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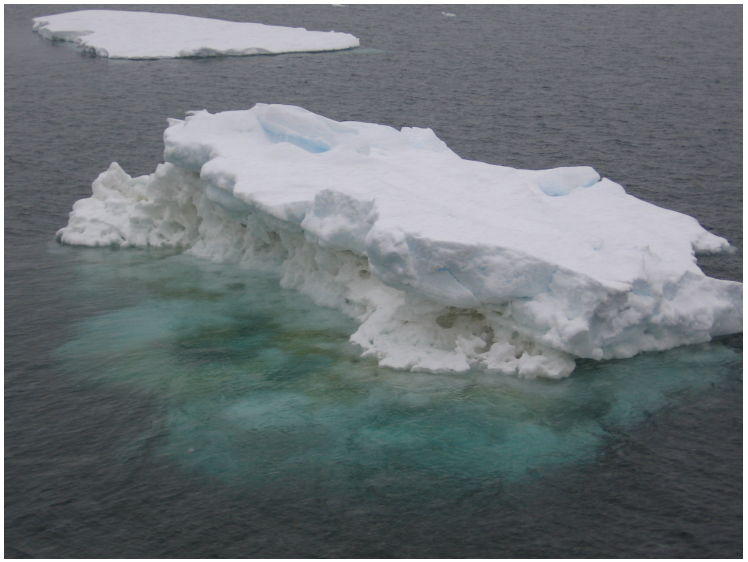
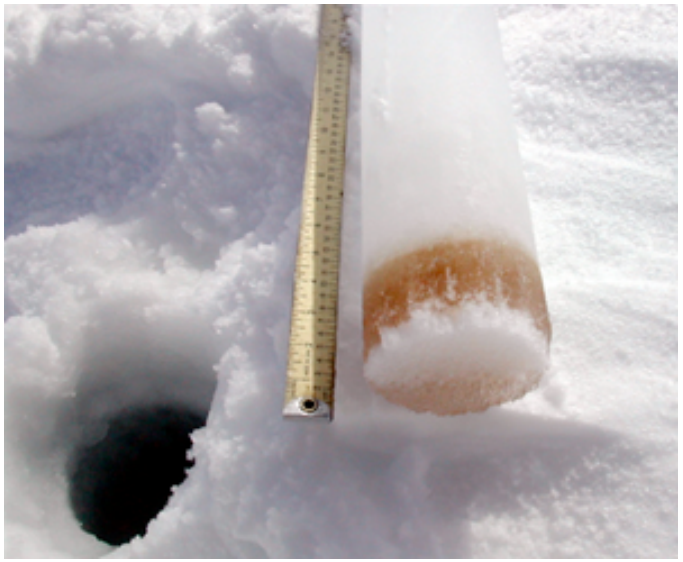




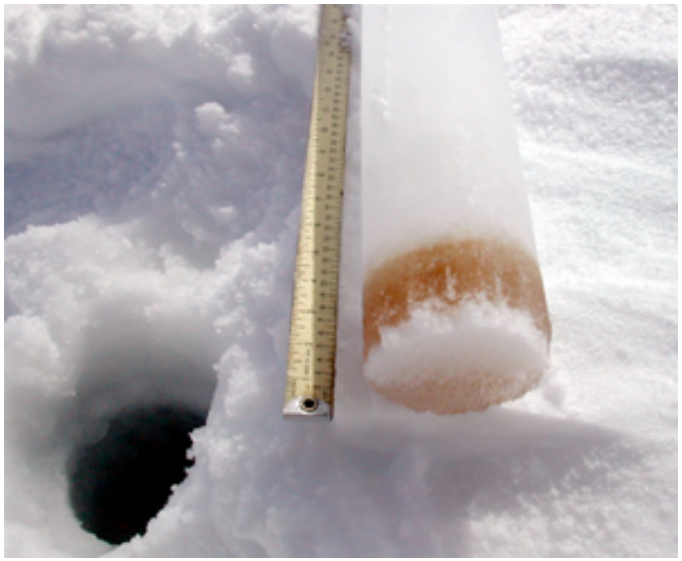
Modeling BGC in the Ice Interior: the CICE release and beyond

Nicole Jeffery, Scott Elliott, and Elizabeth Hunke

Polar Climate Working Group Meeting 11 – 13 Feb 2013 Boulder, CO.

Antarctic

Arctic



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

This Talk

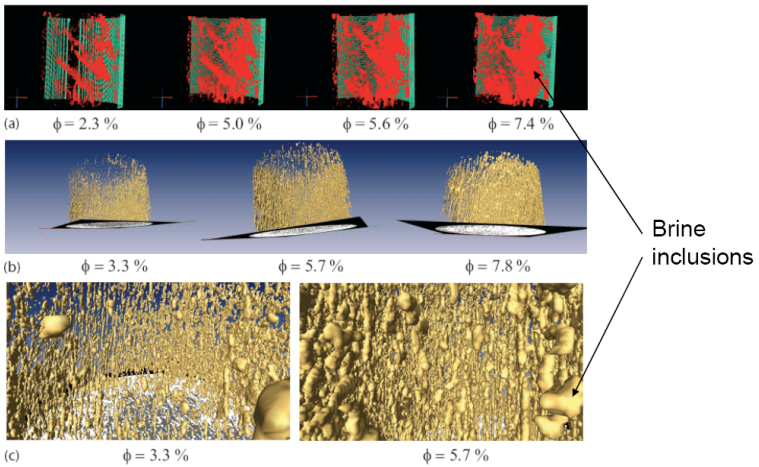
- How recent CICE developments help us model biogeochemistry throughout sea ice:
  a) Temperature, Salinity, bottom biogeochemistry
  b) Vertical tracer transport modeling
- Compare and contrast bottom bgc and zbgc
  a) Flux and transport assumptions
  b) Does it matter?
- Conclusions

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…

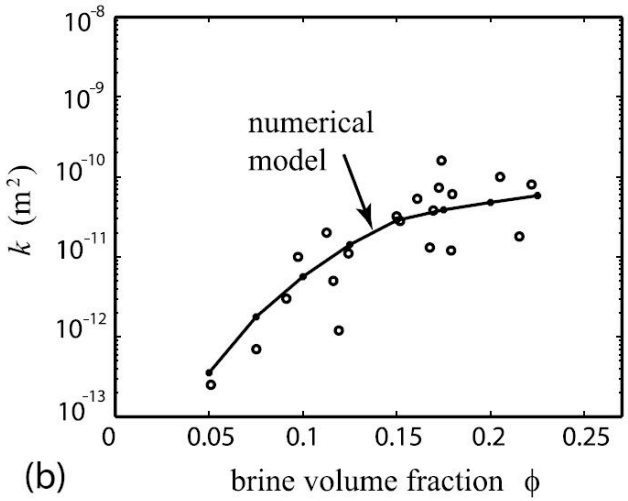
Imaged Sea Ice Structures



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

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

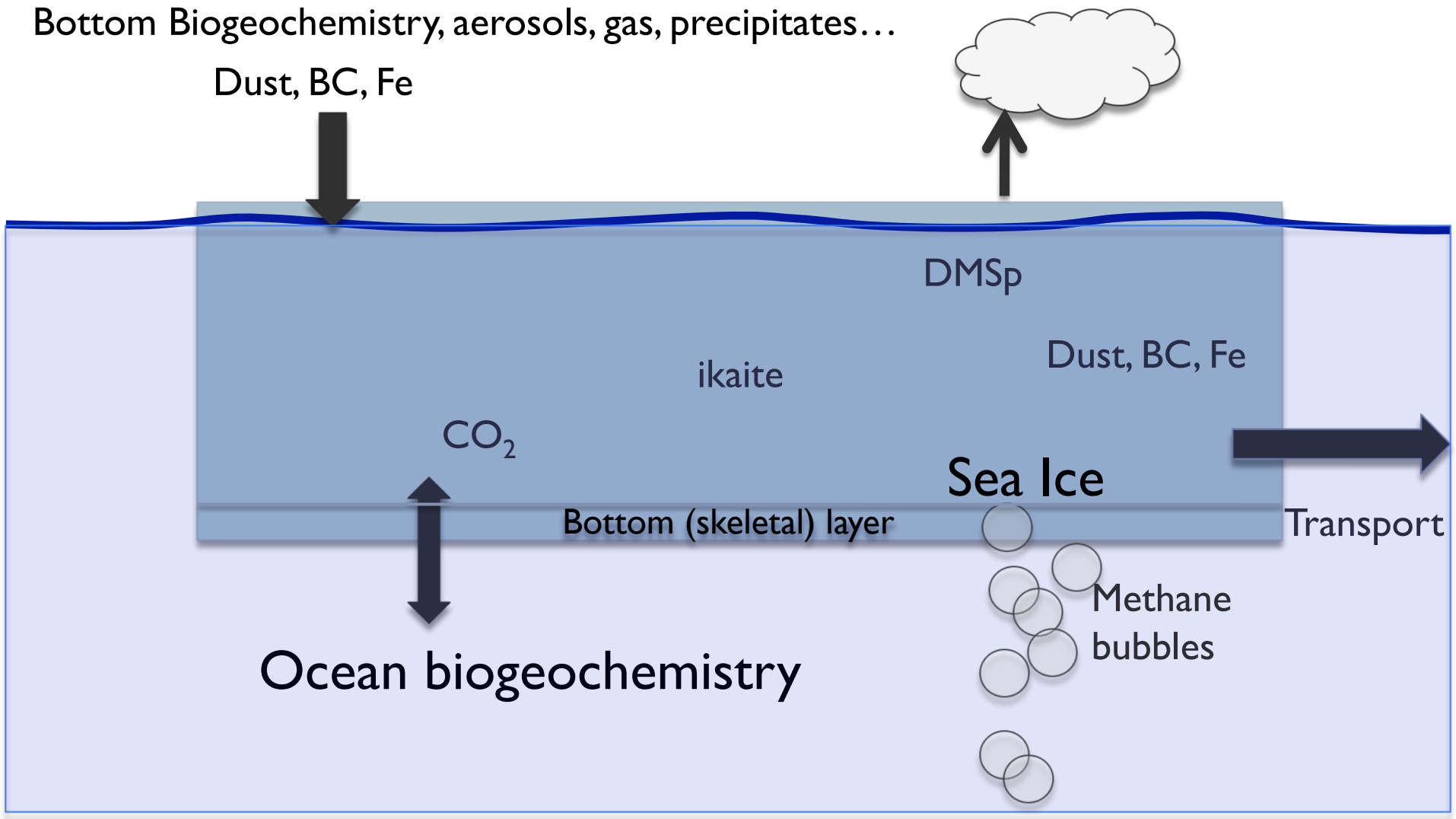
permeability…



Golden et al., 2007

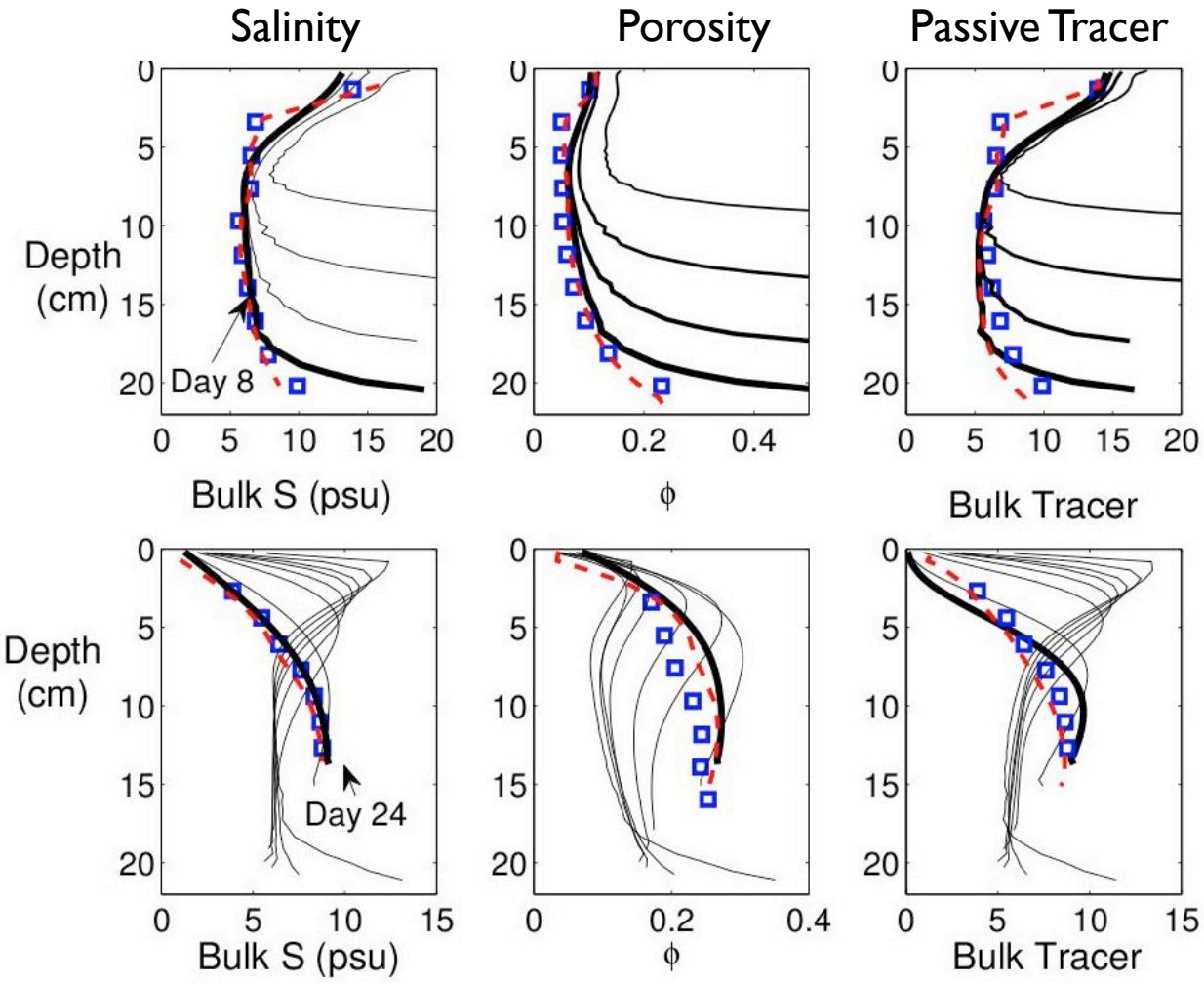
and critical information for parameterizing brine motion.

CICE developments and current work (II)



Recent CICE development (III)

- Vertical tracer transport



Modeling ice biochemistry

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

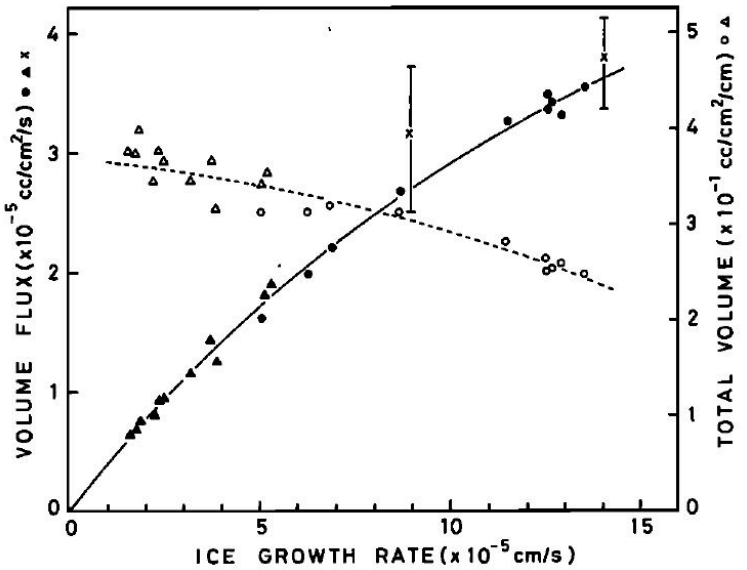
Some important processes:

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)

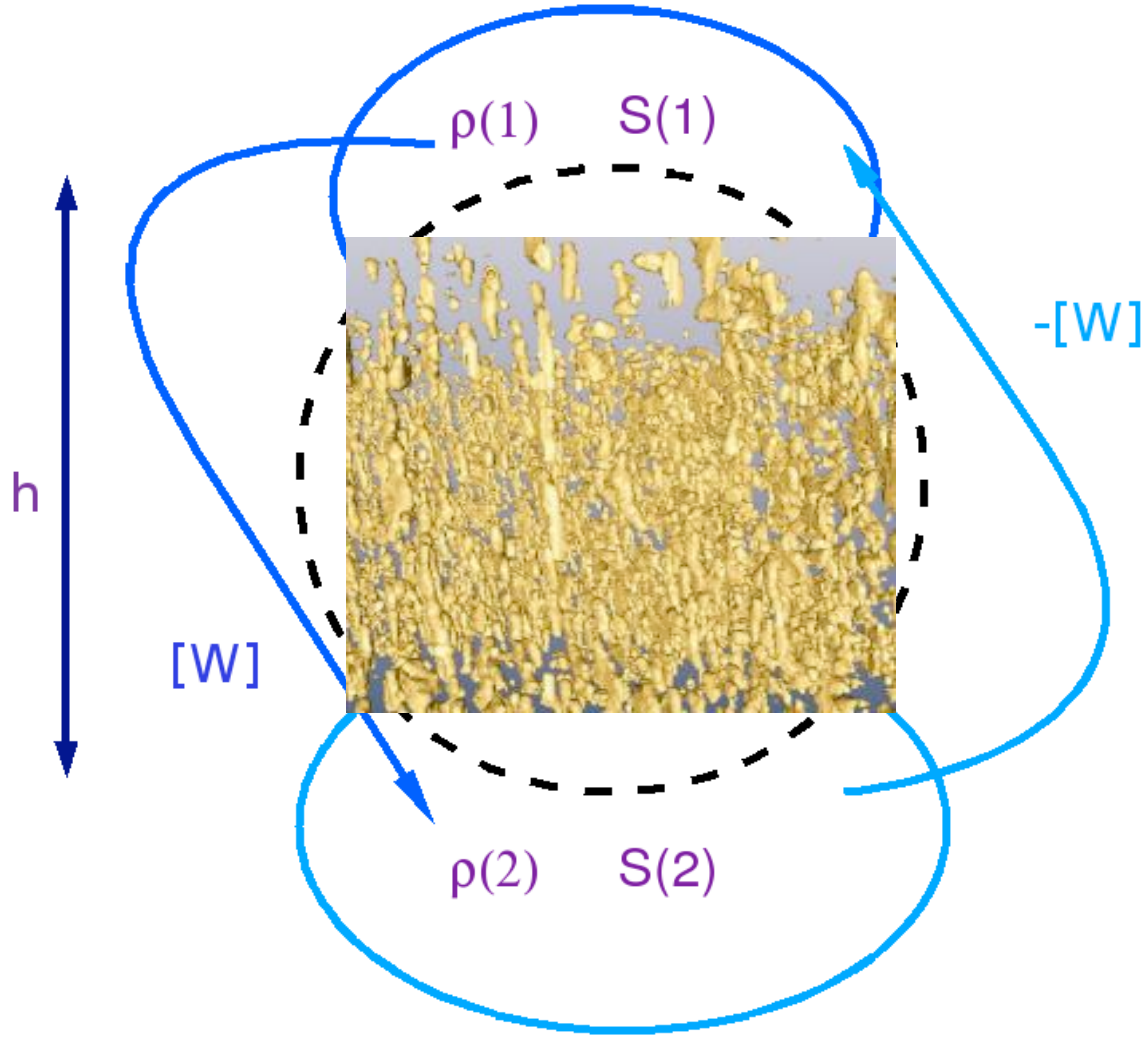
For the Arctic, *any* model of ice bgc needs a representation of the first two processes.

Bottom (skeletal) Ice Algae - Assumptions

- Skeletal layer thickness and porosity
- Compounds (nitrate, silicate…) are advected between the ice/ocean via a piston velocity (Vp)
- When ice growth dominates, Vp is a function of the growth rate after brine flux measurements of Wakatsuchi&Ono multiplied by a tuning parameter.
- When ice melt dominates, Vp is a function of melt.



Interior biogeochemistry (zbgc)



Cold Heavy Brine

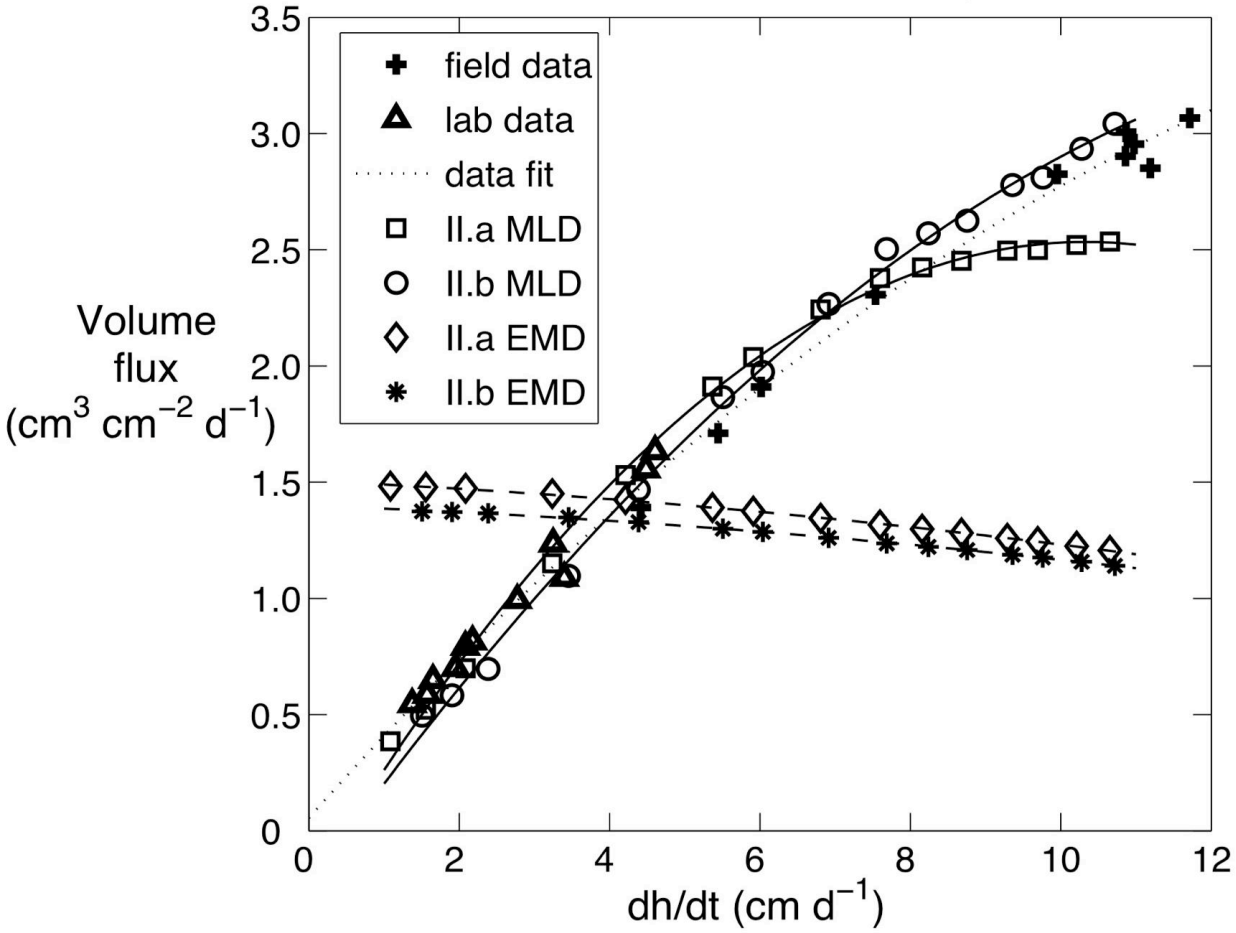
Mixing

Warm Light Brine

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

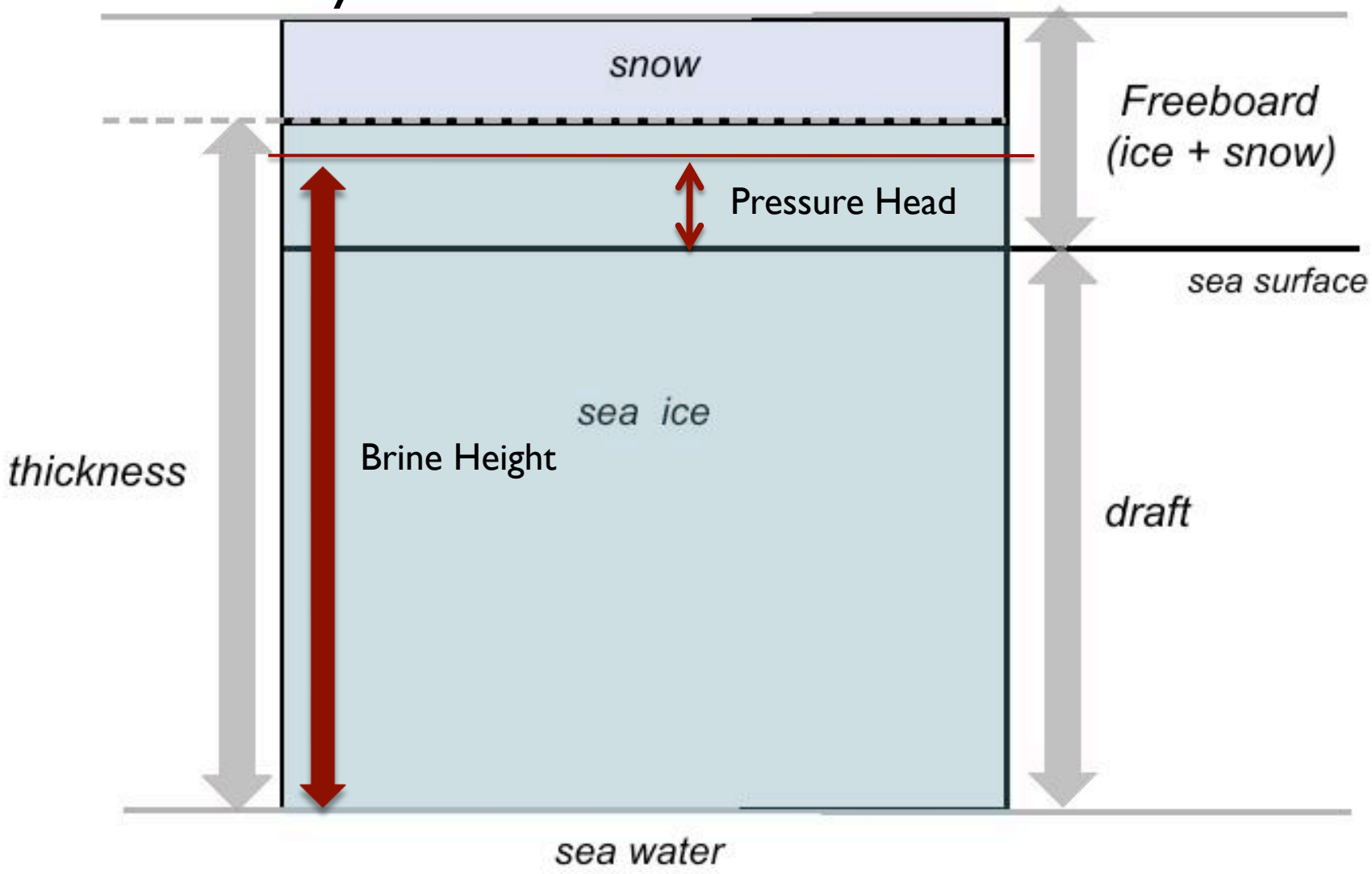
Data from Wakatsuchi & Ono, 1983



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

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

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



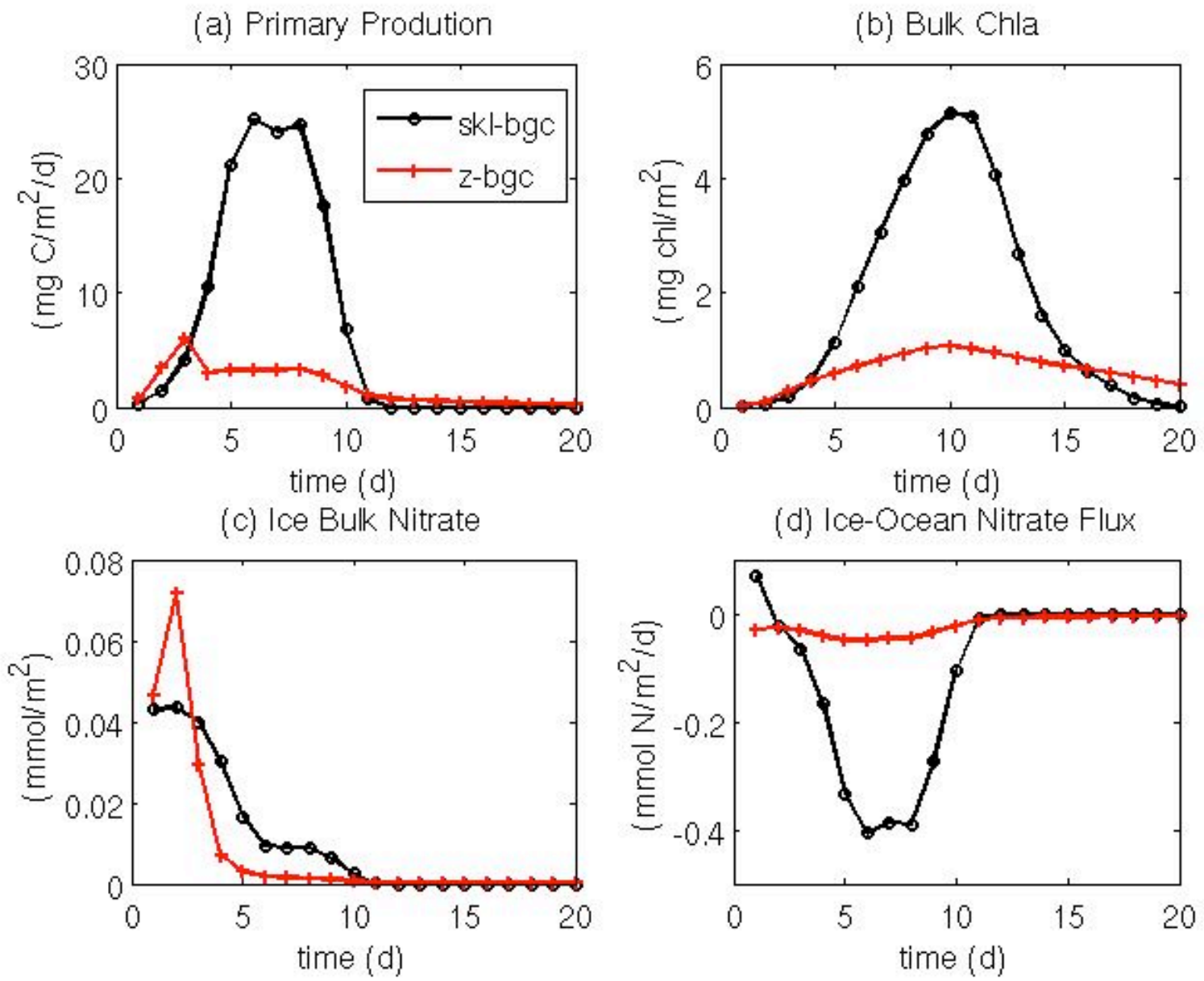
Does it matter?

Tracers : Algal nitrogen and Nitrate

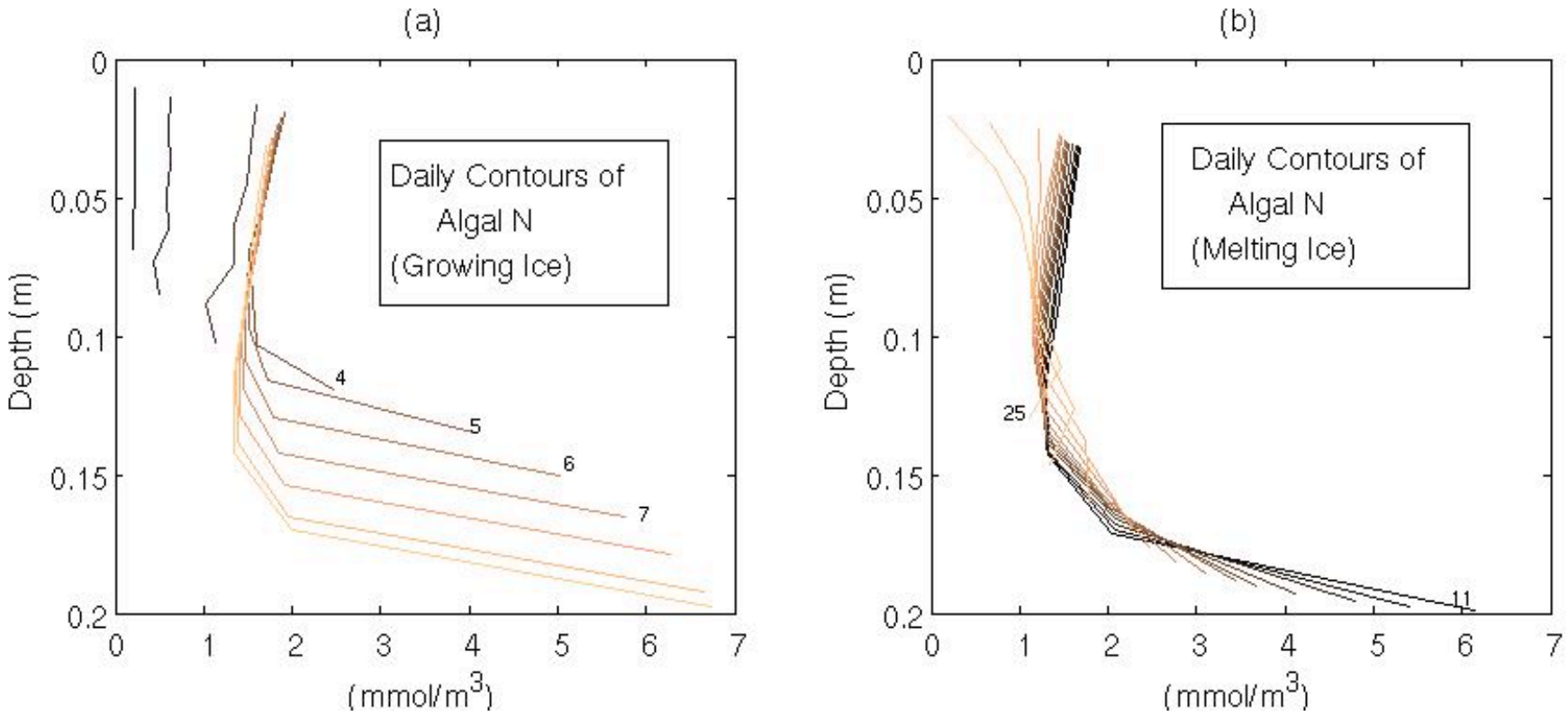
Column Test Case: 25 days of ice growth and melt with light

- 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


(a) Primary Prodution
(mg C/m2/d)
skl-bgc
z-bgc
time (d)
(b) Bulk Chla
(mg chl/m2)
time (d)
(c) Ice Bulk Nitrate
(mmol/m2)
time (d)
(d) Ice-Ocean Nitrate Flux
(mmol N/m2/d)
time (d)

Z-bgc Model:
Peak in Algal Nitrogen in the ice bottom

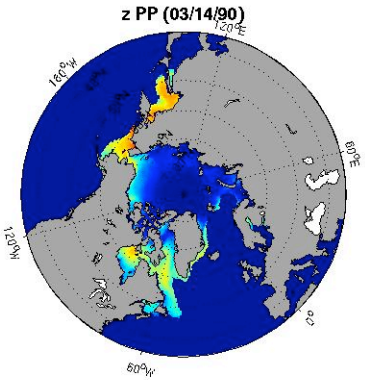
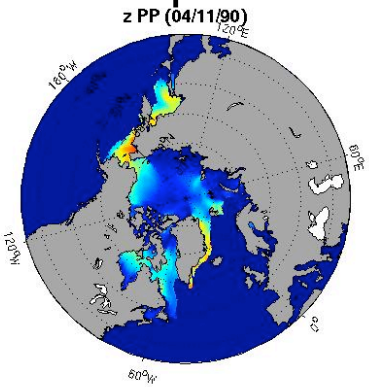
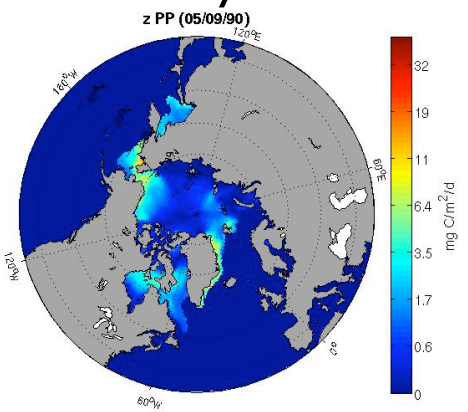
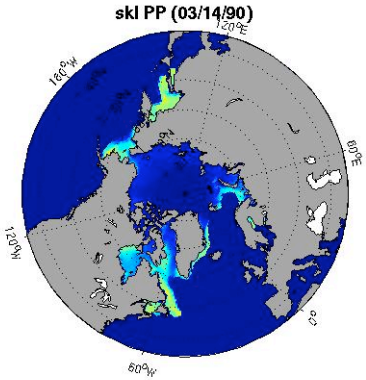
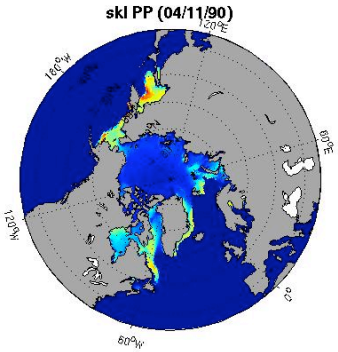
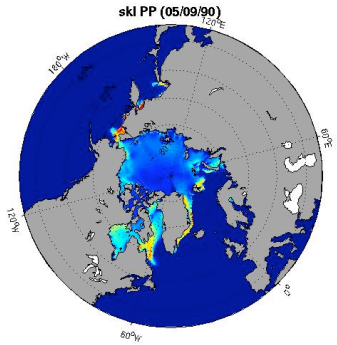
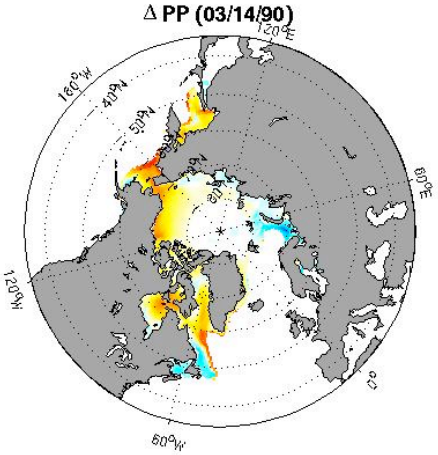
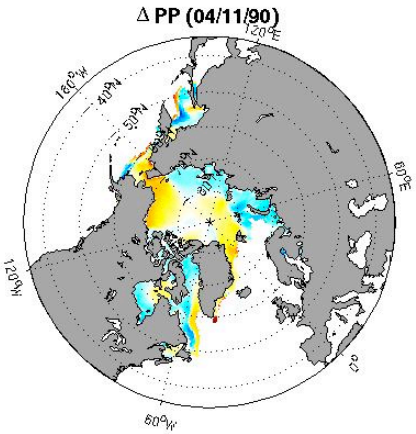
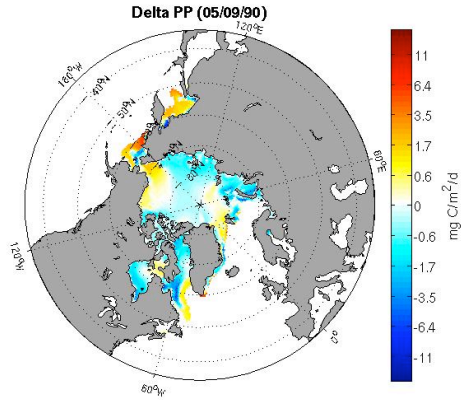


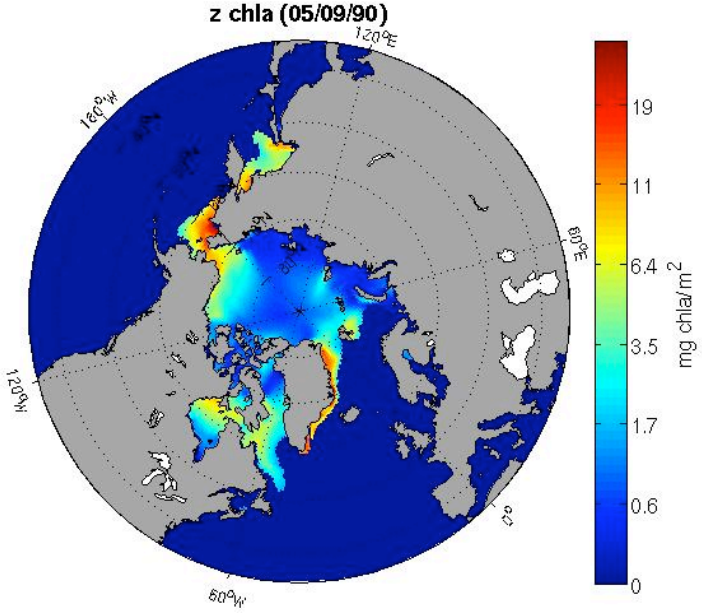
Does it matter? Arctic Scale

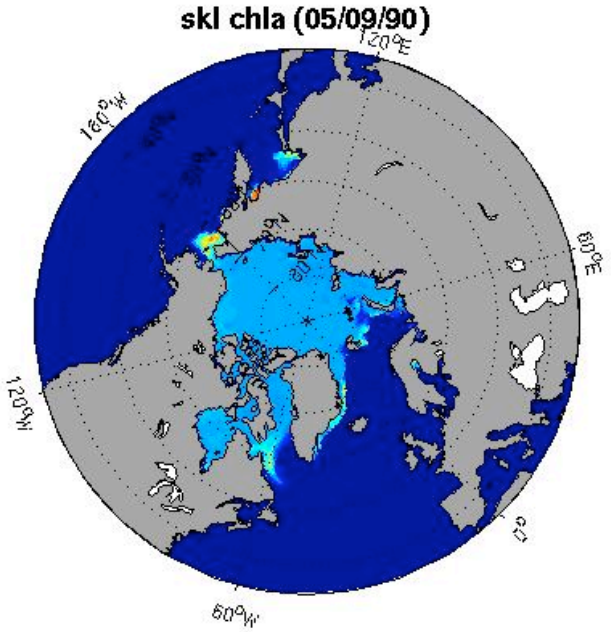
Tracers : Algal nitrogen and Nitrate

- 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.

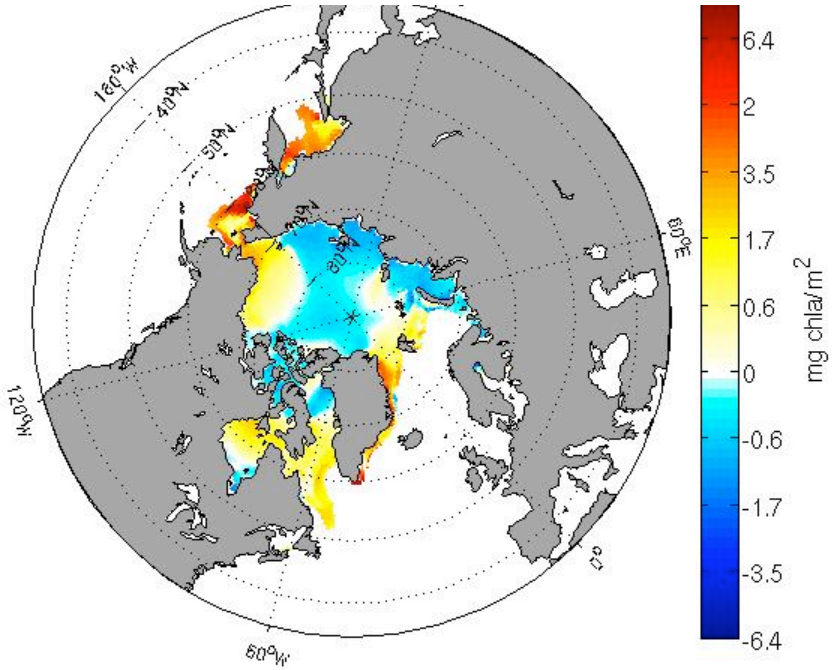
Net Primary Production

	March	April	May
Z bgc			
Skl bgc			
Z – Skl			


z chla (05/09/90)
120°E
180°W
60°E
120°W
0°
60°W
19
11
6.4
3.5
1.7
0.6
0
mg chla/m2


skl chla (05/09/90)
120°E
180°W
60°E
120°W
0°
60°W

May Chla


180°W
40°N
50°N
60°E
120°W
0°
60°W
6.4
2
3.5
1.7
0.6
0
-0.6
-1.7
-3.5
-6.4
mg chla/m2

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.