R: Ocean Simulations with Ice Shelves

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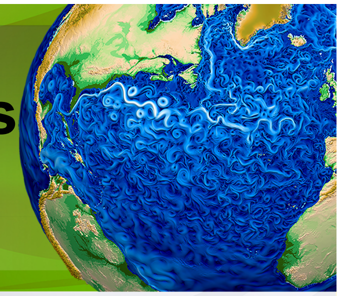
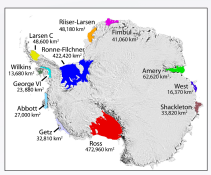
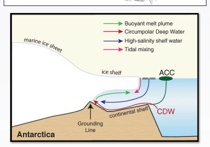


Objective

New MPAS-Ocean domains include active ocean cells below ice shelves, in order to investigate the interaction between ocean currents and land ice. Warmer ocean currents may speed up ice shelf melting and retreat. Changing land ice fluxes could affect ocean temperature, salinity, and currents below the ice shelf. Modeling these regions is particularly important because these dynamics are poorly understood, and observations are sparse.

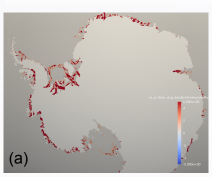
Progress since June includes global simulations out to ten years for lower resolution, and successful high-resolution simulations in ACME. These use the EC 60to30km and RRS 30to10km meshes, with grid cells of 30 and 10 km below land ice, respectively. Preliminary analysis shows currents flowing below the ice shelves, ice sheet melting in the same locations as observational estimates, and melting / freezing rates relatively close to observed values. The Ronne-Filchner and Ross ice shelves sit on top of areas of ocean, each at least the size of California. Despite this, ice shelf cavities have not been included in any fully coupled global climate model to date because of the numerical modeling challenges and lack of observational data for validation.

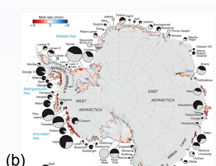


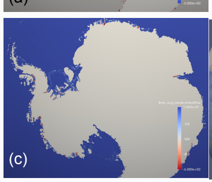


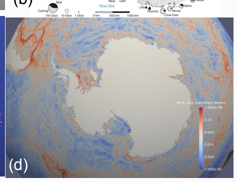
Approach

The following results are from an ACME ocean-sea ice RRS 30to10km simulation with land ice cavities (G case, data atmosphere). Images show a monthly average from April of year one. Ice shelf melt rates in m/yr (a) are of a similar order and have broadly similar patterns to estimates based on altimetry and mass balance models (b, Rignot et al 2013), though ACME's melt rates are generally biased high at this early time.


(a)


(b)

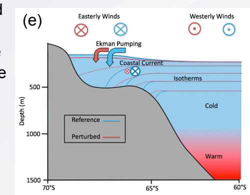

(c)

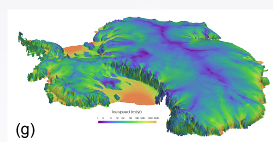

(d)

(c) The upward heat flux in W/m^2 due to melting (red indicates ocean cooling). The barotropic speed (d) in m/s shows the vertical average of currents, including those below the ice shelves.

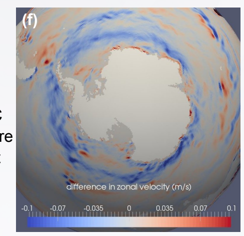
MPAS-Ocean has been validated in many idealized and realistic domains (Petersen et al 2015, Ringler et al 2013, Reckinger et al 2015), as well as ice-shelf test cases (Asay-Davis et al 2015).

The Antarctic Slope Front (ASF) is a region of downward tilted density surfaces near the Antarctic continental shelf that presently limits the access of warm intermediate waters to the base of Antarctic ice shelves (blue lines, Figure e from Spence et al., 2014, hereafter "S14"). The ASF is maintained by downwelling of cold, freshwater as a result of coastward Ekman pumping, which is in turn controlled by the strength of the Antarctic Coastal Current (CC). Current trends and projected changes to the Southern Annular Mode (SAM) include a strengthening and poleward shifting of the Southern Westerlies (S14), which in turn would weaken the CC, Ekman pumping, and the strength of the ASF (red lines, Figure e).

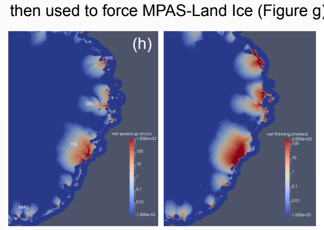

(e)

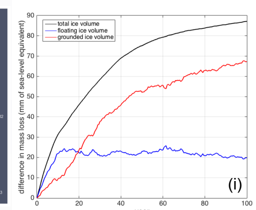

(g)

Similar to S14, we used ACME in an ocean-ice configuration with the EC 60to30km mesh to explore how such changes might affect sub-ice shelf melt rates and Antarctic ice sheet dynamics.


(f)

We conducted two simulations, one using "normal year" (NY) forcing and one using NY forcing with modified winds (after S14) to estimate how Southern hemisphere wind changes could impact; 1) the strength of the CC (Figure f; blue = reduced CC strength), 2) Ekman pumping, 3) the strength of the ASF, and 4) sub-ice shelf melting. *Increases* in the latter were then used to force MPAS-Land Ice (Figure g) offline and estimate the impact on ice dynamics (Figure h; increased ice speed & thinning from melt rate perturbation) and overall loss of ice sheet volume (Figure i).


(h)


(i)

Impact

ACME's capability for representing the coupling between the ice sheet and the oceans in high-resolution, coupled simulations continues to be unique in Earth System Modeling. We are now beginning to validate our simulations against observations and use coupled model output as forcing for Antarctic ice sheet evolution and sea-level rise experiments.

References

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