Geosci. Model Dev. Discuss., 5, C1622–C1629, 2013
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Geoscientific Model Development Discussions

Interactive comment on "A numerical study of the Southern Ocean including a thermodynamic active ice shelf – Part 1: Weddell Sea" *by* V. Meccia et al.

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Response to Referee #1

I would like to thank reviewer #1 for his careful review and thoughtful comments and suggestions. Our point-by-point response follows changes in the text are highlighted in the color blue.

Answer to general comment

The reviewer is correct when pointing out that the experiment M2 (ocean model run with the ice shelves included but their thermodynamic interaction with the ocean turned off) is not useful and actually misleading – this issue was also brought up by reviewer #2. Open water fluxes were not applied in this case, once there an ice shelf, we shut off

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Interactive Discussion

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the air sea fluxes. We opted to remove this experiment and reference to it from the text since it actually does not help in the interpretation of the results and objective of the paper, which is to find out how important, is the inclusion of thermodynamically active ice-shelves.

With respect to M4, the reviewer is correct in that a Southern Ocean Model run without sea-ice doesn't make much since. Indeed, as stated also by reviewer #2 this run without sea-ice and ice-shelves is pretty much unrealistic – the point in the paper is exactly to show how sea-ice is an important mechanism to keep the Southern Ocean from a runaway cooling. The resulting extreme cold temperatures could be the trigger for unrealistic vigorous overturning which would account for the lack of stratification and high surface salinities. Nonetheless, as reviewer #1 points out, models can be run without sea-ice as long as the surface fluxes are relaxed to observed (climatological) T and S. We have added these comments to the text.

Answer to specific comments

"4041/22: I think a more up to date reference for ROMS (e.g. Haidvogel et al., 2008) should be used."

The suggested reference was added to the text

Haidvogel, D.B., Arango, H., Budgell, W.P., Cornuelle, B.D., Curchitser, E., Di Lorenzo, E., Fennel, K., Geyer, W.R.,Hermann, A.J., Lanerolle, L., Levin, J., McWilliams, J.C., Miller, A.J., Moore, A.M., Powell, T.M., Shchepetkin, A.F.,Sherwood, C.R., Signell, R.P., Warner, J.C., Wilkin, J. Ocean forecasting in terrainÂ■following coordinates: Formulation and skill assessment of the Regional Ocean Modeling System (2008) Journal of Computational Physics, 227 (7), pp. 3595Â■3624. C

"4041/22-24: The time discretization given here is not quite correct for the 3D equations, see Section 5 and Table 1 of Shchepetkin and McWilliams (2005)."

As suggested we have also included the reference " A.F. Shchepetkin, J.C. McWilliams,

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The regional oceanic modeling system (ROMS) a split-explicit, free-surface, topography following-coordinate oceanic model, Ocean Modeling 9 (4) (2005) 347–404" in the description of ROMS discretization.

"4042/6: Why are ïňĄgures 1c and d presented before 1a and b?"

The reviewer is correct in pointing this out, the order of the figures was reversed with Figures 1a and 1b presented first in the text.

"4042/6-7: Any issues with having a 15-1 ratio in the grid size over the model domain? I know the BRIOS people were not worried about it, but their ratio (longitudinally) was only 4.5 to 1."

I AM not sure I understood the question, but we chose a grid configuration that would be stable and feasible to run in our system.

"4043/1-3: I don't think the Jenkins et al. (2001) reference is appropriate here."

We agree with the comment and this reference was stricken from the text.

"4043/13-14: By "depth below mean sea level of the ice shelf thickness", do the authors mean that the depth of the bottom of the ice shelf (meters below MSL) is set as the entire thickness of the ice shelf or just the portion of the ice shelf that is below MSL (most of the thickness, but not all)?"

It means just the portion of the ice shelf that is below MSL – this is clarified in the text.

"4043/16-18 and Figure 1b: The ice thickness for the Amery seems much too low. From Figure 1b, it looks to be < 100 m everywhere, while it should be > 400 m over most of the shelf and > 200 m over almost the entire shelf. Too much smoothing perhaps?"

The reviewer is correct and we added this clarification that the ice-thickness for Amery was underestimated due to too much smoothing, to the text.

"4043/25-28: Were any velocities or surface elevations used on the northern open

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boundary?”

No

“C13474044/8-9: I think Fairall et al. (1996) is COARE2.5. Doesn’t ROMS now useCOARE3.0? If so, I think the reference should be Fairall et al. (2003).”

The reviewer is correct and we updated the reference to Fairall et al. 2003

“4044/14-19: I think it would be helpful to include the "standard" (for Southern Ocean models anyway) diagnostic of the Drake Passage transport in order to see if the mean model ACC transport is maintained over the 100 year simulation.”

Considering the barotropic nature of the ACC and the fact the Kinetic Energy has been commonly used to show model equilibration we are very confident in its results. Nonetheless, verification (validation) based on physical metrics is being used in another experiment to be submitted soon (Pereira, J.E. et al., 2013) for the South Atlantic and its Southern Ocean sector.

“4045/19-12: Why not just use the last 9 years of all four simulations?”

The results show no significant difference between the last 9 or 10 year of simulation.

“Section 3, general comment: Since the purpose of this paper is to identify "the relative importance of the cryosphere’s components and their interactions with the ocean in the Southern Ocean," I think it would be useful to compare the freshwater budget (or salt budget, since the surface ïňĆux in ROMS is a salt ïňĆux) by source (i.e. open water surface ïňĆux, sea-ice surface ïňĆux, ice shelf basal melt, surface relaxation term, northern open boundary) for the different experiments.”

This is a very constructive suggestion, which we are already undertaking for a subsequent paper considering the volume of analysis.

“4046/2-17: Since all the parts of Figure 3 look pretty much the same (i.e. the comparison looks pretty good, especially since the minimum value of the scale is -1.0 and thus

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the really cold temperatures in M4 do not stand out), I think it would be helpful to do a more quantitative comparison (at least compute the RMSE with respect to the satellite data) to help differentiate between the experiments."

We have eliminated M2 from this paper, and indeed the comparisons look good. It is hard at this point to obtain a reliable (long enough) satellite SST (or SSS) data for validation. We do state that a thorough validation is not possible given the scarcity and biases of the data in the Southern Ocean.

"4046/18-25: Have the authors looked at a comparison of salinity deeper in the water column? I suspect M1 and M2 wouldn't look nearly as comparable as they do at 10m (see your different cross sections), at least on the Ross and Weddell shelves, helping to explain the big difference in the overturning shown later."

We have not looked in detail at the Southern Ocean water column salinity – the available data has problems in its own. M2 is ill formulated (and thus eliminated from the paper). Effort is being made to gather temperature data obtained from MEOPS Project (CTD's attached to Sea-Lions) in order to validate subsurface temperature and salinity. However, the data for Antarctica is sparse and few. A paper with some of that has just been accepted in a Brazilian Journal .

(Santini, Muelbert, Buss and Wainer; Estrutura termohalina e massas de água ao norte da Península Antártica revelada a partir de dados in situ coletados por Elefantes-marinhos do sul (Mirounga leonina)" ; Revista Ambiente & Água - An Interdisciplinary Journal of Applied Science, 2013 accepted)

"4047/22-26: This explanation makes no sense if the comments on pg. 4053 about the heat and salt ïňĆuxes are correct."

Since M2 didn't make sense and was eliminated the statement doesn't have any meaning and was also stricken from the text.

"Section 3.2: Can the authors add an estimate of the Weddell Gyre transport in order

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to compare with observational based estimates? I guess it would be difficult to do for experiments M2 and M4, but I think it would be illustrative for M1 and M3."

As mentioned above, a dynamical-phenomena based validation is already underway and should be submitted soon. ROMS Weddell Gyre transport, ACC transport, Coastal Current (ACOC), Malvinas Current transport are all being compared to values compiled from the literature. Table 1 (here shown as "Figure 1") has a brief example, values are Sverdrups.

"4050/10-14: I think it's important to also mention the interactions of the water with the base of the ice shelf when discussing the formation of ISW."

We agree with the reviewer and the interactions of the water with the base of the ice shelf when discussing the ISW was is included in the text

"4050/20-22: If the authors want to show WSBW along with all the other water masses, why not do a T-S diagram over the entire Weddell sector instead of just along the 40W line?"

We wanted to be consistent with the work of Kerr et al, 2012

"4051/9-18: The winter extent comparison looks really good. I know there's no good observational data to compare against, but how does the ice volume differ between M1, M2 and M3?"

M2 was eliminated from the analysis and model results for sea-ice concentration differ very little between the experiments.

"4051/18-22: I think this is misleading given the comments on pg. 4053 about experiment M2."

Striking M2 from the analysis solved the problem.

TECHNICAL CORRECTIONS

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We have accepted and change all the suggested technical corrections

Interactive comment on Geosci. Model Dev. Discuss., 5, 4037, 2012.

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Interactive Comment

1 → Antarctic Circumpolar Current	
a. At Drake passage (averaged – ACC Drake	134
b. ACC – Subantarctic Front (SAF) – ACC SA Front	87-148
2 → Agulhas System	
a. North branch at Madagascar area (MD North)	72
b. North branch at Walves ridge (MD Walves)	125
c. Agulhas-Benguela transition (BeC)	10
4 → Brazil Current	
a. Northern area (BzC – North)	2.4
b. Southern area (BzC – South)	11
5 → Malvinas Coastal Current – McoC	
5 → North Brazil Current (NBC)	
a. at Surface (< 1000 meters)	15-35
b. Deep Western Boundary Current (DWBC)	35
7 → Antarctic Coastal Current	
a. Western Atlantic - ACoC West	15

Fig. 1. Transport values for validation.

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