An Implementation of Icebergs in CICE

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June 20, 2012

Annual CESM Workshop, Breckenridge, CO

Motivation

- There is an estimated global iceberg calving flux of $\approx$ 2300 Gt yr^{-1}, about 90 $\%$ of which occurs in the Antarctic.
- Icebergs provide an important vehicle for freshwater injection into the polar oceans, an estimated 60% - 80% of net freshwater flux from land ice to oceans in the Antarctic.
- Icebergs interact dynamically with surrounding sea ice, potentially affecting marine eco systems.

Iceberg Dynamics

Iceberg Momentum Equation

$$m\frac{d\vec{u}_b}{dt} = \vec{F}_a + \vec{F}_w + \vec{F}_c + \vec{F}_{ss} + \vec{F}_{si}$$

- m is iceberg mass, t is time
- $\vec{u}_b$ is iceberg velocity
- $\vec{F}_i$ are the forcing terms (atmospheric, ocean, Coriolis, sea surface slope, and sea ice)
- Icebergs interact dynamically with sea ice through ridging or additional forcing term in sea ice momentum equation.

Lichey, Hellmer, 2001. Modeling giant-iceberg drift under the influence of sea ice in the Weddell Sea, Antarctica.

Iceberg Thermodynamics

Icebergs lose mass primarily through three mechanisms, described by empirical relations:

- Basal melting - turbulence due to differences in oceanic and iceberg motion (also function of difference in temperature between ocean and iceberg)
- Lateral melting - buoyant convection along sidewalls of iceberg (function of ocean temperature)
- Erosion due to waves (function of sea state and ocean temperature)

Gladstone et al, 2001. Iceberg trajectory modeling and meltwater injection in the Southern Ocean.

Model Overview

- Bergs are assumed to be tabular with fixed aspect ratio 1:1.5, shorter side normal to forcings.
- Bergs may rollover if Weeks-Mellor stability criterion is met.
- We track bergs in two frameworks, depending on size

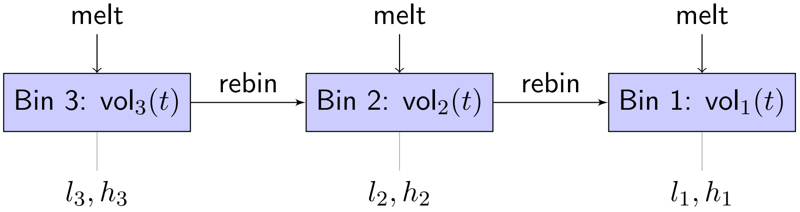
Giant bergs (>10 n.m.)

- Track giant bergs as individual Lagrangian particles.
- Bergs are individually tracked as a single, coherent unit by their center of mass, using fractional grid indices.
- Forcing data is interpolated from grid cell corners to iceberg location by inverse area weighting factors. Berg information extrapolated to grid nodes with same factors.

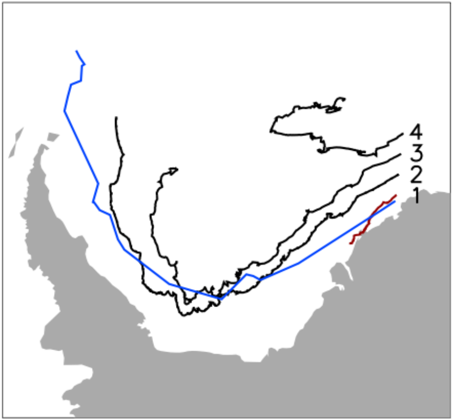
Model Overview

Smaller bergs (<10 n.m.)

- Bergs take up certain fractional area of each grid cell, rather than having precise location
- Bergs advected through sea ice incremental remapping scheme
- Bergs are calved from four spots around the continent, four times a year, to total 50% estimated calving rate of 2000 Gt yr^{-1}.

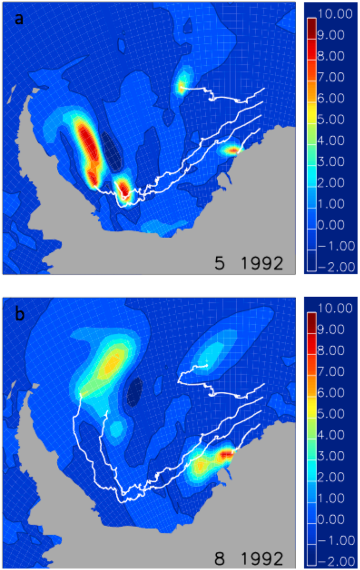


C7 Trajectory



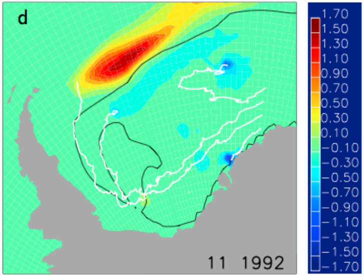
Model runs of iceberg C7 from March 5, 1990 to December 31, 1992 (black/red), actual C7 trajectory using NIC data (blue). C7 dimensions 37km x 18km, 225m height, 1.5×10^{14} kg.

Model Results

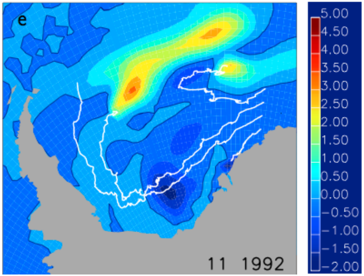


Difference between simulations with and without bergs in sea ice thickness (cm).

Model Results

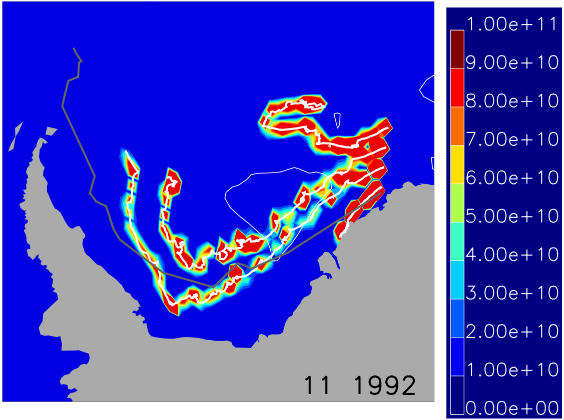


Difference in sea ice concentration (%).



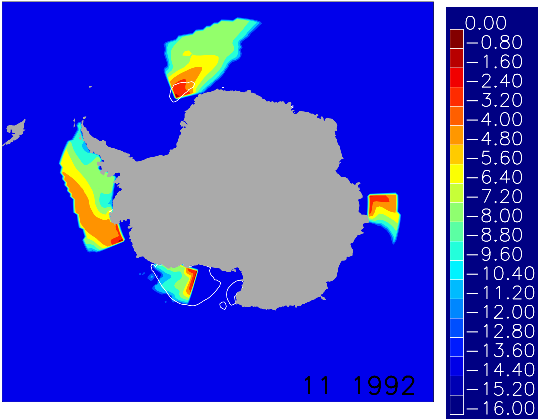
Difference in ridged ice thickness (cm).

Model Results



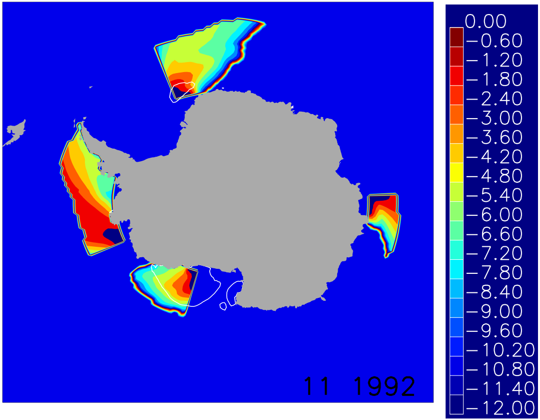
Freshwater shed (kg) from 4 giant bergs totaling ≈ 600 Gt. Total freshwater shed over 3 years is ≈ 29.3 Gt.

Model Results



Smaller bergs total concentration (logscale). Bergs were calved from 16 sites every 3 months, totaling ≈ 1000 Gt/yr.

Model Results



Freshwater shed (kg, logscale) from smaller bergs. Total freshwater shed over 3 years is ≈ 1188 Gt.

Summary

- We have incorporated an iceberg parameterization into the CICE model where sea ice responds to the icebergs, rather than being a static forcing term.
- Icebergs produce highly localized anomalies in sea ice concentration, thickness, and strength. Summer sea ice meltback limits these effects.
- Icebergs shed freshwater as they move, transporting freshwater away from the coast.

References

- Hunke, E. C., and D. Comeau (2011), Sea ice and iceberg dynamic interaction, J. Geophys. Res., 116, C05008,
- Gladstone, R. M., G. R. Bigg, and K. W. Nicholls (2001), Iceberg trajectory modeling and meltwater injection in the Southern Ocean, J. Geophys. Res., 106(C9), 19,90319,915
- Lichey, C., and H. H. Hellmer (2001), Modeling giant-iceberg drift under the influence of sea ice in the Weddell Sea, Antarctica, J. Glaciol., 47, pages 452460.
- Martin, T., Adcroft, A., (2010), Parameterizing the fresh-water flux from land ice to ocean with interactive icebergs in a coupled climate model, Ocean Modelling, Volume 34, Issues 34, pages 111-124,