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Biogeochemistry in Sea Ice: CICE model developments

Nicole Jeffery, Elizabeth Hunke, Scott Elliott, Adrian Turner

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This Talk

- Motivation: Sea Ice, polar biogeochemistry, ocean, atm, climate …
- Constituents of sea ice
- Salt

1) Impacts at the micro scale
2) Impacts at climate scale: Arctic vs Antarctic

- Nitrogen tracers in a simple algal model

1) Arctic vs. Antarctic
2) Nitrification on/off

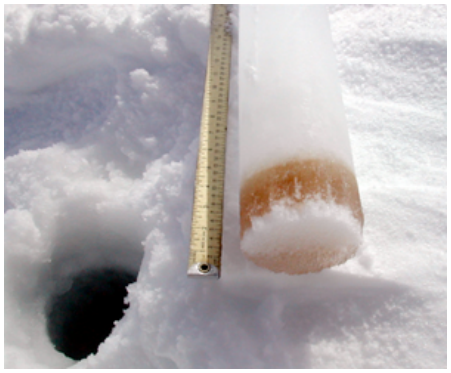
- Conclusions

Sea Ice Algae

(a)

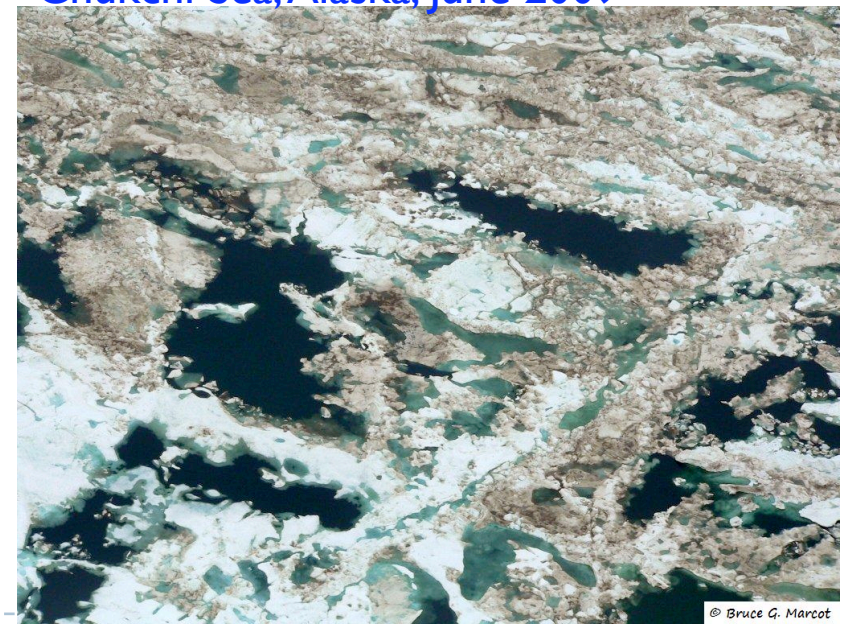
(b)

(c)

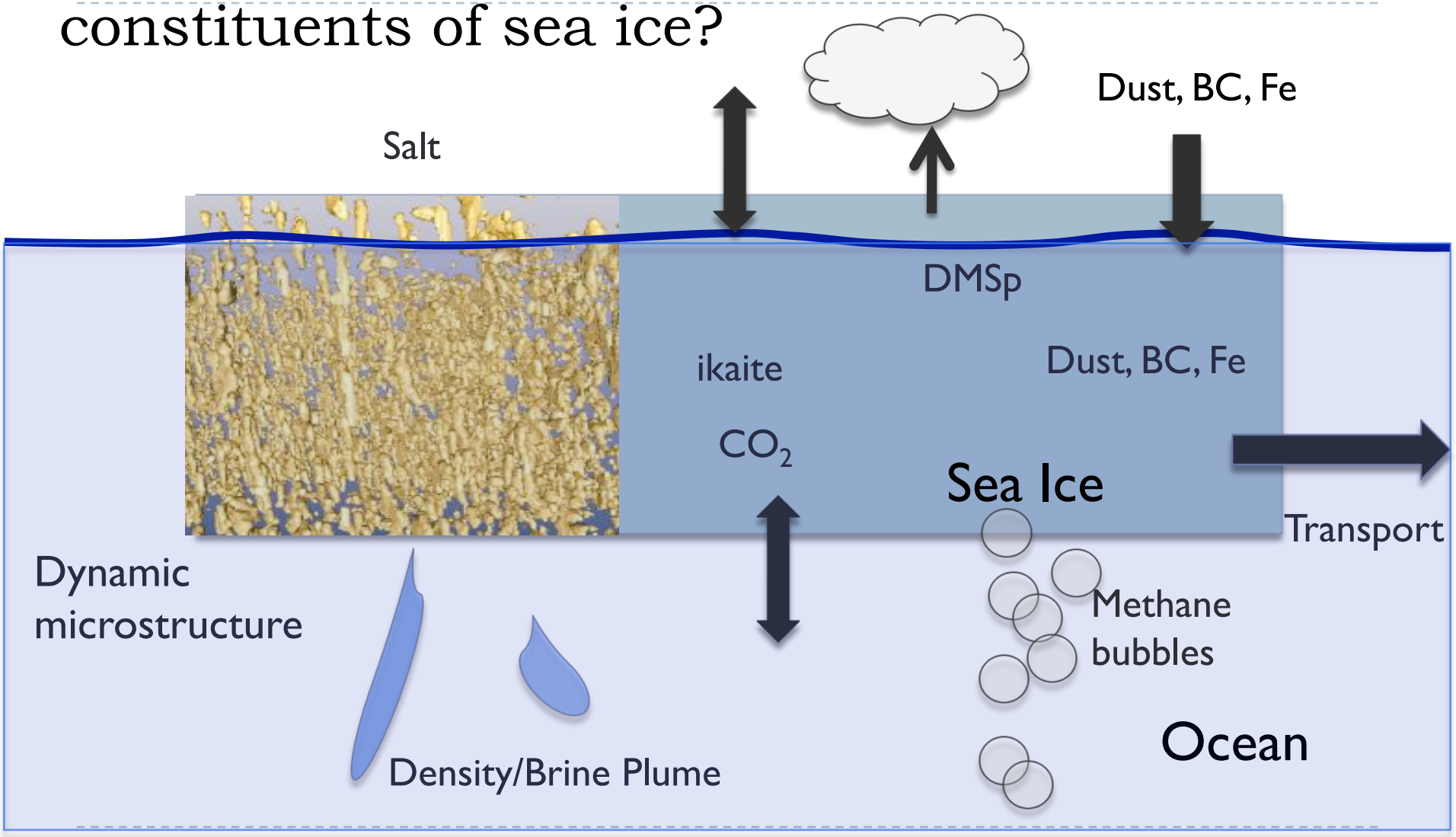


Chukchi Sea, Alaska, June 2009

(d)



More generally…
What are the climatically important constituents of sea ice?



A physics based classification of sea ice constituents:

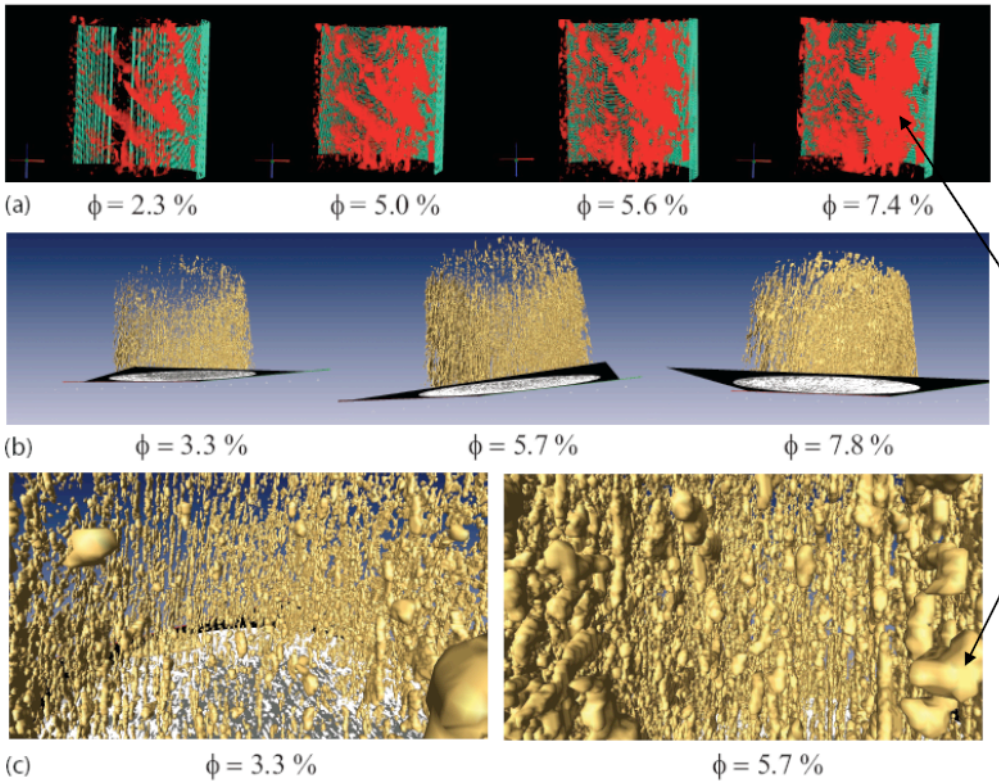
1) Salt – modifies Tmlt, conductivity, heat capacity, ice density, ice porosity, and vertical transport physics
2) Tracers that move like salt – nitrate, silicate, ammonium, phosphate
3) Tracers that cling to the ice crystals – algae, DMSp
4) Tracers that precipitate – DIC (Ikaite)

* Dust (fe), Black Carbon, Methane bubbles

Atmospheric interactions through DOE Polar Project -- Steve Ghan (PNNL), Phil Rasch (PNNL), Hailong Wang (PNNL), Natalie Mahowald (Cornell), Lynn Russel (Scripps)

Impact of Salt (micro scale)

Imaged Sea Ice Structures

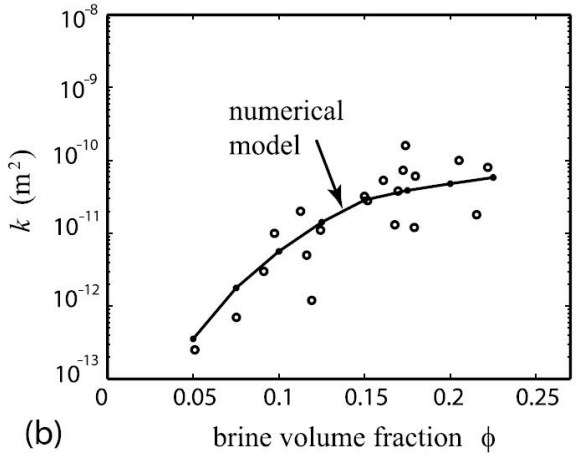


Lab-grown sea ice: reconstructions of X-ray CT of 1 cm cores

Heaton, Miner, Eicken, Zhu,Golden, *in prep* (2006)

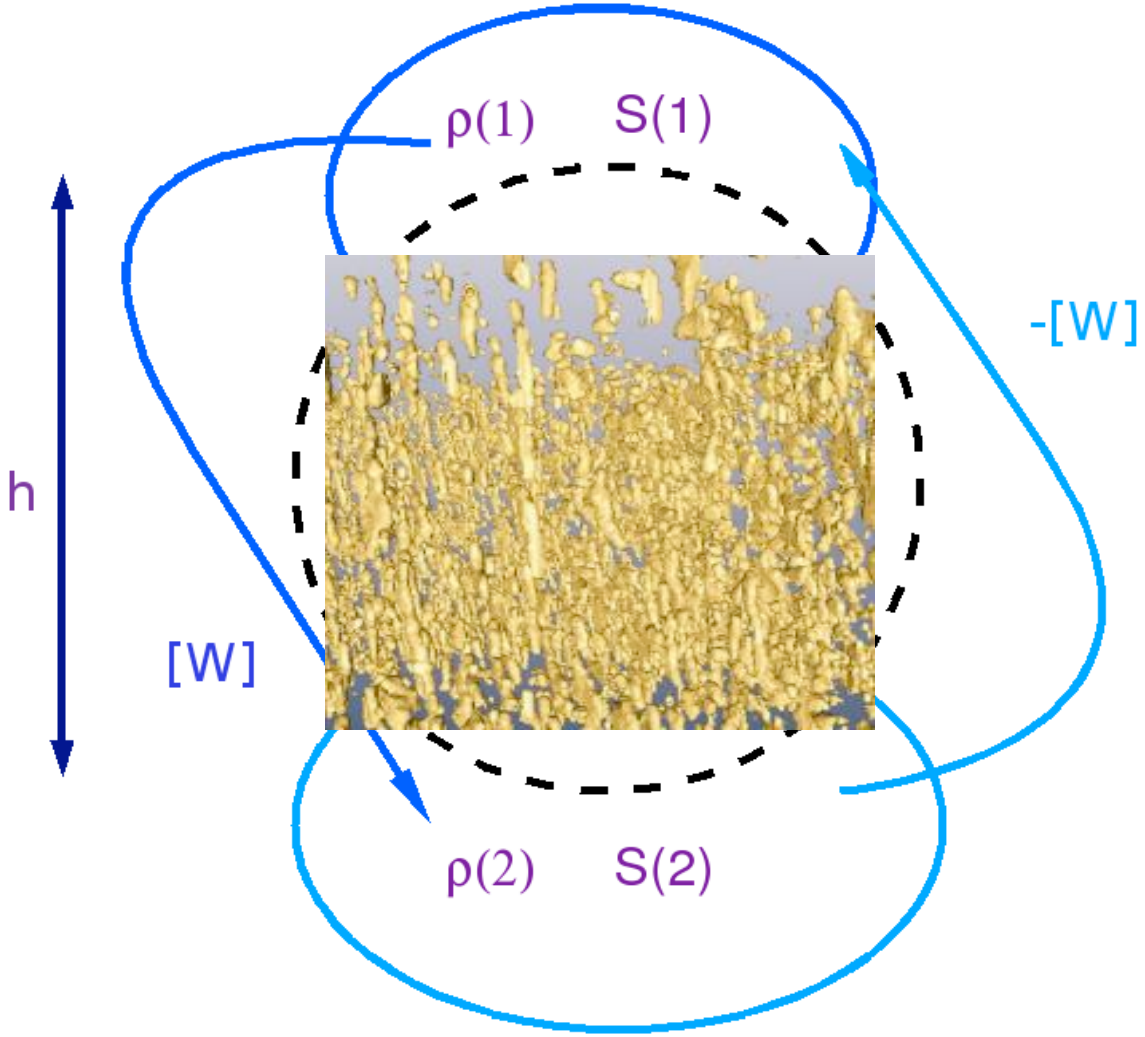
Brine inclusions

Salinity and Temperature determine the porosity, permeability and the desalination rate.



Golden et al., 2007

Brine Motion during Ice Growth: Gravity Drainage



Cold Heavy Brine

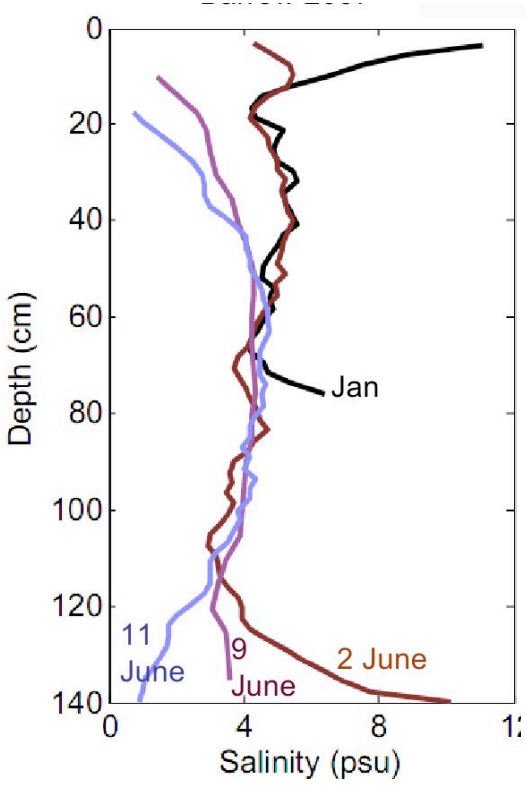
Mixing

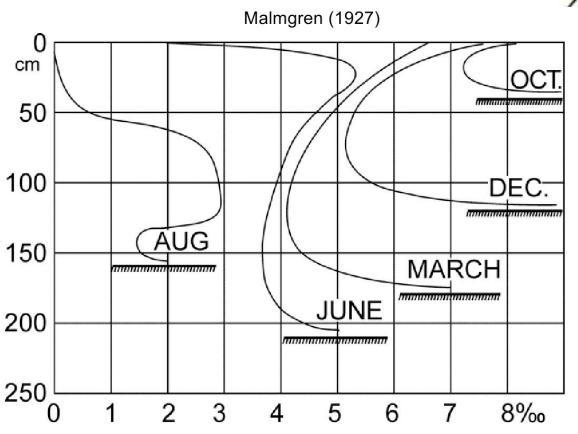
Warm Light Brine

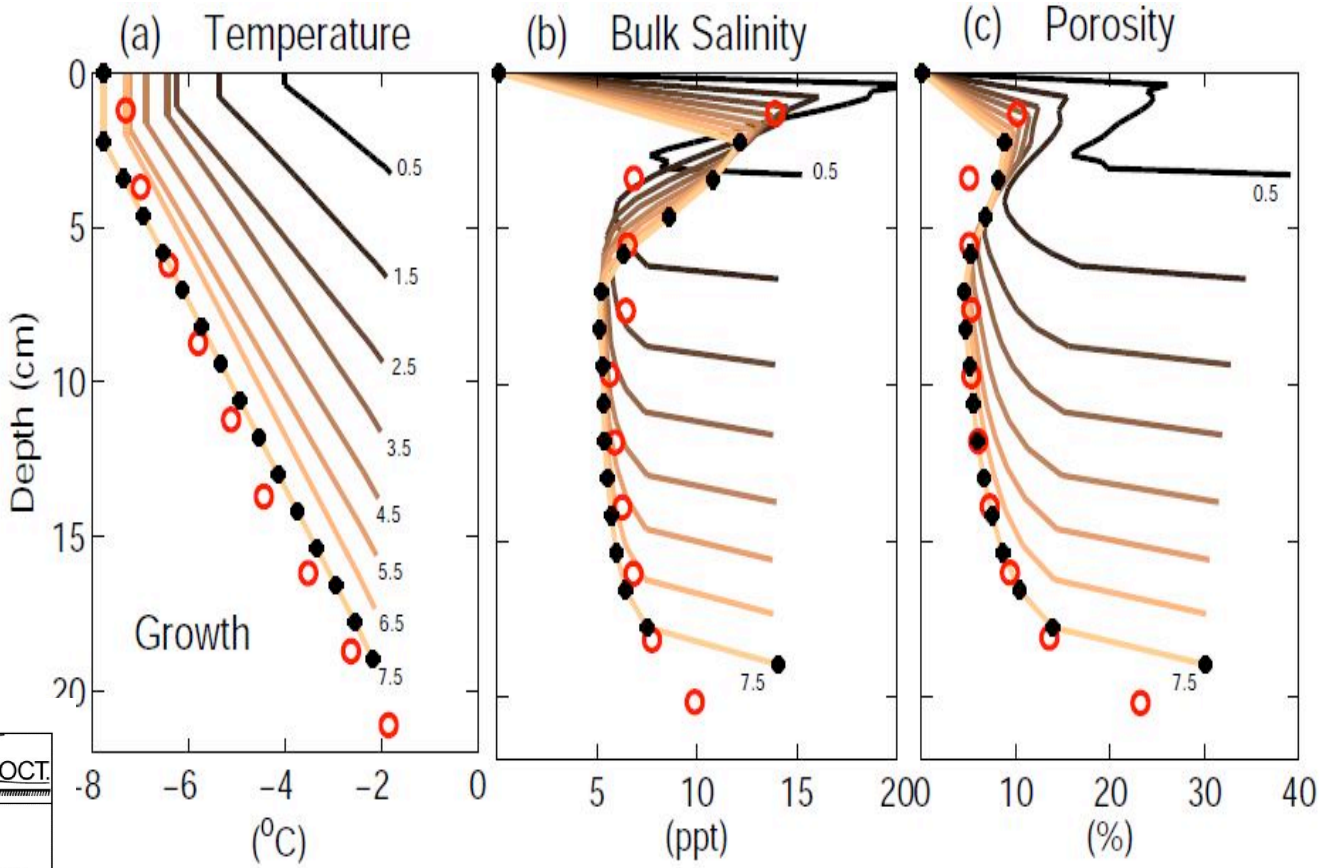
As the ice desalinates, more sea ice solidifies, which decreases the permeability and slows gravity drainage.

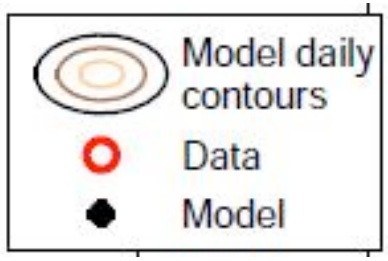
Barrow 2007 C. Petrich (UAF)

Characteristic 'C' Profile





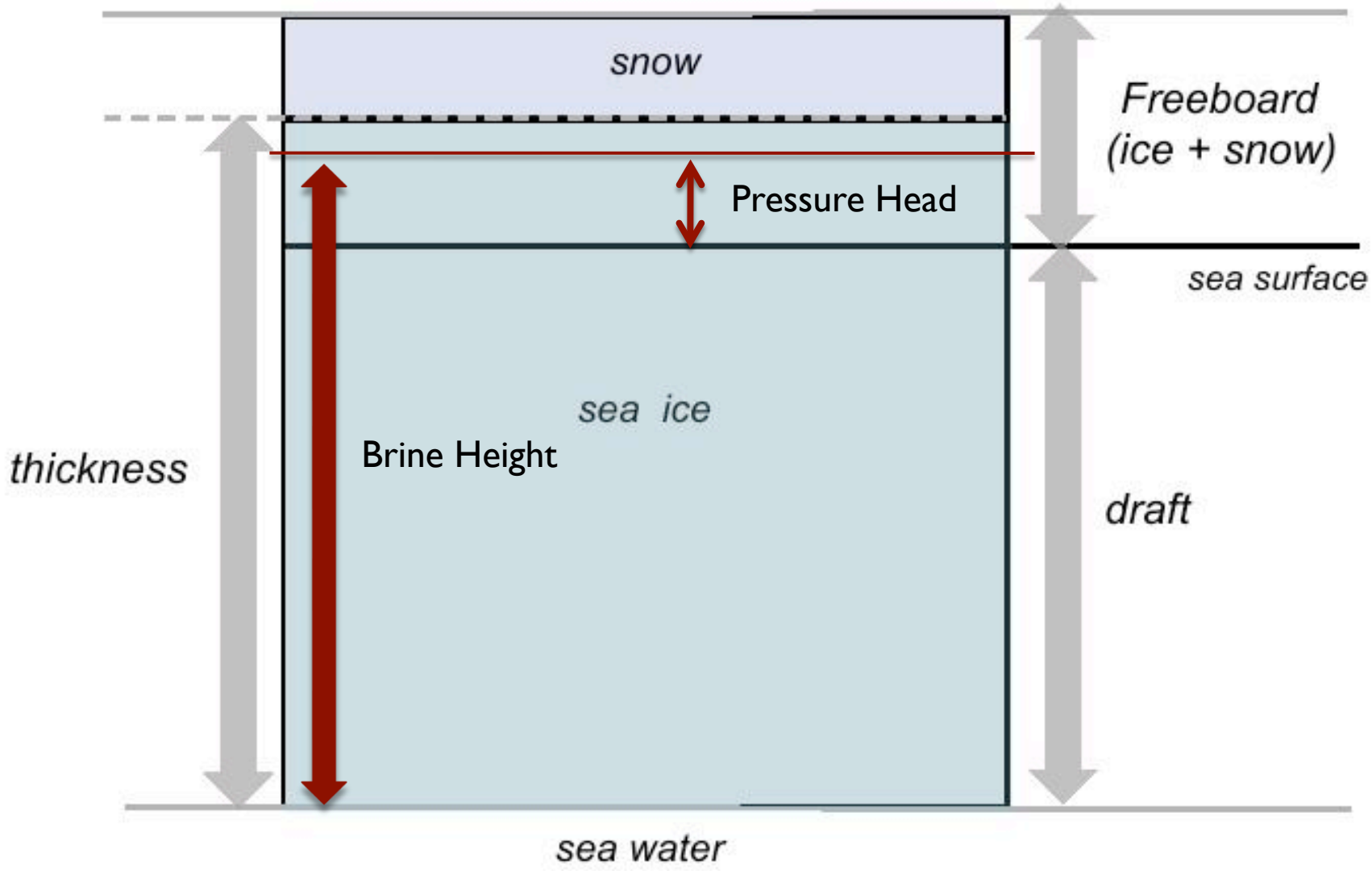




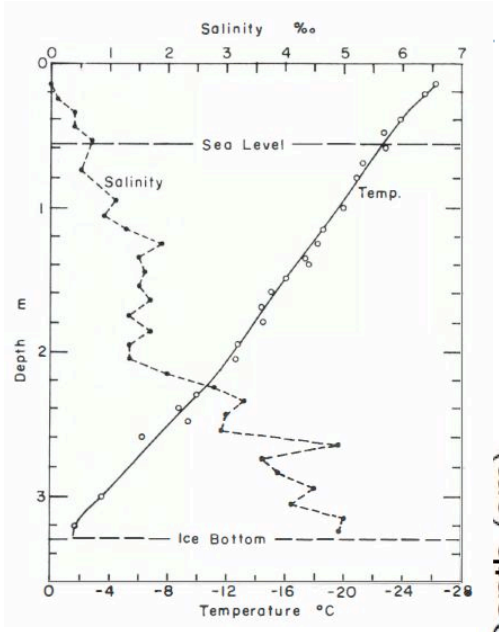
Brine Motion during Melt

Flushing

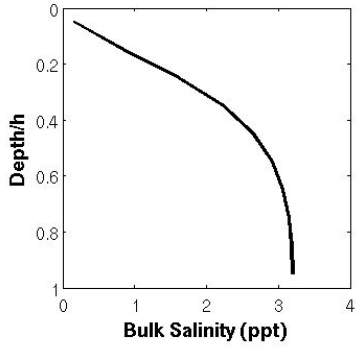
1) Flushing – downward flow: low salinity meltwater desalinates ice
2) Snow accumulation – upward flow: ocean water replenishes depleted nutrients



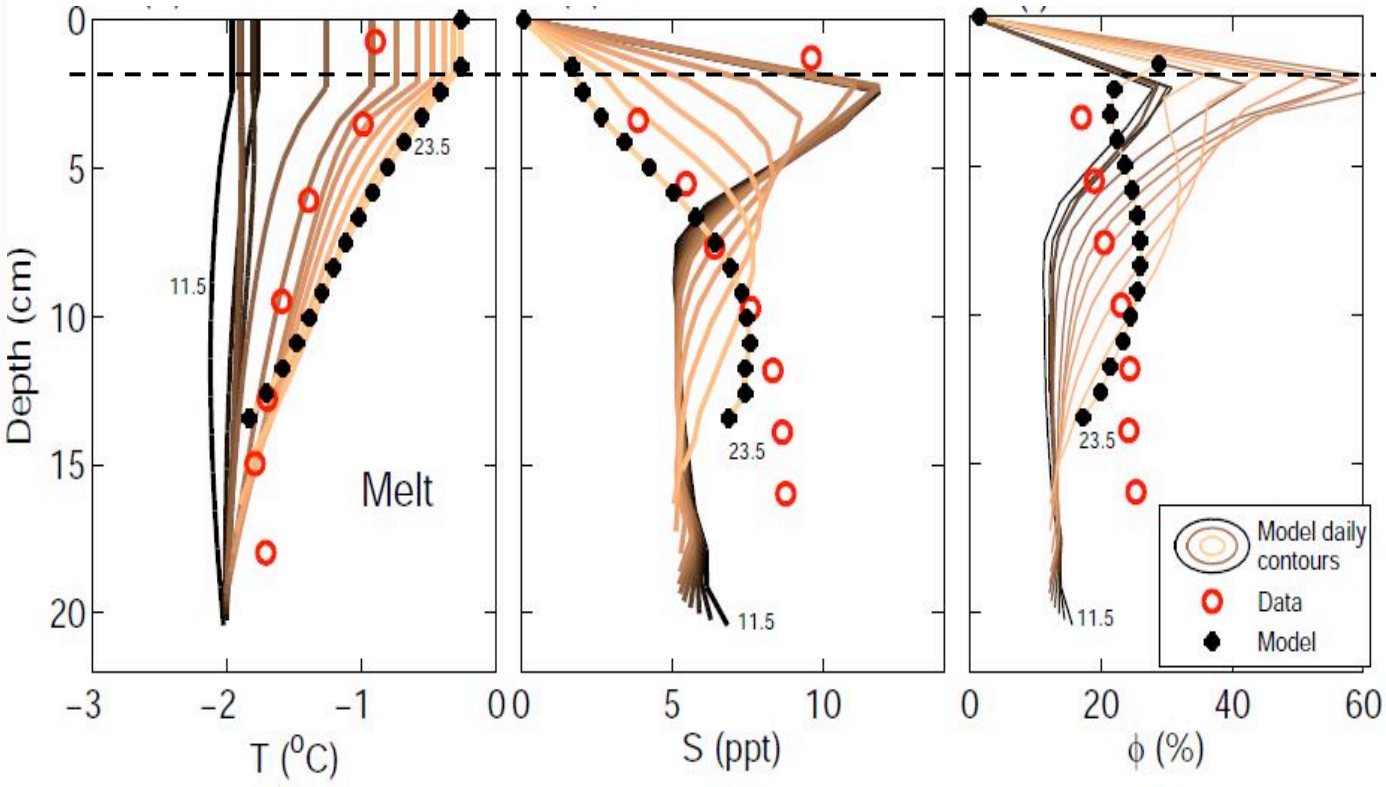
Melting and Multi-year Ice profile



Cox & Weeks (1974)



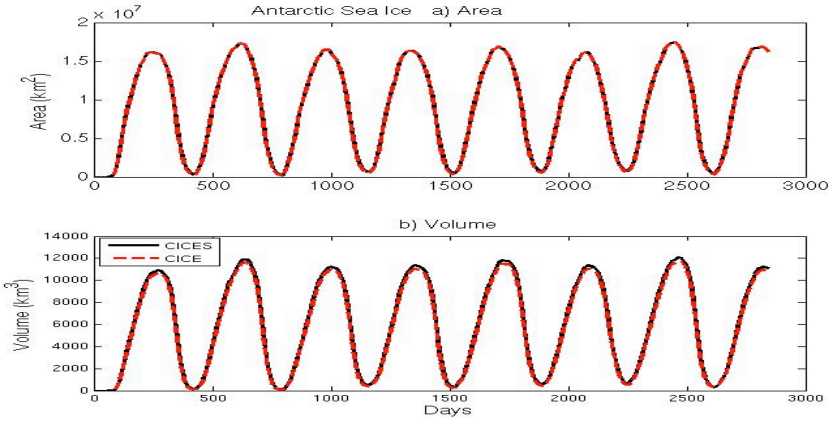
Model Simulation (1D configuration of CICE with S)



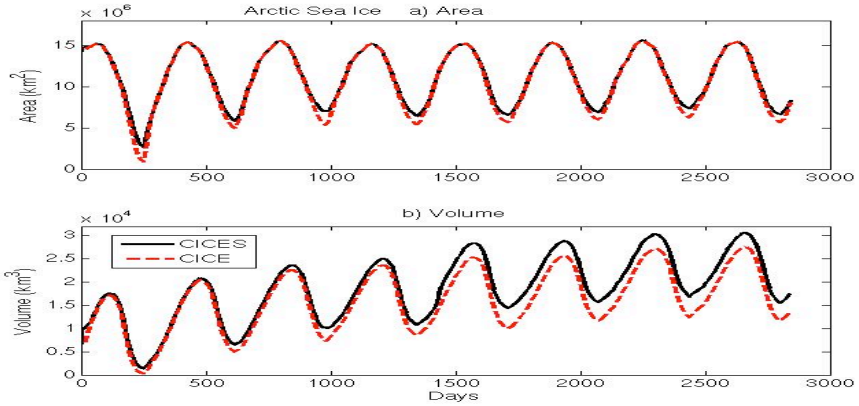
Standard CICE currently assumes a fixed S profile

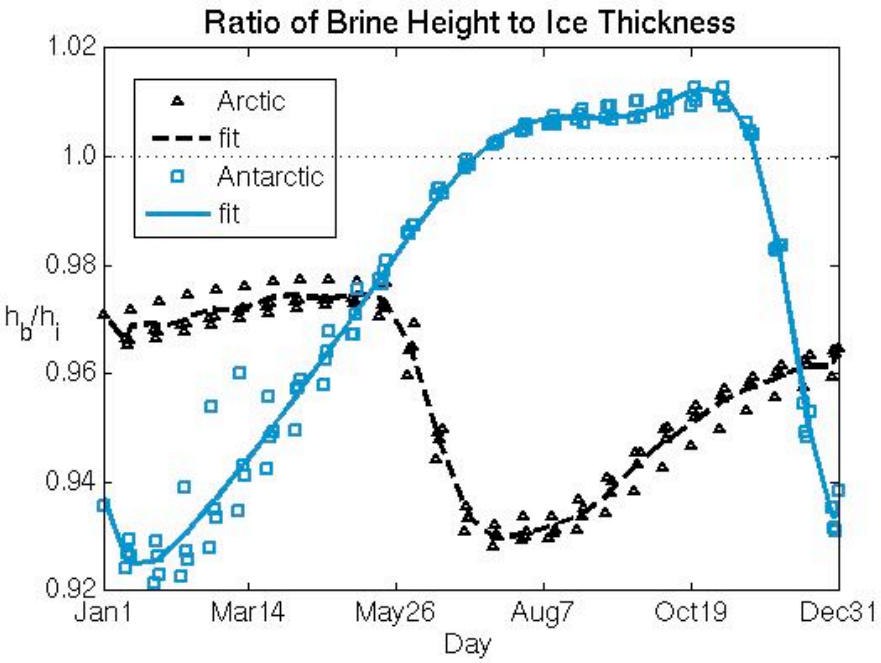
Impact of Salinity (climate scale)
7 Year Control Run: CICE vs CICES

Antarctic



Arctic

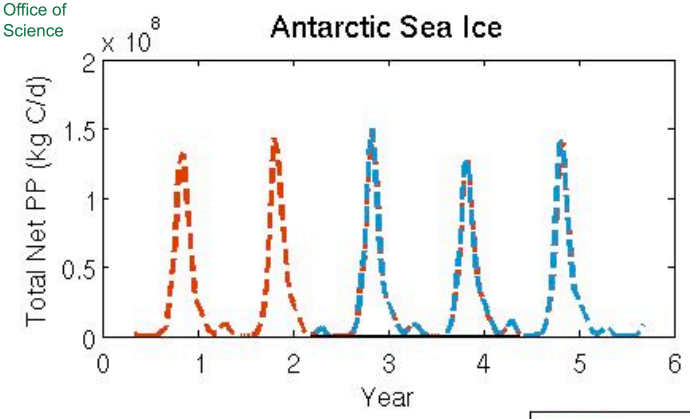


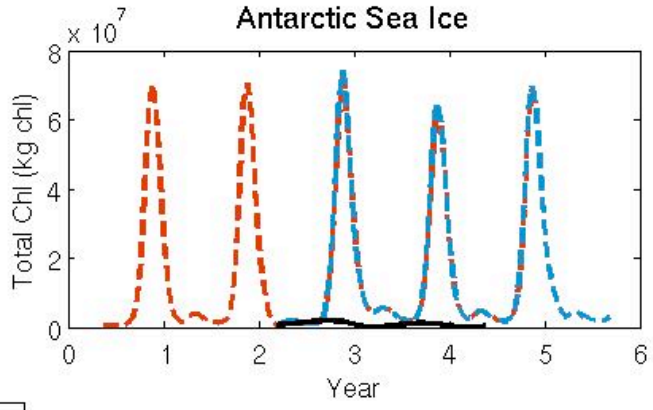


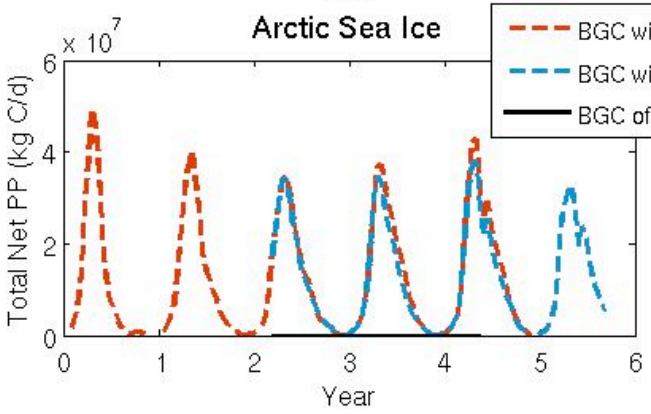
Nitrogen-Based Ice Algal Biogeochemistry (Tracers that move like S, Tracers that cling)

Tracers : Algal nitrogen, Nitrate, Ammonium and Silicate

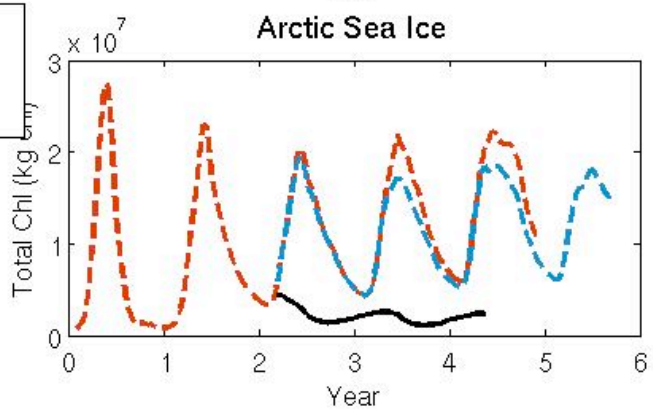
- Nitrate/Silicate Arctic ocean climatology
- Maximum growth-rate is 0.5 doublings/day
- Light, Silicate, and Nitrate/Ammonium can limit growth
- Nitrification timescale 67 days
- No additional salinity, light, iron or temperature Inhibition.

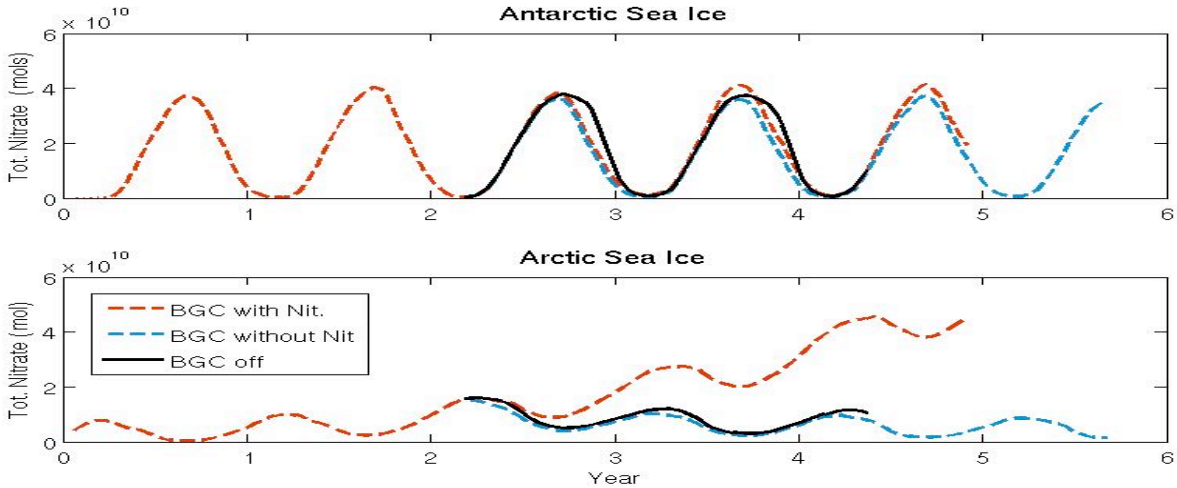

Antarctic Sea Ice
x 10^8
Total Net PP (kg C/d)
Year


Antarctic Sea Ice
x 10^7
Total Chl (kg chl)
Year


Arctic Sea Ice
x 10^7
Total Net PP (kg C/d)
Year

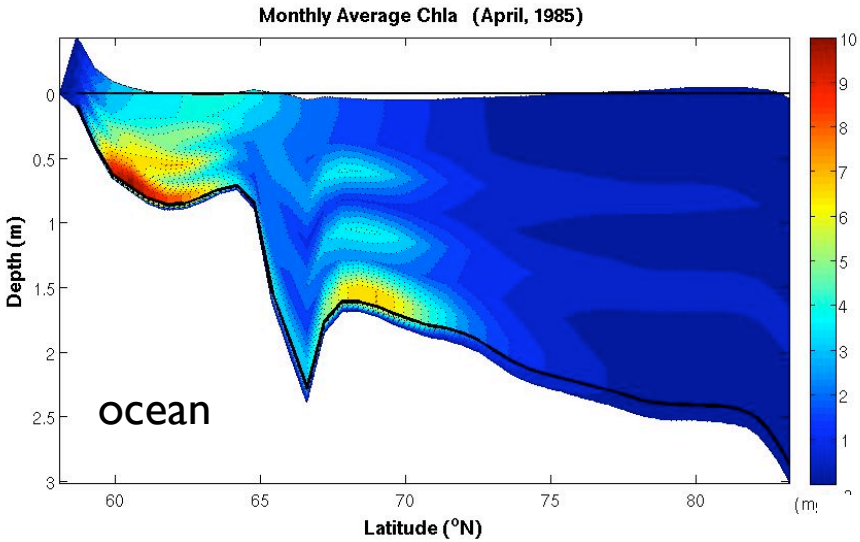
BGC with Nit.
BGC without Nit.
BGC off


Arctic Sea Ice
x 10^7
Year

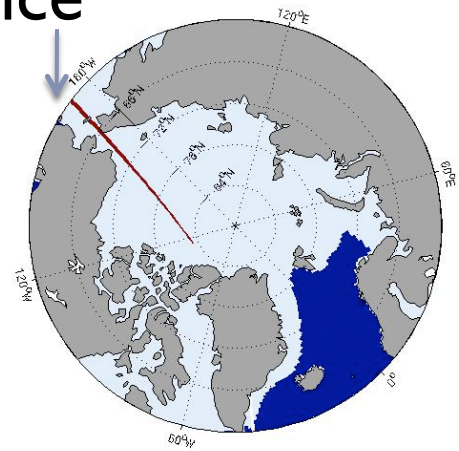

Antarctic Sea Ice
x 10^10
Tot. Nitrate (mols)
Arctic Sea Ice
x 10^10
Tot. Nitrate (mol)
BGC with Nit.
BGC without Nit
BGC off
Year

Year 4; Monthly Average

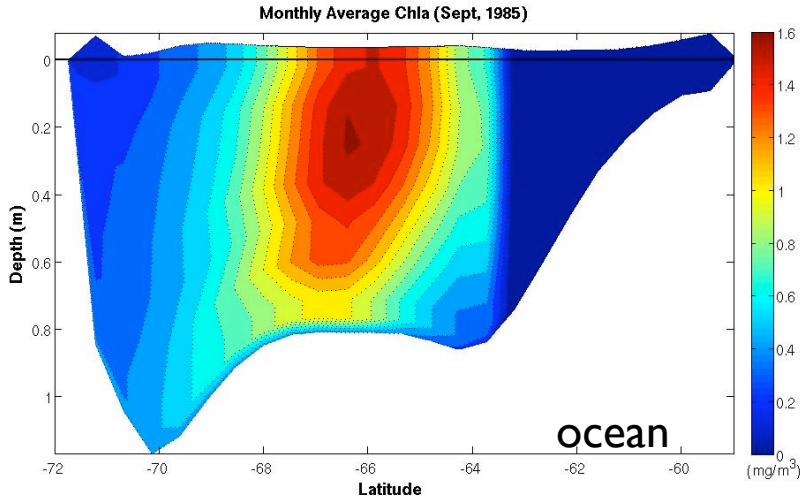
Arctic Chla
April



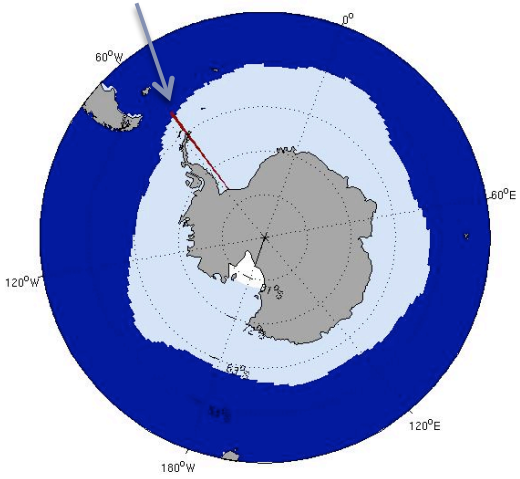
Slice



Antarctic Chla
September



Slice



Future work

- Coupling with POP/CESM
- Feedbacks between ice constituents/bgc and ice radiative transfer
- Dust (fe), black carbon