Response to Reviewer 1 (John Dunne):

Reviewer comments are red font. Replies are in black font.

The manuscript “Datasets and protocols for including anomalous freshwater from melting ice sheets in climate simulations” by Schmidt et al provides an interdisciplinary assessment of the state of understanding, uncertainties, and many technical issues involved in representing the transient liquid and solid freshwater forcing from the Greenland and Antarctic ice sheets in coupled climate Earth system models as efforts to couple these models with ice sheet models continue to advance. It certainly makes the case that this is a very technically complex problem and progress on the interim solution of applying freshwater anomalies is an important step in improving the representativeness of the ocean circulation and climate responses to anthropogenic climate change in general and the recent observed changes to ice sheet mass balance.

Thank you very much for your support and constructive review.

My main issues with the present version are:

- The fluxes for Antarctica equivalent to Figure 3 for Greenland are not presented

  We have added figures for all data products.

- The overall value of representing these fluxes to improve representation of sea level rise is not provided… how much of non-steric sea level rise will this provide?

  We’ve added a paragraph on the impacts of these fluxes on the representation of sea level in Section 3.

- There are many occasions of handwavy statements of the status quo being insufficient without clear recommendations to relieve the problem. I have pointed these instances out and made suggestions.

  Thanks. We have tried to be clearer in our recommendations.

See technical suggestions below.

Line 2 – add comma before “and”

Done

Line 5 – add “over the historical period” after “discharge”, replace “accounted for” with “addressed” or “incorporated” or “represented”, and remove “an updateable dataset of”

Done. New phrasing is “but in neither case was the observed increasing discharge over the historical period properly represented. In this paper, we present data products of absolute and

anomalous freshwater mass fluxes from both ice sheets, and recommendations for their use in historical simulations."

Line 14 – doesn't "over the last century" include "and in recent decades"? Suggest removing or changing to "and has accelerated in recent decades"

Added "accelerated" suggestion.

Line 30 – Another example of the role of freshwater on Southern Ocean circulation

Bronselaer, B., Winton, M., Griffies, S.M., Hurlin, W.J., Rodgers, K.B., Sergienko, O.V., Stouffer, R.J. and Russell, J.L., 2018. Change in future climate due to Antarctic meltwater. Nature, 564(7734), pp.53-58.

Added.

line 63 - There does not seem to be consistency between the definition of "Discharge" here (as an ice flux) compared to the terms in Figure 1 (e.g. "Discharge" not identified but "Subglacial Discharge" seemingly identified as a liquid flux)… is "Discharge" equal to "Iceberg Flux" or to to the sum of several terms in Figure 1?

We have improved Fig 1 and made the definitions consistent.

Line 72 – "Ice front" is not provided in Figure 1, but "Frontal retreat" is provided twice.

Fixed.

Line 74 – "Ice shelf" is not provided in Figure 1

Added.

Line 114 – ", and again this is with respect" should be "relative"

Done, and nearby "with respect to" are also changed to "relative to".

Line 124 – "uasi" should be "quasi"

Done.

Line 129 – I don't think the sentence, "The implications of adding a new forcing dataset needs to be considered for each of these different configurations and experiments." Is helpful without further contextualization and should be removed unless these implications are to be detailed.

We have explicitly linked this statement to the relevant section where we discuss this.

Line 160 – The GFDL CMIP6 models included explicit icebergs: Adcroft, A., Anderson, W., Balaji, V., Blanton, C., Bushuk, M., Dufour, C.O., Dunne, J.P., Griffies, S.M., Hallberg, R.,

Harrison, M.J. and Held, I.M., 2019. The GFDL global ocean and sea ice model OM4. 0: Model description and simulation features. Journal of Advances in Modeling Earth Systems, 11(10), pp.3167-3211.

Added: “to explicit modeling of icebergs (Adcroft et al., 2019)”

Line 181 – add comma before “it”

Disagree, no change.

Line 185 – “observational changes” should be “observations” to avoid repeating “changes”

Changed.

Line 295 – Before moving on, it would be helpful to know how these freshwater fluxes compare to those in Swart et al., 2023 for SOFIA which is cited earlier.

The SOFIA protocols are substantially more idealized than the fluxes given here, which makes sense. They are interested in doing some additional experiments with these historical forcings, but this is still to be determined. We’ve put in some text alluding to that.

Line 310-312 – Is “with respect to the 1850–1900 pre-industrial period” mean that 1850-1900 is the “baseline period”? I think so from line 102, but it is not clear why different wording is being used for these two things if they are indeed the same thing.

We have now reserved the term “pre-industrial” for the standard PIcontrol setup. The baseline period is now clearly 1850-1900 (for Greenland) and is not described as pre-industrial.

326 – remove “the choices available in”

Done.

Line 402 – “1.5 orders of magnitude” should be “50 times”

Done.

Line 404 – remove “, such as that provided by”

Done.

Line 412 – a good reference for “estuarine box model” is

Sun, Q., Whitney, M.M., Bryan, F.O. and Tseng, Y.H., 2017. A box model for representing estuarine physical processes in Earth system models. Ocean Modelling, 112, pp.139-153.

And

Sun, Q., Whitney, M.M., Bryan, F.O. and Tseng, Y.H., 2019. Assessing the skill of the improved treatment of riverine freshwater in the Community Earth System Model (CESM) relative to a new salinity climatology. Journal of Advances in Modeling Earth Systems, 11(5), pp.1189-1206.

Added.

Line 434 – add comma before “and” Not done.
Line 449 – add comma before “and” Done.
Line 450 – remove comma before “and” Done.
Line 451 – add comma before “or” Done.
Line 515 – add comma before “but” Done.

Line 515-517 – I do not understand the statement “One could remove an equivalent mass of deep water at the continental boundary to match the mass of freshwater coming from the floating source to allow the freshwater fluxes to be accurate, while also matching the sea level rise.” Is the assumption here that models have rigid lids and virtual salt fluxes? This suggestion would not seem to appropriate with models that use a free surface and real freshwater fluxes.

We don’t think this is correct. The issue is whether the model will correctly adjust for a change in the floating mass of ice shelves. Even with a free surface and natural freshwater fluxes, if there is no ocean under the ice shelf, it would need to be corrected for. Also if the pressure of the ice shelf on the ocean was fixed (or the cavity treated as a rigid space), this term would also be missing. For a model with a rigid lid (and constant volume), the sea level changes would not be represented properly in any case. We have clarified in the text under what circumstances this might be needed in the added discussion of sea level implications in Section 3.

Line 537 - add “spread” before “uniformly”

Done.

Line 557 – The statement “Increasing meltwater can act as a negative feedback on ocean temperatures, potentially reducing the relevant climate sensitivities” has two parts that have opposing influences on ocean stratification and surface warming response – the extraction of ocean heat and buoyancy for warming and melting of ice, and the addition of buoyancy from freshwater. I don’t think it helps to combine them as a single statement unless one effect strongly outweighs the other on density depending on the fraction added as liquid.

We think that in practice, modeling has shown that the net effect is likely to be a negative feedback (see Schmidt et al (2023) and other cited papers). But we have rewritten this sentence to leave that open.

Lines 576-581 – These sentences should be restructured as explicit guidance rather than as a set of hypotheticals, i.e. “For models that do not include explicit ice sheets, we propose that freshwater forcing be included as part of the anthropogenic suite of forcings”

We don't think that this should be so definitively recommended. It is an open science question to be explored. We are not in a position in this paper to give a ruling on how much of the anomalous flux is anthropogenic, probably a lot, but it is hard to be certain.

Line 585 – Indeed, the GFDL models both had interactive dust in CMIP6.

This isn't quite what is meant. Interactive dust generally allows for varying dust emissions as a function of soil wetness, wind, etc. But there are additional anthropogenic sources of dust (from agricultural, recreational and construction activities) which can be inferred from the observations, but have not yet been incorporated into historical simulations. Conversely, the actual record of biomass burning is incorporated, but there is no split between natural and anthropogenic components.

Line 589-608 – I am surprised that no recommendation is made here to at least maintain the same freshwater fluxes from the end of the historical run through the future projections. This would seem preferable to using no freshwater fluxes. It would seem ill-advised for models to try to participate with these historical freshwater fluxes without having a plan for what to do with those fluxes through the transition to projections.

Agreed. We have added this to the section.

Line 599 – add comma before "and"

Done.

Line 613 – I would rephrase "judge the credibility of future simulations" as "judge the credibility of historical and future simulations"

Done.

Line 619 – remove "the" before "very"

Done.

Line 631 – Need to add something like "we therefore highly encourage ice sheet models to same long term averages"

Assuming that this was meant to read "save", we have added that to the sentence.

Line 635 – Need to add the implication of this long term imbalance for the provision of forcing, required length of ESM simulation, or otherwise… "We therefore highly encourage…"

Added.

Line 639 – Helpful here would be a recommendation for observational reconstruction references that should be considered as helpful to provide these constraints.

This is a moving target since these reconstructions are also being updated regularly. We have added a reference though.

Line 644 – is there a recommendation to be made here?

Not really, it's just a word of caution.

Line 654-657 – These two sentences are wandering and hand-waving. How about, "While the community makes long term progress on explicit coupled ESM-ISMs, there remains urgent need to make near term progress with interim configurations treating freshwater anomalies as external forcings."

Replaced.