Final Response : Technical note: HydroModPy – a Python toolbox for deploying catchment-scale shallow groundwater models

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Referee comments on "Technical note: HydroModPy – a Python toolbox for deploying catchment-scale shallow groundwater models" by A. Gauvain et al., Hydrology and Earth System Sciences Discussions., https://egusphere.copernicus.org/preprints/2026/egusphere-2026-868/.

Thank you for your review. Referee comments are shown in black, and our point-by-point responses are provided in blue italics.

1 RC2: "Comment on egusphere-2026-868", Anonymous Referee 2, 19 May 2026

Gauvain et al. present the framework HydroModPy that constitutes a method for script-based construction of groundwater models. The framework uses existing functions from well established packages like WhiteboxTools. The framework allows to extract watershed delineation information, setup the model with the required parameter data, calibrate the model against observation data, and export model results for further analysis or directly visualise them. I appreciate the author's work to develop a framework that simplifies the creation of groundwater models for catchments.

We thank the reviewer for this positive and constructive assessment.

While referee 1 already pointed out quite some important points, I feel that currently the paper is missing a recognition of how uncertainty and equifinality might influence the model calibration framework. Coming from a hydrological modelling perspective, uncertainty of input data, model structure, model parameters and even scenario uncertainty are relevant because those influence the model results. While I dont think a technical implementation has to be included at this point for this paper, the relevance and its implications for the framework application should be discussed. This especially applies to potential equifinality of model parameters. Here, a recognition of this aspect should be included and, in for future version, technical approaches to evaluate uncertainty and equifinality in model calibration could be discussed.

We agree that uncertainty and equifinality are important considerations in groundwater model calibration. The calibration framework in HydroModPy is currently under development, and we are actively working on incorporating methods to evaluate parameter uncertainty and equifinality, such as sensitivity analysis and multi-objective calibration approaches. We clarified this in the manuscript by acknowledging the importance of these issues and outlining our plans for future enhancements to address them.

We added this paragraph in the "Strengths and limitations of current examples" section: "Beyond structural simplifications, uncertainty and equifinality represent important methodological considerations that are not yet explicitly addressed in the current calibration framework. In particular, multiple parameter combinations may produce equally acceptable model fits which can limit the interpretability of calibrated values and the robustness of model predictions. Uncertainty in input data (e.g., recharge estimates, stream network maps) and model structure further compounds this issue."

We also added this paragraph in the "Improvements and perspectives" section: "These developments will also address the equifinality challenge inherent in catchment-scale groundwater model calibration, by enabling formal uncertainty quantification and the identification of parameter sets that are non-uniquely constrained by the available observations."

Major comments:

Lines 41 to 47 and lines 455 to 461: In the introduction, you mention the disadvantage of GUI-based model development environments in their limitation to explore parameter sensitivity and uncertainty of model parameters. However, HydroModPy currently does not allow for sensitivity analysis or estimation of parameter uncertainty as well. Then, later in lines 455 to 461 you mention that HydroModPy is further developed to incorporate a graphical interface. This seems to clash with what you wrote in the introduction.

Thank you for this comment. As we mentioned in the previous response, we are actively working on incorporating sensitivity analysis and uncertainty estimation methods into HydroModPy. The planned graphical interface doesn't correspond to a traditional GUI-based model development environment, but rather to a user-friendly interface that will allow users to easily access and utilize these new features. We clarified this in the manuscript to avoid any confusion and to better align the introduction with our future development plans.

Line 114, Figure 1: Why is model calibration not a step in this workflow overview if it is quite central for model development?

Agreed. In this version of HydroModPy, the calibration step is still under development and not yet fully integrated into the automated workflow. However, we recognize its importance and are actively working on incorporating it. We clarified this in the text and updated Figure 1 to include calibration as a key step in the workflow, even if it's currently a manual process that will become more automated in future versions.

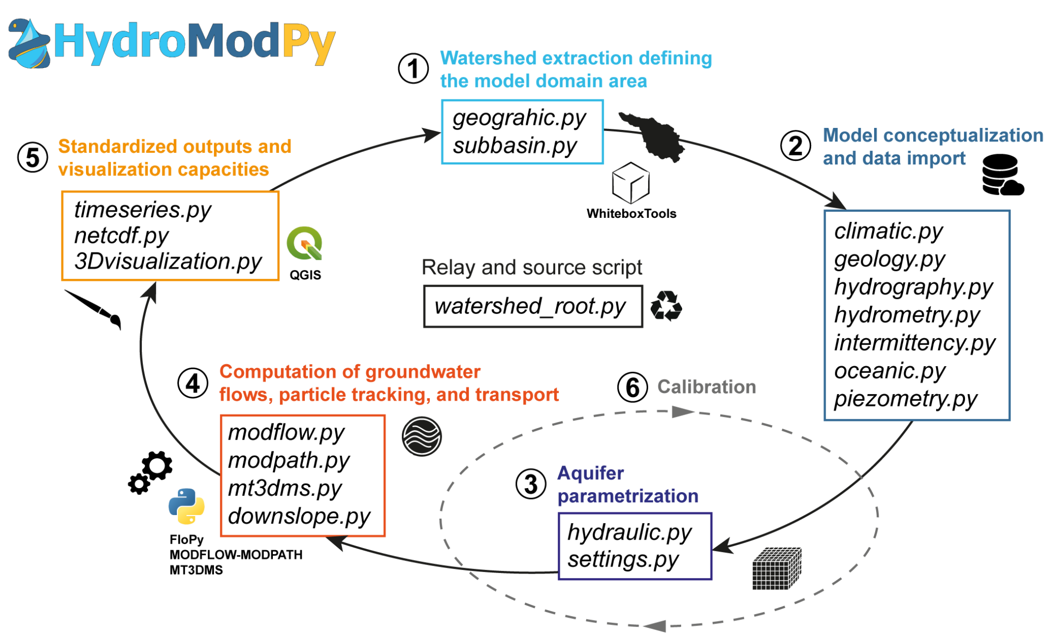

Figure 1. *Workflow of HydroModPy, illustrating the organization and interconnection of Python scripts within the toolbox across five main stages: (1) watershed extraction defining the model domain area from digital elevation models and outlet coordinates, (2) model conceptualization and data import, including climatic forcing, hydrographic networks, and observational datasets for calibration, (3) aquifer parameterization, specifying hydraulic properties, geometry, and boundary conditions, (4) computation of groundwater flows using MODFLOW-NWT via FloPy, with optional particle tracking (MODPATH) and transport simulations (MT3DMS), (5) standardized outputs and visualization, exporting results in geospatial formats (GeoTIFF, shapefile, NetCDF, VTK) and providing 2D/3D visualization tools for interactive exploration and analysis, and (6) comparison of outputs and data for calibration.*

Line 127: That sounds like the buffer value is chosen quite arbitrarily? Wouldn't it make more sense to have a workflow where this model domain extention is chosen based on the discrepancy between discharge-effective precipitation and measured discharge? In KarstMod, for example, the parameter RA (Recharge Area) scales the effective area of the catchment to close the water balance when precipitation and ETa are well constrained.

We agree that the choice of the buffer size should be informed rather than arbitrary, and we thank the reviewer for this valuable perspective. However, increasing the buffer size does not necessarily improve the agreement between effective precipitation and measured discharge. Groundwater seepage may occur beyond the catchment boundaries, and not all effective precipitation contributes to streamflow at the catchment outlet. In addition, enlarging the domain in HydroModPy creates new lateral outlets, meaning that a larger model domain does not necessarily translate into a larger recharge area for the main outlet.

For the study area considered here, we performed sensitivity tests with increasing buffer sizes and found that enlarging the domain beyond 20% of the catchment extent had a negligible impact on the simulation results. Consequently, a 20% buffer was selected as a reasonable compromise between capturing potential cross-boundary groundwater exchanges and limiting computational costs. We also note that this parameter is fully user-defined in HydroModPy and can be adjusted according to the characteristics of the study area and the objectives of the modelling exercise.

Line 144: If the model takes groundwater recharge as input rather than precipitation, isn't that limiting the applicability? I would guess that groundwater recharge time series data would have to be derived from hydrological models.

We agree that requiring groundwater recharge as an input may limit the applicability of the model in cases where recharge estimates are not directly available, as recharge time series are often derived from hydrological models or other preprocessing approaches. This is one of the motivations behind our ongoing work to implement the HELP package in HydroModPy, which will provide a more consistent and integrated framework for recharge estimation. We have mentioned this development as a future extension in the discussion section.

However, HydroModPy is not restricted to externally derived recharge time series. Users may also provide precipitation and actual evapotranspiration (P–ETR) data as inputs through the EVT package, allowing recharge to be estimated within the modelling workflow. This option reduces the dependence on external hydrological models and broadens the applicability of the framework.

Line 321: Does that mean the whole 30 m aquifer is simulated as a single layer? I feel like that could be a calibration rather than parameterisation parameter.

In this specific case study, yes: a 30 m single-layer aquifer conceptualization was used for parsimony and for ensuring comparability across catchments. We agree that this choice can be interpreted more as a calibration-related structural assumption than a fixed parameterization, and we have clarified this point in the revised manuscript:

"The top of the aquifer is defined by the land surface topography, while the bottom is set at 30 meters below ground level (Line 20 in Code 1), with only one layer. This thickness represents the typical depth of the interface between the shallow weathered and/or fractured zone with the underlying fresh bedrock (Roques et al., 2016; Kolbe et al., 2016; Dewandel et al., 2006; Mougin et al., 2015)"

Lines 339 to 340: Does that mean that the evaluation was done over 10 values? I think the sentence can easily be misunderstood.

Thank you. We rephrased this sentence to clearly indicate that 10 candidate Sy values were tested and evaluated for each catchment :

"the optimal model is selected from a set of 10 candidate values of specific yield (Sy), regularly spaced and independently evaluated for each catchment, within the range of 0.1% to 10%."

Minor comments:

Line 3: development

Corrected to "development".

Line 157: coefficient

Corrected to "coefficient".

Line 158: Point within sentence

Corrected punctuation in the sentence.

Line 159: either implemented or specified

We removed this sentence

Lines 159 to 161: Both sentences say the same

Agreed. We removed the redundancy and kept a single clear statement.

Lines 164 to 165: Why is Figure 2d linked here?

The reference to Figure 2d is simply intended to follow the workflow shown in Figure 2 and to illustrate the solver and the computational flow.

Line 359: perennial

Corrected to "perennial".

Line 361: Citation incorrectly embedded in text

Corrected citation placement and punctuation.

References

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