The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2019-325-AC3, 2020

Interactive comment on "21st century estimates of mass loss rates from glaciers in the Gulf of Alaska and Canadian Archipelago using a GRACE constrained glacier model" *by* Lavanya Ashokkumar et al.

Lavanya Ashokkumar et al.

lashokkumar@email.arizona.edu

Received and published: 2 June 2020

We would like to thank the reviewer for this constructive review. In this discussion comment we would like to broadly address and share our thoughts on these comments. We look forward to addressing these comments in detail in a revision of our manuscript.

Generally, in reference to the novelty of our glacier model, it was not our intention to create the most state of the art or complex glacier model. Our work's novelty stems

from the use of GRACE $monthly$ observations as our regional constraint. In particular, we choose to produce our own GRACE mass balance estimates because we constrain our glacier model at the monthly time resolution of GRACE. We do not use the multi-year trend of mass change, but 163 months from 2002-2017. Because of this, we chose to use modeling procedures common to several other models so that we could compare our results with theirs and examine the impact of using GRACE data as a model constraint.

1a. **Use of volume area (V-A) scaling**: Yes there are more sophisticated methods than the V-A scaling. We chose to use V-A scaling because we wish to directly compare our results against other models, and examine the impact of using GRACE data. 5 of the 6 models in the GlacierMIP paper (Hock et al., 2019 table 1) and 5 of 11 models in the GlacierMIP2 paper (Table 1 in Marzeion et al., 2020) use some form of volume-area scaling relation (v-a, v-a-l, v-a-l-response time, etc.). We think V-A scaling is preferable for the ease of comparison to prior work.

1b. **Use of ERA-I**: Our use of ERA-Interim was partly due to ERA5 not being available at the project start, and partly due to improve comparison to prior work. Since submission we have migrated to ERA5 and we can easily update these results to ERA5 in our revision.

Use of CMIP5 results: We use CMIP5 GCM output specifically because it covers the same time period as our GRACE observations. CMIP6 output only begins in 2015, and therefore would not allow us to solve for the bias parameters necessary during 2002-2017. It also appears the equilibrium climate sensitivity of CMIP6 models is quite different from CMIP5, and this would likely make a comparison to prior glacier models very challenging.

1c. **Comparsion with GlacierMIP2**: We are aware of the recent publication in glacier model, GlacierMIP2. It must be noted that some of the models are regionally focussed such as the AND2012, GloGEMflow, KRA2017 and PyGEM, which leaves us to include GLIMB, JULES and OGGM in the comparsion (Anderson et al., 2012; Kraaijenbrink et al., 2017; Maussion et al., 2020; Rounce et al., 2020; Shannon et al., 2019; Zekollari et al., 2019). We will try our best to use the same set of conditions in the model comparsion such as the initial volume, boundary conditions in the revised manuscript.

1d. see point 2

2. **Regional parameter calibration**: We have matched the regional mass balance with a single set of parameters for each region (option 2b), and as a result we would expect that any individual glacier within the region would likely have poor agreement between model and observed mass balances. Our purpose in using monthly GRACE data is that it is very different and independent from what is used in other models. (By this we mean glacier specific mass balance estimates which are perhaps at best annualized) We believe that we could, in the future, use the spatial information in GRACE with our glacier model to improve performance. And perhaps the way forward on that is to ascribe the regional mass balance to each individual glacier such that it is consistent with the broad spatial pattern from GRACE. However, as we mention in point 3, this is a much more complex process which we have reserved for future work.

3. **Use of GRACE data**: We do not use a single number (such as the trend) from GRACE to constrain our glacier model. Instead we use all the 163 monthly observations between Jan 2002 and June 2017, which capture the seasonal processes, as constraints in our model. In-situ mass balance observations are typically limited to annual temporal resolution. Individual glacier mass balance estimates from DEMs are typically annualized from multi-year DEM differencing (e.g. Shean et al., 2020).

Additionally, we believe there is additional information in the GRACE data that could be used to improve our model in future work. For example, currently we constrain our model on the total integrated mass of the region. In future work, we plan to apply this to the timeseries of each Slepian basis function, which will allow us to use the spatial information from GRACE within the region to constrain our model. Our first step in this paper is to show the initial performance with GRACE data.

4. **Matching GRACE derived mass balance**: We agree that this is a weakness in our manuscript. We believe part of the poor agreement is due to the poor representation of precipitation in ERA products. When we re-run the model results using ERA5 input fields, we are very willing to examine this disagreement further by e.g. testing an even wider range of parameter space.

References

Anderson, B. and Mackintosh, A., 2012. Controls on mass balance sensitivity of maritime glaciers in the Southern Alps, New Zealand: the role of debris cover. Journal of Geophysical Research: Earth Surface, 117(F1).

Kraaijenbrink, P.D.A., Bierkens, M.F.P., Lutz, A.F. and Immerzeel, W.W., 2017. Impact of a global temperature rise of 1.5 degrees Celsius on Asia's glaciers. Nature, 549(7671), pp.257-260.

Marzeion, B., Hock, R., Anderson, B., Bliss, A., Champollion, N., Fujita, K., Huss, M., Immerzeel, W., Kraaijenbrink, P., Malles, J.H. and Maussion, F., 2020. Partitioning the Uncertainty of Ensemble Projections of Global Glacier Mass Change. Earth's Future, p.e2019EF001470.

Maussion, F., Butenko, A., Champollion, N., Dusch, M., Eis, J., Fourteau, K., Gregor, P., Jarosch, A.H., Landmann, J., Oesterle, F. and Recinos, B., 2019. The Open Global Glacier Model (OGGM) v1. 1. Geoscientific Model Development, 12(3), pp.909-931.

Rounce, D.R., Khurana, T., Short, M.B., Hock, R., Shean, D.E. and Brinkerhoff, D.J., 2020. Quantifying parameter uncertainty in a large-scale glacier evolution model using Bayesian inference: application to High Mountain Asia. Journal of Glaciology, 66(256), pp.175-187.

Shannon, S., Smith, R., Wiltshire, A., Payne, T., Huss, M., Betts, R., Caesar, J., Koutroulis, A., Jones, D. and Harrison, S., 2019. Global glacier volume projections under high-end climate change scenarios. The Cryosphere, 13, pp.325-350.

Shean, D.E., Bhushan, S., Montesano, P., Rounce, D.R., Arendt, A. and Osmanoglu, B., 2020. A Systematic, Regional Assessment of High Mountain Asia Glacier Mass Balance. Front. Earth Sci, 7, p.363.

Zekollari, H., Huss, M. and Farinotti, D., 2019. Modelling the future evolution of glaciers in the European Alps under the EURO-CORDEX RCM ensemble. The Cryosphere, 13(4), pp.1125-1146.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2019-325, 2020.