# Review of Schmitt et al. (2025) ‘The Open Global Glacier Data Assimilation Framework (AGILE) v0.1’

The manuscript presents a new data assimilation framework named AGILE for OGGM. It is based on automatic differentiation and the optimization algorithm L-BFGS-B, and it improves glacier geometry, specifically bed height and volume along the flowline. The method is tested and analyzed using synthetic observations, namely distributed surface elevation and total volume estimates for one year, as well as geodetic mass balance over a 20-year period. The results from 12 different settings show that AGILE improves the initial guess of glacier geometry in an efficient and consistent way. Only a noisy pattern at the upper end of the flowline persists, and the Baltoro Glacier appears to be challenging for both the initial guess and AGILE. An analysis of the weighting between the cost function and regularization provides first insights into the impact of regularization; however, as the authors note, the findings are limited to idealized settings and may not be directly transferable to real observations.

The framework is well presented, and the description of the experiments is comprehensive. The use of automatic differentiation is an elegant and efficient tool for optimizing a large set of control variables. The framework has the potential to significantly improve glacier projections. The authors also made a notable effort to ensure reproducibility through the published code on GitHub and Zenodo, as well as the use of Docker. I consider the manuscript highly suitable for Geoscientific Model Development after addressing some minor structural and clarity issues in the Results section, clarifying the choice of observations, and improving the guidance for running the example code. Some of the comments are suggestions for the authors’ consideration to further enhance the presentation quality.

# General comments

1. The choice of total ice volume as an observation could be explained more clearly, as it is not a directly measured quantity but depends on assumptions about glacier geometry or dynamics. It would be helpful if the authors could elaborate on how such a volume estimate could realistically be obtained in practice. The results already show that AGILE can improve the initial guess even without this information, which is encouraging. Using pointwise measurements from ground-penetrating radar would be a more realistic option, even if such data are rare. Likewise, spatially distributed elevation change data could be a valuable alternative to a single geodetic mass balance value per glacier, as they allow for easier comparison along a flowline. The choice of observations could be better justified by referencing actual observational datasets.

2. The structure of the Results section could be improved. The separation into Sections 4.2 and 4.3 likely reflects the incremental development of the study but does not read

smoothly. Sections 4.3.1, 4.2.1, and 4.2.3 could be grouped under *“Proof of Concept for AGILE Functionality”* and *“Influence of First Guess.”* The current title *“Functionality of Minimizing the Cost”* is not very informative.

3. Sections 4.2.2 and 4.3.3 have similar scopes, with 4.2.2 focusing only on Aletsch Glacier and 4.3.3 extending the analysis to four glaciers and three dynamic states. It is reasonable to present one detailed example, but I suggest merging 4.2.2 and 4.3.3 for a smoother presentation. The results from the four glaciers in the λ-sensitivity study could also be aggregated. Although the authors note that the influence of λ varies between glaciers, similar trends can be observed, especially in the three-observation setting. The results for individual glaciers could be moved to the Supplementary Material, while a single figure aggregating the results across all eight settings would make it easier to generalize an appropriate λ value for untested glaciers and keep the manuscript uncluttered. This is a suggestion for the authors’ consideration and can be omitted if an aggregated figure does not provide meaningful insights.

4. Although the code is provided via GitHub and Docker, I was unable to execute a simple showcase scenario e.g. reproducing Figure 5. I am not very familiar with Docker nor OGGM, so this may be due to my setup. I would suggest including a “first_steps” Jupyter notebook, similar to the one in the GitHub-repository, directly in the Docker image. Additionally, the example for agile1d seems somewhat hidden at the end of “first_steps.ipynb” and may not be fully compatible with the Docker image. I would appreciate a step-by-step instruction in the README to run a showcase setting.

# Specific comments

- **Line 13:** What is meant by *“diffusive nature of glacier systems”*? Please provide a reference or clarify the intended meaning.

- **Line 88:** Is there a way to estimate the uncertainty of the control variables?

- **Line 155:** Emphasizing that *i* starts at 0 suggests that the highest point might be at *i = 1*. I recommend omitting the specific index and simply stating that an additional grid point is included.

- **Line 166:** The distinction between variables and parameters could be improved. The term *control variables* should be used consistently. The phrase *“unknown parameters or variables”* is followed by no variables in the example; it could instead refer to *flowline-geometry variables*, because these are later referred to as control variables.

- **Line 187f:** The chosen percentages seem arbitrary as well as the ten extra grid points. What happens if the initial guess is very poor?

- **Line 194:** How can these values be used as control variables? Please clarify.

- **Line 210:** A short description of the algorithm would be helpful, especially since the low number of model runs per iteration is emphasized in the results. Additionally the relation to 4D-Var should be explained, since it is mentioned in the abstract and introduction.

- **Line 223:** How can *volume* be considered an observation? Please explain.

- **Line 255:** A reference for these uncertainties would strengthen the statement. The choice could influence the results under the different cost function settings.

- **Figure 2:** Why do the different dynamic states have different volumes in 1980? How is the initial volume chosen? This might need to be added to Sect. 3.1.

- **Line 280:** The temporal mismatch mentioned here is unclear. Please clarify.

- **Figure 5:** Using a color gradient between iteration colors and increasing the step size to five could allow convergence to be visualized without relying on the legend. This is more a personal preference.

- **Figure 6:** The figure appears cramped vertically, and the y-axis is missing an additional tick (e.g., 0). If possible, give the figure more vertical space. An aggregation with Figure 9 could be considered.

# Technical corrections

- **Line 66:** *4D-Var*

- **Line 166:** *optimized*

- **Line 178:** *area–height*

- **Figure 2:** The *–1* should be in the exponent.

- **Figure 3:** Remove the first *“first guess”* in the caption.

- **Figure 4:** Be consistent in notation, use either *(a–c)* or *(a to c)*.

- **Line 368:** *(Figure 4, panel g)*

- **Figures 6 & 9:** Title and caption, use *after 20 iterations* (not *after the 20. Iteration*).

- **Figure 6:** Caption, *“The gray shaded area …”*
- **Line 409:** *minimization, minimizing*
- **Line 427:** *analyzed*
- **Line 505:** *semi-implicit* (no capital letter)
- **Line 534:** *generalized*