MATILDA-Online v1.0.1: A Cloud-based Open-Source Workflow for Modeling Water Resources in Glacierized Catchments

(EGUSPHERE-2025-3461)

Response to Reviewer Comments RC2

Opening remarks

Dear Reviewer,

Thank you for taking the time to review our manuscript and for drawing our attention to additional literature. Your review raises important questions about the geographic framing, the intended users, the level of practical application claimed for MATILDA, and the representation of spatial variability. We have considered these points carefully and propose substantial clarifications while maintaining our position that the manuscript presents a valid model and workflow contribution.

However, in our opinion, the valid criticisms of framing and spatial scope do not demonstrate that the model structure, implementation, calibration framework, or sensitivity analysis are scientifically invalid. We therefore consider substantial revision more appropriate than rejection and hope the suggested changes can convince you to reconsider this verdict.

Since this manuscript forms the first part of a two-part publication, the review processes of both submissions affect each other to a certain extent. Part 1 describes the MATILDA model and the integrated online workflow. Part 2 applies the workflow to a glacierized catchment and presents the detailed calibration, evaluation, climate-impact analysis, uncertainty assessment, practical applicability, and limitations. The review of Part 2 is currently further advanced, but it also depends on the review of Part 1. Comments and revisions arising from that process may affect the presentation of Part 1 and vice versa. The resulting additional revisions to Part 1 are summarized in the final section, “Additional revisions.”

As the written review focuses on the study's framing and spatial aggregation, it does not discuss many of the manuscript's central technical elements in detail, including the online implementation, data-processing chain, calibration framework, sensitivity analysis, and most model routines. If you are willing to consider a revised manuscript, we would be grateful for further technical assessment of these parts of the work as the review proceeds.

Reviewer comments are shown in blue boxes. Responses follow directly below.

Respectfully,

Phillip Schuster (for all authors)

Proposed Revisions following Reviewer Comments

R2-01 — Overarching assessment and recommendation

The authors present MATILDA-Online v1.0.1 as a useful tool for Global South countries (which, according to the authors, have limited institutional experience in hydrological modeling) whose water availability is heavily dependent on the cryosphere. However, the first premise is not only poorly substantiated but also contradicts empirical evidence. Furthermore, due to its lumped nature, the proposed model is unfeasible for large mountain ranges (with massive altitudinal gradients) such as the Andes and the Himalayas—regions with dense populations that rely heavily on snow and glacier melt. In its current form, the manuscript should be rejected because it presents an inherent contradiction (aporia): while the model could be valuable in educational settings, its technical characteristics prevent it from fulfilling the authors' own presupposition of being applicable to decision-making in Global South countries. My specific arguments are detailed below:

Response: We agree that the broad geographic terminology should be more precise, that the level of claimed decision support should match what the manuscript demonstrates, and that the model's spatial representation requires a clearer explanation. We address these points individually in R2-02 to R2-04.

We respectfully disagree that these points create an inherent contradiction or make MATILDA generally unfeasible in the Andes, the Himalayas, or other mountain regions. MATILDA is designed for glacierized catchments. It is not presented as one model domain for an entire mountain range, but as a semi-distributed tool for mesoscale catchments. Its suitability depends on the catchment scale, its internal gradients, the available observations, and the scientific question. A default configuration will not be suitable for every catchment. While we agree that the online setup makes it particularly useful for education, it does not restrict the workflow's value to that. As an accessible tool that handles most of the data acquisition and preprocessing and strongly supports reproducibility, MATILDA can also support research, climate-impact assessment, scenario comparison, and vulnerability assessment. Its results can contribute to strategic planning when the model configuration and evidence are appropriate. However, this scientific and planning relevance is distinct from an operational forecasting or water-allocation system. This distinction needs to be clearly stated. Both the scientific applications and the limitations are discussed in detail in Part 2.

Proposed changes: We will narrow the geographic and decision-making claims, define the intended catchment scale, and explain the model's spatial structure more precisely. We will also distinguish scientific, educational, technical, and planning applications from direct operational deployment. The detailed changes are set out under R2-02 to R2-04.

R2-02 — Evidence for geographic and institutional framing

L36-L42. The authors argue that in the Global South (which includes, for instance, South America and China), very few models are used on a regular basis; however, they provide no evidence to support this claim. Countries like China lead global scientific and technological output, and in South America, there is an extensive scientific literature documenting the implementation and development of hydrological models within academia, along with practical applications and knowledge transfer to decision-makers (e.g., Ayala et al., 2020; Caro et al., 2025; Carrillo-Rojas et al., 2019; Murillo et al., 2022; Poveda et al., 2007; Toum et al., 2025—among many others). In the case of the world's longest mountain range, the Andes, where the cryosphere plays a fundamental

role in water availability (Masiokas et al., 2020; Saavedra et al., 2026), there is even an organized and consolidated community that connects science, universities, and decision-makers called ANDEX (https://www.andex-rhp.org/, which belongs to GEWEX and WCRP).

Response: Thank you for providing these valuable examples. Some of the studies mentioned in the review were published after our submission, and we will gratefully consider these recent contributions. The examples demonstrate substantial hydrological and cryospheric research, model development, and scientific cooperation in the Andes and other regions. We also fully agree that the claim that “very few models have made the step into regular application in countries of the Global South” (L36-42) is indeed too broad and will benefit from more nuanced qualification and citations.

However, our argument was not that hydrological science is absent outside Western Europe and North America. The term "Global South" is often disputed, and we regret that it caused an unintended interpretation. The literature listed in the review does not contradict the problem that MATILDA is intended to address. Academic model development and scientific publication are different from the routine use of modelling workflows by practitioners in water-resource management and planning, especially in remote mountain areas. Strong scientific communities can coexist with practical barriers related to data access, preprocessing, computing resources, software infrastructure, workflow maintenance, and specialist expertise. By “regular application,” we refer to the institutionalized integration of hydrological modeling into water-resource planning and decision-making at the catchment scale. We do not refer to the absence of scientific expertise, which we neither claim nor believe. We fully agree that our original phrasing lacked this clear distinction. The Kyrgyz-German research project in which the tool was developed explicitly focused on the gap between scientific capability and sustained practical use in local communities such as the one targeted in Part 2. While transferability beyond the original project setting must be evaluated case by case, MATILDA is designed so that the same workflow can be assessed in other glacierized catchments where comparable challenges are documented.

We agree that phrases such as “very few models,” “most developing countries,” and “mostly limited to developed countries” are too broad and insufficiently supported by the cited evidence. These formulations obscure the intended distinction between scientific capacity and the transfer of scientific tools into practical application. Our suggested correction is to describe the specific barriers that MATILDA is designed to reduce where they occur. Geography should not be used as a substitute for evidence about scientific or institutional capacity.

Proposed changes: We will revise the Abstract, Introduction, and Conclusions to replace broad geographic generalizations with a more precise account of data, computing, software, access, maintenance, and expertise barriers. We will distinguish scientific model development from sustained practical application. We will also define any geographic terminology that remains and support retained claims with literature that directly addresses them. The revised discussion will acknowledge global scientific contributions more explicitly, including relevant recent work identified during review.

R2-03 — “International scientific community” and intended users

The standpoint adopted by the authors regarding the potential users of their proposed model (referring to themselves as "the international scientific community"; L36 "...the international scientific community may assist in compensating for this.") is somewhat WEIRD. The arguments written in this direction sharply contrast with empirical reality: Is science only conducted in Western Europe and North America (~12% of the world's population)? Do these countries alone represent the international scientific community? Are there no universities, research centers, or

technical institutions dedicated to water management in the rest of the world? I believe anyone with a basic education would agree that ~88% of the world's population represents an overwhelming majority, making it highly probable that these countries harbor institutions dedicated to the study and application of hydrology, including the development and use of numerical models. The references cited by the authors denote a complete lack of awareness regarding the bibliographic material published in international journals (e.g., HESS) by authors and institutions from the Global South.

Response: We appreciate the opportunity to clarify this wording. We agree that connecting "developing countries" too directly with "limited capacity" distracts from the distinction we intended to make. Also, the intended roles of contributors and users will be made more explicit.

"International scientific community" was meant literally. It includes researchers worldwide who develop models, datasets, software, documentation, and other resources and make them available to others. It was not a reference to the authors, Western Europe, or North America as a separate source of science. We therefore do not accept the interpretation that the manuscript defines a Western "us" and a non-Western "them." MATILDA itself emerged from Kyrgyz-German collaboration and draws substantially on established methods and open-source models. These include HBV.IANIGLA, cited by the reviewer, from which MATILDA adopts the glacier storage-release scheme described by Toum et al. (2021).

We do support a provider and recipient relationship in the practical sense that openly shared scientific resources have providers and users. However, these groups are not divided geographically. The intended users include practitioners in water-resource management and planning, students, hydrologists, and researchers from neighboring fields such as glaciology and ecology who may benefit from an accessible modelling workflow. The gap addressed by MATILDA is between scientific development and accessible application. It is not a gap between Western science and the rest of the world.

Proposed changes: We will clearly define the international scientific community as a global network of contributors and users. We will describe the intended user groups more clearly and explain how open models, datasets, documentation, and computing services can make established scientific methods easier to apply. We will separate this argument from broad geographic categories and claims of limited capacity. We will also place greater emphasis on education, research, interdisciplinary use, and planning support while narrowing claims of direct operational application.

R2-04 — Spatial aggregation, mountain applications, and usefulness

In the section "5.1 Spatial Aggregation," the authors acknowledge that the model is lumped by nature and, consequently, does not adequately represent snow accumulation and melt gradients. If the model is intended for users (whether in academia, technical roles, or decision-making positions) in the Global South, how useful can a model be if it cannot accurately simulate snow accumulation and melt in critical mountain ranges like the Andes or the Himalayas? In these regions, water availability depends heavily on snowpack (Masiokas et al., 2020; Saavedra et al., 2026; Viviroli et al., 2020; 2026).

Response: We agree that the default configuration does not resolve the full spatial variability of snow accumulation, precipitation, temperature, radiation, aspect, shading, and snow redistribution in complex terrain. This limitation is relevant when judging whether a particular catchment and scientific question are suitable for the default setup. We also agree that the model's spatial structure can be explained more consistently.

MATILDA is a semi-distributed conceptual catchment model. The standard configuration separates glacierized and ice-free areas and uses forcing representative of their mean elevations. The HBV snow and hydrological calculations are lumped only within these model units. Glacier geometry is represented in elevation bands through the Δh routine, and glacier and non-glacier runoff are combined. MATILDA is intended for individual mesoscale glacierized catchments. Its applicability in the Andes, the Himalayas, or any other mountain region must therefore be evaluated at catchment scale. We recognize that catchments with strong internal gradients or questions that require more spatially explicit process representation may require additional spatial subdivision.

While the current version of the calibration routine only covers the standard setup, additional spatial subdivision is already possible by combining separate MATILDA core instances in a user-developed setup. A bulk-runner extension is currently under development for applications with a large number of sub-catchments or hydrological response units. It is planned for inclusion in the MATILDA core model when it is production ready. However, the current MATILDA-Online workflow remains focused on the accessible standard configuration that allows it to be run on a single CPU on MyBinder.org.

Thus, the default configuration represents a deliberate trade-off between spatial detail and usability since further spatial detail makes the calibration more complex and increases processing costs. However, it is not a structural ceiling. Greater spatial complexity can be valuable when the research question requires it and when observations are available to constrain the additional parameters. However, the manuscript also discusses that additional spatial complexity does not universally improve predictive skill. The study of Finger et al. (2015) cited in the manuscript, for example, found that additional HBV complexity did not significantly improve consistency with the tested observations, while calibration against multiple datasets improved process consistency. The appropriate model configuration therefore depends on the application goal, the available data, parameter identifiability, computational demand, and the required spatial detail.

MATILDA is part of a dissertation project consisting of three related studies. This manuscript contributes the model description and the integrated workflow. The companion application paper (Part 2) demonstrates the standard workflow in a glacierized Tian Shan catchment and provides detailed calibration, uncertainty analysis, and clearly discusses application scenarios and limits (cited below in the section on additional revisions). The third study currently in development applies a multi-catchment setup to the whole Issyk-Kul basin in much greater spatial detail.

Proposed changes: We will make the use of “lumped” and “semi-distributed” consistent and explain the model units and elevation-dependent glacier component more clearly. We will define the intended catchment scale and explain which snow and meteorological gradients remain unresolved. We will expand Section 5.1 to present spatial complexity as a trade-off among process representation, available observations, calibration, computation, and usability. We will also explain how advanced users can increase spatial detail through multiple core-model instances and distinguish this option from the standard online workflow. Finally, we will align the practical-use claims with the scientific, educational, technical, and planning applications supported by the workflow and discussed in Part 2.

Additional revisions

The software and its scientific application have continued to develop during the long review period. The review of the companion application paper (Part 2) is currently further advanced,

and its first revision round provided useful lessons for presenting the two parts as distinct and self-contained contributions. The preprint and its discussion can be accessed here:

Schuster, P., Osmonov, A., Georgi, A., Schneider, C., and Sauter, T.: *Climate Impacts on Water Resources in a High Mountain Catchment: Application of the Open-Source Modeling Workflow MATILDA in the Northern Tian Shan*, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-3462, 2025.

Following the reviewers' recommendations on the companion paper and the technical developments of the past year, we propose the following updates to keep Part 1 current and improve its presentation:

1. We will clarify that the scientific contribution of Part 1 lies primarily in integrating established model components, public datasets, automated preprocessing, calibration support, climate projections, analysis, visualization, documentation, and online execution into one reproducible workflow. We will define Part 2 as a self-contained detailed application and uncertainty study. We will also distinguish technical accessibility, educational value, and scientific application from demonstrated operational adoption.

2. The manuscript will also be updated to describe the software developments since submission at an appropriate level. This includes the current MATILDA core and MATILDA-Online releases, corrections made during continued testing, simplified tutorials, and the revised Earth Engine access. Detailed implementation information will remain in the versioned code and documentation, while the manuscript will provide the information needed to understand and reproduce the workflow.

This includes a substantial update to the data-acquisition routine. Following Reviewer 1's comment about changes to Google Cloud policies and interfaces, we revised the authentication process and now provide two workflow versions:

1. MATILDA-Online v1.0.2 is the latest stable release. It allows experienced users to work through their own Google Cloud project and Earth Engine account. This route is useful for larger workloads and for users who prefer to work with their own service quotas.

2. MATILDA-Online v2.0.0-beta.1 provides a more convenient route through a hosted web service. Users do not need to register or authenticate their own Earth Engine project. However, as a shared service, this route may be subject to rate limits when several users are active.

Note: *Until final security layers are in place for public use, the web service requires an API key. We previously sent it to the handling editor for private distribution to the reviewers. Because this response will be public, we do not reproduce the key here, but we will gladly provide it again if necessary.*