Final response

Referee comment on "HydroModPy: A Python toolbox for deploying catchment-scale shallow groundwater models" by Alexandre Gauvain, et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/egusphere-2024-3962-RC1

Referee comments are shown in black. *Our responses in blue italic.*

General comment:

Dear reviewers, dear editor,

First, we would like to thank the reviewers for their constructive feedback, which will be very helpful in improving the quality of our manuscript.

Regarding the reviewers' suggestion to consider GMD as a potential journal, we would like to clarify that our manuscript does not present the development of a new model, but rather the implementation of a tool designed to support the parameterization and deployment of hydrogeological models. We agree with the reviewers that our work does not fully qualify as a Research Article. For this reason, we believe that our contribution would be better suited as a HESS Technical Note. While our manuscript does not introduce a new model, it addresses an important methodological challenge in hydrological sciences: the regional-scale application of hydrogeological models through a flexible and scalable software architecture. This tool may be particularly useful for the HESS community, including hydrologists, critical zone scientists, and other researchers interested in the representation of subsurface processes. Beyond research applications, the tool can also serve educational purposes. Given these considerations, we would appreciate the editor's guidance on whether continuing the review process as a HESS Technical Note would be appropriate, or whether the editorial committee would still recommend transferring the manuscript to GMD.

After reading the comments, we feel that the main message we intend to convey in this manuscript has been somewhat diluted among the numerous points raised by the reviewers, including the tool's capabilities, future developments, etc. Therefore, before addressing the reviewers' comments, we would like to clarify our intentions and the main message of this manuscript – that we plan to include/clarify in the new version of this manuscript.

In this study, we aim to tackle the challenge of regional-scale deployment of hillslope/catchment hydrogeological models. We have designed HydroModPy to address this challenge. The main objective of HydroModPy is to provide a solution to automatically generate all the input files required for MODFLOW to be run and calibrate models, then propose post-processing functions to extract and visualize the results. In

this paper, we develop the capabilities of this solution with an example focus on bedrock French region, Brittany (recognized as a basement aquifer region with shallow unconfined aquifers), and discuss the main outcomes. To enhance the clarity of our manuscript based on the reviewers recommendations, we propose the following actions:

- *Revise the introduction to better introduce the role of catchment scale hydrogeological models, their strengths, and the challenges associated with their deployment at the regional scale.*
- *Add a paragraph to motivate and clarify the ambitions of HydroModPy.*
- *Move Table 1 to the appendix section and focus the discussion on the method deployment.*
- *Remove technical information that is not directly related to the deployment presented in the results, as well as discussions on future developments that may obscure the main message of the paper.*

In the following, we provide answers to each of the comments raised by the reviewer.

RC1: 'Comment on egusphere-2024-3962', Anonymous Referee #1, 24 Jan 2025

General comment:

The manuscript Gauvain et al. presents a groundwater modeling toolbox HydroModPy. While the toolbox and its description are certainly of great interest to the community, the current quality of the paper makes it hard to understand its value.

Answer:

We are thankful to the reviewer for highlighting the interest of our manuscript. We agree that the quality of the manuscript can be improved, and we strongly believe that comments and suggestions raised by the reviewer will be helpful for this.

First, I do not understand why this paper was submitted to HESS. I suggest resubmitting it to GMD. I also suggest that the authors consider submitting the framework itself to the Journal of Open-Source Software (JOSS) for a thorough review of the code and documentation quality. I mention this explicitly since the code example provides a bad example of well-written code (see my notes below).

Answer:

We chose to submit this paper to HESS because this paper does not present a new model, but rather a software solution that integrates existing models to facilitate the deployment of hydrogeological models. The focus of this work is to demonstrate the possibility to *explore parametrization and calibrate several catchment-scale models based on one methodology proposed in the literature* (Abhervé et al., 2023), and to show how HydroModPy can *facilitate the implementation of such an approach. This is why we believe*

HESS Technical Note is the most suitable journal for this study rather than GMD. We acknowledge your suggestion regarding JOSS, and we will consider submitting a separate publication there to assess the quality of the documentation and the code in order to enhance the proposed tool

Regarding the code example, as stated in the code title, it is a conceptual illustration that does not represent the script used in our study. We will carefully consider all your comments to improve the clarity of the code and ensure that the intended message is effectively conveyed.

I further suggest that the authors more clearly motivate what this toolbox should be used for and how it is similar to existing frameworks within the hydrogeology and hydrology communities. I wonder if it could enable model coupling to further bridge the hydrogeology and hydrology communities.

Answer:
We will include a paragraph clearly presenting the core objectives of HydroModPy. Its main ambition is to facilitate the integration of groundwater processes into catchment-scale models, as these are still often overlooked in hydrological studies. By lowering the technical barrier, HydroModPy makes subsurface flow modeling accessible beyond the hydrogeology community. It also enables the coupling of hydrological and hydrogeological models and supports the representation of key surface–subsurface interactions, such as river network generation from groundwater tables. In addition, HydroModPy is designed as an educational tool, offering a clear and modular framework well suited for teaching groundwater modeling concepts. The proposed Python tool has already been used in 3 universities over the past two years: approximately 120 students to date.

I also suggest that the authors substantially change the specific discussion of the model examples in France. It currently serves no purpose in explaining the modeling toolbox. Instead, it seems like an attempt by the authors to get a peer-reviewed article on multiple groundwater models as a side-product of a software article. I don't understand why Table 1 and Figure 4 are necessary and how they help to explain or evaluate the functionality of the toolbox.

Answer:
The example of the French catchments is not intended to present calibrated model results as a scientific outcome in itself, but rather to illustrate the deployment capabilities of HydroModPy through a practical application. This case study demonstrates how the toolbox can be used to implement a methodology for regional-scale hydrogeological modeling, as described in (Abhervé et al., 2023). We acknowledge that the current presentation may not sufficiently emphasize this objective. We will revise the section accordingly to clarify that the purpose is to evaluate the ability of the toolbox to support model deployment across multiple catchments, not to validate or interpret the hydrogeological calibration/results.
Our responses to the remarks regarding Table 1 and Figure 4 can be found in the specific comments below.

In its current state, the article seems rushed and could benefit from a much more focused approach to the toolbox's actual value. I suggest the authors focus on improving the manuscript before resubmitting it to GMD instead of HESS.

Answer:
To maintain its relevance to HESS, we will improve the manuscript by providing a clearer and more structured discussion of the added value of HydroModPy, particularly in facilitating the deployment of hydrogeological models. Additionally, as an open-source software, HydroModPy is made available to the HESS community, ensuring accessibility and fostering further developments in the field.

Specific comments:

0: Is there a growing demand, or do you simply suspect there is one?

Answer:
We will clarify this point by providing the following references that demonstrate the increasing demand for tools that facilitate hydrogeological model deployment and coupling : *(Clark et al., 2015; Blöschl et al., 2019; Fan et al., 2019; Condon et al., 2021)*

31: That is something FloPy also was capable of. What is the addition of this toolbox?

Answer:
It's true, and Flopy is widely used within HydroModPy. HydroModPy allows to build and configure the hydrogeological model with few lines of code considering certain assumptions in MODFLOW-Flopy python scripts. The framework proposed in HydroModPy is to couple GIS tools and simple use of Flopy without the need to know each function of FloPy and MODFLOW. The formatting of model inputs to match the specificities of FloPy arguments is managed by HydroModPy pre-processing framework. This higher level of abstraction makes it possible to use HydroModPy directly with common datasets and data formats, unlike FloPy. In addition, HydroModPy propose post-processing and visualization framework to easily manipulate and compare results. The workflow architecture is designed to be fully interoperable with other codes and software.

34: What does "advanced" mean exactly?

Answer:
With HydroModPy, we offer various figures (2D, 3D) automatically generated. Some of these figures require post-processing of the model results to be displayed. This is why we use this term. We will clarify this point.

60: What qualifies as a systematic approach?

Answer:

A "systematic approach" refers to a standardized method for implementing and deploying hydrogeological models, enabling consistent and reproducible management of data and parameters.

62: Could you expand on these categories a bit? The following examples do not provide much information if one is unfamiliar with the tools.
65: What advanced software? Is the software already part of the original modeling tools, or are there other libraries or modeling tools? Please be more specific.
67: This sentence is convoluted as it is unclear how the first part links to the second. Further, Zipper et al. talk about a web portal that makes models accessible, not a modeling platform or program.
71: What about:
https://ngwa.onlinelibrary.wiley.com/doi/10.1111/gwat.12654
https://www.sciencedirect.com/science/article/pii/S1364815216311331
https://gmd.copernicus.org/articles/15/5371/2022/gmd-15-5371-2022.html
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021WR031753
https://gmd.copernicus.org/articles/12/2463/2019/
https://doi.org/10.1016/j.envsoft.2020.104728

Answer:

Thank you for these comments and references. We propose to rewrite this paragraph by taking these comments into account and incorporating the mentioned references:

- Raven hydrological modelling framework *(Craig et al., 2020)*
- *MARRMoT* *(Knoben et al., 2019)*
- *Community Workflows* *(Knoben et al., 2022)*
- *The eWaterCycle* *(Hut et al., 2022)*
- *Automated setup* *(Lewis et al., 2018)*
- *FREEWAT* *(Foglia et al., 2018)*

75: Hydrogeology?

Answer:

Yes. We will modify "hydrology" by "hydrogeology" in this sentence.

80: Is building groundwater models based on catchment boundaries is a good idea? Groundwatersheds are not necessarily the same. What is the motivation here precisely?

Answer:
In this paper, we focus on shallow groundwater flow (as mentioned in the title of the paper). In the context of shallow flow, it is generally reasonable to assume that the boundaries of the groundwater model are close to those of the catchment. Additionally, to avoid boundary effects in the model, a buffer is added around the catchment boundaries to increase the model area. Furthermore, it is entirely possible to manually specify the model boundaries using a shapefile in cases where inter-watershed flows may occur.

99: Unnecessary technical detail. Also, why do you implement that as a static method and not through the object's constructor? (btw. it seems that has been updated in your gitlab – please make sure this is consistent with the paper and a specific version)

Answer:
We will revise the manuscript to reduce unnecessary technical details. Regarding the static method, we will ensure the manuscript reflects the latest version and correct any inconsistencies with the GitLab repository. We will replace "This object is created by calling a static method: watershed_root" by "This object is created by the class: Watershed".

Code:

“W”, “K”, “Sy” are not a good variable name. This solidifies bad practices. Why is the initialization of parameters and inputs (recharge) called “update”? Why did the parameters change suddenly (269)? And why are you resetting the same parameters in each loop? If you are using the same parameters why not initialize them outside of the loop – same for the particle tracking settings? Code line 249: Needs code comment.

I propose first to submit the code to JOSS to get feedback on your code quality and possibilities for community engagement.

Answer:
The code presented in this section is a simplified conceptual example designed to illustrate the steps of the methodology. It does not reflect the current HydroModPy code in any way.

We will replace the variable “W” with “Watershed” for better clarity. “K” and “Sy” represent the hydraulic conductivity and specific yield, respectively. We propose to keep this notation, as it is introduced just before in the text at line 257. These notations are generally used in the hydrogeological community.

Line 269: The parameters change because we calibrated K and Sy using the functions “W.calib” (lines 263 and 266). These two functions return the calibrated values of K and Sy, which we then use (line 269).

We will replace line 260 with: W.hydraulic.update_parameters(lay=1, thick=30).
We will remove line 270, which relates to particle tracking.

Regarding parameter initialization: In each loop iteration, we process a new watershed and thus a new 'Watershed' object. Each object needs to be initialized.

125: What kind of databases are these? What kind of regions are they covering? For what regions is no data available? What does the user need to do to supply their own data? What kind of data format and resolution is necessary? Can data be mixed from various sources? How is the spatial and temporal consistency of the data checked?

Answer:
We will complete section 2.2 with the level of detail mentioned in your questions.
The answers to your questions can be found, at least in part, in section 3.1.

132: Fig. 2a is not referenced.

Answer:
Fig. 2a is referenced line 111.

168: Again, why did you make this choice?

Answer:
This comment refers to the following sentence: "HydroModPy is especially suited for shallow unconfined aquifers". We made this choice primarily due to the automatic extraction of the watershed. In the case of a deep watershed, exchanges between watersheds may occur. Although it is possible to model deep aquifers with HydroModPy, defining the hydrogeological basin in this context requires user intervention to specify the study area.
In the case of an automatic deployment over many watersheds, the model domain area corresponds to the topographical watershed with a buffer (approx. + 20% of the catchment area), which may be associated to the watershed of shallow unconfined aquifers.

Section 3.2 and Table 1: I do not understand why this section is necessary. You are utilizing existing modeling software, which has been tested in other publications, and the particular example region you are modeling is irrelevant to describing the package. I understand that an example region is necessary to demonstrate the use of the package, but how the catchments are then modeled massively depends on the data you are using and the assumptions you are making, which is an entirely different kind of assessment that requires an in-depth analysis.

Answer:

In this section 3.2, we present the deployment results without delving into the analysis of the results, as that is not the objective of this paper. Furthermore, the aim of this section is not to test the modeling software, but to show that the software workflow (HydroModPy) has a very limited impact on computation times.

Table 1: The table presents the parameters used as input in HydroModPy (FAIR principles) and the results of the deployment. We acknowledge that the usefulness of this table may be questioned, as no detailed analysis is conducted afterward. The objective of this paper is not to analyze the hydraulic properties of these catchments but rather to demonstrate the feasibility and ease of deploying a method with HydroModPy. We propose moving this table to the appendix.

Figure 4 : However, Figure 4 seems essential to us, as it shows that the tool (HydroModPy) has no impact on the overall computation time and that the hydrogeological model (MODFLOW) is the main factor determining the computation time. For large-scale deployment (across multiple watersheds), computation time is crucial, as it dictates the number of study sites and the feasibility of such a deployment. Therefore, we propose keeping this figure and focusing the discussion on the deployment of this method. This figure shows that beyond common watershed areas (100 km²), the computation time of HydroModPy becomes neglectable before the computation time of the hydrogeological model (MODFLOW).

365: Reference error. Is that referencing Fig. 5? Because I could not find another reference. IF that is the case, this is a much better example than your current table. Why not use existing models to showcase how easy or complicated it is to build these models and how they differ?

Answer:

This reference error indeed refers to Fig. 5. We will correct this mistake. In this paper, HydroModPy is used for shallow unconfined aquifers. For the example presented assuming homogeneous and effective hydraulic properties at the catchment scale. The models shown in Fig. 5 are actually very similar in design to those presented in the study in France. To simplify, only the inputs (recharge) and model parameters such as depth, hydraulic conductivity, and specific yield differ. Therefore, we have chosen to present a deployment in a specific region (Brittany, France). Furthermore, we focus on regions where we have extensive experience and access to high-quality data. In these basement regions, precise observations of river networks and validated streamflow measurements are available, ensuring robust model evaluation and validation.

References of the final response document

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