

Dear Reviewer 2,

Thank you very much for reviewing our manuscript. We found your comments very helpful for improving the overall quality and, in particular, the readability and clarity of the manuscript. Below, we provide our responses to each of your comments. Line numbers refer to the revised manuscript with tracked changes.

Reviewer 2:

The authors present a new global hydrological modeling framework, VIC-WUR v3.0, which couples VIC-WUR with MODFLOW 6 to improve the representation of surface water–groundwater interactions. The manuscript is well written overall, and I have only a few comments, as detailed below.

1. Section 2.3: It is not entirely clear to me how the modeling framework operates, particularly given the different temporal resolutions of VIC-WUR and MODFLOW 6. VIC-WUR operates at a daily time step, whereas MODFLOW 6 operates at a monthly time step. Regarding the statement, “Within the next daily VIC-WUR run, the MODFLOW-derived baseflow is added to each river reach prior to routing, thereby augmenting surface discharge with groundwater contributions,” does this mean that VIC-WUR-derived groundwater recharge and total surface streamflow are provided as inputs to MODFLOW 6 at the end of each calendar month, and that the resulting MODFLOW-derived baseflow is then provided to VIC-WUR at the beginning of the following calendar month? Please clarify the temporal coupling and data exchange between the two models.

Response: Thank you for this comment. Your understanding of the temporal coupling is correct. We have revised Section 2.3 to clarify the sequence and timing of data exchange between VIC-WUR and MODFLOW 6 (line 172-176). In addition, we have added a table that explicitly summarizes the temporal resolution, exchanged variables, and timing of the coupling between the two models (line 124).

2. Section 3.1: VIC-WUR and MODFLOW 6 use different grid systems. Could the authors clarify the rationale for using different grids rather than adopting a consistent spatial grid for both models? It would also be helpful to briefly discuss whether the differences in spatial discretization affect the exchange of information between the two models.

Response: Thank you for this comment. We have clarified the flux exchange in the newly added table. In this study, MODFLOW 6 is implemented on an orthogonal structured grid, whereas VIC-WUR retains its regular geographic (latitude–longitude) grid, which is consistent with the native spatial representation of most climate forcing and land-surface datasets. To account for the resulting differences in grid-cell area, all exchanged fluxes are scaled by the corresponding cell areas prior to transfer between the two models, ensuring consistent water-volume exchange across the two grid systems.

3. Section 3.2: The computational times for VIC-WUR and MODFLOW 6 are reported separately. Since the two models are coupled within the proposed framework, could the authors clarify whether they are run sequentially or concurrently? It would

also be helpful to report the total computational time required for a complete coupled VIC-WUR–MODFLOW 6 simulation.

Response: Thank you for this comment. VIC-WUR and MODFLOW 6 are executed sequentially rather than concurrently. For each calendar month, VIC-WUR is run first, after which the aggregated groundwater recharge and surface streamflow are passed to MODFLOW~6. The resulting baseflow, capillary rise, and updated water tables are then returned to VIC-WUR for the following month. We have clarified this sequential coupling procedure in Sect 2.3.

We have also updated Section 3.2 to report the computational time for the complete coupled workflow (line243-245). The previously reported throughputs of 2.2 and 16.1 simulated years per day refer to the VIC-WUR and MODFLOW~6 components, respectively. Including both components and the associated monthly data-exchange steps, the complete coupled workflow used to produce the 1980-2009 analysis required approximately 17~d of wall-clock time, corresponding to an overall throughput of approximately 1.8 simulated years per day.

4. Section 4.2: Line 194 mentions that available large-scale observation-based groundwater datasets (Fan et al., 2013; Jasechko et al., 2024) were used for model evaluation. Could the authors specify which datasets were used and explain how they were incorporated into the evaluation?

Response: Thanks for the comment. We have clarified how did we use the dataset and adapt it to the comparison of the observation and simulation (line222-226). The direct observation-based evaluation of VIC-WUR used the monitoring-well water table depth data compiled by Jasechko et al.,2024. The annual observations were aggregated to the 5~arcmin model grid and temporally averaged. Because the model evaluation was performed using water table elevation, the observation-based elevations were calculated as the HYDROSHEDS land-surface elevation minus the observed water table depth. These values were then compared with simulated water table elevations in the corresponding grid cells. Only cells with valid values in both datasets were retained, resulting in 46,733 overlapping grid cells for the main evaluation.

The water table depth estimate of Fan et al.,(2013)was not used as observational dataset to validate our model but relates to the intermodel comparision. We have made it more clear in the manuscript.

Specific comments:

1. Line 178: “A steady-state solution of MODFLOW provides initial water tables”. Does it refer to a previous work? If so, add reference.

Response: Thank you for this suggestion. It is indeed necssary to clarify that the steady-state MODFLOW~6 solution was generated specifically for this study and was not taken from previous work. To ensure consistency with VIC-WUR, we reconstructed the river network, floodplain elevations, river depths, and river stages according to the VIC-WUR model structure. The steady-state MODFLOW~6 simulation was forced using the 40-year mean groundwater recharge from an uncoupled VIC-WUR simulation. The resulting steady-state water tables were then used as the initial conditions for the transient coupled simulation. We have added this information to Sect. 3.1 (line 196-201).

2. Figure 6: Too small to see the details.

Response: Thanks for the comment. We have adjusted the layout of figure 6 to make it more visualized (Page 17) .

3. Figure 7: High groundwater support ratios also appear in cold regions, such as Canada and Russia. Please explain.

Response: Thank you for pointing this out. We agree that the high groundwater support ratios simulated in some cold regions, particularly northern Canada and Russia, are likely overestimated. In the current configuration, MODFLOW 6 does not represent permafrost or groundwater-freezing processes, and therefore does not account for the associated restrictions on groundwater flow and groundwater–surface water exchange under frozen conditions. We have now clarified this in the manuscript and explicitly identified it as a limitation of the current model configuration when interpreting results in high-latitude cold regions.