Ice Biogeochemistry in CICE.v5

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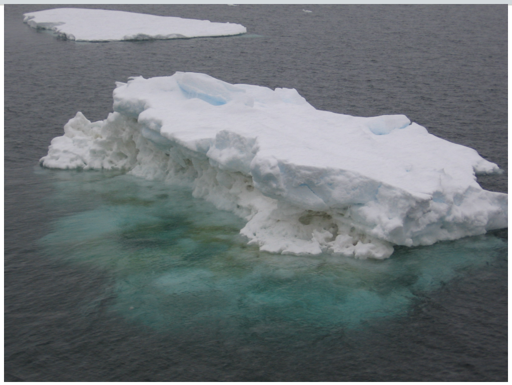
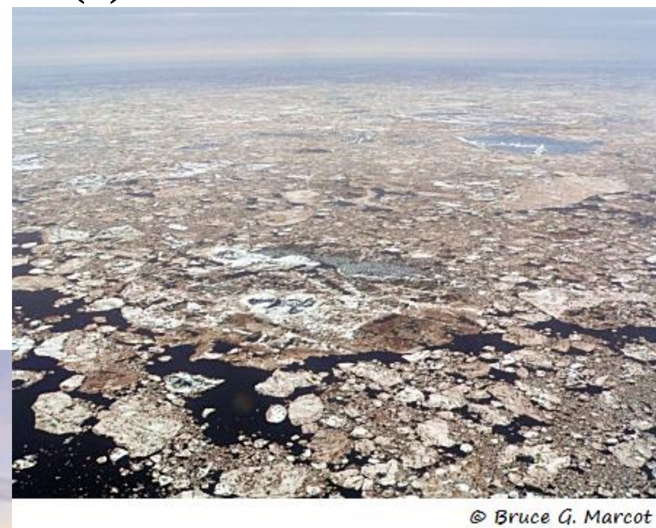
IARC

Why model ice algae?

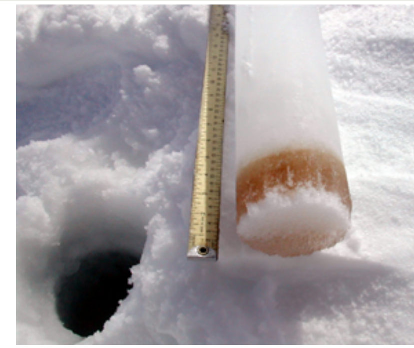
(a)



(b)

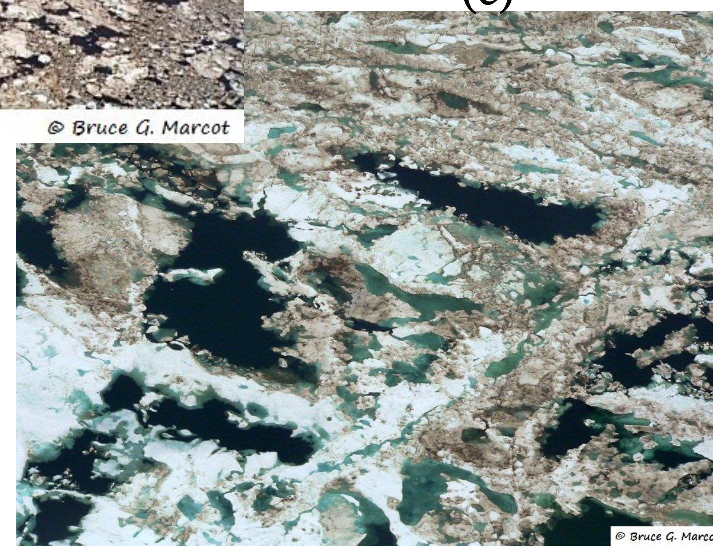


(c)

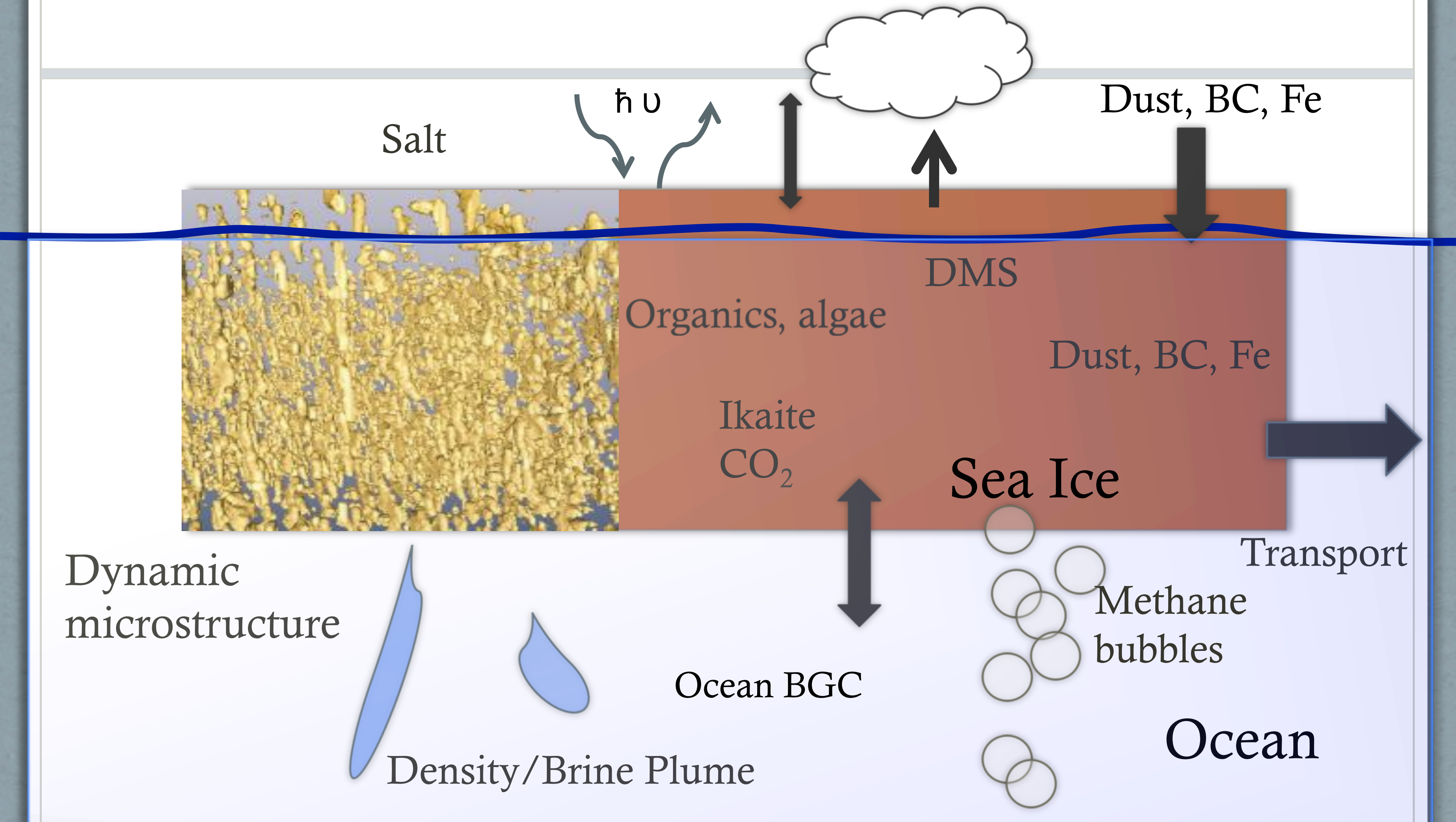


(d)

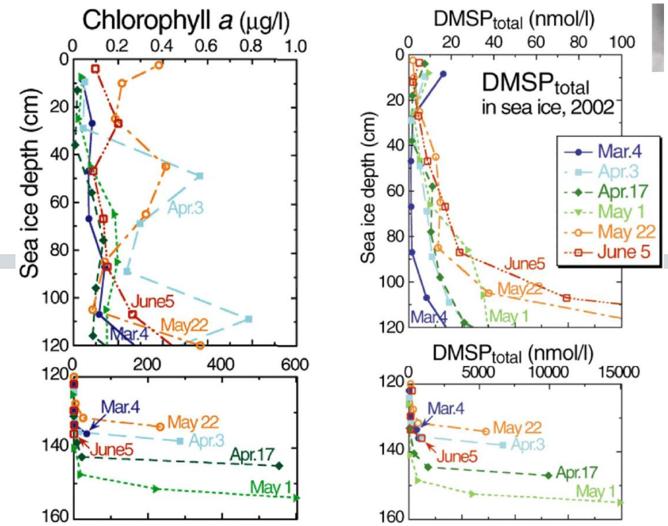
(e)



Coupled Ice BGC

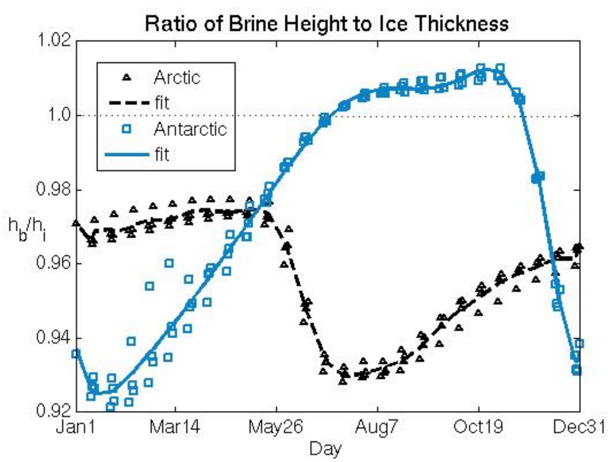


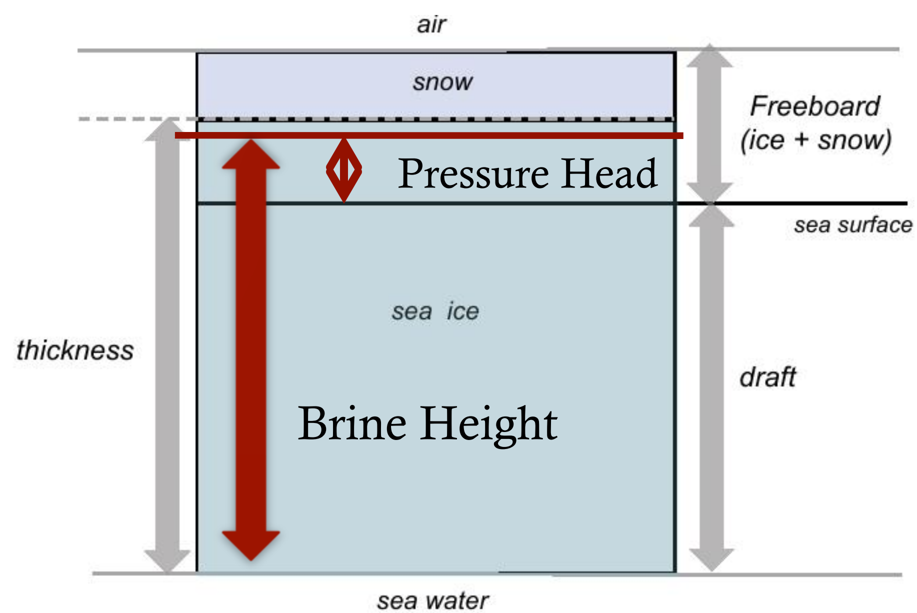
What's in CICE.v5



Shin et al. 2003 Uzuka et al. 2003

- Bottom layer Biogeochemistry appropriate for Arctic
- Bio-grid
- Brine height tracer





What's Not (yet) in CICE.v5

- A brine-dynamics parameterization of vertical tracer transport
- Biogeochemistry appropriate for upper and interior ice algal communities or Antarctic communities
- Aerosol deposition and migration via brine-dynamics

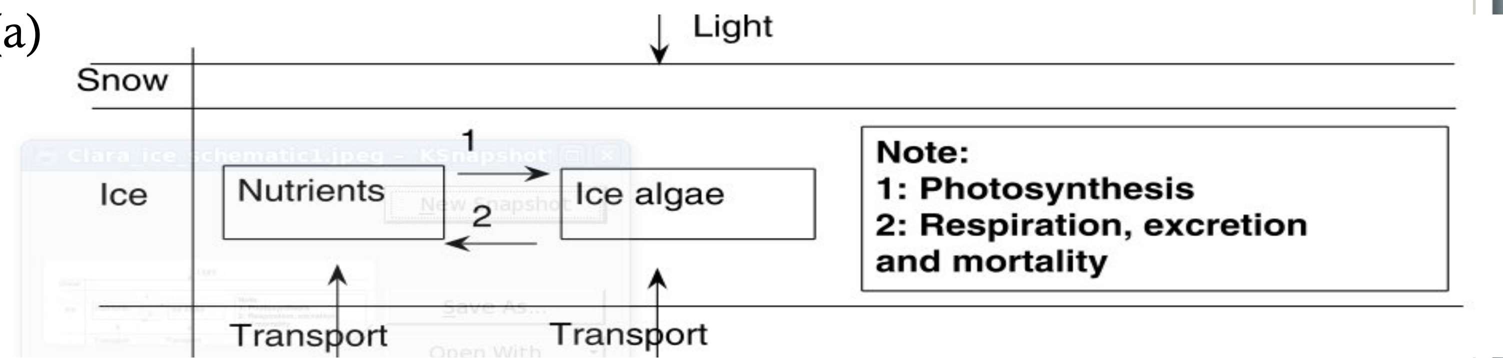
In development with Scott Elliott, Elizabeth Hunke, and Shanlin Wang

Bottom/Skeletal Layer BGC

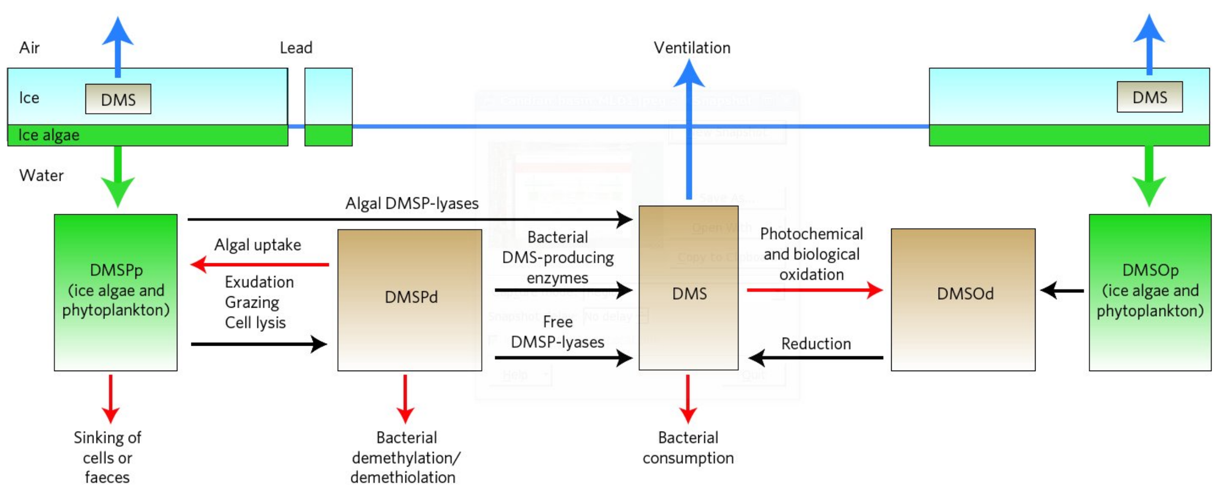
Nutrients:
- Nitrate
- Ammonium
- Silicate

Ratios:
- Algal C
- Algal Chla

(a)



(b)



DMS cycle:
- DMSPp
- DMSPd
- DMS

CICE.v5 (1982-1992)

- 10 year spin-up, 1992 (Deal et al, JGR 2011)
- WOA Nitrate and Silicate climatology – Instant restoring.
- Ice Ecosystem: Algal N, Nit, Am and Sil

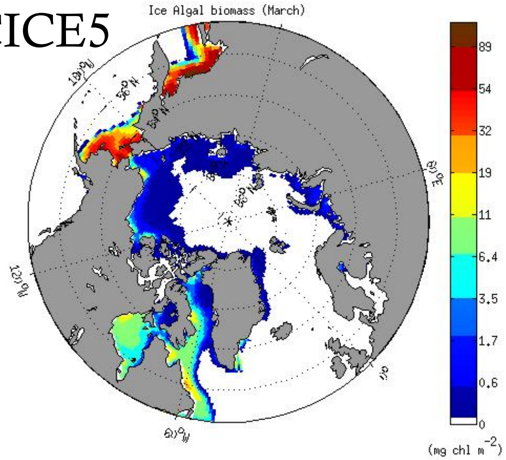
Value

- Estimates of ice algal chlorophyll and production in the Arctic
- Sensitivity of ice bgc to ice physics, ice-ocean fluxes, ocean nutrient concentrations

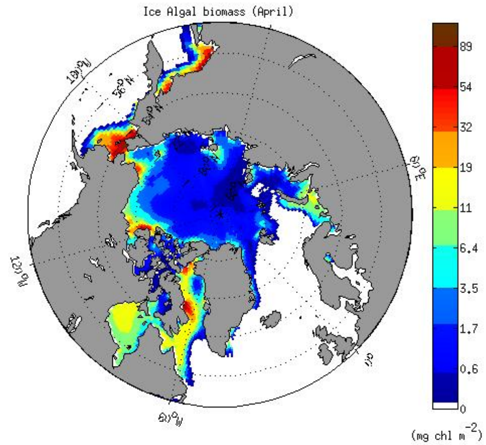
1992 (Comparison with Deal et al, JGR 2011)

CICE5

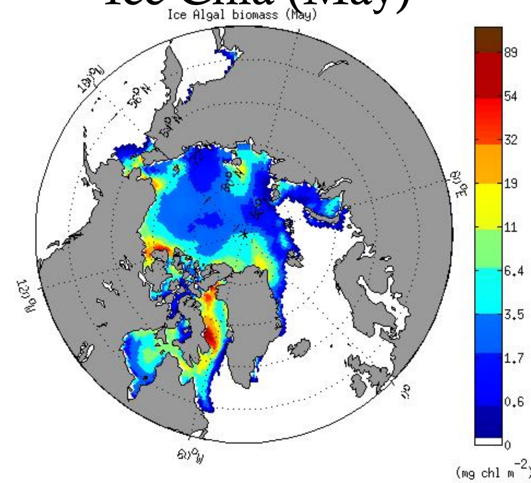
Ice Chla (March)



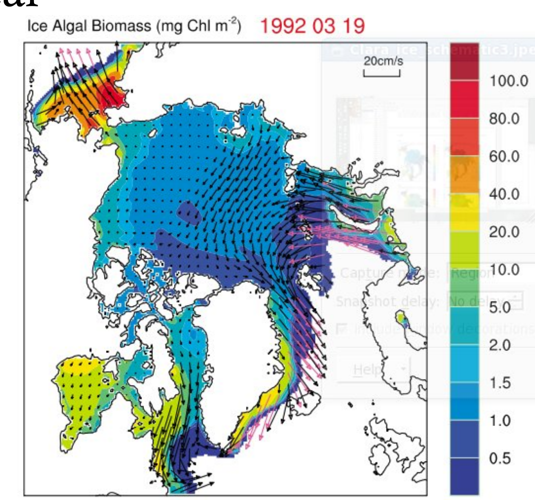
Ice Chla (April)

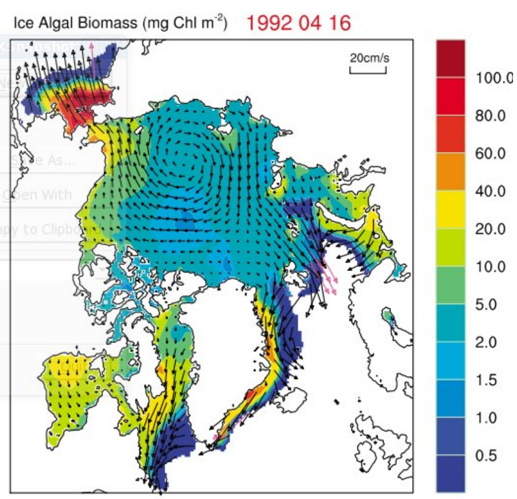


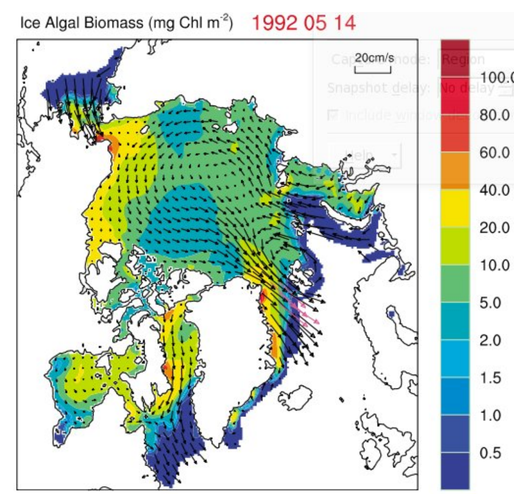
Ice Chla (May)



Deal







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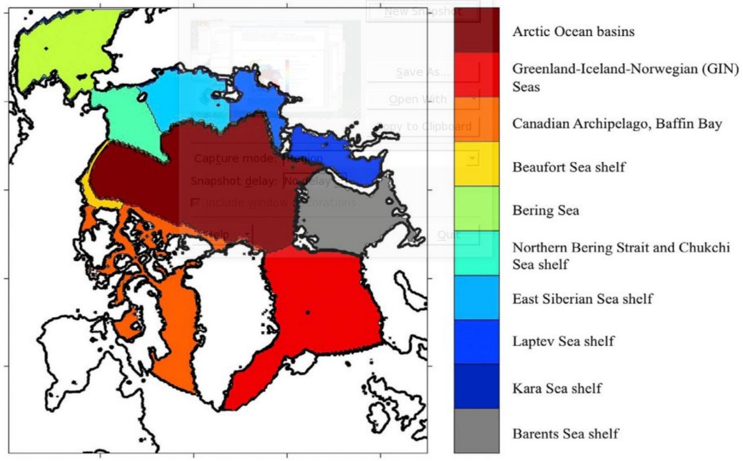
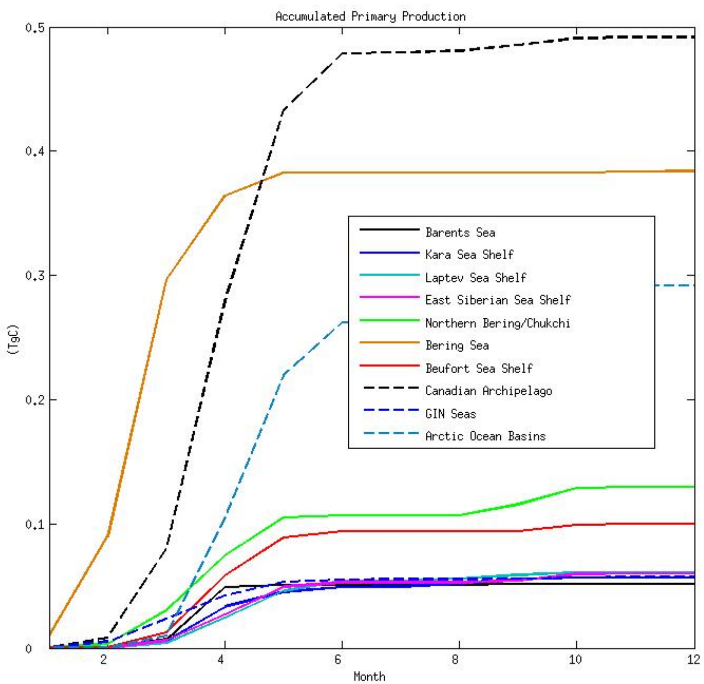




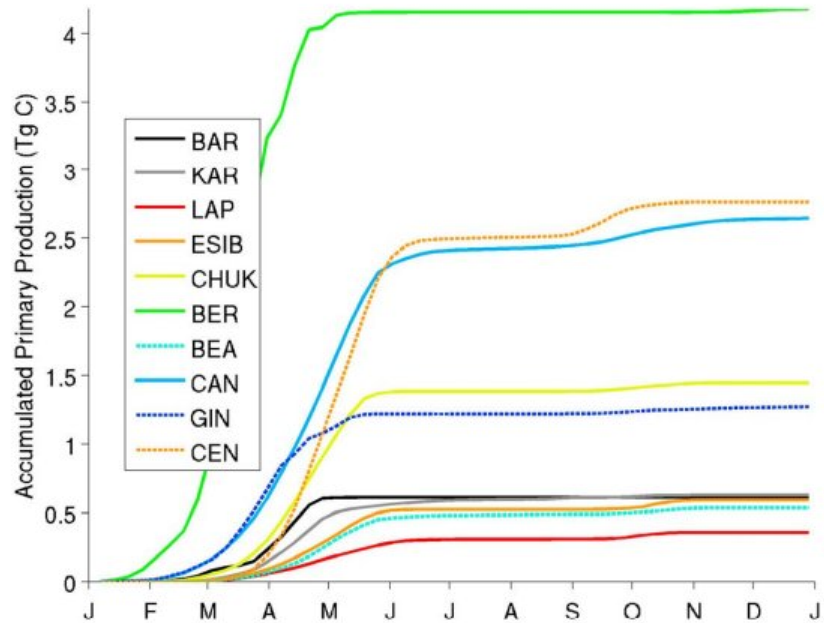


Figure 5. Simulated total primary production within arctic sea ice (Tg C) during 1992. For abbreviations see caption for Figure 3.

Table 1. Arctic Sea Ice Primary Production Averaged Over Ice Area in the Ten Study Regions (g C m^{-2} yr^{-1}) and for the Total Arctic (Tg C yr^{-1})

Arctic Subregion	Value	Reference, Comment	This Study Value
Arctic Ocean Basins	6[a]	*Gosselin et al.* [1997]	2.8
Bering Sea	0.2–1.5	*Alexander and Chapman* [1981]	4.2
	0.2–0.4	*McRoy and Goering* [1974]	
Chukchi Sea shelf	1–2	*Gradinger* [2009]	1.5
Barents Sea	0.2–5.3[a]	*Hegseth et al.* [1998]	0.6
	1.5	*Vetrov and Romankevich* [2004]	
Beaufort Sea	0.7	*Horner and Schrader* [1982], nearshore	0.5 (shelf)
Kara Sea	—		0.6
Laptev Sea	—	—	0.4
East Siberian Sea	4.7	*Petrova et al.* [2004]	0.6
Canadian Arctic	5	*Bergmann et al.* [1991], Barrow Strait area	2.7 (>62°N)
GIN Seas	—	—	1.3
Total Arctic	6 9–70	*Subba Rao and Platt* [1984], young ice *Legendre et al.* [1992]	15.1

[a]These values include estimated production from subice algae in addition to ice bottom algae.

Options/Sensitivities

Skeletal Ecosystem:

- Nitrate/Algal N minimum

Biochemistry parameters:

- Internally defined for Arctic Bottom community

*Thermodynamics: BL99, mushy layer (Turner 2013)

*Ice-Ocean flux parameterization

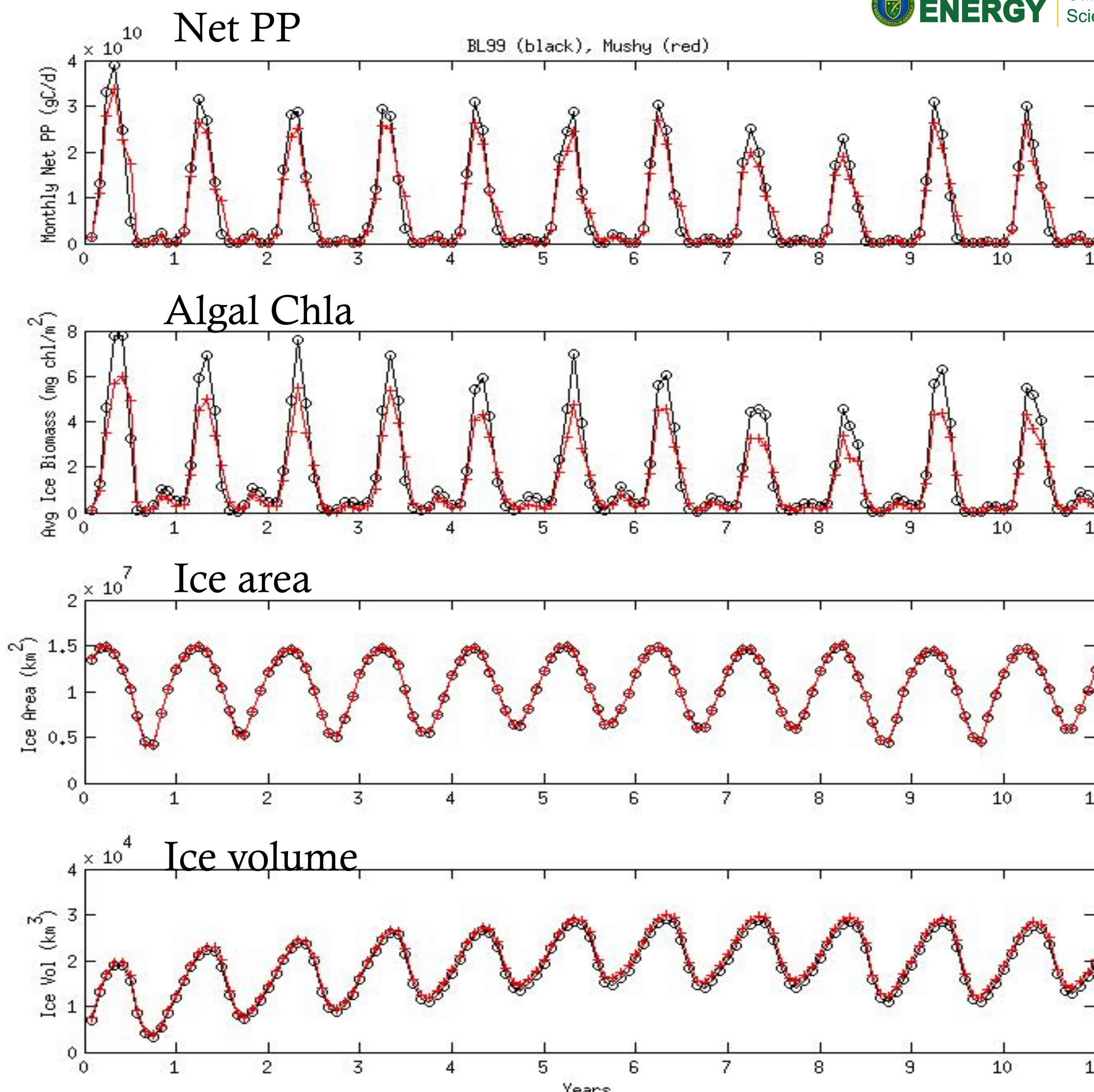
- 'default' : constant piston velocity if ice growth is positive
- 'Jin2006'

*Ocean nutrients: Demand of ML nutrients? (still needs coupling with ocean biogeochemistry)

Using two thermodynamic schemes

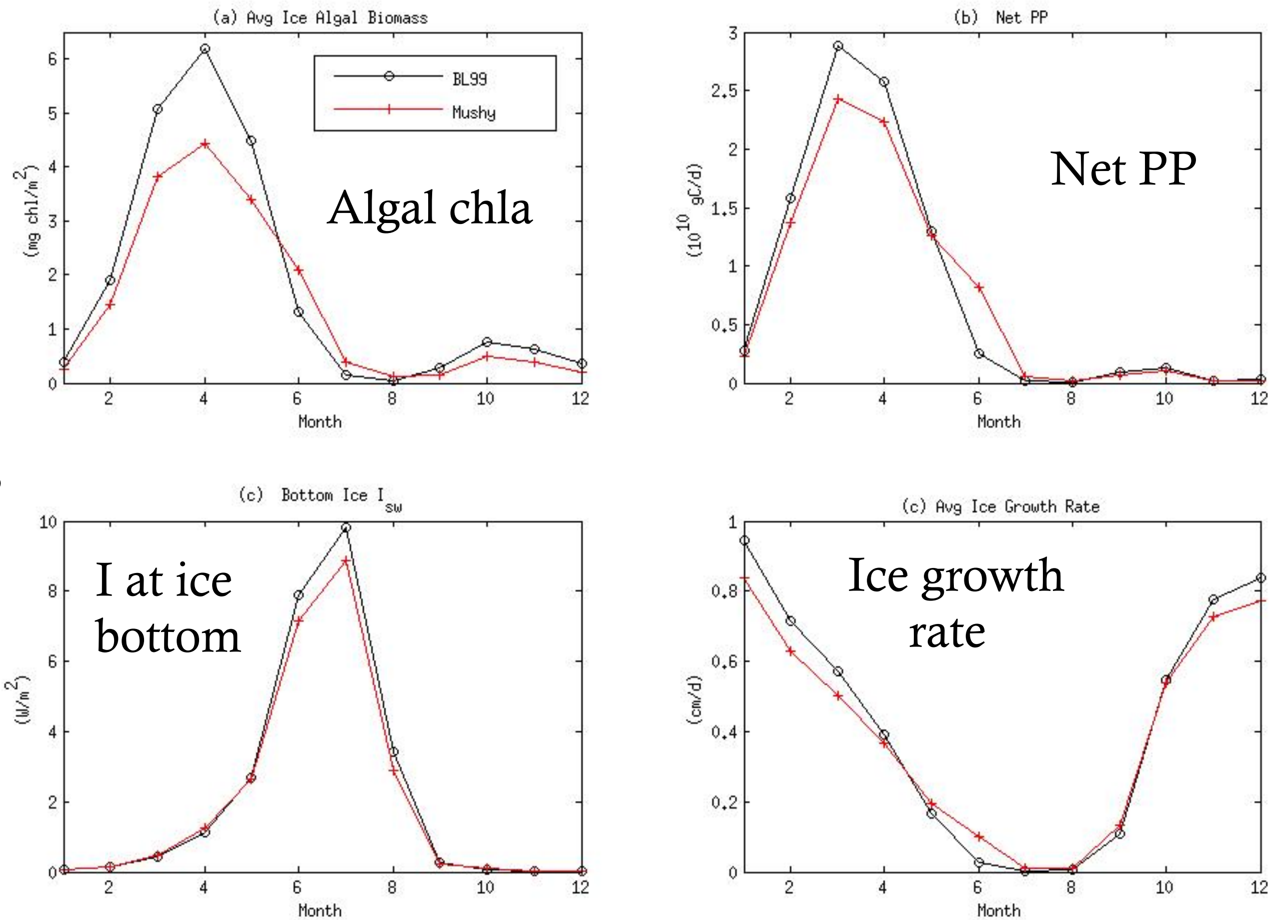
1) New—Mushy Layer

2) CICE.v4-BL99 Fixed salinity

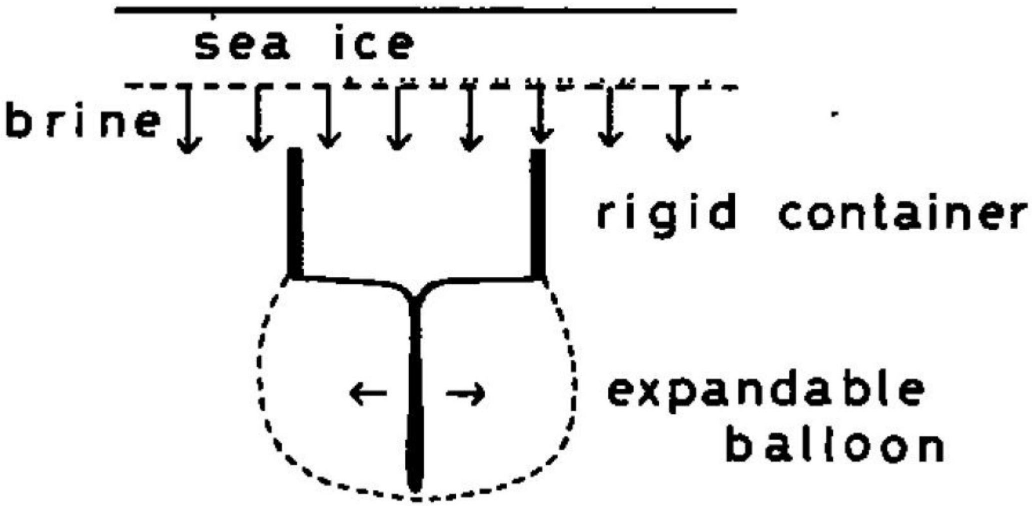


Thermodynamic Scheme: mushy/BL99

- Spring Peak in March/April
- Small Oct peak
- Reduced biomass/PP in mushy T. Why?



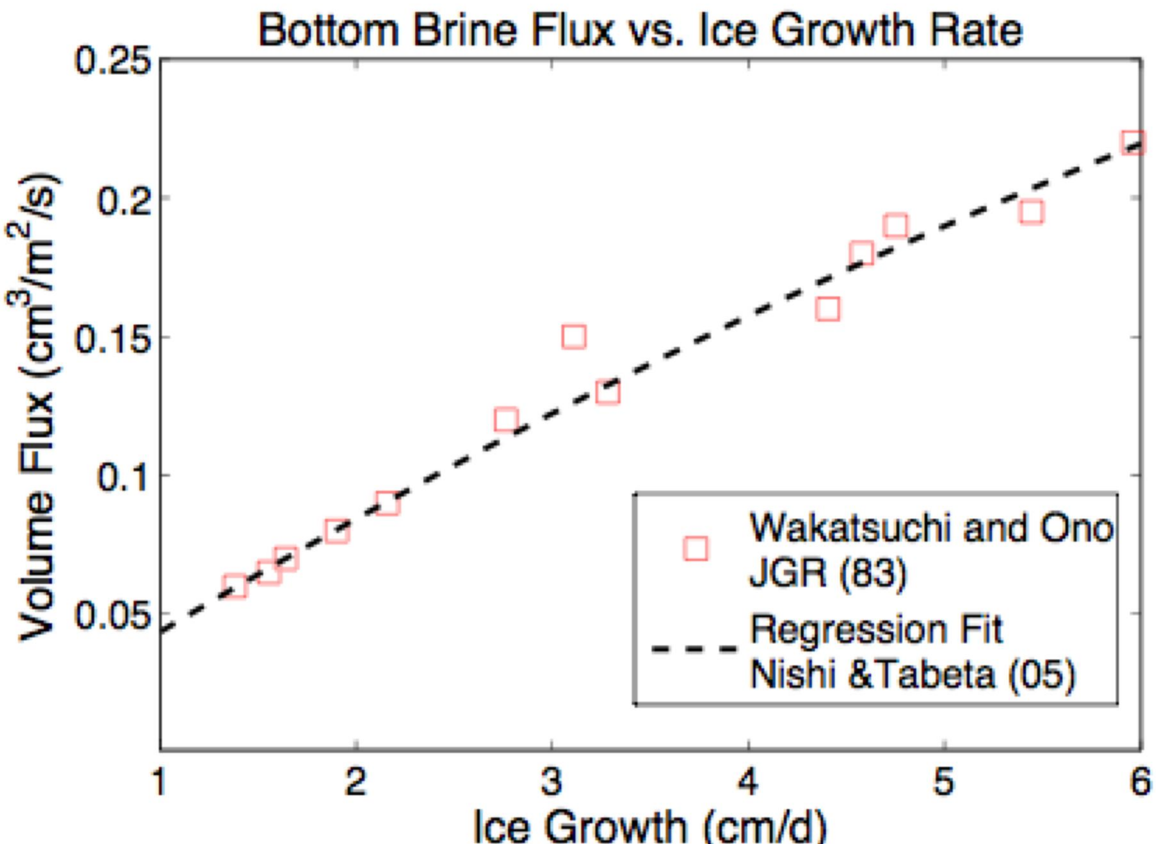
Brine collection Exp. (Wakatsuchi and Ono, 1983)



Brine collection schematic

'Jin2006', Piston velocity ≈ Vol Flux

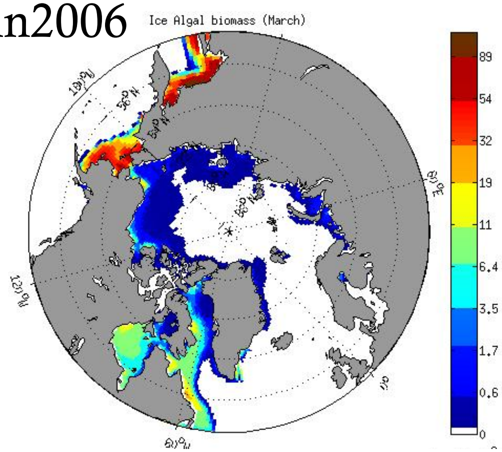
- Bottom Nutrient flux ∝ Vol flux
- Interior entrainment?
- Melting?
- Skeletal layer thickness: 2, 3, 4 cm…?

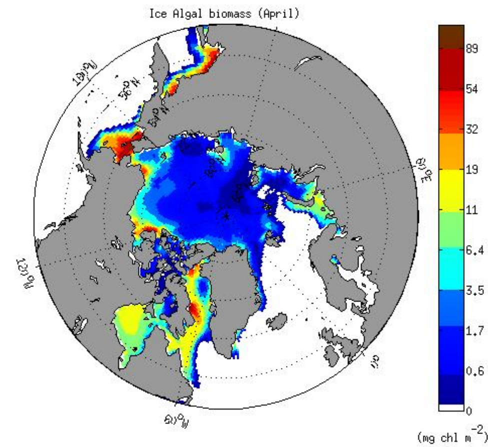


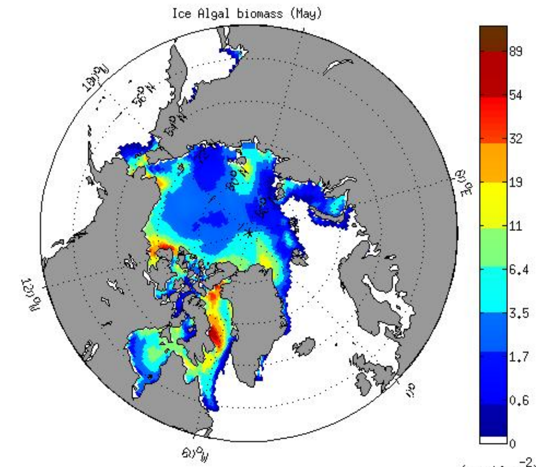
1992 (Default – 'Jin2006')

March Chla | April Chla | May Chla

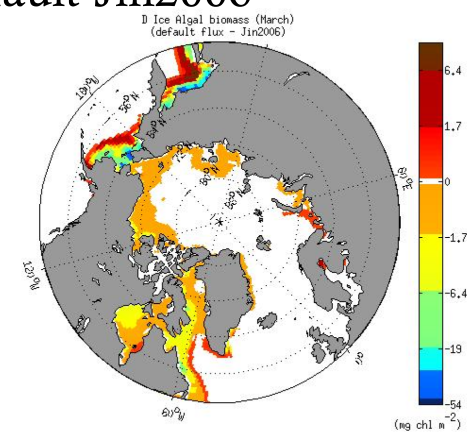
Jin2006

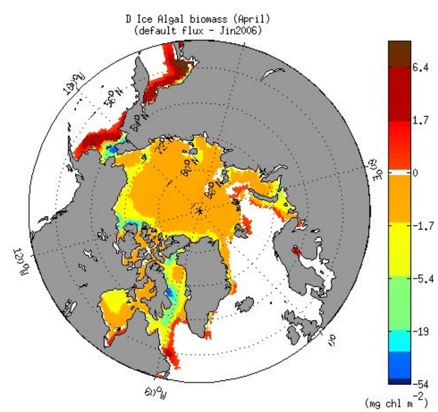


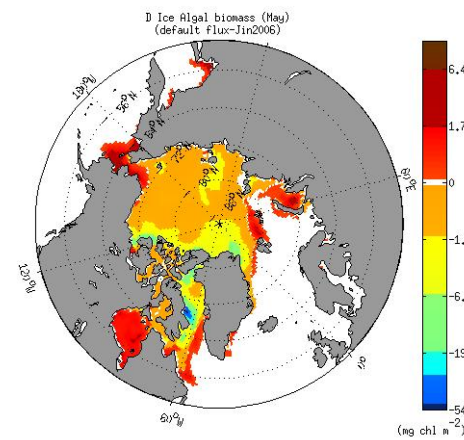




Default-Jin2006







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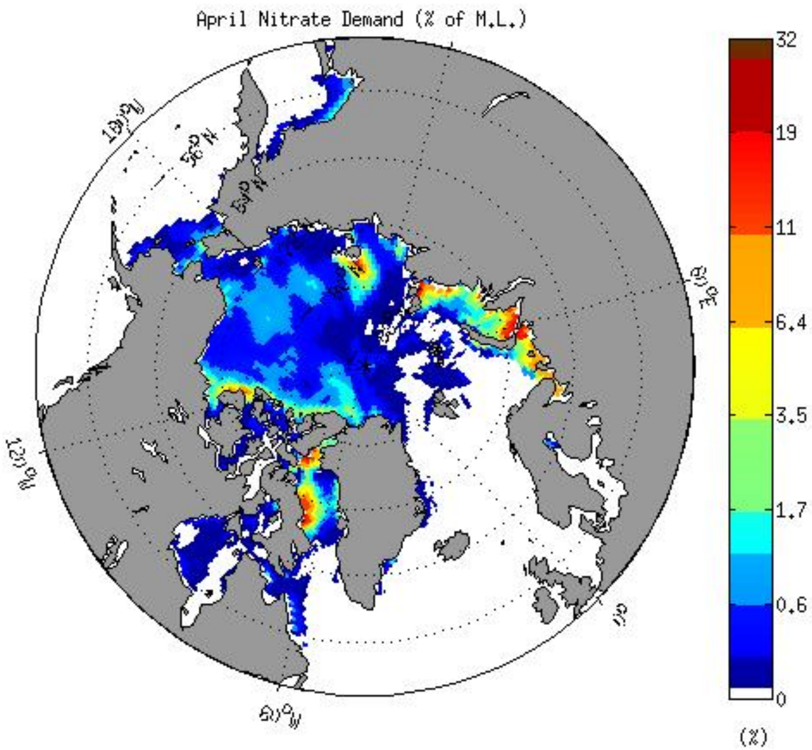
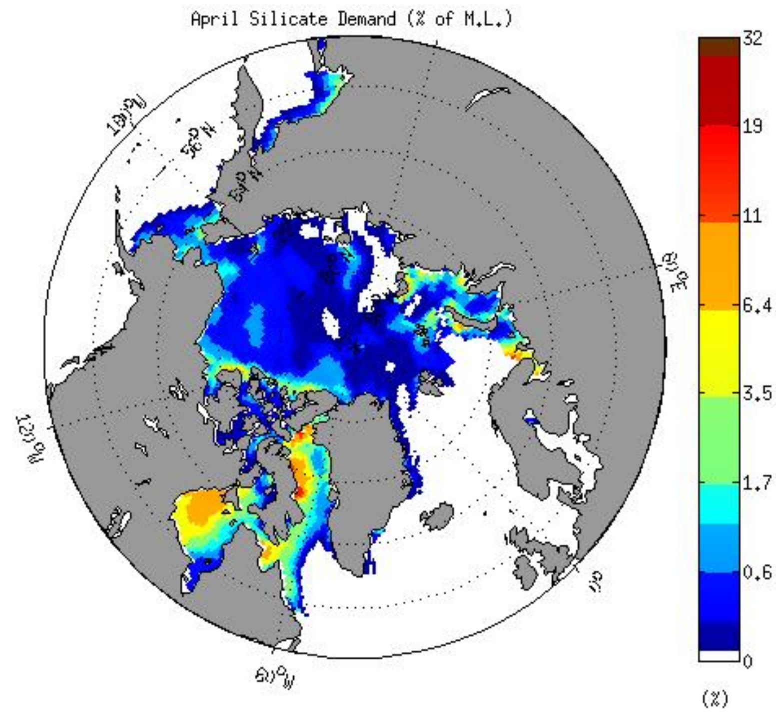
What is the ice algal demand for M.L. nutrients?

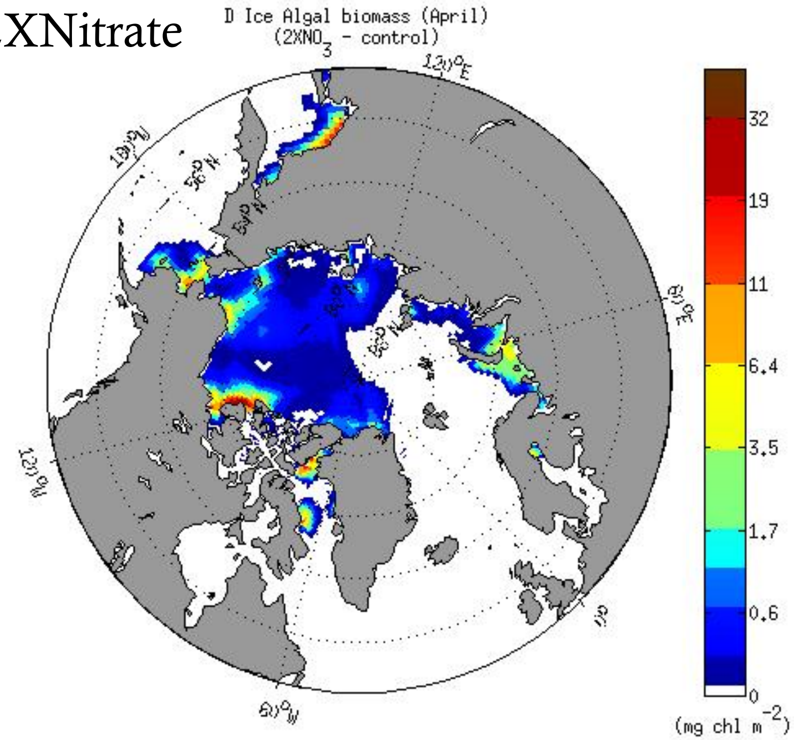
% of M.L. Nitrate/Silicate required by ice algae in April



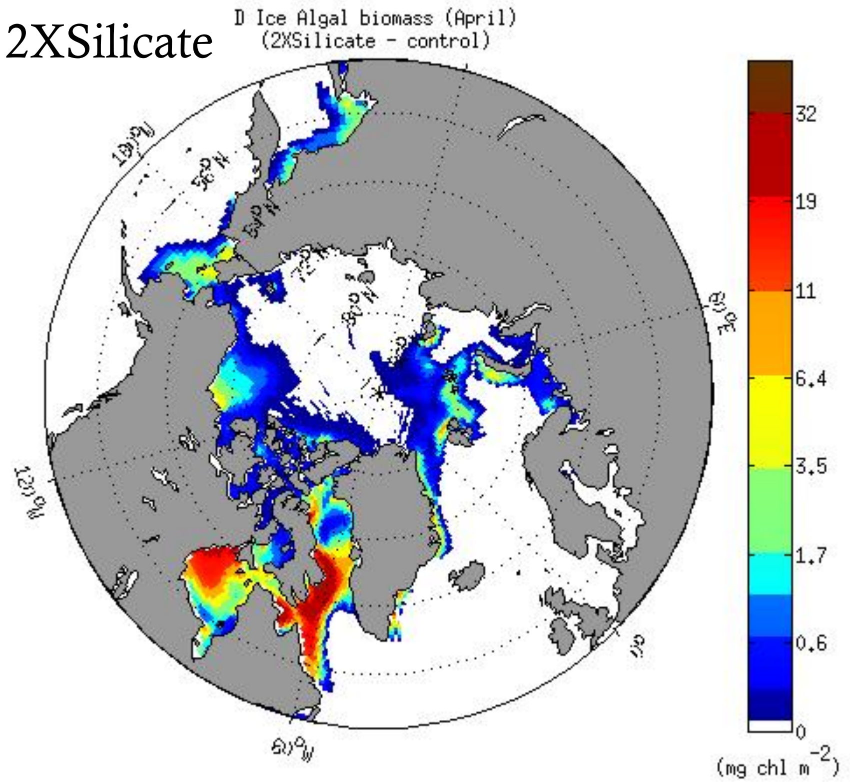


Is the ice bgc sensitive to M.L. values? Doubling M.L. Nutrients?

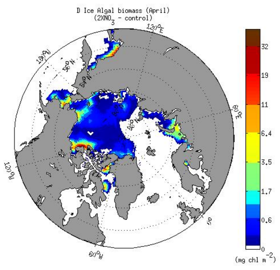
2XNitrate

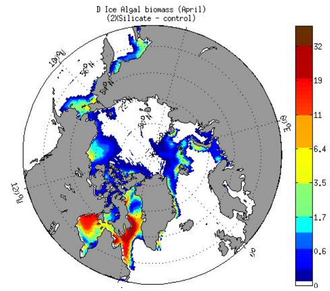


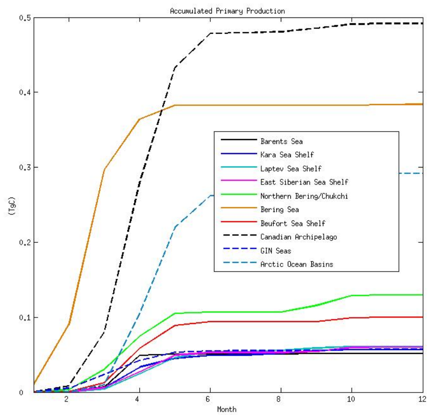
2XSilicate

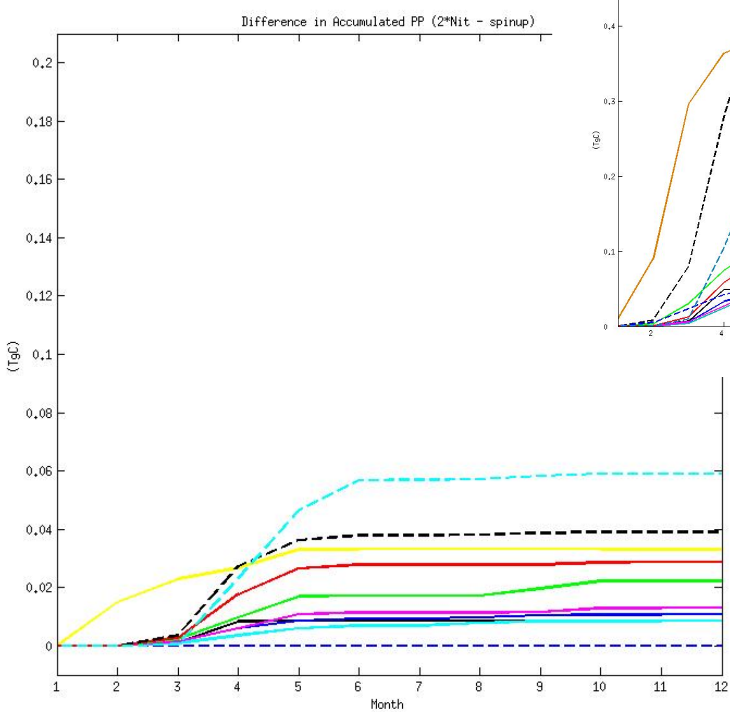


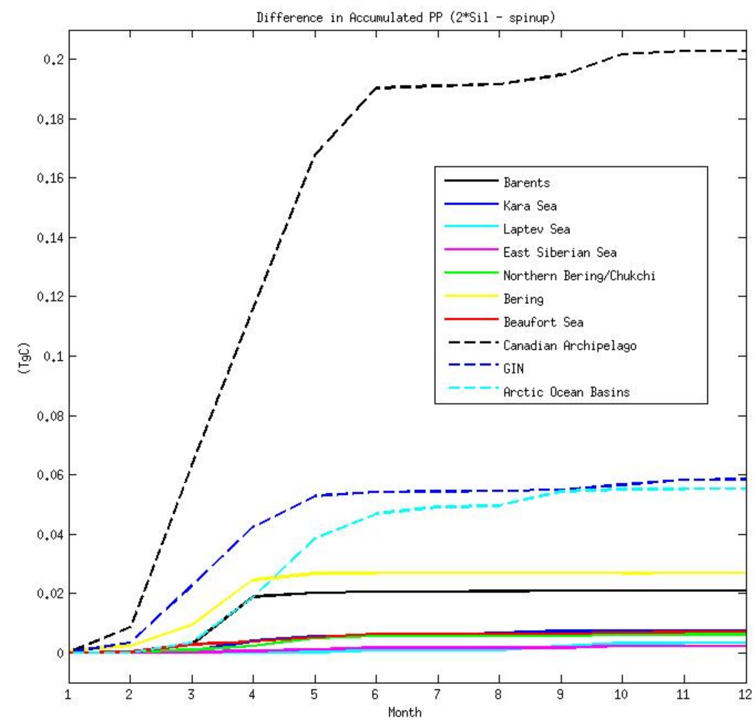
Doubling M.L. Nutrients?









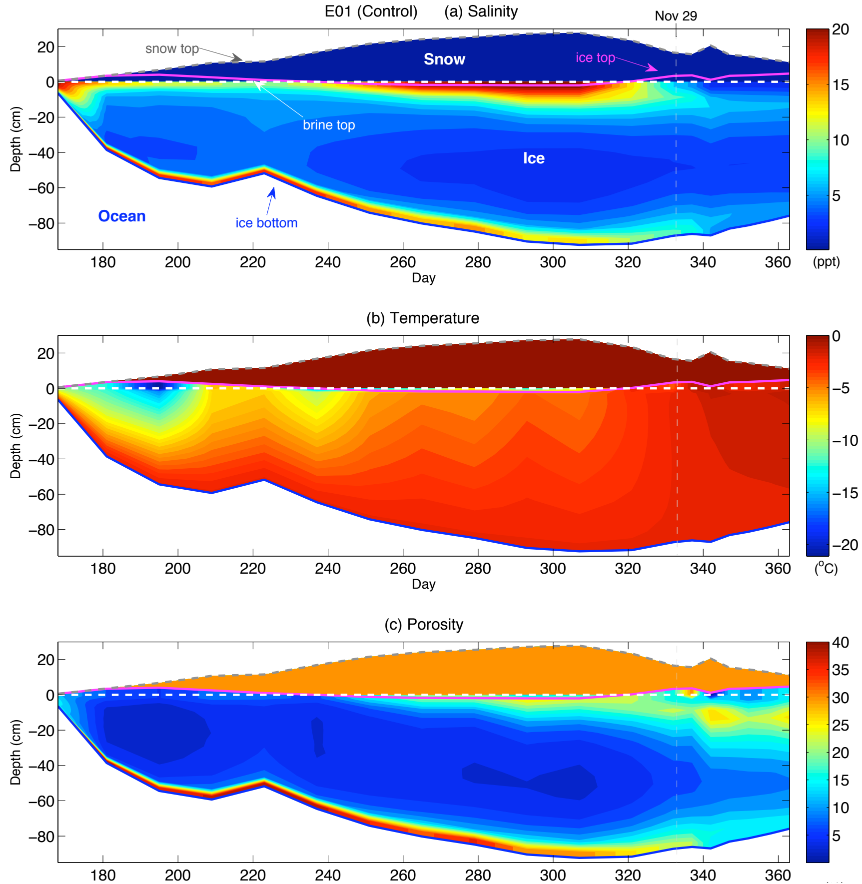


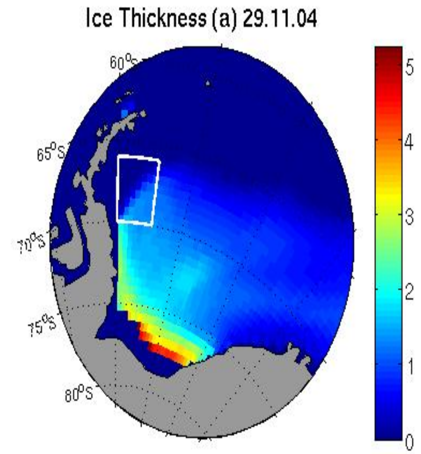
Conclusions

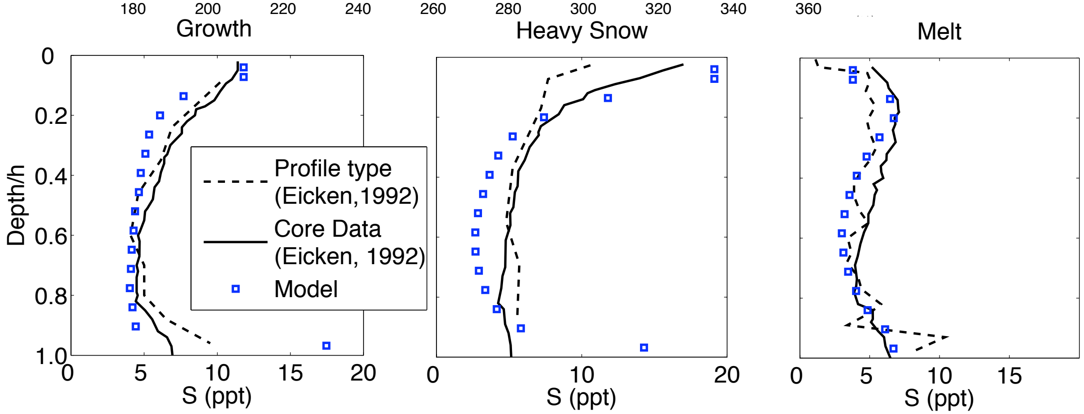
- There is bottom layer biogeochemistry in CICE.v5
- Algal N, Nitrate, Ammonium, Silicate, DMSPp, DMSPd and DMS
- Appropriate for estimates of Arctic algal production

(currently underestimates chla and production)

- Two ocean-ice nutrient flux options (Jin2006 depends on ice growth rate)
- Ocean M.L. bgc will impact the ice bgc.
- Ice bgc will impact polar ocean M.L. bgc
- Ice-ocean coupling of bottom ice bgc will directly transfer to coupling of the vertical ice bgc.


E01 (Control)
(a) Salinity
Nov 29
snow top
Snow
ice top
brine top
Ice
Ocean
ice bottom
Depth (cm)
Day
(ppt)
(b) Temperature
(°C)
(c) Porosity


Ice Thickness (a) 29.11.04
60°S
65°S
70°S
75°S
80°S
m


Growth
Heavy Snow
Melt
Depth/h
Profile type (Eicken,1992)
Core Data (Eicken, 1992)
Model
S (ppt)

Simulations of Ice Algae in the Weddell Sea from a simple Nitrate-Algal model in CICE

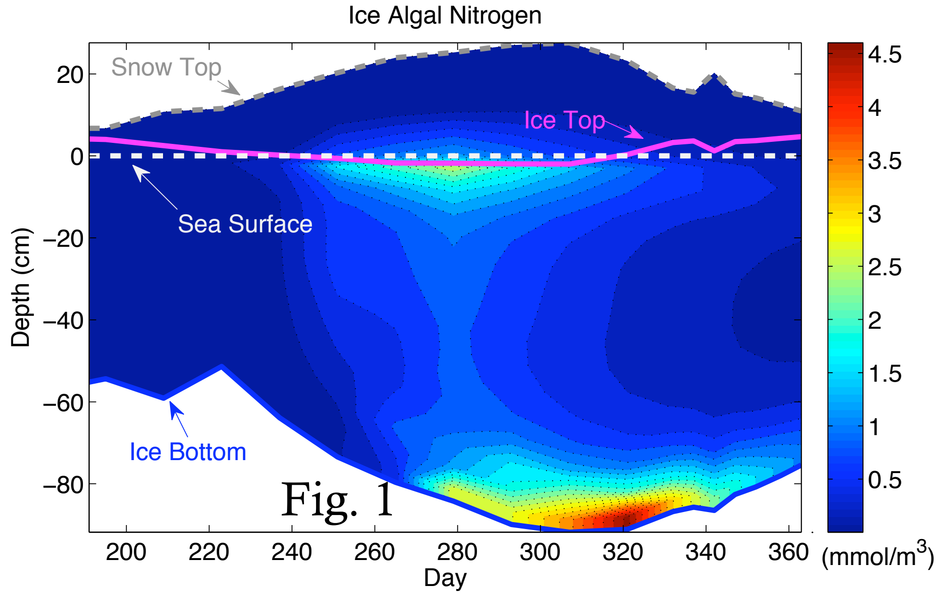


Fig. 1

1. (Fig. 1) Algae first accumulate in the upper ice depleting the snow-brine intrusion of nitrate. Bottom accumulation follows with increasing irradiance.

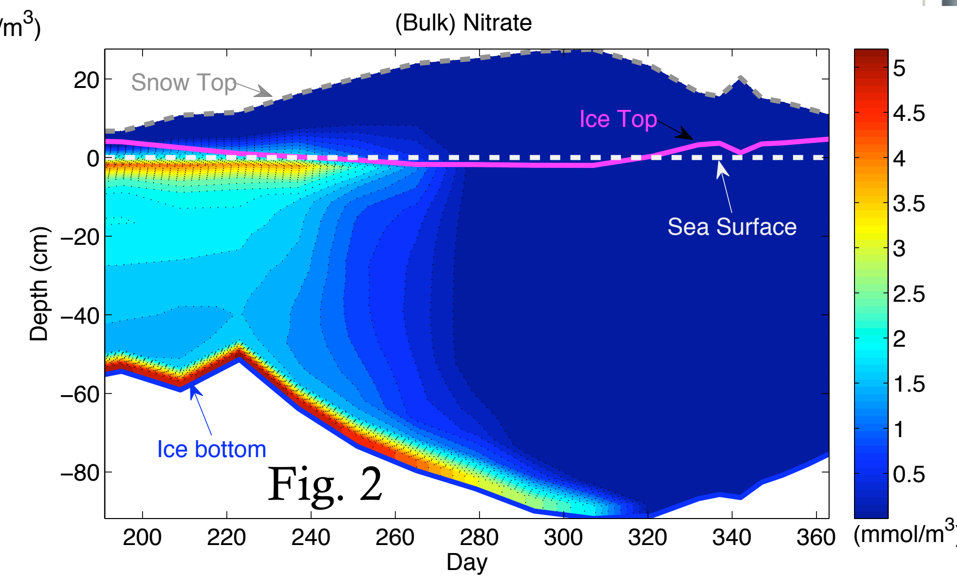


Fig. 2

2. (Fig. 2) Nitrate in young ice mirrors salinity until irradiance levels support algal growth.

3. Currently, higher complexity ice algal models (DOM, DMS, Silicate, PON…) are in the development and testing phase in CICE.

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