Rebuttal documents for the manuscript no. HESS-2024-26 entitled:
"The impact of future changes in climate variables and groundwater abstraction on basin-scale groundwater availability", submitted to the Hydrology and Earth System Sciences Journal

Editor comments:

Considering the reviewers' feedback, I recommend proceeding with the publication of the manuscript following minor revisions.

Response to Editor:

We sincerely thank you for the effort you have allocated to manage the reviewing and open discussion process of our manuscript. We see that one reviewer has suggested to accept the manuscript as it is, while the other one suggested to accept subject to minor revision. We have responded to both reviewers, while also accommodating the comments from the latter in our latest revision. All the issues have been addressed accordingly. Looking forward to your and the referee's response to this. Thank you very much.

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Referee #1 comments: I thank the authors for revising their manuscript. I believe the novelty is now more clearly articulated. Response to Referee #1: We would like to thank you for the effort the referee provided to review our manuscript. Indeed, thanks to your previous comments and suggestions, we believe the overall quality of the manuscript, especially how the novelty is articulated is now improved. Below we responded to your further comments individually.
Referee #1 specific comment no. 1: Regarding the added details on recharge calculation, the sentence added on lines 262-265 is not entirely clear. How does the "maxleakage" parameter enter the calculations? Can you give the equation? Also, you seem to equate groundwater recharge with vertical groundwater movement between shallow and deep aquifers, which is confusing. Response to Referee #1 specific comment no. 1: Thank you for your feedback. Regarding the 'MaxLeakage' parameter, we agree to add more information, and to that extent, quoting the definition of the parameter from the model documentation itself. In the wflow_sbm model, MaxLeakage is usually only used for linking to a dedicated groundwater model, where it represents the water that 'lost' to the model. Normally set to zero in all other cases, when the MaxLeakage is set to be higher than zero, the simulated water is treated to be lost from the saturated zone (and runs out of the model). As wflow_sbm model only take into account the first couple of meters of soil below the surface level, the water that leaves the saturated zone is then treated as the groundwater recharge. We hope this explanation makes things clearer and easier to understand. Additionally, this description is now added in subsection 2.4.2 'Wflow_sbm model setup', paragraph 2, line 258 to 263 (clean version).
Referee #1 specific comment no. 2: Since parameter "maxleakage" controls recharge in the model, the question arises whether this parameter can change. The assumption here seems to be that it is constant. But what if it changes? Is this plausible or not? And would that affect the recharge projections in any way? Some additional discussion on this seems relevant, for example around lines 534-545 where assumption of one-way model coupling is discussed. And can you explicitly state there whether it may be useful to revisit these assumptions in future work, and if not, why you think these assumptions are inconsequential for your conclusions. Response to Referee #1 specific comment no. 2: Thank you very much for this great suggestion. Indeed, when we set the model up, we started with the assumption that the MaxLeakage parameter remains constant during the simulation period. Your point is absolutely valid, as soil characteristics might evolve, albeit in a much longer time scale than the surface features. In our opinion, changes in soil characteristics would influence the MaxLeakage parameter, therefore also impacting the simulated projected groundwater recharge. While these changes are gradual, they are likely to affect recharge over time, potentially causing significant deviations from current projections. However, the tendency of how soil characteristics evolve long term, particularly regarding groundwater recharge generation, remains uncertain. Whereas, accurate future projections require constant soil monitoring and modeling. This further highlights the importance of data, especially soil-related data and hydrological information as the benchmark for model calibration and verification.

Consistent data assimilation that are validated through updated observation and simulation would decrease the uncertainties, making it possible to make the MaxLeakage parameter setup dynamic over time. Again, thank you again for such an interesting and critical question. We have added this to the discussion section as your suggested in subsection 4.2 'Impact assessment on future groundwater level projections', paragraph 3, line 534 to 545 (clean version).
Referee #1 specific comment no. 3: Line 265: suggest to say "river discharge" instead of "discharge" Response to Referee #1 specific comment no. 3: Thank you for your suggestion. It has been adjusted accordingly.
Referee #1 specific comment no. 4: Figure 9: what do you mean by "aquifer water balance of groundwater recharge and abstraction"? Is it abstraction minus recharge? Response to Referee #1 specific comment no. 4: Thank you for your question. We basically aim to plot and show the development of the two variables overtime: while the recharge (as impacted by the changes in climatic variables) remains relatively consistent, the groundwater abstraction (as the direct consequences of changes in anthropogenic factors) has a much higher change in relation to the aquifer water balance. Therefore, your deduction is right, and even one step further by looking at the difference between the propagation of the two variables (hence abstraction minus recharge, as you stated).

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Referee #2 comments:

Accepted as is. No suggestions, major comments have been incorporated in the revised manuscript.

Response to Referee #2:

We would like to thank you for the effort the referee provided to review our manuscript. We believe the inclusion of response and suggestions from the previous round of reviews have improved the manuscript, thanks to your excellent review.