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

Alexandre Gauvain[1,2], Ronan Abhervé[1,3,4], Bastien Boivin[1], Clément Roques[3], Martin Le Mesnil[1], Alexandre Coche[1], Tristan Babey[1], Jean Marçais[5], Camille Bouchez[1], Sarah Leray[6], Etienne Marti[6], Etienne Bresciani[7], Ronny Figueroa[3], Mathias Pélissier[3], Luca Guilaumot[8], Théa Touzeau[1], Imene Issolah[11], Enzo Maugan[1], Rock S. Bagagnan[1], Camille Vautier[1], June Sallou[9], Johan Bourcier[10], Benoit Combemale[11], Philip Brunner[3], Laurent Longuevergne[1], Luc Aquilina[1], and Jean-Raynald de Dreuzy[1]

[1]Geosciences Rennes – UMR 6118, CNRS, Université de Rennes, Rennes, France
[2]Laboratoire de Météorologie Dynamique (LMD), CNRS, Sorbonne Université, Paris, France
[3]Centre for Hydrogeology and Geothermics (CHYN), Université de Neuchâtel, Neuchâtel, Switzerland
[4]UMR SAS 1069, INRAE, Centre Bretagne-Normandie, Rennes, France
[5]UR RiverLy, INRAE, Centre Lyon-Grenoble Auvergne-Rhône-Alpes, Villeurbanne, France
[6]Pontificia Universidad Católica de Chile, Santiago, Chile
[7]Instituto de Ciencias de la Ingeniería, Universidad de O'Higgins, Rancagua, Chile
[8]BRGM - French Geological Survey, F-45060 Orléans, France
[9]INF, Wageningen University & Resarch, Wageningen, Netherlands
[10]ISA/LIUPPA, Université de Pau et des Pays de l'Adour, Pau, France
[11]Inria, IRISA, CNRS, Université de Rennes, Rennes, France

**Correspondence:** Alexandre Gauvain (alexandre.gauvain.ag@gmail.com) and Ronan Abhervé (ronan.abherve@inrae.fr)

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 RC1: "Comment on egusphere-2026-868", Anonymous Referee 1, 18 Apr 2026

GENERAL COMMENTS

Gauvain et al. introduce a highly useful toolbox for groundwater modelling that is sure to appeal to readers of HESS. Based on established tools, the toolbox integrates them effectively and reproducibly. The explanations are clear and it is illustrated with a practical example.

*We thank the reviewer for this positive assessment of the manuscript.*

In my view, the main limitation of the current version is the type of aquifer systems that can be simulated: 'unconfined shallow aquifers where hydrogeological boundaries roughly correspond to topographic divides' (L82-83) 'where the water table lies close to the surface and topography strongly influences goundwater flow dynamics' (L113). In my experience, aquifer systems do not align with the boundaries of surface catchments as often as one might expect, and the issue of boundary conditions is often a key challenge in hydrogeology. When I consider which of my models this tool could be applied to, I ultimately cannot think of so many examples. It would certainly be an advantage to incorporate the way in which geology shapes aquifer systems. In this sense, I am not entirely convinced by the idea that the tool 'bridge[s] the gap between detailed site-specific studies and regional-scale hydrogeological assessments' (L355-356, see also L383-384) — at least when considering aquifer systems at a regional level (e.g. multi-layered systems).

*Indeed, the present scope is mainly limited to shallow, unconfined and topography-controlled systems. Nontheless, HydroModPy includes an optional buffer-based domain extension to capture possible groundwater flow between neighhboring catchments, and the ability to manually import watershed boundaries using shapefiles.*

*We also clarified this in the text (L355-356 and L383-384) to avoid overstatement and to better reflect the current scope:*

*L355-356 : "This systematic implementation demonstrates HydroModPy's scalability across catchment sizes within its targeted scope of shallow, unconfined, and topography-controlled groundwater systems, providing a standardized and efficient framework for comparative analyses using widely accessible datasets."*

*L383-384: "This approach offers a scalable solution for comparative hydrogeological analysis across multiple catchments, within the current scope of shallow unconfined aquifers where topographic divides approximate hydrogeological boundaries. It is worth noting that HydroModPy supports a buffer-based domain extension to capture potential inter-catchment groundwater exchanges, and model boundaries can also be defined manually via shapefiles to accommodate cases where surface and groundwater divides diverge."*

Nevertheless, the authors put forward many promising prospects, which will surely be attractive to numerous modellers. In the meantime, I think it would be useful to release the current version. While reading through it, I had a number of minor queries and comments, which I have set out below as I went through the text. These in no way call into question its publication in HESS. You will also find a few technical comments.

*Thank you for this comment. We have addressed all minor and technical comments below with corresponding revisions in the manuscript.*

SPECIFIC COMMENTS

L67-74: This paragraph seems a little idealised to me. In my experience as a developer, there is never a perfect 'magic box', and you always have to write some code to adapt it to your specific situation. Proof of this lies in the wide range of initiatives mentioned.

*We agree and our goal is not to present HydroModPy as a perfect solution, but rather as a useful toolbox that can easily build a grounwater model with a high degree of automation and reproducibility, while still allowing for user adaptation and customization. We modified this paragraph:*

*"Although numerous tools have been developed to address specific aspects of hydrogeological modeling, often with varying levels of complexity and scope, their integration into a coherent workflow frequently requires substantial user intervention. In practice, users often need to develop custom scripts and interfaces to connect model domain extraction, model setup, code coupling, model execution, deployment across multiple sites, and FAIR-compliant data management. While this flexibility allows adaptation to diverse applications, it can also increase workflow complexity and hinder reproducibility, portability, and large-scale deployment."*

L73: Similarly, it is always easy and smart to refer to the critical zone, but while this type of groundwater tool may be useful for educating the community, I don't see exactly how it currently 'bridges the gap' and 'promotes collaboration' between hydrogeologists and other communities within the critical zone.

*Thank you for this comment. The possibility of creating a groundwater model with HydroModPy can indeed facilitate collaboration with other critical zone communities by providing a common framework for integrating groundwater processes into broader critical zone studies. We modified this paragraph as follow:*

*"This highlights the need for an integrated and adaptable toolbox that can bring these concepts together within a coherent workflow. Rather than a generic solution, such a framework should combine a high degree of automation and reproducibility with the possibility for user adaptation to site-specific data, assumptions, and objectives. In practice, this type of tool can support interdisciplinary Critical Zone studies by providing reproducible scripts, explicit model settings and metadata, and standardized outputs that can be readily exchanged with other disciplinary tools and workflows. This does not remove all disciplinary barriers by itself, but it provides a common technical basis that can facilitate collaboration between hydrogeologists and other Critical Zone communities (Gaillardet et al., 2018; Wang et al., 2025; Staudinger et al., 2019)."*

L78-80 'patterns of seepage areas can be used to represent the dynamics of the hydrographic network' & L200-204: However, if I understand correctly, this capacity only applies to baseflow, right?

*Yes, the flow representation primarily reflects baseflow-driven groundwater exfiltration and associated seepage dynamics. We modified this sentence as follow:*

*"Thanks to the spatio-temporal simulation of groundwater flow and hydraulic heads, groundwater discharge zones naturally emerge, allowing for studying the dynamics of baseflow."*

L97 'for calibration': The next four steps make no mention of calibration.

*Thank you. Following your comment and the comment of reviewer #2, we revised the workflow description to explicitly include calibration as a key step, and we updated the corresponding figure 1 to reflect this.*

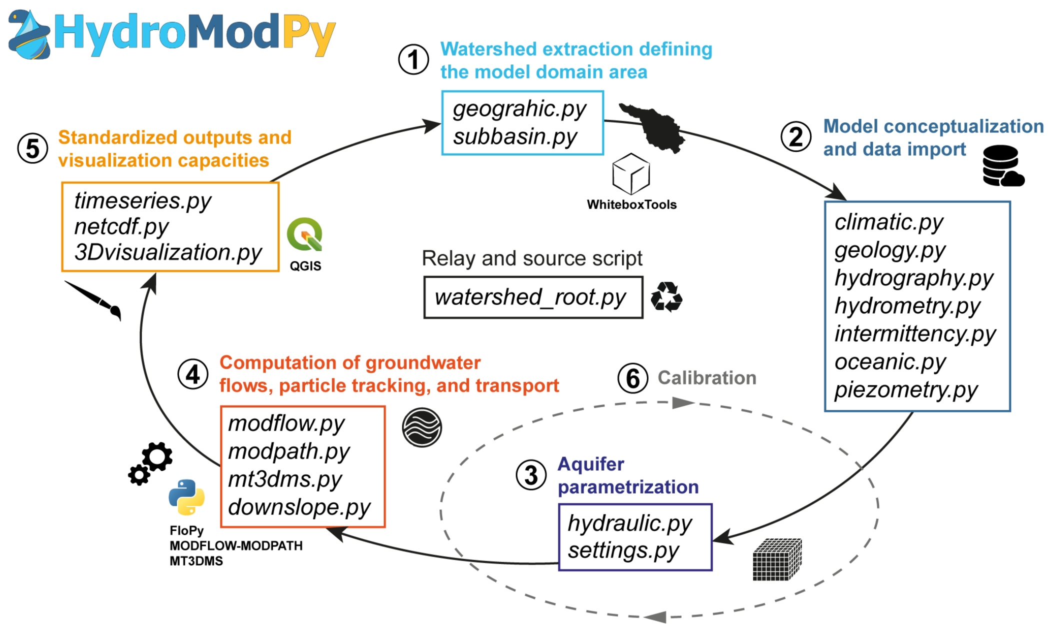


**Figure 1.** *Workflow of HydroModPy, illustrating the organization and interconnection of Python scripts within the toolbox across five main stages: (1) watershed extraction defining the model domain area from digital elevation models and outlet coordinates, (2) model conceptualization and data import, 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.*

L133 'DEM resolution': Is this the best possible resolution for the model? Can it be adjusted?

*In this version of HydroModPy, the DEM resolution is the resolution of the model grid. We are currently working on allowing for independent DEM and model grid resolutions, which will provide more flexibility. We added a sentence in discussion :*

*"Another planned development is to dissociate the model grid resolution from the resolution of the input DEM. In the current version, the DEM resolution defines the model grid, whereas future versions aim to allow these two resolutions to be specified independently, providing greater flexibility to balance topographic detail, model design, and computational cost."*

L136 'by an ocean/sea/lake/river': Or any other lateral aquifer?

*We agree and have rephrased this sentence.*

*"Nevertheless, constant hydraulic head can be imposed at prescribed domain limits to represent boundary conditions imposed by an ocean, sea, lake, river, or by lateral groundwater inflows from adjacent aquifer systems."*

L155 'with the aquifer base specified at a given elevation': Is it a single value, or can it vary across the space? One might wish to interpolate contour lines for the aquifer bottom, which are sometimes available.

*It can be either a single value or spatially variable. We clarified that the aquifer base can be prescribed as a raster/elevation field over space:*

*"The model thickness may be defined as constant, assuming an aquifer base parallel to the topography with a uniform depth, or as spatially variable, with the aquifer base prescribed either as a single elevation value or as a spatially distributed elevation field (e.g., raster)."*

L158 'can be assumed uniform and isotropic across the entire model domain. but heterogeneity' & L160-161 'vertical heterogeneity' 'through anisotropy': 'Heterogeneity' and 'anisotropy' are two distinct concepts.

*Thank you, we agree. We corrected the wording to clearly distinguish spatial heterogeneity from anisotropy, and removed the ambiguous sentence:*

*"Vertical variability of hydraulic properties can be represented as a function of depth or stratigraphic layering, for example through an exponential decay of $K$, $Sy$, and $Ss$ with depth (Figure 2e). Anisotropy is treated separately as directional differences in conductivity (e.g., $K_h \neq K_v$)."*

L160 'defining parameter zones based on geological maps or user-specified units': Could a stochastic approach be used instead?

*Yes, stochastic approaches are possible and relevant. This is a future extension for parameter uncertainty and heterogeneity representation.*

L165-166 'MODFLOW-2005': The current version of Modflow is Modflow 6. There are plans to upgrade to the new version (L413-414). Will this include the Particle Tracking (PRT) Model of Modflow 6 (vs MODPATH) and its Groundwater Transport (GWT) Model (vs MT3DMS) (L184-187)?

*Thank you. We mentionned in section 4.2 that MODFLOW 6 is ongoing and that integration of MF6-native modules (including PRT/GWT) is part of the planned roadmap, while current stable workflows rely on MODPATH/MT3DMS.*

L186: Is it single- or multi-species solute transport? Does it cover basic chemical reactions?

*In the current version, transport is implemented with MT3DMS. In fact, at this stage, we are able to simulate the advection, dispersion, and diffusion of a single chemical species (for example, NO3 in the example provided on the documentation). We can enable a zero-order or first-order reaction. However, the application allows you to enable heterogeneous concentration input and chemical degradation in the 3D model. We clarified as follow:*

*"Solute transport is implemented using the MT3DMS (mt3dms.py) suite (Bedekar et al., 2016), enabling simulation of single-species transport with advection, dispersion, and diffusion. Basic reaction processes are supported through zero-order and first-order degradation kinetics (e.g., for conservative or moderately reactive solutes such as nitrate). Heterogeneous initial concentration distributions can be specified. More advanced reactive transport and multi-species configurations are envisioned as future extensions."*

L172-173 'the storage coefficient corresponds to the vertically integrated specific yield': I don't think the specific yield needs to be vertically integrated, since it has the same dimension as the storage coefficient (unlike the specific storage) and there can only be one unconfined layer.

*We agree and corrected this statement:*

*"For a unconfined (resp. confined) layer, the storage coefficient corresponds to the specific yield ($S_y$) (resp. vertically integrated specific storage $S_s$)."*

Code 1: Wouldn't it be better to calibrate the hydraulic conductivity and the specific yield together rather than separately?

*We used sequential calibration (following this recent paper: https://doi.org/10.1002/hyp.15167) because the calibration methods are based on steady and transient simulations, which are more sensitive to hydraulic conductivity and specific yield, respectively. However, we agree that a joint calibration approach could be more efficient and we are currently working on implementing this in HydroModPy.*

L254-255 'how HydroModPy can be systematically employed to set up, simulate, calibrate, and analyze hydrogeological models across multiple catchments': Does such systematic work risk overlooking hydrogeological features, such as surface formations or faults?

*We agree this is a risk. In our approach, we primarily focus on the effective hydraulic properties of the aquifer, taking into account all potential heterogeneities at the catchment scale. Nevertheless, study sites can also be constrained by site knowledge (geology, structures, faults) and that HydroModPy will allow the integration of such features when data are available in future versions notably by adapting the model grid and parameterization to capture key hydrogeological controls. We modified this sentence :*

*"The objective is to illustrate how HydroModPy can be systematically employed to set up, simulate, calibrate, and analyze hydrogeological models across multiple catchments, with calibration primarily targeting catchment-scale effective hydraulic properties."*

L319: Shouldn't we adjust the spatial resolution according to the size of the catchment area (see L313-314)?

*We agree that it is a good idea to adapt the spatial resolution to catchment size and complexity. But in this example, we want to show the capability of HydroModPy to deploy groundwater models from a regional DEM, and we chose to keep the same resolution across all catchments for comparability. In future versions, we will allow the possibility to adjust the resolution by separing the DEM resolution from the model grid resolution.*

L345 'to assess the simulation results': Sorry to stay on the basics, but what about hydraulic heads?

*In this example, we focused on the representation of seepage area (hydrographic patterns) and streamflow dynamics. Seepage areas are directly related to hydraulic heads, which are implicitly considered in the analysis. We agreed that the hydraulic head are not compared with measurements in wells (https://doi.org/10.1016/j.jhydrol.2026.135118 and https://doi.org/10.1016/j.jhydrol.2024.131859). We choose to focus on the seepage area and streamflow in this example because these data are more widely available for a deployment across multiple catcments.*

L353 'across diverse hydrological conditions, catchment scales, and topographies': Can we say that the hydrological conditions and topography really do vary between catchments in the Armorican Massif?

*Thank you. We moderated this sentence to avoid overstatement and now describe variability more cautiously within the Armorican Massif context:*

*"Consistently high model performance across the range of hydrological settings, catchment sizes, and topographic contexts represented within the Armorican Massif dataset confirms the reliability of the simplified conceptual framework and automated calibration methodology."*

L378 'across diverse [...] topographical, and geological settings': The same. All of them are crystalline basement aquifers, and their hydraulic conductivities are very similar (L379-380).

*Agreed. We have revised this sentence as follows:*

*"First, the automated workflow successfully calibrated all models with consistent performance metrics ($NSE_{log}$ > 0.75), demonstrating robust convergence across a range of catchment sizes (7–526 km$^2$) within a relatively homogeneous crystalline basement context. The calibrated effective hydraulic conductivity values ($1.75 \times 10^{-5}$ to $2.79 \times 10^{-4}, \mathrm{m.s}^{-1}$) are relatively similar among catchments, which is consistent with the shared geological setting and with values reported in the literature for crystalline basement aquifers (Lachassagne et al., 2021)."*

L360: Cite Gleeson et al. 2011 (see Figure 1) for calibrated regional-scale hydrogeologic models. doi:10.1029/2010GL045565

*Thank you for this reference. We added Gleeson et al. (2011) at the relevant location.*

L385 'to integrate multiple data sources': Assuming they are indeed available for all catchments.

*Absolutely. A user-check is required to ensure that the necessary data sources are available for the catchments of interest. We clarified this point in the text :*

*"Third, HydroModPy's ability to integrate multiple data sources, when these datasets are available for the catchments of interest, substantially reduces the time and technical barriers typically encountered in catchment-scale groundwater modeling. In practice, successful integration still depends on the user verifying data availability, completeness, and quality for each study site."*

L394-395: It all depends on how the recharge is calculated. In fact, this key parameter is not calculated within this modelling framework, but specified as an input instead, which could be seen as a limitation (but it is being resolved, L420-421).

*We agree, recharge is currently an external forcing in the presented setup (obtained from an independent land surface model), and we now better explain ongoing coupling work to improve internal consistency of recharge estimates.*

L395 'Similarly'; 'default assumption of homogeneous effective hydraulic properties'; L398 'assumption of spatially uniform recharge': These default options, which can be overridden (see L401-405), are not as significant as the other limitations.

*Agree. We have rephrased this part as follows:*

*"Additional, more easily addressable limitations include the default assumption of homogeneous effective hydraulic properties within each catchment which may fail to capture the heterogeneity typical of geological contacts or stratified aquifers. The instantaneous surface routing scheme neglects key processes influencing surface – subsurface interactions, such as reinfiltration. Finally, the assumption of spatially uniform recharge cannot capture variations in precipitation, evapotranspiration, land cover, or land use-factors that must be considered when addressing specific scientific questions and hydrological challenges."*

L414-420 'additional tools' 'multiple groundwater flow solvers' 'other open-source codes': I'm not sure exactly what these additional tools are.

*We agree that this sentence is vague. The main objective of HydroModPy is to provide a flexible framework that can integrate various groundwater flow solvers (e.g., MODFLOW, HS1D) and other tools like recharge estimation models (HELP, GR4J). We clarified this in the text by providing specific examples of the types of tools and solvers that are planned for integration in future versions.*

L423 'will allow': Does the integration of land surface models work effectively? Or is it still a work in progress?

*It is still work in progress. We revised : "Currently two land surface models are under implementation in HydroModPy"*

L425-427: a 'non-iterative approach' means 'feedback mechanisms' are not fully resolved?

*Thank you for this comment. We removed : ", using a non-iterative approach"*

L429-430 'we aim to extend HydroModPy's applicability to a broader range of hydrological contexts': That's fine, but it will mean straying from HydroModPy's core philosophy.

*We agree with this caution. However, the philosophy of HydroModPy may depend on the intended application and hydrological context.*

L436 'for piezometry and climate data': It is somewhat unfortunate that the example given in Section 3.2 does not make use of either groundwater levels or climate data.

*Good point. As we said in a previous response, the example focuses on streamflow and seepage area patterns because these data are more widely available across multiple catchments. We chose to higlight the capability of HydroModPy to deploy calibration groundwater models across multiple catchments, and we wanted to use a consistent set of data for all catchments.*

Section 4.3: In terms of teaching, the tool offers a wide range of features. But to what extent could this type of tool also be used for synthetic modelling?

*Thank you for this comment. Although HydroModPy is primarily designed for real-world applications, it can also be used for synthetic modeling by allowing users to create idealized scenarios and test specific hypotheses.*

TECHNICAL CORRECTIONS

L4-5: I suggest adding 'tools' as a word is missing in 'The current version integrates well-established geospatial tools, such as Whitebox Tools'.

*Corrected, "tools" was added in the abstract sentence.*

L29 'pressures.'; L129 'study site.': Remove the punctuation mark.

*Corrected, the extra punctuation marks were removed.*

L41-44 'and the ability to explore the sensitivity and uncertainty of model parameters.': The end of this sentence seems incomplete.

*Thank you, the incomplete sentence was rewritten and completed.*

L84: level ('water table' (without level) on its own might also work).

*Corrected. We revised the wording to "water table level" (or "water table" where most appropriate).*

Figure 1 (2) 'hydrography.py': Appears twice.

*Corrected. The duplicate occurrence of "hydrography.py" in Figure 4 was removed.*

Figure 2 (a): No matter how much I zoom in, I can't see the 'pink-highlighted' area. Is it just the pink colour on the map?

*Thank you. We improved the figure styling and caption wording so the highlighted area is clearly visible.*

Figure 2 (e) 'exponential decay with depth': Link this to $1/\alpha$.

*Agreed. We now explicitly link the exponential decay formulation to the $1/\alpha$ scale parameter.*

Figure 2 (f–i) 'watertable depth': water table depth.

*Corrected to "water table depth".*

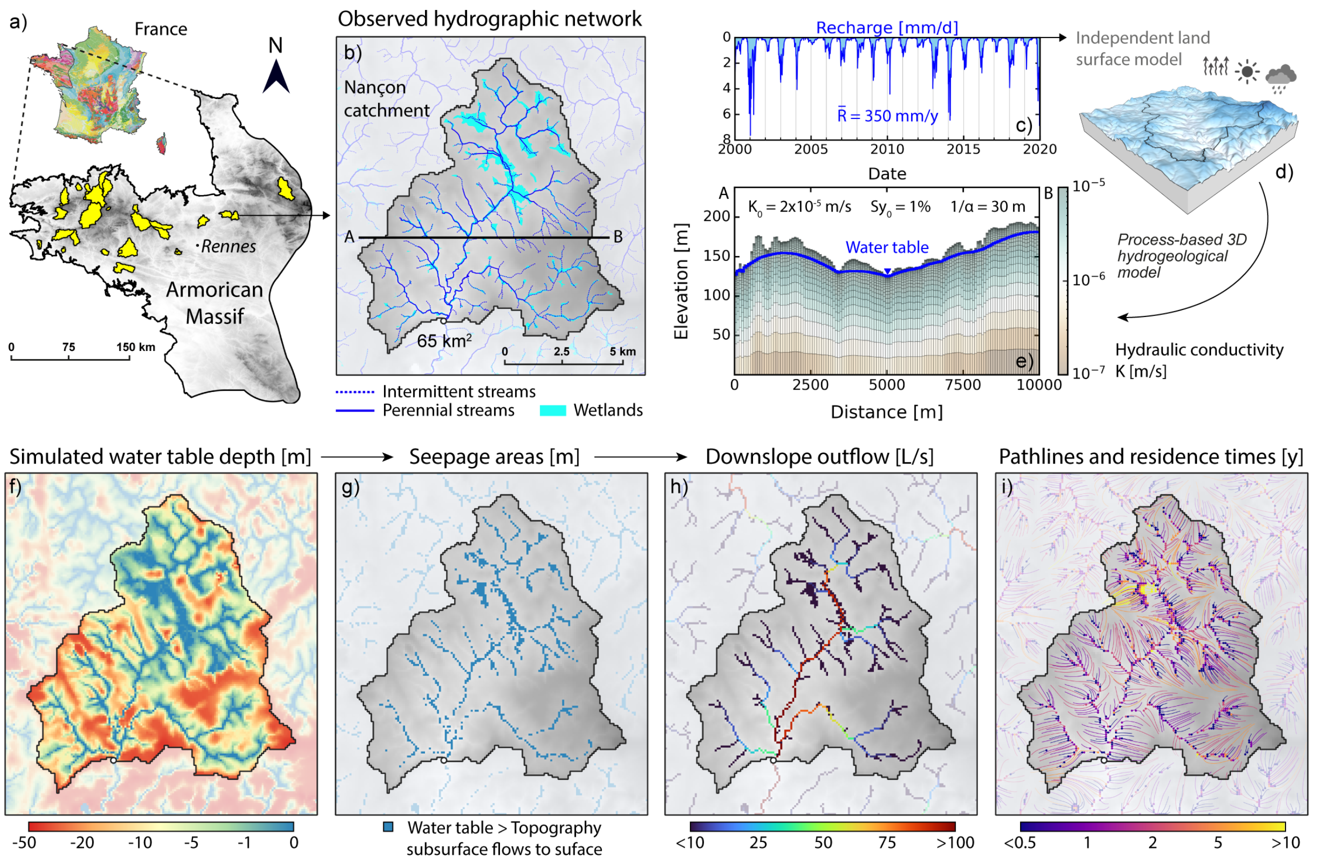


**Figure 2.** *HydroModPy modeling steps illustrated for the Nançon catchment, Brittany (France). (a) Extraction of the watershed from a regional DEM, located to the west of the Geological Map of France. (b) Clip data based on the watershed extent. (c) Recharge time series provided from an independent land surface model. (d) 3D diagram illustrating the model conceptualization and parameterization based on data available and assumptions. (e) The cross-section (A-B) illustrates the vertical grid discretization and the resulting water table. The parameters include an exponential decay $1/\alpha$ with depth from the maximum hydraulic conductivity $K_0$ and specific yield $Sy_0$ (%) in the first layer. (f–i) 2D map top-view visualization displaying spatial data and model results in steady state across the study area (left to right): water table depth, seepage areas, accumulated outflow, pathlines, and residence times.*

L158-159 'but heterogeneity of these parameters can be easily implemented specified using geological maps or user-defined zones.': To be removed.

*Done. The redundant sentence was removed.*

L186: And advection.

*Corrected. Advection is now explicitly mentioned in the transport description.*

L205-206: visualization (with a ’z’).

*Corrected to American spelling (“visualization”) for consistency throughout the manuscript.*

L210-212 ’This includes the topography and model grid, water table elevations and depths, seepage areas, and the associated accumulated surface flow.’: Repeated twice.

*Corrected. The duplicated sentence in this section was removed.*

L206 & L216: Standardise the writing of ’vedo’.

*Corrected. We standardized the library name as “vedo” throughout the text.*

Figure 3: knickpoints

*Corrected.*

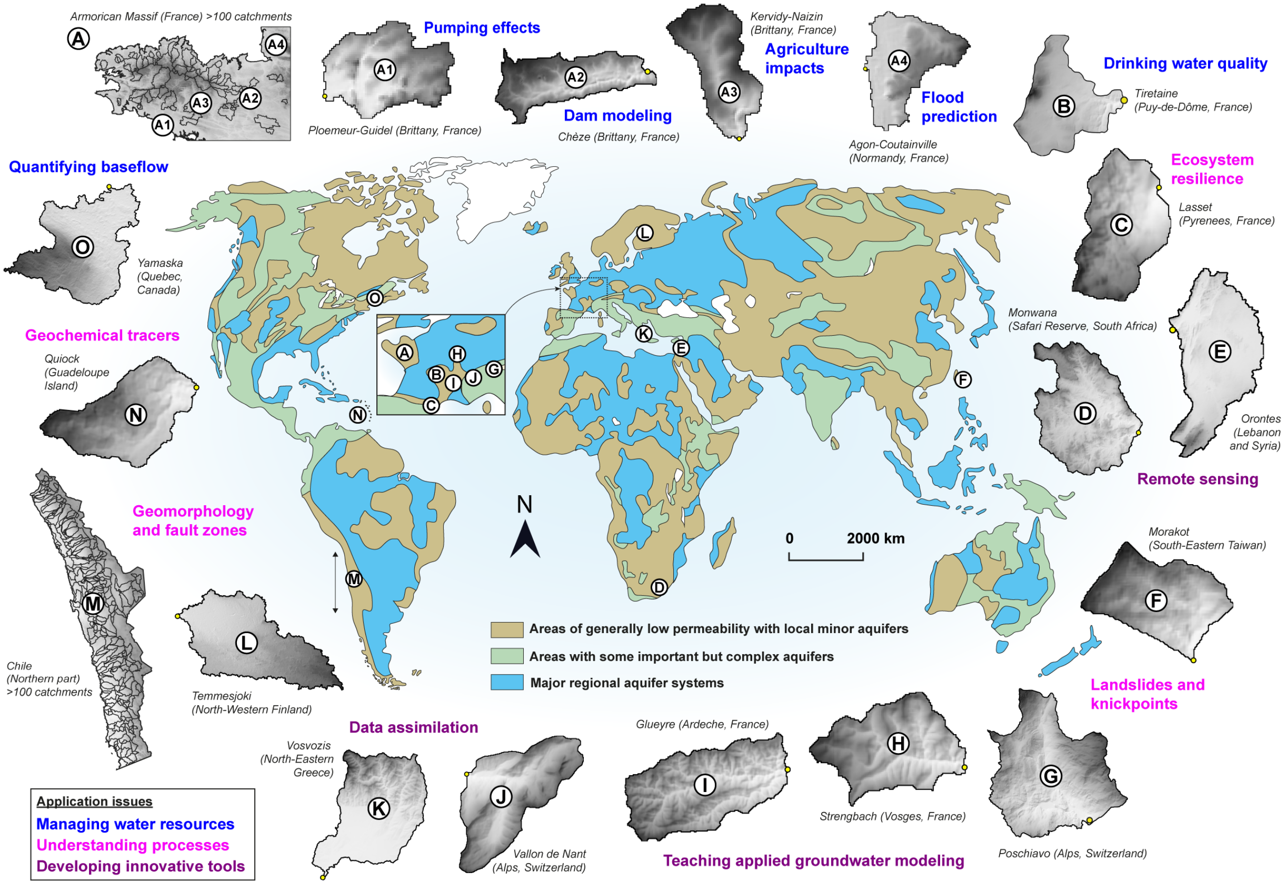


**Figure 3.** *Worldwide application sites of HydroModPy. Simplified global groundwater resources map (Duscher et al., 2015), modified from Taylor et al. (2013) and originally obtained from Struckmeier et al. (2008). Catchments are grouped into three main application fields: water resources management, process understanding, and tool development. Since HydroModPy primarily focuses on subsurface–surface interactions, all catchments are located in areas of generally low permeability with shallow, local, minor aquifers (brown areas on the world map). Extensive applications of HydroModPy have been carried out in France (A) and Chile (M) across multiple catchments.*

L220 'on the hydrogeological map IHME1500 (Duscher et al., 2015): The references given in the caption for Figure 3 are different 'Simplified global groundwater resources map, modified from Taylor et al. (2013) and originally obtained from Struckmeier et al. (2008)'

*Thank you. We harmonized the Figure 3 source references so they are consistent between text and caption.*

L305: What do you mean by '3.2.3'?

*That's a mistake. We've removed it.*

L322 'the mesh grid sizes range from 2,800 to 207,152 cells': the number of grid cells ranges from 2,800 to 207,152

*Corrected as suggested ("the number of grid cells ranges from 2,800 to 207,152").*

L323 ’weathered or fractured’: Is that incompatible?

*They are not incompatible; they can coexist. We clarified the wording to “weathered and/or fractured” to avoid confusion.*

L324 ’in the Armorican Massif region’: in the Armorican Massif

*Corrected to “in the Armorican Massif”.*

L334 ’while DOS represents the inverse’: represents the reverse

*Corrected to “represents the reverse”.*

L342 ’a simulation’: a transient simulation over the 3-year period?

*Yes. We clarified that this refers to a transient simulation over the 3-year period.*

L359 (and elsewhere): I don’t think the units should be written in italics (don’t use LaTeX’s math mode); to be checked with HESS

*Thank you. We revised unit formatting to match journal conventions and avoided unnecessary italic math formatting for units where required.*

L361 ’measurements. Dewandel et al. (2021)’: measurements (Dewandel et al., 2021).

*Corrected to “measurements (Dewandel et al., 2021)”.*

L363 ’simulations’: Is the plural form correct?

*Yes. Corrected.*

L421 ’both’: two

*Corrected: “both” was replaced by “two”.*

L843: Fix the DOI ’https://doi.org/10.1007/S42452-022-05082-0’

*Corrected. The DOI was fixed to https://doi.org/10.1007/S42452-022-05082-0.*

## 2 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 "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."*

*and we added this paragraph in "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.*

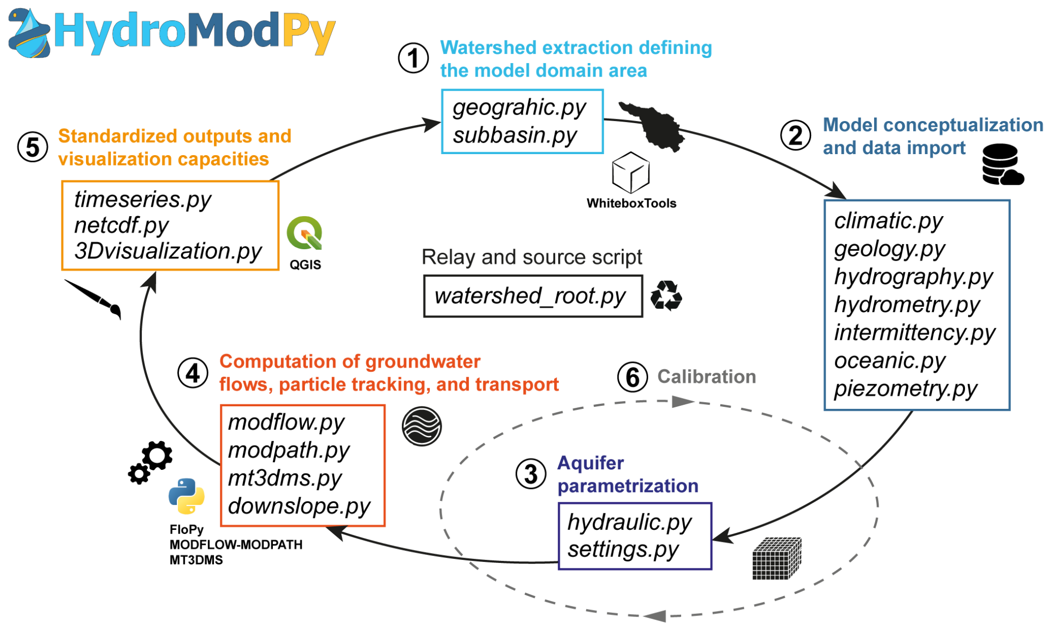


**Figure 4.** *Workflow of HydroModPy, illustrating the organization and interconnection of Python scripts within the toolbox across five main stages: (1) watershed extraction defining the model domain area from digital elevation models and outlet coordinates, (2) model conceptualization and data import, 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 Figure 2d reference is just to follow the workflow of Figure 2 and 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.*

## 3 RC3: "Comment on egusphere-2026-868", Anonymous Referee 3, 21 May 2026

The authors present a toolbox for developing groundwater models entirely within a python workflow. This is a valuable contribution that will be useful as a research and teaching tool. Reviewers 1 and 2 have already provided positive assessments and I agree with their comments. I have a few minor comments to add:

*We thank the reviewer for this positive feedback and useful suggestions.*

In exploring the GitLab page I do not see a section for bug reports, feature requests, etc. from outside of the core development team. If this does not exist can it be added? Or if it does exist it should be mentioned in the paper and ideally be more obvious on the GitLab/ReadTheDocs page. If HydroModPy is a community initiative that welcomes members of the community to suggest or contribute new features, code, examples, teaching tools, etc. this should be stated somewhere with the recommended approach to doing so. If not that should also be stated.

*Thank you. The GitLab repository has been mooved to a GitHub repository (https://github.com/HydroModPy/HydroModPy/tree/v1.0) to facilitate community engagement, and we have added a clear section for issues where users can report bugs, request features, and contribute to discussions (https://github.com/HydroModPy/HydroModPy/issues). We also updated the paper in "code and data availability section: "Bug reports can be submitted at the following link: https://github.com/HydroModPy/HydroModPy/issues"*

The ReadTheDocs page has some great examples that appear to run 'out-of-the-box' - ie., they come with all the data required to run them. These are mentioned in the code and data availability section but I think they should feature more prominently in the paper. At the very least, in Section 3.2 it should be mentioned that the full example, including data, is available as a jupyter notebook. These examples could also be highlighted in Section 4.3.

*Thank you for this suggestion. The examples ar now available at this link : (https://hydromodpy.github.io/v1.0/examples.html). We strengthened the manuscript text to highlight reproducible out-of-the-box notebook examples and explicitly referenced them in Sections 3.2 and 4.3.*

*In Section 3.2: "Note that other examples, including all required input data and expected outputs, are provided as fully executable Jupyter notebooks in the HydroModPy documentation at https://hydromodpy.github.io/v1.0/examples.html, enabling users to immediately replicate and adapt the workflow to their own study areas."*

*In Section 4.3: "HydroModPy's documentation includes a comprehensive set of ready-to-run Jupyter notebook examples (available at https://hydromodpy.github.io/v1.0/examples.html) that demonstrate key functionalities with pre-packaged datasets. These out-of-the-box examples significantly reduce the barrier to entry, allowing students and researchers to immediately engage with the tool, visualize results, and modify parameters."*

It's unclear if the model could be used to simulate groundwater on small islands (including the freshwater lens), or saline water intrusion in coastal aquifers. The authors mention solute transport but not specifically variable density flow. If it is possible, I think this application should be mentioned.

*We thank the reviewer for this comment. Variable-density flow (and therefore applications such as freshwater lens dynamics in small islands or saline intrusion in coastal aquifers) is not supported in the current version of HydroModPy, which assumes constant fluid density.*

*However, this limitation is not fundamental to the modelling framework, and such processes could be implemented in future developments by coupling HydroModPy with a variable-density groundwater flow formulation.*

L 158: Some repetition

*Corrected. The repetition at this location was removed.*

L 349: Is this the NSE of streamflow? Does HydroModPy also provide workflows to calibrate to groundwater heads?

*Yes, this NSE refers to streamflow. We clarified this and added that HydroModPy will support in the future a calibration workflows using groundwater head observations when such data are available (see this references for this topic if you are interested : https://doi.org/10.1016/j.jhydrol.2026.135118 and https://doi.org/10.1016/j.jhydrol.2024.131859).*

Line 401: It's unclear what is meant by a 'better understanding of the code structure'. Is integration of a 3D geological model currently supported or would this require edits to the source code? Is there an example showing how to do this?

*Thank you. We rewrote this sentence to be explicit: "However, it is important to note that many of these limitations can be overcome by making use of HydroModPy's advanced functions and modular structure."*

*3D geological model integration is not currently supported in this first version of HydroModPy and would require source code modifications.*

Section 4.2: The authors propose quite a long list of areas for future development. Are all of these additions realistic? Can the authors provide an estimated timeline for their development or indicate which are being prioritized?

*Yes these additions are realistic, and some of them are already in development since the submission of the manuscript. these developments can be viewed in the GitHub repository (dev branch): https://hydromodpy-docs.readthedocs.io/en/dev/index.html*

Line 421: should read "Currently two land surface models...". The writing here is also a bit confusing - it says the models are already implemented but the benefits (e.g. specifying spatially variable climate data) are in the future tense. Please clarify.

*Agreed. The models are not yet fully implemented and integrated, but we are actively working on this. We clarified the wording to reflect that the integration is in progress : "Currently two land surface models are under implementation in HydroModPy."*

Line 436: Specify Metropolitan France unless overseas territories are included.

*Overseas territories are included.*

Line 437: It's not clear if the authors plan to create tools for importing data from all these resources (CAMELS, Caravan, GRDC, ERA5-Land, etc.)?

*Yes, this is our objective. We clarified that connectors to these resources are planned progressively:*

*"At a global scale, for instance, we can cite resources such as Caravan (a series of CAMELS: Catchment Attributes and Meteorology for Large-sample Studies) (Kratzert et al., 2023), GRDC for the Global Runoff Data Centre (https://grdc.bafg.de/), or ERA5 for climate information (Hersbach et al., 2023). We plan to progressively develop connectors to these and other global data sources, prioritizing resources based on API maturity, data licensing terms, and community demand. Once implemented, these connectors will enable users to directly harvest diverse datasets (topography, geology, land cover, water use, etc.) relevant to their specific modeling objectives."*

Line 484: I think a more correct citation for CMIP scenarios would be the Earth System Grid Foundation (https://esgf.github.io/nodes.htm and O'Neill et al (2016). Copernicus simply redistributes these data.

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*Thank you for this recommendation. We added the suggested CMIP scenarios reference (O'Neill et al., 2016)*

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