Dear Editor and Reviewers,

We sincerely thank you for the thorough and constructive reviews of our manuscript. We greatly appreciate the time and effort you dedicated to examining the details of our work. Your insightful comments have helped us substantially improve the clarity, focus, and overall quality of the paper.

Our detailed, point-by-point responses are provided below in blue font. If permitted, a tracked-changes version of the revised manuscript will be submitted for your reference. The main revisions reflect the major issues raised by the reviewers. In particular, we have carefully revised the manuscript to reduce unnecessary detail as noted by both reviewers, which has overall reduced the length of the paper.

On behalf of all co-authors,
Morven Muilwijk

Reviewer #2

This manuscript provides an insightful multi-model analysis of Southern Ocean regional responses to Antarctic Meltwater fluxes, including an estimate of the feedback on ice shelf basal melt. The key robust result is that Antarctic meltwater causes less-positive temperature anomalies along the continental shelf of the West Antarctic than for East Antarctica; since West Antarctica is currently experiencing large melt rates, they conclude that this meltwater feedback would tend to make melt rates more uniform. Beyond this headline result, the results are more mixed, because in some models "less positive" means a net cooling response, whereas in others it means "reduced warming". A particularly perplexing result is how similar the GFDL models' response to Antarctic meltwater is – in sign, magnitude, and pattern – to the SSP5-8.5 response. The manuscript is long but I think worth it, as I anticipate the various discussions of model-specific behaviors (complemented by extensive referencing to relevant literature) will inspire future work to resolve the open questions about which model responses are correct. The authors have made a convincing case that the value of this controlled model intercomparison project outweighs the caveats about the unrealistic distribution of meltwater. (Additionally, they point out that several of the most important caveats will be addressed by later phases of this collaborative project.) I recommend the manuscript be accepted for publication after addressing the following comments.
We thank the reviewer for the thoughtful assessment of our work and appreciate the recognition of the value of the SOFIA intercomparison and the usefulness of the regional analyses. We have addressed all comments below and are grateful for the positive evaluation.

Main comments

Needs more precise language around West Antarctic cooling induced by meltwater. In various places, but most importantly in the concluding paragraph (L. 783-786) and the abstract (L. 10-11), it is stated that the "cooling or reduced warming" on the West Antarctic continental shelf "suggest[s] a negative feedback" or "indicated a dampening feedback". This is misleading, since more than half of the models in the ensemble still show net warming on the continental shelf, meaning a net positive/amplifying feedback. I believe you are trying to make one or both of the two subtler points:

1) The net feedback in West Antarctica is less positive than the circumpolar average, suggesting compensation by a negative feedback process.

2) The two models that you seem to have the most confidence in (GFDL ESM4 and CM4), because of their relatively small biases and higher resolution, exhibit a clear net negative feedback on West Antarctic temperatures in response to meltwater forcing (which, surprisingly, arises even under SSP5-8.5 forcings), suggesting that the feedback in the natural world is net negative.
We thank the reviewer for this important clarification. In general, point one is the primary point we are trying to make, which is supported by the fact that most models either show a net cooling or at least a

reduced warming in West Antarctica. We agree that our original phrasing could be interpreted as implying that the ensemble generally exhibits a net negative feedback in West Antarctica, whereas in reality only a subset of models shows actual cooling, and most others (except AWI-ESM) only show reduced net warming. To avoid ambiguity, we have revised the abstract and the conclusions to explicitly distinguish between "cooling" and "reduced warming," and clarify that only a subset of models exhibits a net cooling response. We believe these revisions improve the precision and interpretability of the manuscript.

Figure 3 - How is P-E + Runoff larger than the total in some models, e.g. HadGEM3, under SSP5-8.5 forcing? This implies the residual (sea ice melt/freeze and iceberg calving) is negative. But surely sea ice volume does not increase from 60ºS-90ºS under such high forcing… This either needs to be explained here or else there needs to be a concrete statement about how this is resolved in Pauling et al. (in prep), and this companion manuscript needs to be made accessible to the reviewers. This result makes me also wonder what is going on in the other models…
Thank you for this very good comment, this issue has puzzled us as well. We double-checked the CMIP6 output and, unfortunately, the freshwater flux terms associated with sea-ice growth and melt are not available for HadGEM (nor for most other models). This makes it impossible to close the freshwater budget and give a definitive explanation. However, a negative residual does not necessarily imply that sea ice is a net sink of freshwater in a warming world.

The most likely cause is that the atmospheric fields (P-E) represent fluxes over the entire grid cell surface (open ocean + sea ice). Precipitation falling on sea ice, and evaporation/sublimation from sea ice or snow, do not directly enter the total ocean flux (wfo). These fluxes change the mass of the sea-ice/snow layer, not the ocean, unless the ice melts locally. Thus, when we compute P-E using atmospheric fields, even with land masked out, we inadvertently include fluxes that may not reach the liquid ocean. This can cause P−E+R to be systematically larger than wfo in regions with seasonal or intermittent sea-ice cover. In addition, advection of sea ice out of the domain is not accounted for. Even in a warming climate with declining Antarctic sea-ice volume, the 60–90°S region can still be a net sink of freshwater if ice forms near the continent and is exported northward to melt outside our domain. This would also contribute to a negative residual without implying local sea-ice expansion. Finally, we cannot entirely rule out model-specific flux-correction terms (e.g., salinity restoring), because the corresponding diagnostics are not available. If present, such corrections could contribute to a mismatch between wfo and the individually diagnosed budget terms.

In summary, we likely overestimate P-E because the atmospheric fields include fluxes over sea ice, and it is physically plausible for sea-ice processes and ice export to produce a negative residual in this region. Ideally we would close the budget to provide a definitive answer, but this is not possible with the available data. A sentence summarizing what we explain here has been added to the manuscript. For the SOFIA simulations discussed in Pauling et al., the situation is different: in those experiments sea ice cover expands consistently in all models and is a substantial freshwater sink because strengthened stratification and surface cooling allow sea-ice cover to expand. In SSP5-8.5 this signal is superseded by the strong warming trend.

Minor comments

L. 114 - Remove "both" since you then have 3 references after
"Both" has been removed and commas added.

L. 172 - Missing citation
Corrected.

L. 757-759 - I don’t understand the flow of this sentence. Misplaced commas?

Good catch. The sentence has been rephrased to: “Local shelf-break dynamics, including a strengthened Antarctic Slope Front (ASF) that limits Circumpolar Deep Water (CDW) intrusion, an accelerated Antarctic Slope Current (ASC) that advects anomalous Weddell waters, and reduced Dense Shelf Water (DSW) formation, play a crucial role in shaping regional responses”.