reference list. Please check carefully the coherence of references within the manuscript and the reference list.

We thank the reviewer for identifying this. After a thorough review of the entire manuscript, we have added the references that were cited in the manuscript, but were not included from the reference list:

- Liu, Y., Hejazi, M., Li, H., Zhang, X., and Leng, G.: A hydrological emulator for global applications – HE v1.0.0, Geoscientific Model Development, 11, 1077–1092, https://doi.org/10.5194/gmd-11-1077-2018, 2018b.
- Sanmuganathan, K., Frausto, K., Heuperman, A., Hussain, K., Maletta, H., Prinz, D., Anguita Salas, P., and Thakker, H.: Assessment of irrigation options, Cape Town: Final Draft, WCD Thematic Review Options Assessment IV, 2, 2000.
- Vernon, C. R., Hejazi, M. I., Turner, S. W. D., Liu, Y., Braun, C. J., Li, X., and Link, R. P.: A Global Hydrologic Framework to Accelerate Scientific Discovery, Journal of Open Research Software, 7, 1, https://doi.org/10.5334/jors.245, 2019.
- Zhao, X., Calvin, K. V., Wise, M. A., Patel, P. L., Snyder, A. C., Waldhoff, S. T., Hejazi, M. I., and Edmonds, J. A.: Global agricultural responses to interannual climate and biophysical variability, Environ. Res. Lett., 16, 104037, https://doi.org/10.1088/1748-9326/ac2965, 2021.

R1.9. Fig 8: Please write in the figure caption the thick black line.

Thank you for your suggestion. We have revised and included an explanation for the thick black line in the Figure 8 caption:

“The thick dashed and solid lines in orange and blue are for 2030 and 2050 and the thin solid lines are for the rest of the periods. The thick black line represents the supply curve for the *Reference/Climate Impacts* scenarios, which is created from the existing GCAM supply curve approach described in *section 2.2.3*.”

R1.10. Fig 9: suggest to extend the figure caption to better grasp the content solely from figure and figure caption.

Thank you for your suggestion. We have enhanced the caption of Figure 9 to better illustrate the concept of the fraction of low-cost renewable water. The new caption reads as:

Figure 9. (a) Fraction of low-cost (\$0.001/m^3) renewable water over total runoff for 2050, and (b) Changes of low-cost fraction from 2020 to 2050 under Feedback scenario. The fraction of low-cost renewable water is affected by runoff amount, reservoir unit construction cost and reservoir yield characteristics. Changes in the fraction of low-cost renewable water represent shifts in the supply curve concerning water price at \$0.001/m^3.