Review of the manuscript entitled:

Initialization of a global glacier model based on present-day glacier geometry and past climate information: an ensemble approach

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Summary

The authors present an initialisation strategy for the Open Global Glacier Model (OGGM). The aim of this strategy is twofold. First, the initialisation should produce a best estimate for the glacier extent and geometry at the end of the little ice age (LIA). Second, the spin-up into present day should appropriately reproduce the observed geometry. The latter aim is formulated as an optimisation of an inverse problem. For testing and validation of the initialisation, the authors suggest synthetic experiments for which the past and present geometry is perfectly known. The main target parameter for the optimisation is a so-called 'temperature bias' β. The authors show that their strategy allows to constrain the possible parameter space significantly, certainly if the optimisation accounts for geometric information beyond the glacier length.

The manuscript is of great interest to the community as it aims at formulating a standard procedure that should provide the initialisation basis for regional or global ice-dynamic simulations of glacier evolution. In this sense, the authors are trying to solve a pressing issue. Moreover, the manuscript is well written and structured. However, I have major concerns on the pursued parameter sampling strategy in light of other a-priori parameter choices concerning ice-dynamics and surface mass balance. Consequently, I fear that the single parameter problem is oversimplifying any real-world application. To address my comments, the authors will certainly have to expand the manuscript to better justify and motivate their decisions. Consequently, I recommend a major revision of the manuscript.

General comments

Temperature bias

For the synthetic experiment, you prescribe a 'random climate scenario'

(p5l26). I think that this term refers to a random permutation of the climatic forcing around the year 1850 (within a 30 year period). Is that right? I assume that the climatic forcing is taken from HISTALP. You then add a temperature bias of -1K to this climatic forcing. This bias is not well motivated. Why is it necessary? Initially, I thought that HISTALP provide you with the perfect climatic conditions. On second thought however, I see many reasons why this bias is necessary. This point is very important as the temperature bias serves as on of the main target quantities for the subsequent optimisation/data assimilation. Please provide a firm motivation for this bias, why it varies from glacier to glacier and consequently has to be inferred.

A-priori OGGM calibration vs. parameter sampling

Initially, the first question which came into my mind was why you did not enlarge the ensemble by including other uncertain parameters, as for instance the rate factor, basal friction or parameters linked to the SMB model. So ultimately this question links to the comment above. In other words, how do you ensure that the other parameters are well constrained. I understand that you present a synthetic setup but with regard to any real-world application this issue is very important. Even if there was an a-priori calibration of a combination of the rate factor and the melting parameters, other combinations might also produce plausible glacier geometries at present. Yet the exact choice will affect the past glacier geometry. In many other glaciological applications, basal friction or the rate factor are the central unknowns that are calibrated during the model initialisation. I therefore think that it is inevitable that you include a section on the OGGM procedure for the calibration/choice of these other parameters. On this basis, you should motivate your parameter choice for you ensemble generation. Dependent on how the other OGGM parameters are calibrated, it might well be necessary to include further parameters in the ensemble generation. At the moment, two climatic quantities are varied: the permutation of the climatic forcing and the temperature bias. Throughout the manuscript, I sensed some redundancy because I did not find any discussion of the ‘acceptable ensemble states’ in terms of the initial parameter choice. To put it bluntly, were you able to infer the -1K temperature bias prescribed in the synthetic experiment from your data assimilation? Otherwise, the specific climatic permutation might have had a significant influence? In short, please justify your choice to exclusively focus on climatic quantities in the optimisation. From my experience, you should include other parameters in this optimisation. If you disagree, please provide good arguments for you choice.

I wonder about the necessity to permute the initial climate time series during the initialisation. Do you really attain distinctly different glacier geometries in 1850 that you could not generate by only changing β. Please re-assess the dual sampling of climatic variables/input in the ensemble generation.

Climatic forcing
For the generation of an ensemble of initial states, two quantities are varied. On the one hand, the climatic forcing around 1850 is permuted temporally within a 30 year period. On the other hand, an offset temperature bias β is varied within -2K to +2K. Once the 'equally space' ensemble members are selected, forward simulations are start using climatic forcing from the HISTALP record. The past-to-present volume evolution of Guslaferner of all ensemble members is shown in Fig. 3. It suprised me that all ensemble members readily converge to a very similar present-day value. Certainly if you consider the large range of β-values used for the initialisation. On page 8 lines 10- 11, my attention was then drawn to the fact that all forward runs are conducted with 'exactly the same climate time series' and use the 'same parameter set'. Does this include β? If not, why does the -2K ensemble memebr not stick out in terms of present ice volume. If β was set to zero after the initialisation, I would be highly concerned about the abrupt climatic shift you introduce when switching from the initialisation to the forward experiment. A reason for the latter case is the overall quick convergence during the forward simulations. Supporting evidence comes from a formulation on page 6 line 2 where you say that β is an initial bias, invoking that it is set to zero in the forward simulations.

In any case, this question directly relates to my second concern on the a-priori calibration of OGGM in terms of the SMB module. What climatic forcing is used for the a-priori OGGM calibration. Is it HISTALP. Is the temperature bias β included? Please clarify.

Detailed comments

P1L20 Sentence is difficult to understand. Reformulate.
P2L17 'Despite of the importance ...' --> 'Despite the importance ...'
P2L28 Introduce a comma (,) before which. Please check throughout the document.

P3L1 '... glacier's length ...' --> '... glacier length ...'. Please avoid the 's genitive throughout the document.
P5L5 Please omit the bedrock difference in Equation (4). As the bedrock does not change during your initialisation this term is zero.
P5L22 Remove comma.
P5L28 Delete 'this' at the beginning of the line.
P6L11-P7L5 The initialisation ensemble is formed by the variation of two parameter: β and a permutation of the 30-yr climate forcing time series. For both quantities it remains unclear how many ensemble members are created. As you reduced the ensemble later on to 200 members based on an equal spacing argument, I would assume a sufficiently dense sampling. Anyhow, please provide some numbers.
P6L13 It remains vague how the permutation is done. You permute the climatic forcing per year, month, etc.
P9L6 Please provide values for glacier area and estimates for mean ice thickness for Guslarferner and Hintereisferner at present. Hinterisferner covers a much larger area and is probably much thicker. These values are informative and they are difficult to infer from Figs. 3 and 5. **P9L10** 'has' --> 'have'
P10L2 'not' --> 'no'

Figure 2 There is a discrepancy between the range of temperature biases given in the caption [-2.65, 2.95] and shown in panel (a) [-3.0, 1.95]. Moreover, I would try to remove some redundant information. For panel (b), limit the graph to the stagnation period. For panel (c), do show the initialisation period with the coloured points but extend the figure by the forward simulation 1850-2000 as in Fig3c.