Modeling BGC in the Ice Interior: the CICE release and beyond

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Does sea ice physics largely determine which type of algal bloom occurs? And when? And how?
This Talk

- How recent CICE developments help us model biogeochemistry throughout sea ice:
  a) Temperature, Salinity, bottom biogeochemistry
  b) Vertical tracer transport modeling
- Compare and contrast bottom bgc and zbgc
  a) Flux and transport assumptions
  b) Does it matter?
- Conclusions
Recent CICE developments (I)

1) Thermodynamics: mushy layer in addition to B&L99
2) Salinity: mushy layer and scheme for use with B&L99

Provides a dynamic, vertically resolved porosity...

Imaged Sea Ice Structures

Lab-grown sea ice: reconstructions of X-ray CT of 1 cm cores

and critical information for parameterizing brine motion.

Golden et al., 2007

Polar Climate Working Group Meeting 11 – 13 Feb 2013 Boulder, CO.
CICE developments and current work (II)

Bottom Biogeochemistry, aerosols, gas, precipitates…

Dust, BC, Fe

Dust, BC, Fe

Transport

CO₂

Bottom (skeletal) layer

Sea Ice

Methane bubbles

Ocean biogeochemistry

Polar Climate Working Group Meeting           11 – 13 Feb  2013                       Boulder, CO.
Recent CICE development (III)

- Vertical tracer transport

During Ice growth

During Ice melt
Modeling ice biochemistry

If we assume that physical properties and processes determine the when/where of an algal bloom…

Some important processes:
1) Flushing (surface and snow melt, meltponds)
2) Gravity drainage (modulate ocean-ice fluxes during ice growth)
3) Snow loading (high snow thickness/ice thickness ratio)

For the Arctic, any model of ice bgc needs a representation of the first two processes.
Bottom (skeletal) Ice Algae - Assumptions

- Skeletal layer thickness and porosity
- Compounds (nitrate, silicate…) are advected between the ice/ocean via a piston velocity (V_p)
- When ice growth dominates, V_p is a function of the growth rate after brine flux measurements of Wakatsuchi & Ono multiplied by a tuning parameter.
- When ice melt dominates, V_p is a function of melt.
Parameterize gravity drainage in ice and between ocean-ice using a diffusivity based on a characteristic velocity and length scale.
Consistent with Piston velocity formulation of the skeletal layer model

A tuning parameter (unknown length scale) is still needed, but it can be determined independently of the biochemistry using the salinity contours.

Data from Wakatsuchi & Ono, 1983

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For melt...the brine tracer is advected by the Darcy velocity.

1) **Flush**ing — downward flow: low salinity meltwater desalinates ice.
2) **Snow accumulation** — upward flow: ocean water replenishes depleted nutrients.
Does it matter?

Tracers: Algal nitrogen and Nitrate

Column Test Case: 25 days of ice growth and melt with light

- Light and Nitrate can limit growth
- Skeletal biochemistry and Z biochemistry are identical
- Dynamic salinity in both cases
- Ice growth and melt are identical

Differences: Ice-Ocean and Ice bottom-ice interior fluxes
Z-bgc Model: Peak in Algal Nitrogen in the ice bottom
Does it matter? Arctic Scale

Tracers: Algal nitrogen and Nitrate

- Simulations from a 9 year Arctic spinup with salinity
- Biochemistry added Dec 1, 1990
- Nitrate uses Arctic ocean climatology
- Light and Nitrate can limit growth
- Skeletal biochemistry and Z biochemistry are identical
- No additional salinity, light, iron or temperature Inhibition.
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Summary

- Tracer transport portion of zbgc scheduled for release but not with biochemistry.
- Works with any salinity model or prescription, but works better with more realistic salinity profiles.

- Representation of ice-ocean fluxes can radically change algal production estimates.
- In zbgc, the gravity drainage strength is tuned independently from the biochemistry. Could help constrain the fluxes in bottom bgc.