Response to Reviewer 1

R1.1 The submitted manuscript develops a new parameterization of iceberg melt, blocking, and drag effects into the pre-existing iceberg package of the MITgcm. The representation of blocking and drag reduces the magnitude of the iceberg-induced freshwater flux and the spatial variability in velocity and temperature across a simulated representative fjord. The new developments also increase the computational efficiency of the iceberg package. The manuscript is well-written, and I recommend minor revisions.

We thank the reviewer for their time and careful consideration of our manuscript.

R1.2 Lines 85-95: I am not sure I agree with the description of the way the MITgcm treats the partial cell factors hFacC, hFacS, hFacW. The authors state that they are "reset" by the non-linear free surface calculation at each time step. In fact, the background h0FacC, etc., remain the same, and they are only rescaled by the stretching of the vertical coordinate. This is an intended feature, and I do not agree that it is something that should be corrected in the case of iceberg blockage. Iceberg blocking effects and the vertical stretching of the coordinate system should both be allowed the same time. In this vein, I also do not necessarily agree that the previous studies that used the r coordinate were deficient in that regard (I was not involved in any of those previous papers). Maybe the authors can revisit their case, and if they are still certain, they can present their argument more convincingly.*

The reviewer is precisely correct. The non-linear free surface option does not "reset" the hFactors (C,S,W) but rather allows for rescaling them via r* prior to solving for pressure at each time step. This rescaling step respects the geometry defined by the bathymetry of the model (`h0FacC,S,W`), but this step does not respect the presence of icebergs as defined within the previous version of *iceberg*. Upon further investigation it appears the root of this issue is that `h0FacC,S,W` (as opposed to `hFacC,S,W`) are never set by *iceberg*, rather only `hFacC,S,W` are set to include icebergs. In this way, when the non-linear free surface method is enabled (but not necessarily used), each timestep re-calculates the hFactors in a way that ignores icebergs by using `h0FacC,S,W`, which never were updated to include iceberg effects. Our phrasing of this as a "reset" is misleading, and we now more properly describe this process and our confirmation of this effect in the revised manuscript.

This was confirmed by inspecting the hFactors from MITgcm, which are default exported state variables, at various time steps. When the non-linear free surface method is enabled in `CPP_OPTIONS.F` (but not necessarily used in `data`), the initial time step hFactors do include the effect of icebergs throughout the domain (hFactor <1 where there are icebergs), but for timestep 2 and onward the hFactors do not include the effect of icebergs (hFactor $=1$ everywhere in the ocean domain). In part inspired by this comment, it became clear that compatibility with the non-linear free surface option can be accomplished by setting `h0FacC,S,W` in addition to `hFacC,S,W` in the *iceberg* source code file `iceberg_init_fixed.f`, which we have now done. This change has been updated in the public code repository. This allows compatibility with enabling `NONLIN_FRSURF` in `CPP_OPTIONS.F`.

Importantly, this change does not impact our results, which we confirmed to be identical to numerical accuracy when `NONLIN_FRSURF` is enabled compared to the previous model runs of the new *iceberg* within this manuscript. This is expected, as nowhere do we actually utilize the options enabled by `NONLIN_FRSURF`, like `nonlinFreeSurf` and `select_rStar`. We leave these to their defaults following previous studies using *iceberg* (Davison et al., 2020, 2022, etc.) as well as the benchmarking studies of Hughes (2022, 2024).

To summarize, enabling but not using the option of `NONLIN_FRSURF` in `CPP_OPTIONS.F` had the unintended consequence of removing icebergs from the hFactors in previous versions of *iceberg*, after the first timestep. This resulted from only setting `hFacC,S,W` and not setting `h0FacC,S,W` in the initialization code `iceberg_init_fixed.f`. In the first version of this manuscript we blocked `NONLIN_FRSURF` to resolve this issue, but have now enabled compatibility with `NONLIN_FRSURF` via properly setting `h0FacC,S,W` in `iceberg_init_fixed.f`, which has no numerical impact on our results but increases compatibility for future uses. We have adjust the verbiage of the manuscript to clarify this.

To the reviewer's comment that the previous *iceberg* implementation using r* is not necessarily deficient: we note that the previous studies did not utilize r*, but rather only had the option to do so enabled. Davison et al. (2020, 2022), etc used the default `select_rStar = 0`, though they did enable the option in `CPP_OPTIONS.F`, but as discussed above this is the root of the issue. We do still make use of this hFactor effect, which we call "blocking" and we detail the separate influence of blocking and drag in section 4.2 and show that blocking alone produces anomalous acceleration of the ocean in cells containing icebergs.

R1.3 Section 2: You should describe the underlying assumptions behind the representation of iceberg dynamics and thermodynamics in this package. You may even consider a brief introduction to the pre-existing package and its capability. For instance, how is "udrift" in line 65 of the manuscript defined? How is the iceberg drift estimated? More generally, please state clearly which iceberg properties and fluxes are assumed to be constant in time.

We now include a more detailed description the previous version of *iceberg* and of u_{drift}, and clarify that iceberg geometries are held constant in time. Additionally, we more clearly state that heat, salt, and freshwater fluxes are solved for each timestep and thus can vary in time.

R1.4 Lines 169-172: Could you explain more clearly why you need to set up the nonphysical temperature field? Is it not possible to achieve the same match to Hughes (2022) using the combination of 0°C temperature and 36.24 PSU salinity that you yourself mention?

It is indeed possible to match the density alone using salinity, running the same experiment with only a salt gradient as shown in Figure R1 of this response. We show two cases producing an identical density gradient from either a linear variation in temperature (tGrad) or salt (sGrad), which results in identical resulting velocity fields. However, we still feel that reproducing the non-physical temperature field is the most straightforward way to benchmark against the previous study so we have kept the temperature-gradient results. We have added a sentence explaining the original motivation for considering the temperature gradient case was for numerical efficiency, which can be helpful context, and have also added a sentence to clarify that a more physical salt gradient would produce the same results.

R1.5 Figure 2 legends: "Anomonly" should read "Anomaly"

We have corrected this typo in Figure 2.

R1.6 Line 246: You may consider rephrasing "the sinusoidal nature of velocity" as "the sinusoidal profile of velocity."

We have made this change for improved clarity.

R1.7 Line 285: Point the reader back to Table 2.

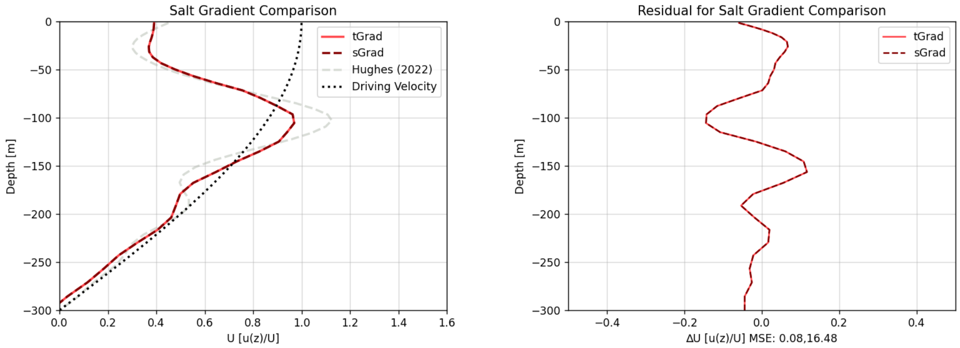

Figure R1: Comparison of the $U = 0.12, \overline{\lambda} = 0.20$ case of the FF model geometry. The temperature gradient (tGrad) case relies on using temperature variation to produce a density gradient, as discussed in the main text and Hughes (2022). Additionally we consider a salt gradient (sGrad) case where a linear salt gradient of 34 PSU at $z = 0\,\mathrm{m}$ to 36.24 PSU at $z = 600\,\mathrm{m}$ and temperature is constant $T = 0°C$ at all depths. Results from Hughes (2022) are plotted in a dashed gray line, and the driving velocity is a black dotted line. Residuals compared to Hughes (2022) are plotted as well.

> We now point the reader back to table here. We agree this is a useful reminder to decode the numerous model configurations we consider.

References

Davison, B. J., Cowton, T., Sole, A., Cottier, F., and Nienow, P. (2022). Modelling the effect of submarine iceberg melting on glacier-adjacent water properties. *Cryosphere*, 16(4):1181–1196.

Davison, B. J., Cowton, T. R., Cottier, F. R., and Sole, A. J. (2020). Iceberg melting substantially modifies oceanic heat flux towards a major Greenlandic tidewater glacier. *Nature Communications*, 11(1):1–13.

Hughes, K. G. (2022). Pathways, Form Drag, and Turbulence in Simulations of an Ocean Flowing Through an Ice Mélange. *Journal of Geophysical Research: Oceans*, 127(6):1–17.

Hughes, K. G. (2024). Fjord circulation induced by melting icebergs. *Cryosphere*, 18(3):1315–1332.