LA-UR-12-22286

Approved for public release; distribution is unlimited.

Title: Biogeochemistry in Sea Ice: CICE model developments

Author(s): Jeffery, Nicole
Hunke, Elizabeth
Elliott, Scott
Turner, Adrian

Intended for: 17th Annual CESM Workshop, 2012-06-18/2012-06-21 (Breckenridge, Colorado, United States)

Los Alamos NATIONAL LABORATORY EST. 1943

**Biogeochemistry in Sea Ice: CICE model developments**

N. Jeffery[1], E. Hunke, S. Elliott[1], and A. Turner[1]
[1]*Los Alamos National Laboratory, Los Alamos, USA*

Polar primary production unfolds in a dynamic sea ice environment, and the interactions of sea ice with ocean support and mediate this production. In spring, for example, fresh melt water contributes to the shoaling of the mixed layer enhancing ice edge blooms. In contrast, sea ice formation in the fall reduces light penetration to the upper ocean slowing primary production in marine waters. Polar biogeochemical modeling studies typically consider these types of ice-ocean interactions. However, sea ice itself is a biogeochemically active medium, contributing a significant and, possibly, essential source of primary production to polar regions in early spring and fall. Here we present numerical simulations using the Los Alamos Sea Ice Model (CICE) with prognostic salinity and sea ice biogeochemistry. This study investigates the relationship between sea ice multiphase physics and sea ice productivity. Of particular emphasis are the processes of gravity drainage, melt water flushing, and snow loading. During sea ice formation, desalination by gravity drainage facilitates nutrient exchange between ocean and ice maintaining ice algal blooms in early spring. Melt water flushing releases ice algae and nutrients to underlying waters limiting ice production. Finally, snow loading, particularly in the Southern Ocean, forces sea ice below the ocean surface driving an upward flow of nutrient rich water into the ice to the benefit of interior and freeboard communities. Incorporating ice microphysics in CICE has given us an important tool for assessing the importance of these processes for polar algal production at global scales.

U.S. DEPARTMENT OF ENERGY | Office of Science

Los Alamos NATIONAL LABORATORY EST. 1943


# Biogeochemistry in Sea Ice: CICE model developments

Nicole Jeffery, Elizabeth Hunke, Scott Elliott, Adrian Turner

17th Annual CESM Workshop 18 – 21 June 2012 Breckenridge, CO.

# This Talk

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

Impacts at the micro scale

Impacts at climate scale: Arctic vs Antarctic

Nitrogen tracers in a simple algal model

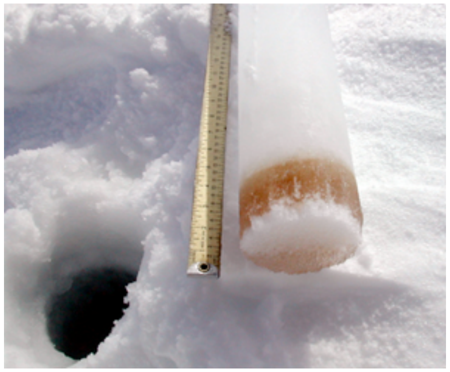
1) Arctic vs. Antarctic
2) Nitrification on/off

- Conclusions

# Sea Ice Algae

(a)

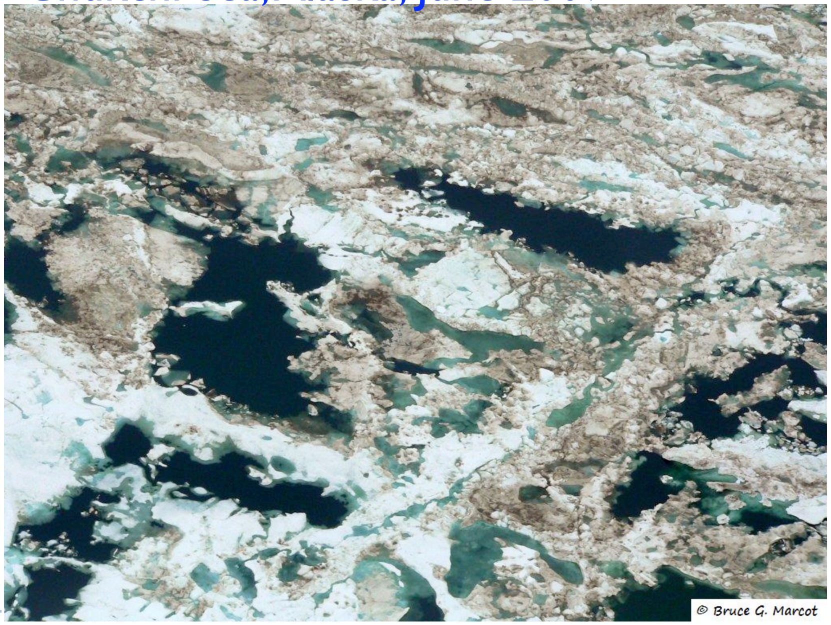
(c)



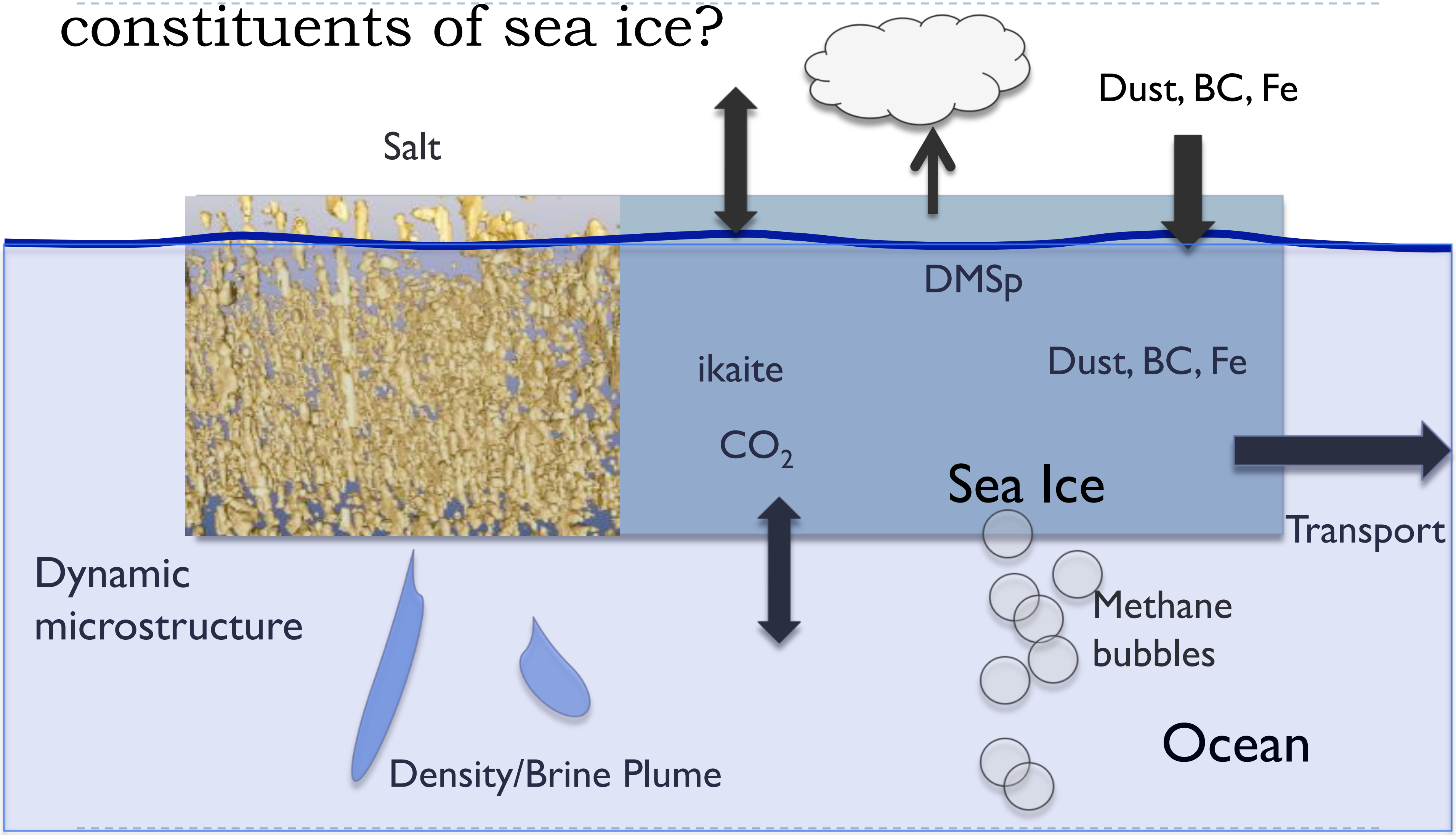
(b)


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:

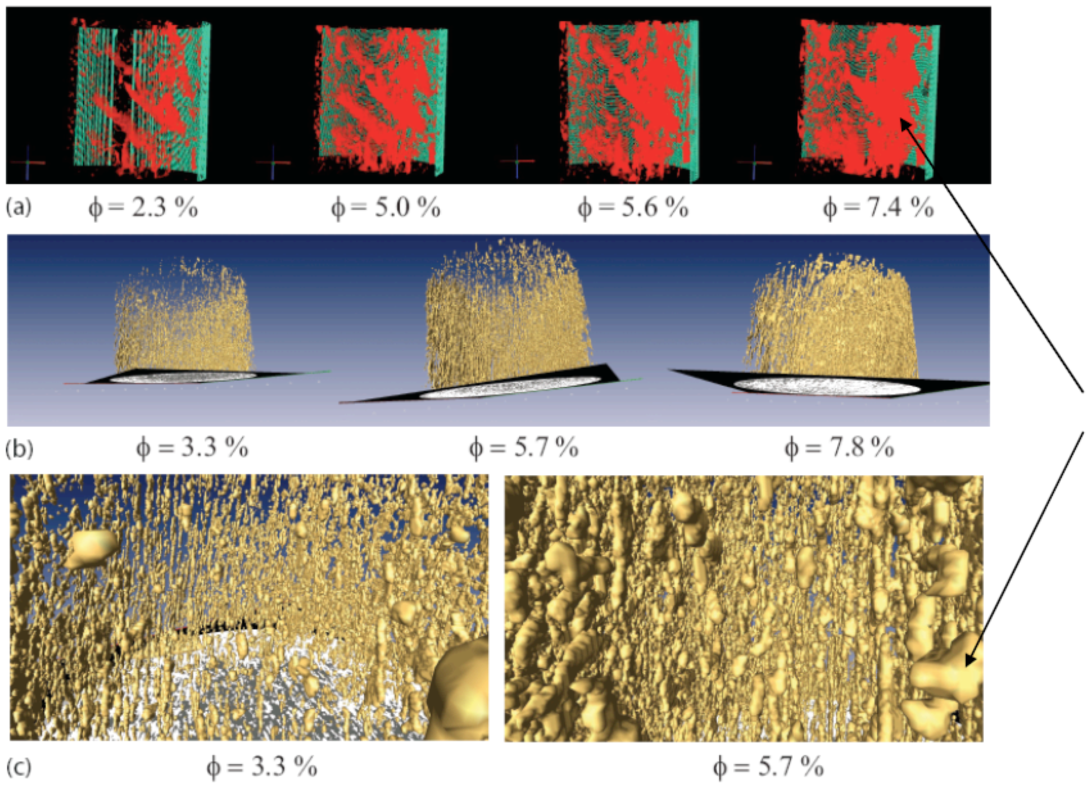
1) Salt – modifies Tmlt, conductivity, heat capacity, ice density, ice porosity, and vertical transport physics
2) Tracers that move like salt – nitrate, silicate, ammonium, phosphate
3) Tracers that cling to the ice crystals – algae, DMSp
4) Tracers that precipitate – DOC (Ikaite)

* 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)

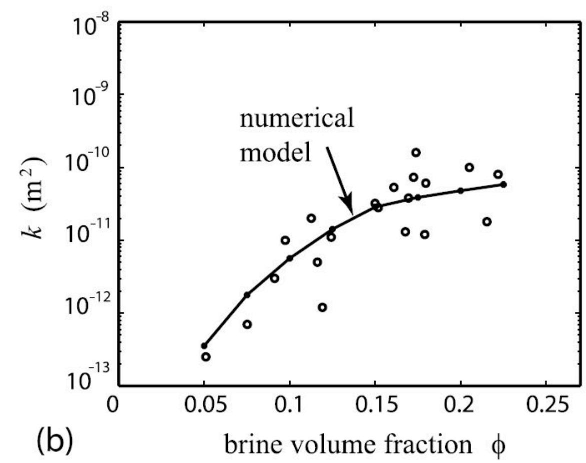
## Imaged Sea Ice Structures




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

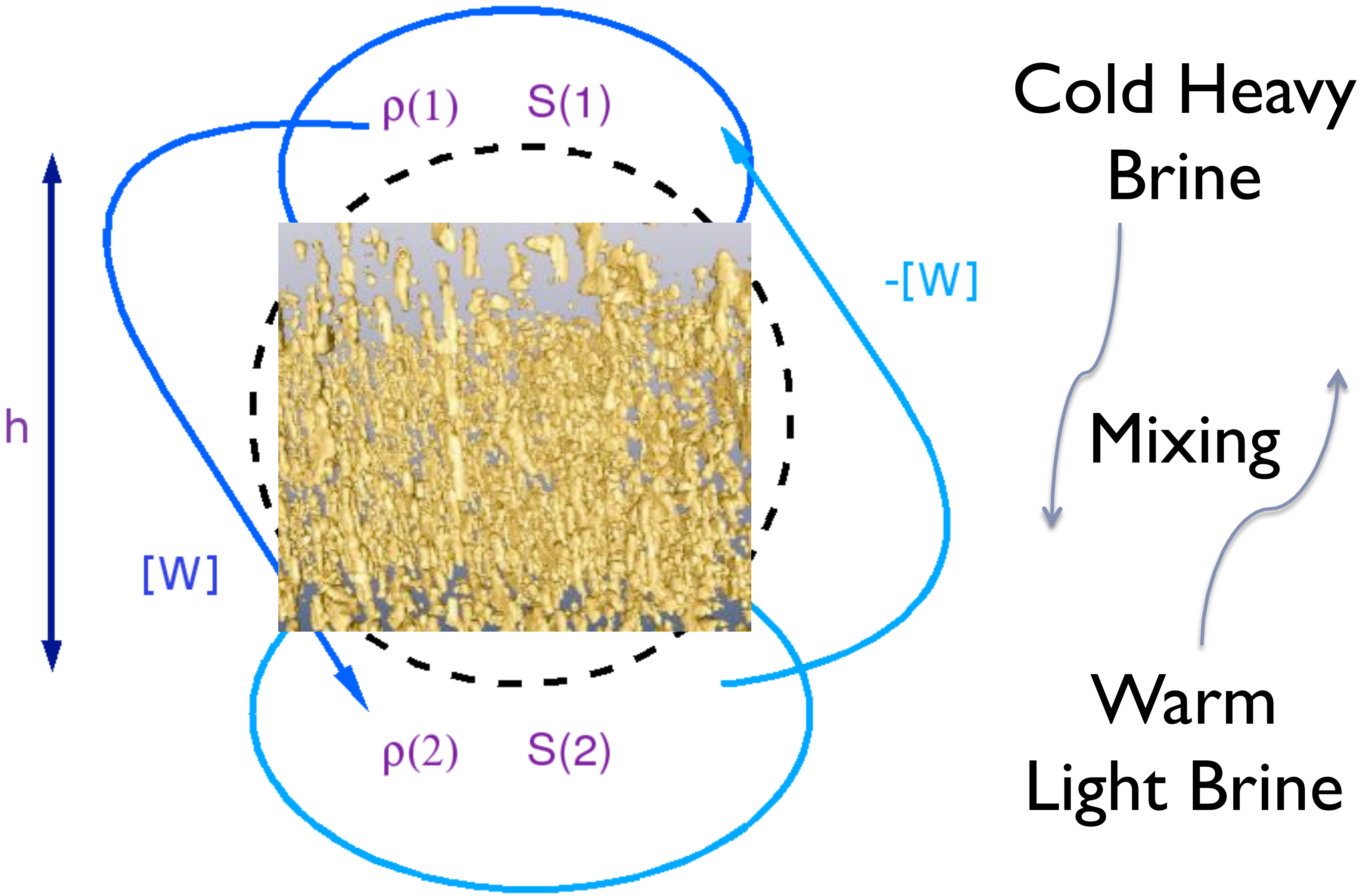
Heaton, Miner, Eicken, Zhu,Golden, *in prep* (2006)

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




Golden et al., 2007

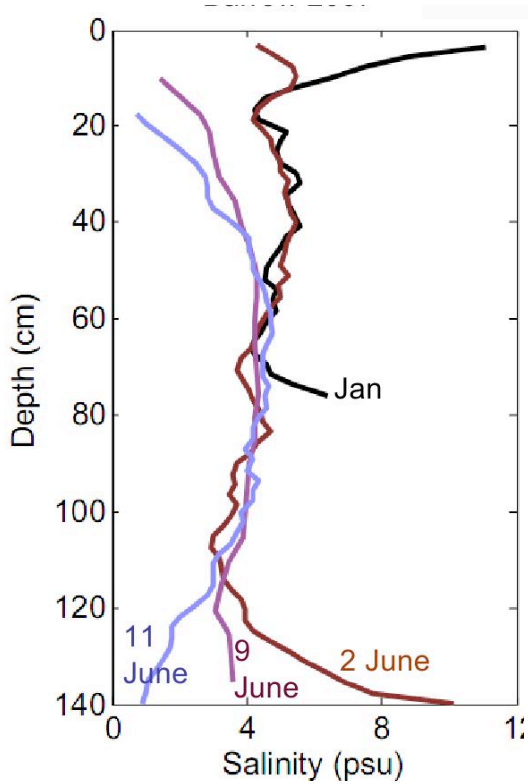
# Brine Motion during Ice Growth: Gravity Drainage

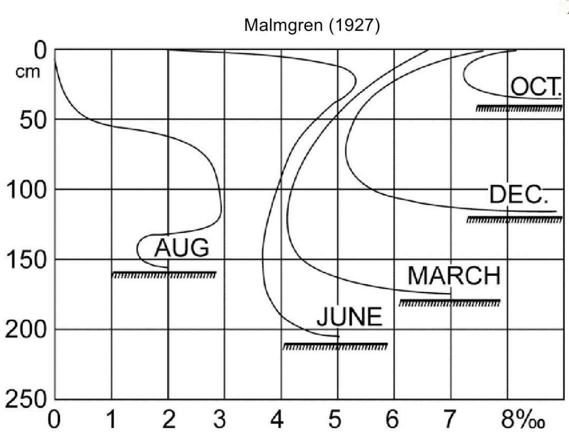


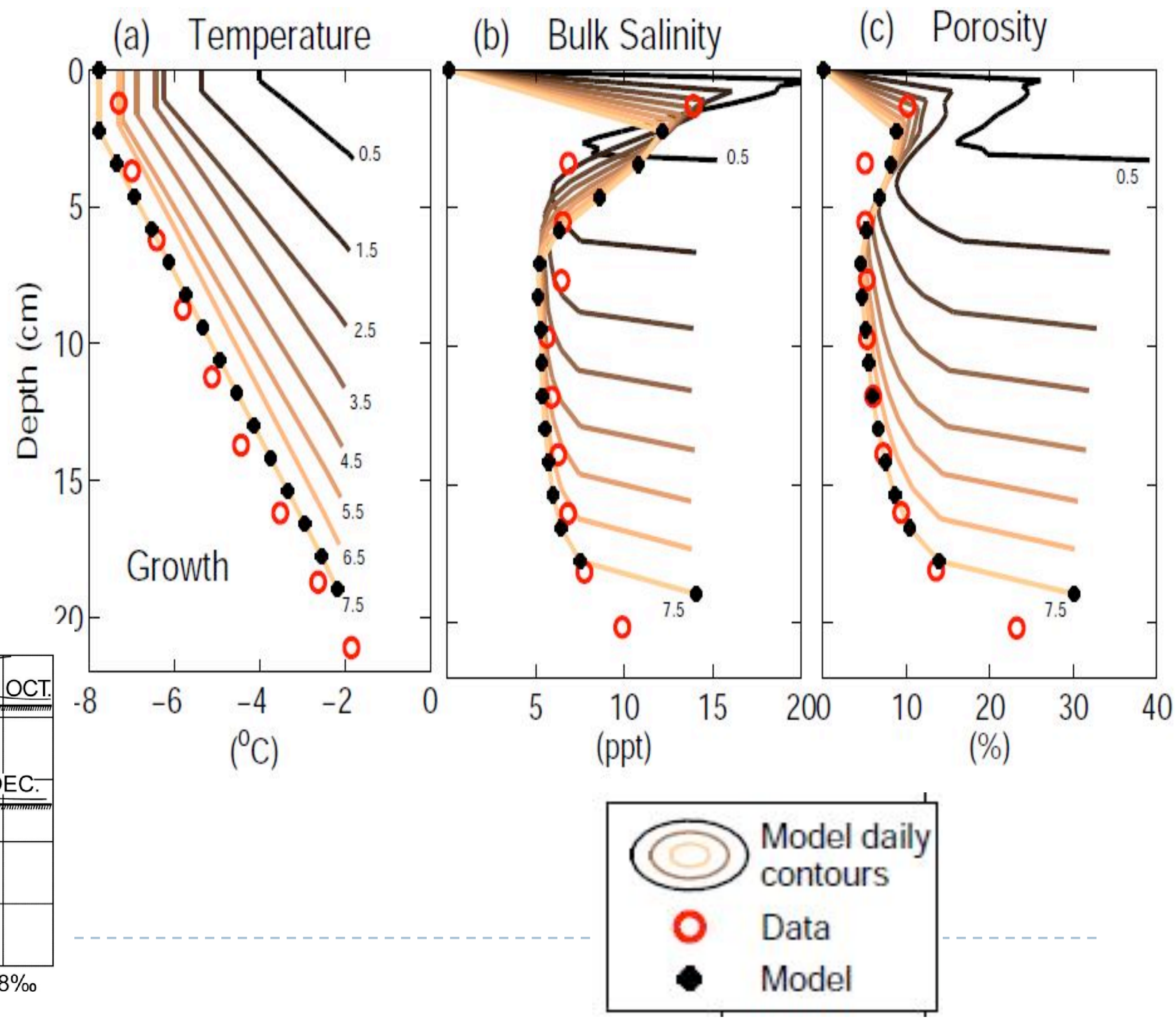

- As the ice desalinates, more sea ice solidifies, which decreases the permeability and slows gravity drainage.

Barrow 2007 C. Petrich (UAF)

# Characteristic 'C' Profile

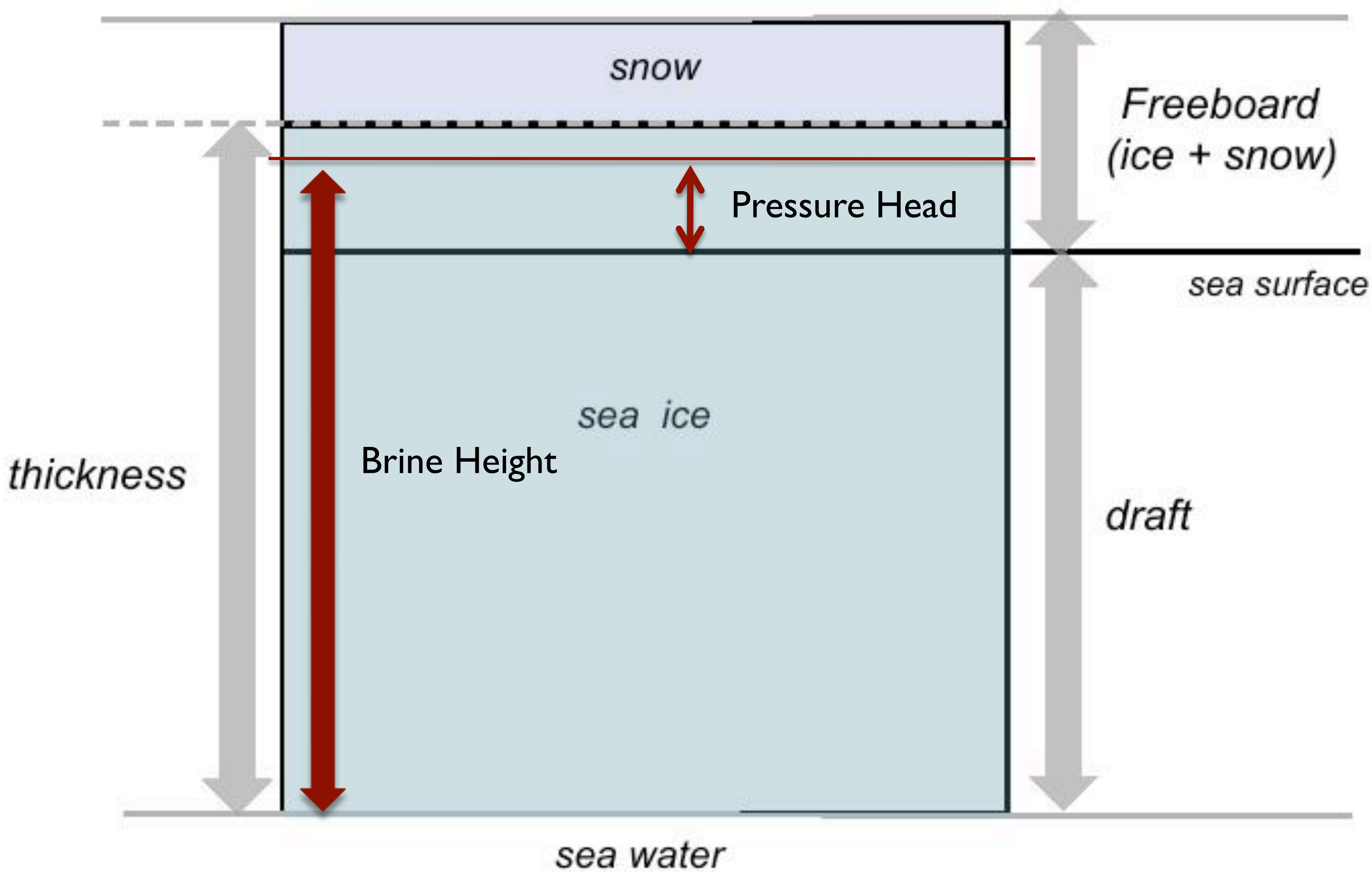


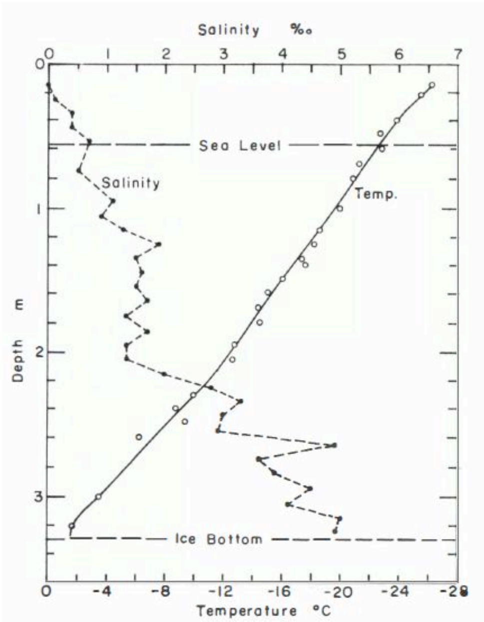



# Brine Motion during Melt Flushing

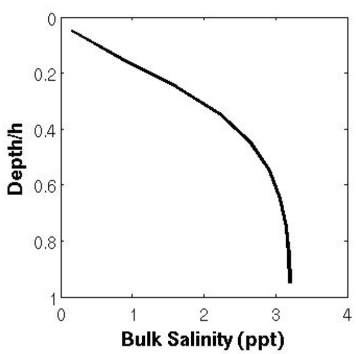
1) Flushing – downward flow: low salinity meltwater desalinates ice
2) Snow accumulation – upward flow: ocean water replenishes depleted nutrients



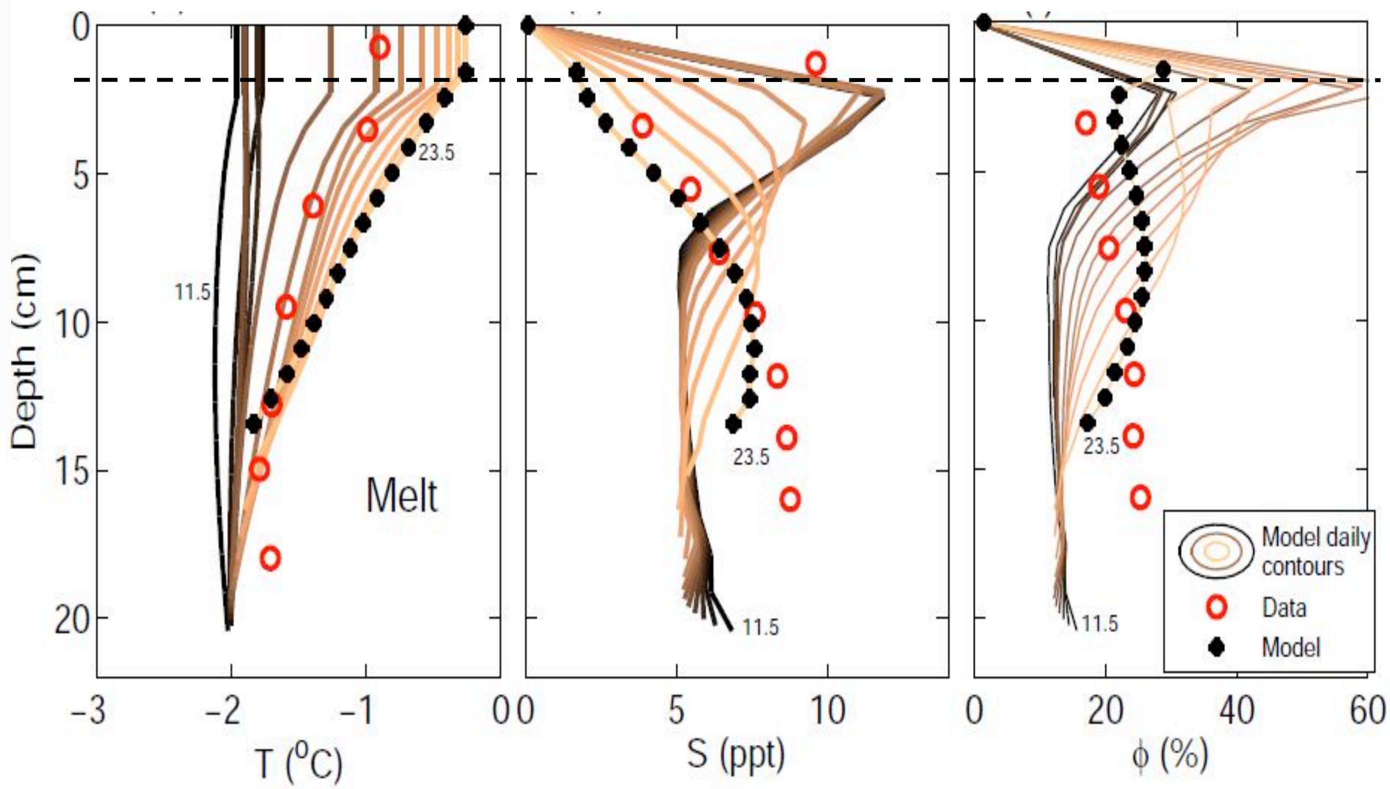
# Melting and Multi-year Ice profile




Cox & Weeks (1974)



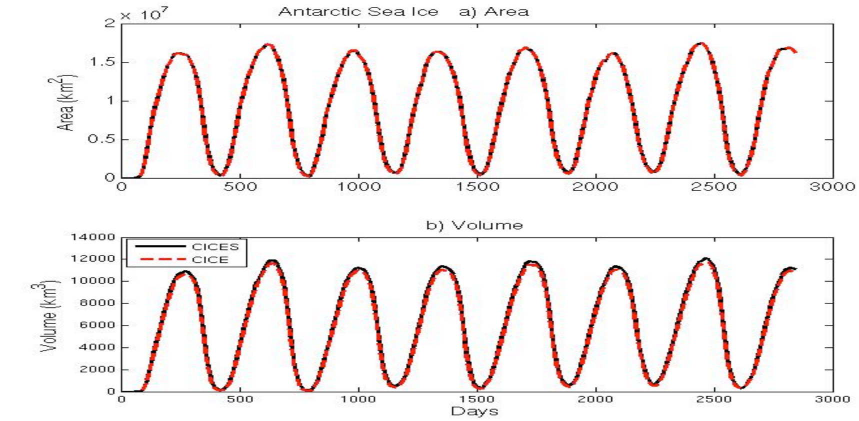

Model Simulation (1D configuration of CICE with S)



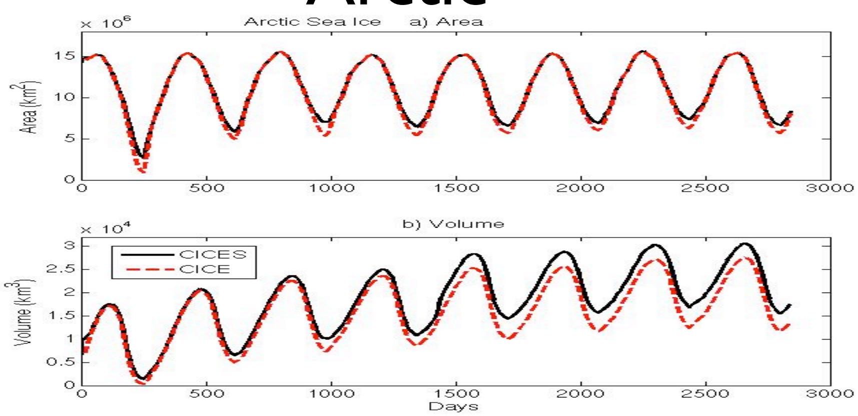

Standard CICE currently
assumes a fixed S profile

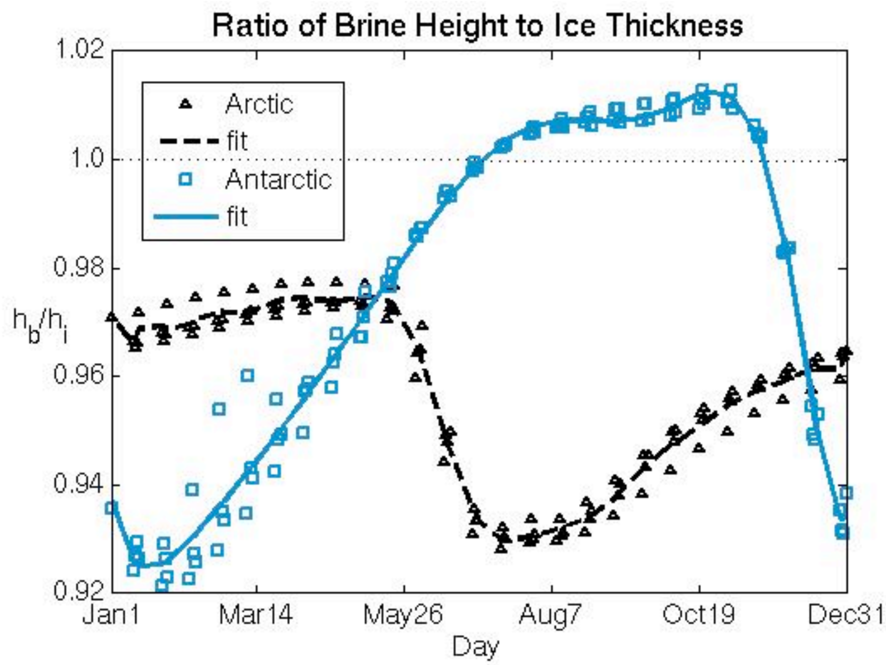
# Impact of Salinity (climate scale)
# 7 Year Control Run: CICE vs CICES

## Antarctic




## Arctic



U.S. DEPARTMENT OF ENERGY | Office of Science

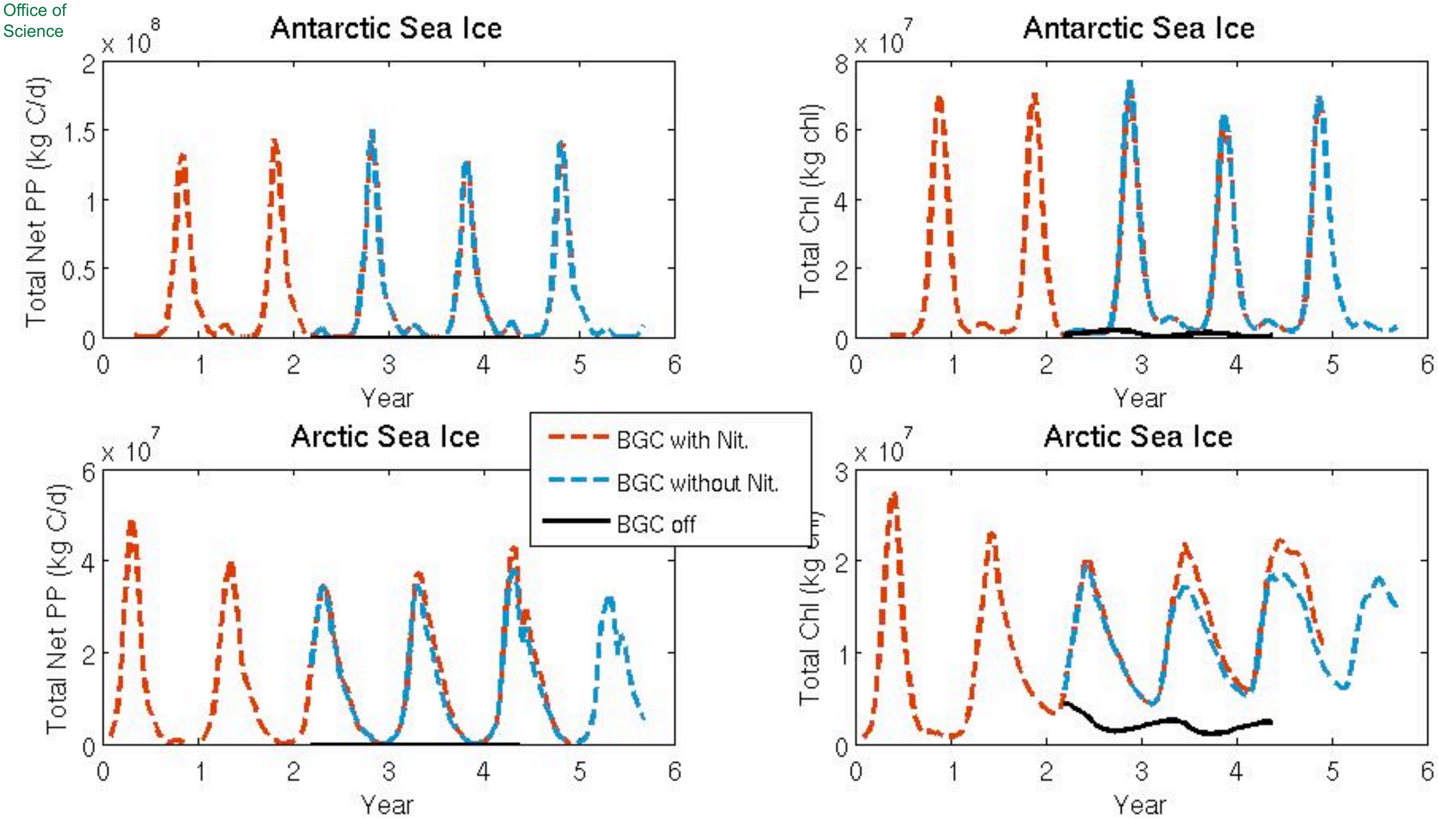
Los Alamos NATIONAL LABORATORY EST. 1943

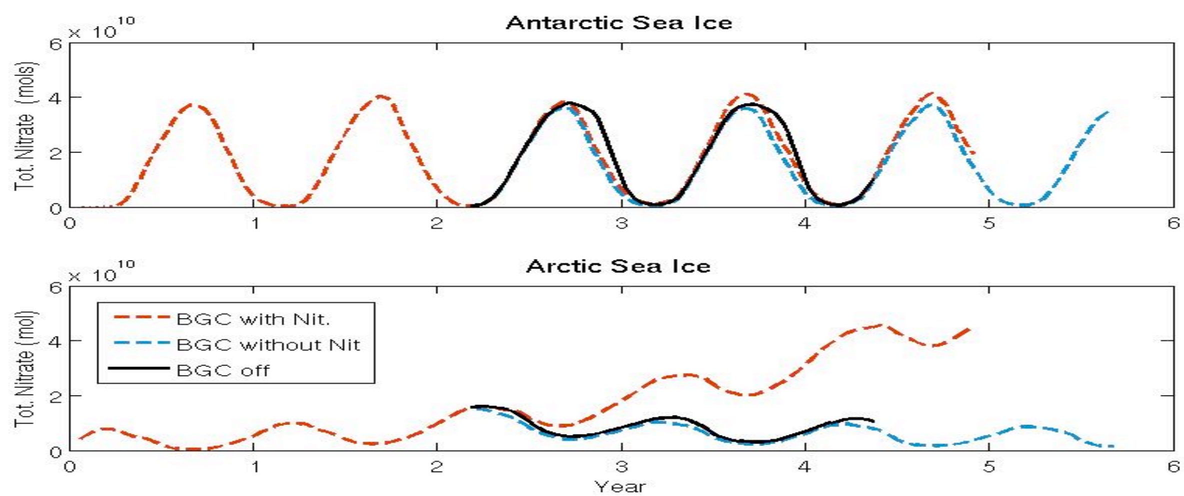
# Nitrogen-Based Ice Algal Biogeochemistry (Tracers that move like S, Tracers that cling)

## 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

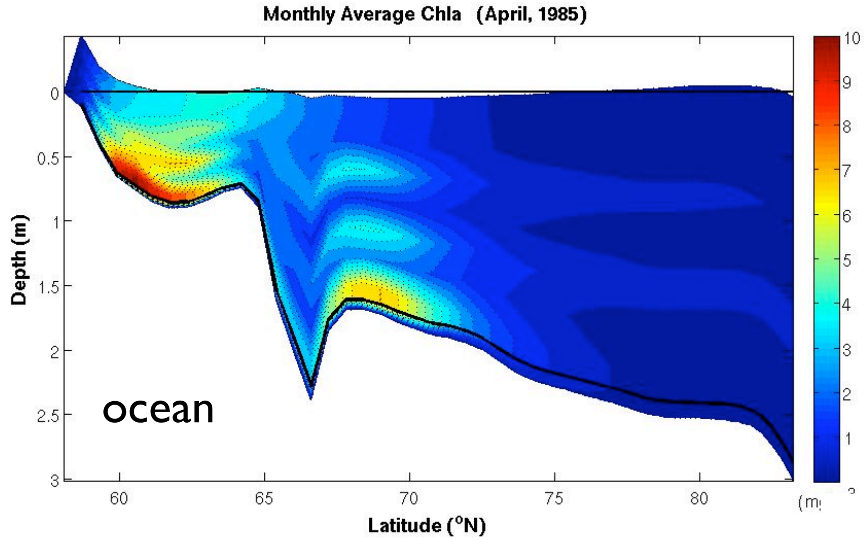
- Nitrification timescale 67 days
- No additional salinity, light, or temperature Inhibition.

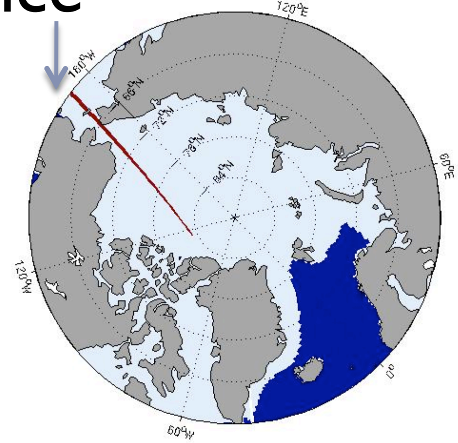

Antarctic Sea Ice
x 10^8
Total Net PP (kg C/d)
Year
Antarctic Sea Ice
x 10^7
Total Chl (kg chl)
Year
Arctic Sea Ice
x 10^7
Total Net PP (kg C/d)
Year
BGC with Nit.
BGC without Nit.
BGC off
Arctic Sea Ice
x 10^7
Total Chl (kg chl)
Year


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

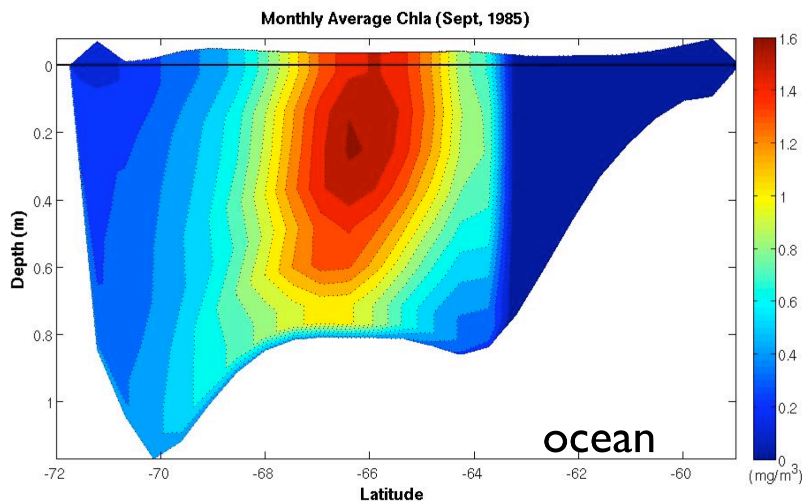
# Year 4; Monthly Average

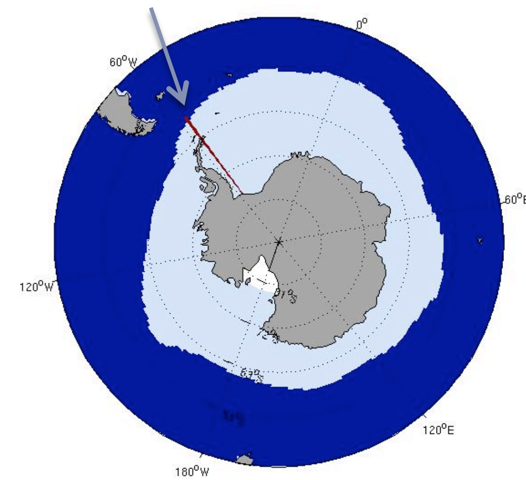
Arctic Chla April




Antarctic Chla September



# Future work

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