Exploring the sensitivity of global ocean circulation to future ice loss from Antarctica

PI Alan Condron

Award: DOE: DE-SC0016105

FINAL REPORT

Following PI Condron's recent move from the University of Massachusetts Amherst (UMass) to Woods Hole Oceanographic Institution (WHOI), this award has now been closed at UMass and will be reallocated to WHOI. At this time, there is an unspent balance of $51,646.93 (41%). The following serves as a summary of the work carried out by PI Condron during his time at UMass Amherst.

PI Condron performed a series of numerical climate model simulations to study the impact of a projected speed-up in the melt rate of the Antarctic ice sheet in the future on ocean circulation and global climate. The Massachusetts Institute of Technology general circulation model (MITgcm) was developed to allow freshwater runoff produced by a stand-alone ice sheet model to be interpolated directly to the MITgcm model grid. In doing so, runoff occurring over the Antarctic Continent was moved to the nearest ocean grid cell using a nearest-neighbor technique to ensure water and ice from the land entered the ocean in a realistic fashion, i.e. at the edge of the Antarctic continent. This point source release provided a considerable improvement over previous studies that tended to uniformly (and unrealistically) freshen large portions of the Southern Ocean when performing similar experiments. The model framework was also updated to allow the ice fraction of the total runoff to be released into the ocean as discrete icebergs using MITBerg – a dynamic/thermodynamic iceberg model developed by PI Condron with funding from a previous DOE SciDAC proposal (DE-FOA-0000452). Extensive testing of the model framework was then carried out to ensure that freshwater runoff was conserved flowing the regridding process. In addition, the computational performance of the iceberg model was improved by allowing single lagrangian (iceberg) particles to represent several bergs at anyone time. A spin-up integration performed under modern-day conditions indicated that the number of icebergs in the Southern Ocean equilibrated at ~100,000 after 5 years (Figure 1) and that, in agreement with observations, icebergs were largely confined to the region south of ~60°S, with significant numbers of icebergs in the Weddell Sea region (Figure 2).

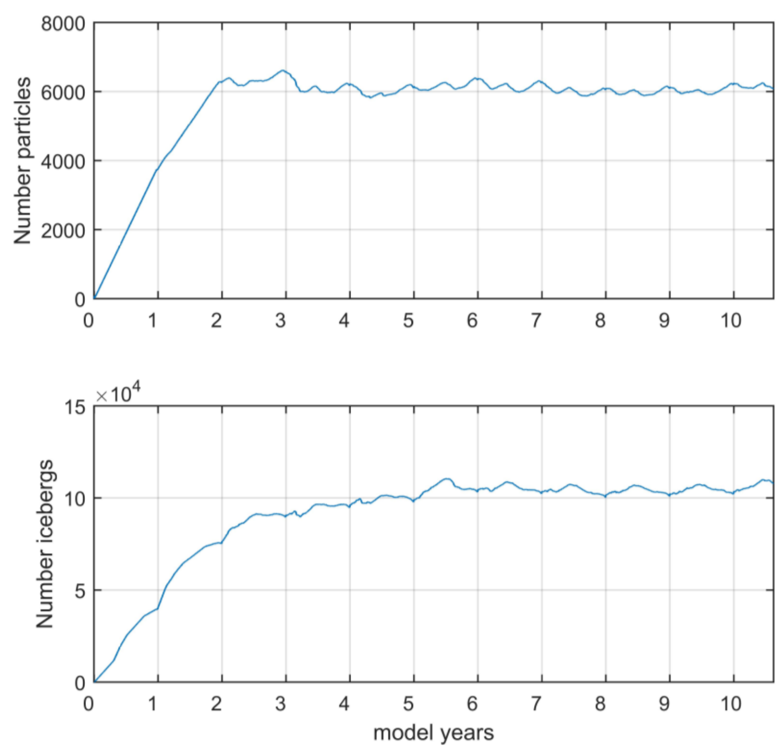

Figure 1: *Iceberg activity in the Southern Ocean in the spin-up integration in which icebergs are explicitly simulated using the thermodynamic-dynamic iceberg model, MITberg.*

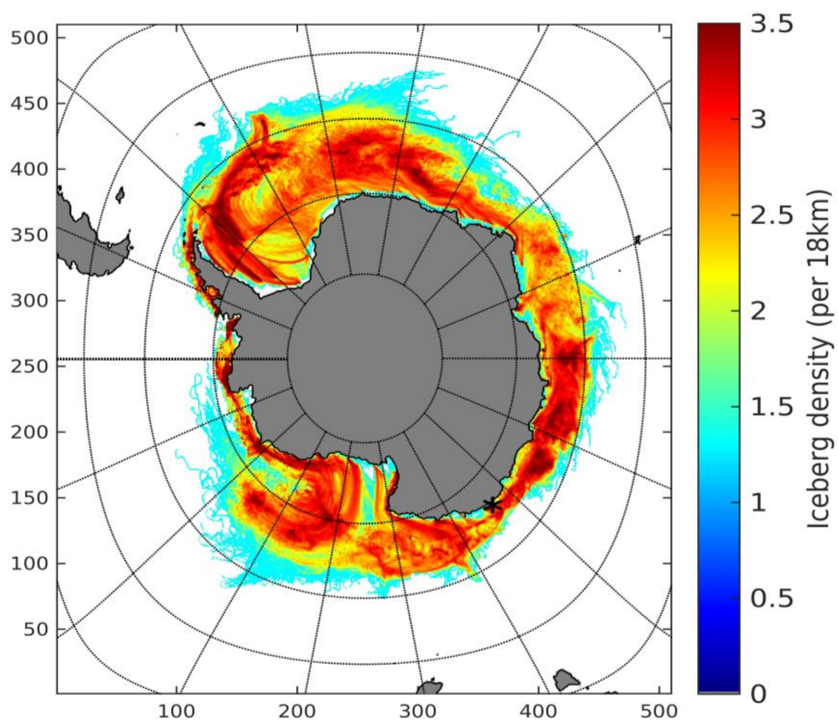

Figure 2: *The annual mean density of icebergs in the Southern Ocean (per 18-km grid cell) for the last 5 years of the spin-up integration.*

A series of numerical simulations were then integrated forward from the end of the spin-up run to explore the impacts of increased Antarctica melting (primarily in the form of a collapse of the West Antarctica Ice Sheet) on ocean circulation. These runs comprised of a modern-day control integration and two perturbation experiments in which a transient freshwater forcing was prescribed using output from a stand-alone ice sheet model integrated forward under IPCC future climate (RCP) scenarios 4.5 and 8.5. An example of this freshwater forcing for IPCC climate scenario RCP 8.5 is shown in Figure 3.

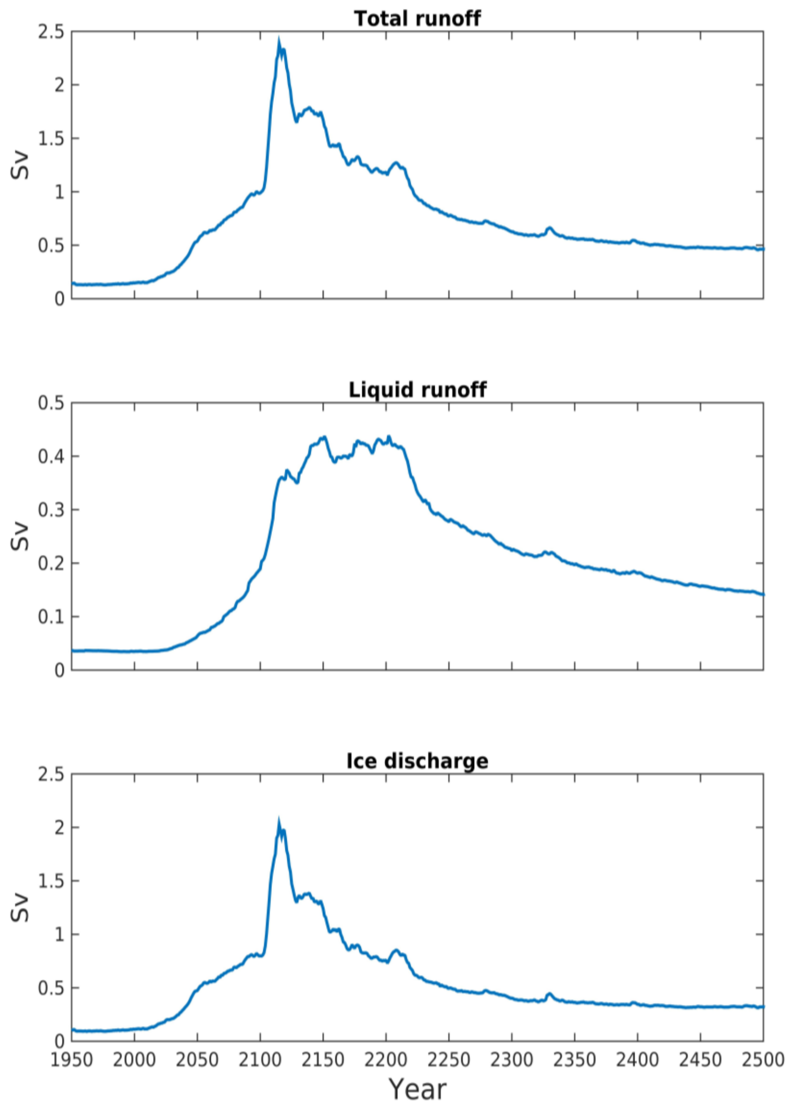

Figure 3: *Freshwater input to the Southern Ocean from 1950 to 2500 simulated by an ice sheet/shelf model forced under IPCC scenario RCP 8.5. The total freshwater flux prescribed to our climate model (MITgcm) is split into a liquid and solid (iceberg flux) component to more realistically simulate freshwater forcing. Freshwater input calculations include contributions from ice loss above and below sea level and exceed 2 Sv in RCP8.5 after yr 2100.*

In each simulation, the role of the Antarctic Circumpolar Current (ACC) and mesoscale eddies in mixing freshwater from Antarctic with the ambient ocean was explored. The change in global salinity in response to the maximum rate of melting predicted under IPCC climate scenario RCP 8.5 showed that the highly energetic and eddying ACC plays a significant role in how freshwater from the ice sheet is dispersed and mixed (Figure 4). At this resolution, runoff from most of the ice sheet remained confined to the near-shore environment except in the Weddell Sea region where freshwater was injected into the ACC. Even then, however, there was limited freshwater transport towards the North Hemisphere. This pattern of freshwater advection is very different from what is predicted by lower-resolution numerical ocean models that do not resolve eddies in the ACC as well as studies that initially freshened large parts of the Southern Ocean. In these experiments, freshwater was rapidly transported away from Antarctica towards the Northern Hemisphere. The response of the Atlantic Meridional Overturning Circulation and movement of heat to North America and Europe to the pattern of freshwater transport simulated here will be examined by PI Condron at WHOI.

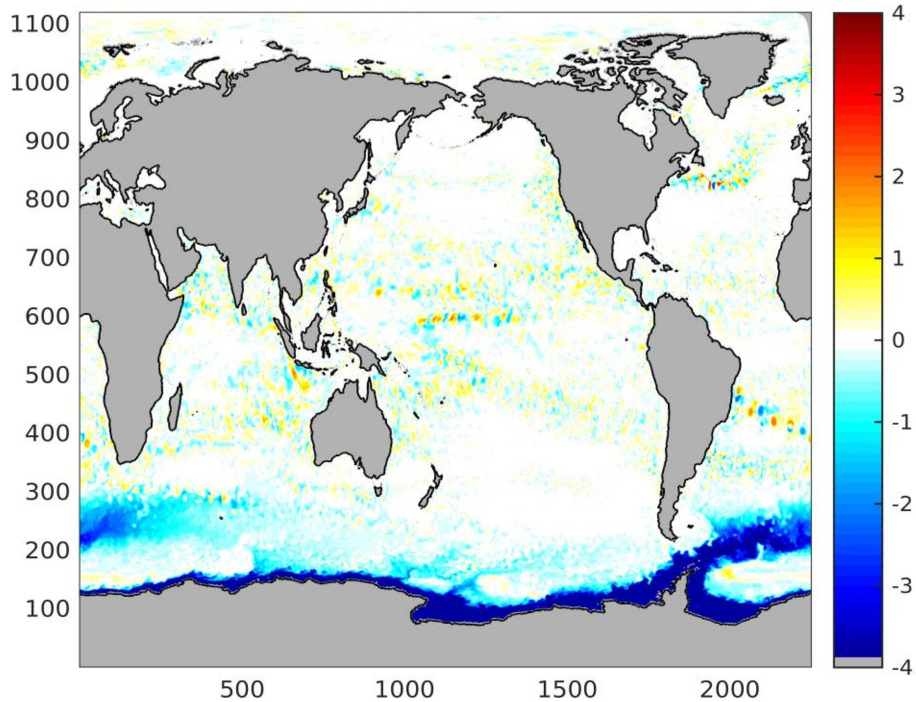

Figure 4: The change in the sea surface salinity (SSS) of the global ocean in response to a rapid collapse of the Antarctic Ice Sheet, assuming a constant 2 Sv freshwater forcing. Note the confinement of the freshwater to the Southern Ocean.