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The Cryosphere Discussions

Interactive comment on "Uncertainty in future solid ice discharge from Antarctica" *by* R. Winkelmann et al.

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This paper uses the PISM-PIK ice sheet model to look at future Antarctic variations in the next 500 years, forced by a range of ECP/CMIP3 scenarios, and an ensemble of model parameter values. It breaks new ground in several ways for future Antarctic modeling: (i) it uses large ensembles and model physics envelopes to assess uncertainties, (ii) it makes a first attempt to validate not just modern steady state but recent decadal acceleration of discharge, and (iii) it physically connects large-scale ocean model changes in temperature and salinity to sub-ice-shelf oceanic melt. The results are usefully partitioned between those due to surface warming alone,and due to additional oceanic warming. More definitive studies of future Antarctic retreat might require higher-resolution models of individual basins, but this paper should be useful as a synthesis and reference point for more detailed studies to come.

The comparisons with observed recent decadal-scale accelerations in section 4 are novel. However, all the model accelerations (Figs. 16-18) are smoothly increasing in character. It is probably too early to tell if the real Antarctic behavior will be the same form, or if it will be dog-legged with much sharper breaks in slope, due to very non-linear thresholds. As a first cut, drawing horizontal lines at particular observed values (Fig. 18) is reasonable, but they are guaranteed to intersect the smooth model curves at some future date. If the real behavior turns out to be more non-linear with discontinuous slope breaks, the smooth form of the model curves may end up being unrealistic.

The model-data comparisons of recent acceleration are all for Antarctic totals. However, regional values are available for both model and data (Peninsula, Amundsen, etc). How well does the model discharge vs. time compare with data-based estimates region by region?

One concern is that the model resolution ($\sim$18 km) may not be adequate to accurately capture grounding-line migration. Although the modern equilibrium grounding-line locations are very realistic, other work (Schoof, JGR 2007; Gladstone et al., JGR 2010; Pattyn et al., TCD 2012) has shown that very fine resolution (few 100's m, at least much less than $\sim$10 km) is needed to avoid spurious behavior of grounding-line motion, unless other measures are used. The animation in Supp. Material in Martin et al. (2011) shows some reversible grounding-line motion for Weddell and Ross, but no detectable motion for the Pine Island/Thwaites embayment. Also, the MISMIP 1 and 2 results shown in Winkelmann et al. (2011) for the resolution closest to here (12 km) show significant offset between advancing and retreating grounding lines where there should be none. This calls into question the robustness of the model's future results for grounding-line retreat, which is quite limited everywhere, and very little if any for Pine Island-Thwaites (Fig. 14).

Fig. 3 shows that the ECP/CMIP GCMs produce almost the same values of global warming as warming over the Antarctic. This lack of polar amplification seems strange

- don't most GCMs predict polar amplification of greenhouse gas warming, due to sea-ice and atmospheric-inversion feedbacks, greater in the Arctic, but still significant in high Southern latitudes?

On pg. 676, for non-specialists, it would help to briefly state here what the enhancement factions ESSA, ESSI are, so they don't have to refer to Winkelmann et al. (2011). Similarly for Fp; also state that Fp replaces the "0.96" in Winkelmann et al. (2011, Eq. 13).

On pg. 679 and 680, what ocean depths are used to obtain water temperature and salinity changes? Are these the depths noted in Fig. 5 caption?

On pg. 680, the account of how Olbers and Hellmer's (O-H) box model is used could be clearer. Say clearly that a reduced model of 2 or 3 boxes is used here, not their full 6 boxes, and that the analytic linearized non-diffusive solution in O-H's Appendix is used (I think). Then, it would help to explain how the total 1-D size of each basin (of which Bg is 1/3 and Bs is 2/3) is determined from the 2-D (x,y) maps of the ice model; perhaps by clarifying the phrase "we find the boxes Bg and Bs recursively for each ice shelf"(?).

On pg. 682 and Fig. 9 caption, to avoid confusion, note that the sense of the co-variation of F and ESSA (higher F, higher ESSA), is perpendicular to the "corridors" (top of pg. 678, Fig. 2) of modern-fit combinations that have F increasing and ESSA decreasing.

Pg. 683: The first sentence seems to say that the primary reason for grounding line retreat due to ocean warming is that "the surface elevation of an ice shelfis lowered, thereby increasing the driving stress across the grounding line". This may be a secondary mechanism, but isn't the primary well-recognized reason that increased sub-ice melting thins the ice, reducing pinning points and lateral drag, decreasing buttressing and back stress at the grounding line? This could be made clearer to avoid confusion.

Pg. 689: the phrase "thermodynamic model" here is confusing. The PISM ice-model already has an internal ice-temperature equation. Perhaps this means basal hydrology, with freezing/melting at the base?

Interactive comment on The Cryosphere Discuss., 6, 673, 2012.