C. Fritsen

A ONE-DIMENSIONAL, MULTI-LAYER, SEA ICE-MICROALGAE MODEL

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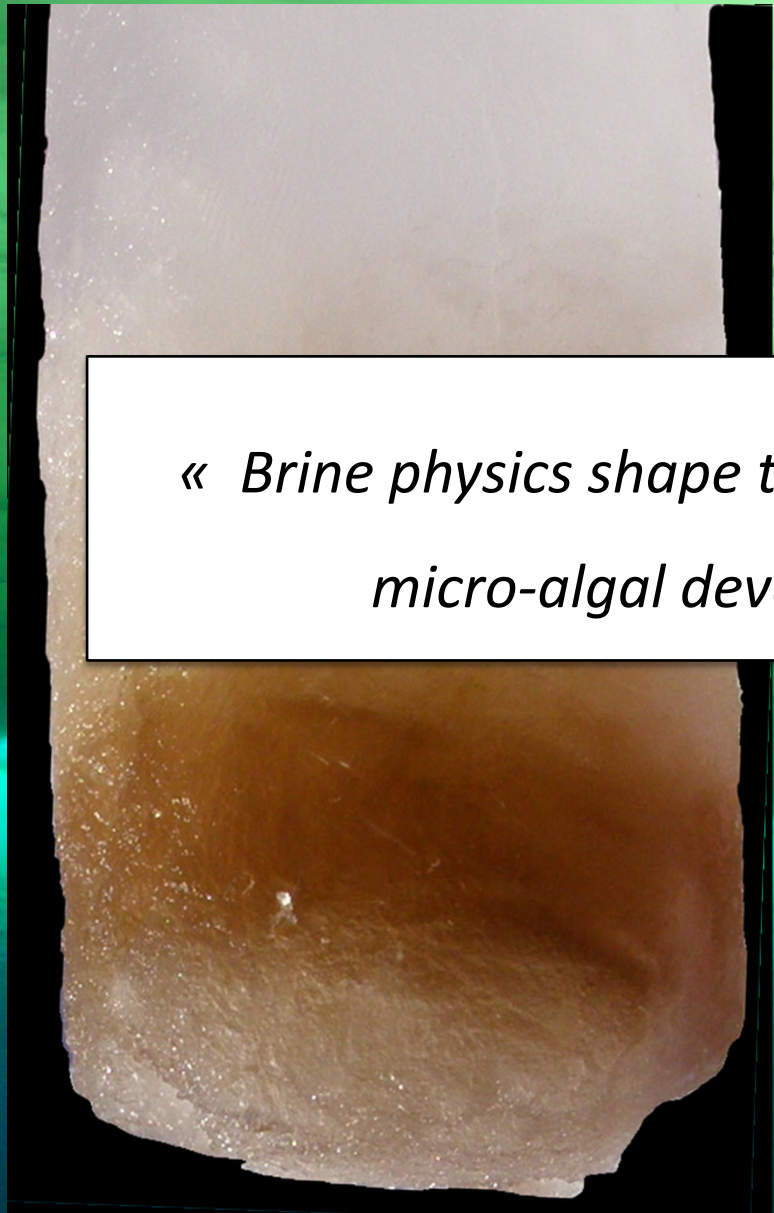
C. Fritsen



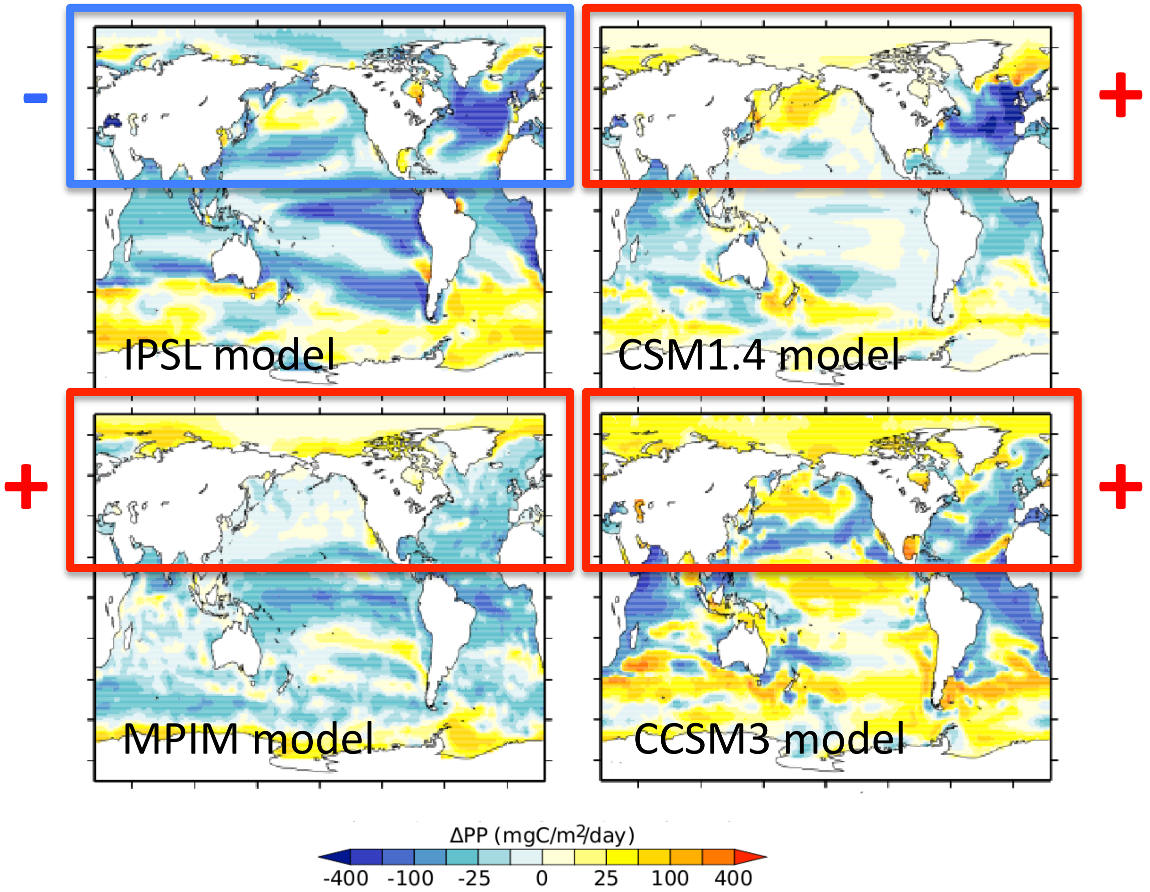
Ice core from McMurdo Sound (Antarctica, Nov 2009)

« Brine physics shape the location and seasonality of micro-algal developments in sea ice. »

Under the ice – Bellingshausen Sea (Antarctica) – October 2007

Simulated biological production diverges among AR4 models in the Arctic Ocean

2090-2099
compared to
1860-1869



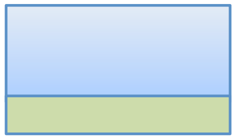
Steinacher et al., 2010

Previous investigations prescribe...

The location of communities

Skeletal layer

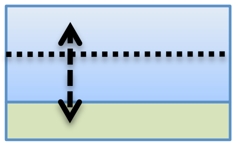
Lavoie et al., 2005
Jin et al., 2006



h_{skel}

Biologically-active layer

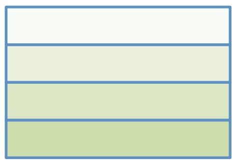
Tedesco et al., 2010



e = 5%

Multi-layer

Arrigo et al., 1993



Δh

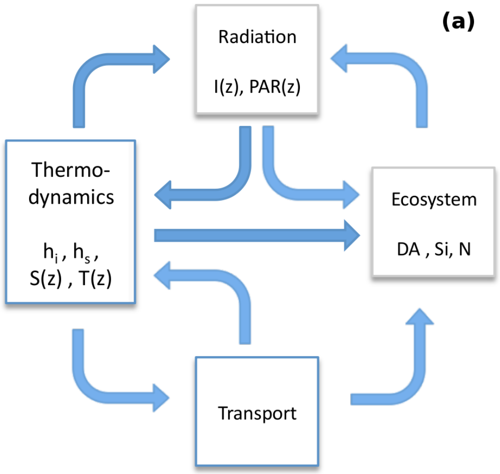
The nutrient fluxes

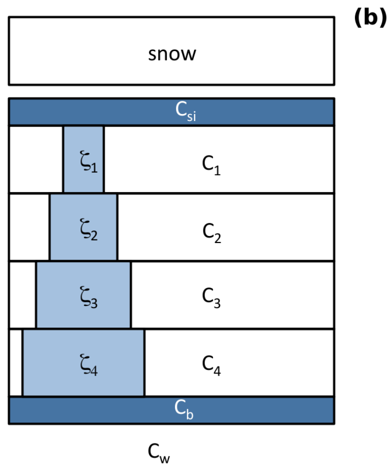
$$\frac{\partial C_N}{\partial t} = D \frac{\partial^2 C_N}{\partial z^2}$$

However

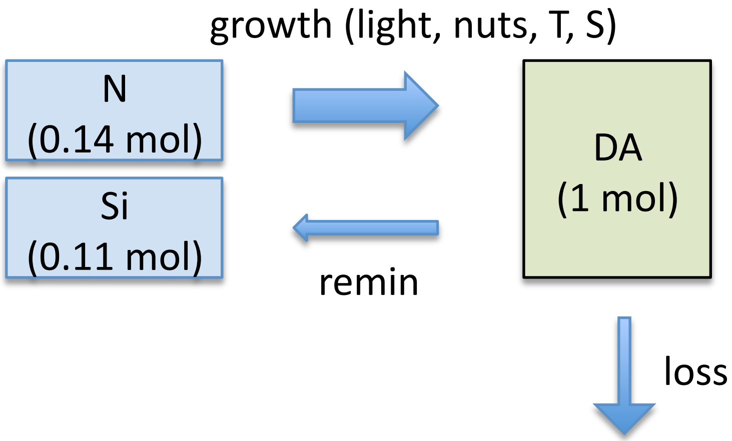
- ✓ communities emerge at any depth
- ✓ nutrient dynamics are more than molecular diffusion: they depend on brine dynamics (*Vancoppenolle et al.*, 2010)
- ✓ nutrient uptake due to snow ice and basal ice formation is ignored

A multi-layer brine and microalgae 1D model





Biogeochemical component



- ✓ 1D thermodynamic sea ice model
- ✓ Brine dynamics + basal ice + snow ice
- ✓ Biogeochemical dynamics
- ✓ **Multi-layer**
- ✓ **Nutrient transport is governed by brine dynamics**

Nutrient budget

$$\frac{\partial [e\zeta_N]}{\partial t} = S_N^{\beta} + \frac{\partial}{\partial z}\left[eD \frac{\partial \zeta_N}{\partial z} \right] - Q \frac{\partial \zeta_N}{\partial z}$$

bio — gravity drainage — flushing

Ice-ocean nutrient flux

$$F_n = F_n^{bd} + F_n^{b,+} + F_n^{si} + F_n^{b,-} + F^{su,-}$$

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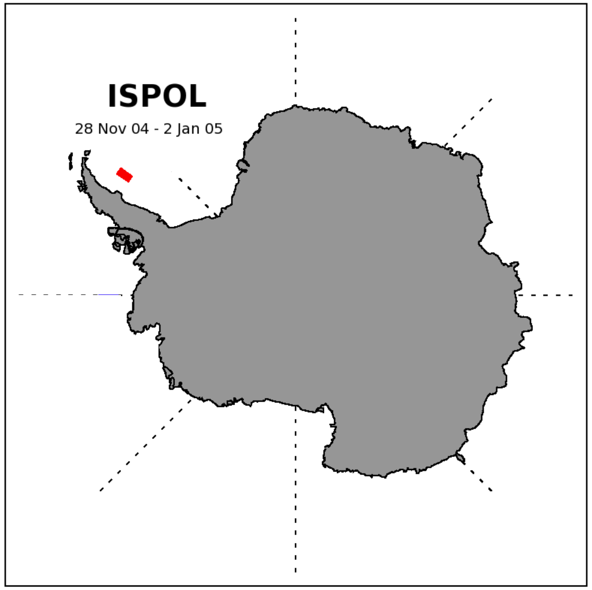
A one-dimensional multi-layer model with brine-ecosystem interactions

Antarctic pack ice setup

- ✓ Location of Ice Station Polarstern
- ✓ Data cover one month (28/11/04-2/01/05)
- ✓ Runs cover one year (15/02/04- 14/02/05)

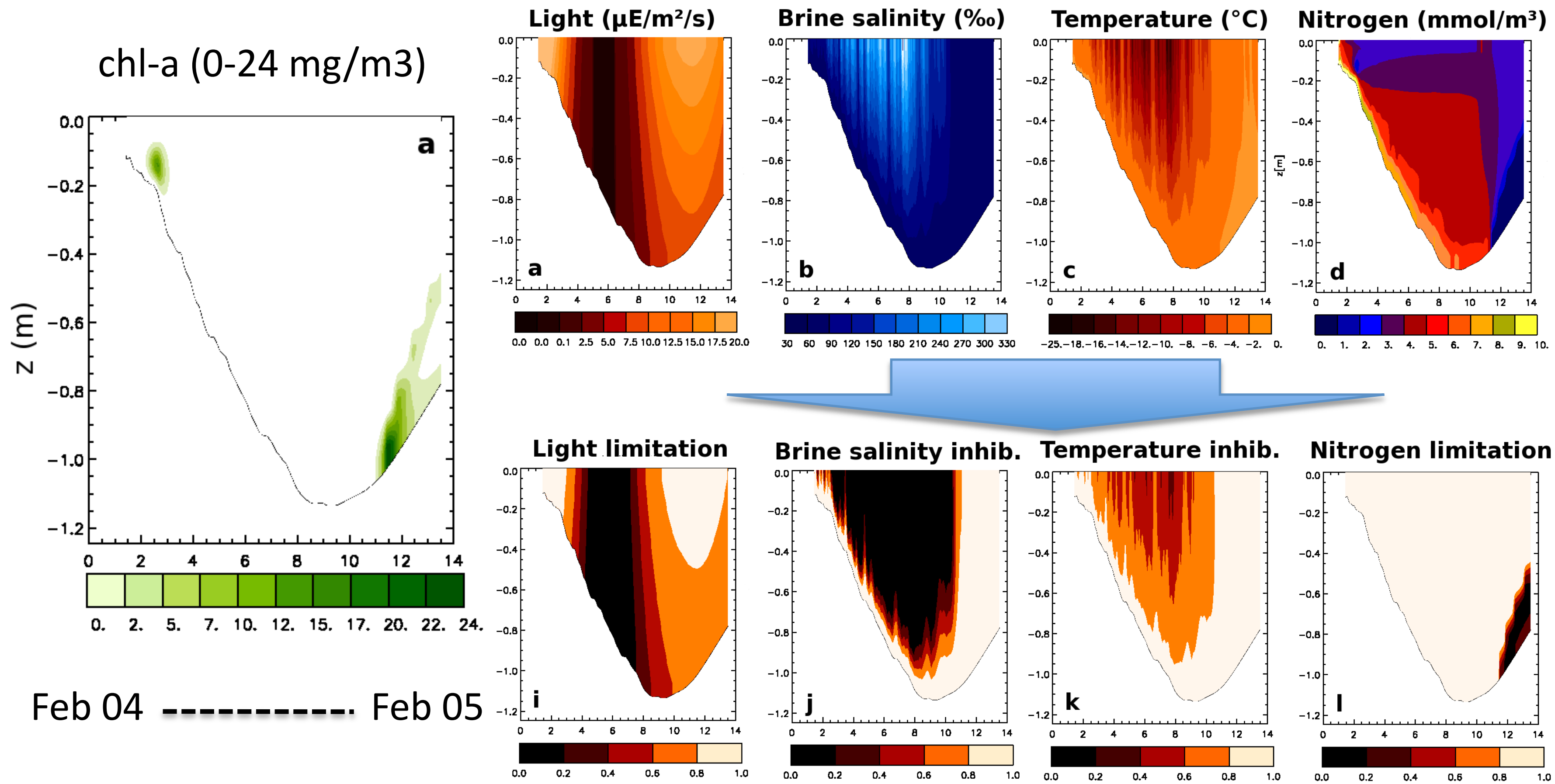


- ✓ Forcing
  - atmospheric heat fluxes from NCEP
  - ocean heat flux = 12 W/m^2
  - snowfall rate = 1 mm/day
- ✓ Ice physics initialization (15/02/04)
  - thin ice characteristics
  - h_i=10 cm S=13psu
- ✓ Initial and boundary conditions for biogeochemistry from best available observations

Var.	*Units*	C_n^{ini}	C_n^w
DA	mmol.m^{-3}	0.01	0.05
N	mmol.m^{-3}	6.725	26.9
Si	mmol.m^{-3}	12.81	51.25

- ✓ Time step = 1h
- ✓ Parameters are calibrated by tuning obs chl

Ice algae communities are spontaneously simulated at the good location



Concentration of chlorophyll-a in mg = 0.5 concentration of DA in mmol

UCL

how realistic?

Model was calibrated for chl-a to fit observations

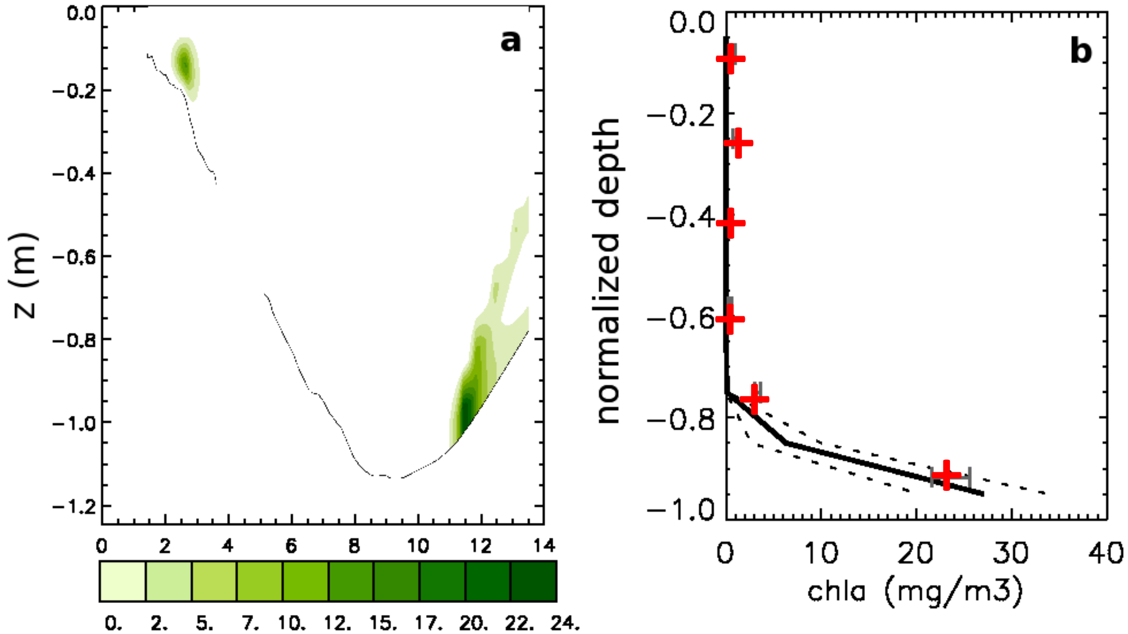
Yearly time series

Chl-a (0-24 mg/m3)

Mean vert. prof. (Dec)

Chla (0-40 mg/m3)

depth (0-1.2m)



Feb 04 ---------- Feb 05

Concentration of chlorophyll-a in mg = 0.5 concentration of DA in mmol

Solid lines = MODEL / Horizontal grey lines = OBS

UCL

Model calibration

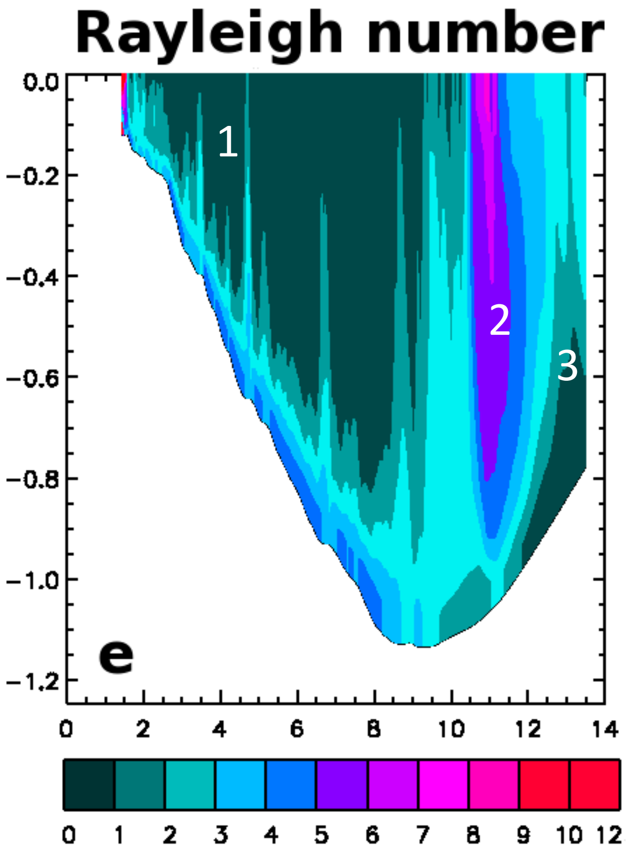
S_p = Standardized response of summer maximum biomass

10 % perturbations

- ✓ μ_m, λ, E_k, r_c^N
  Main physiological params: $|S_p| > 1$
- ✓ Intermediate params: $0.1 < |S_p| < 1$
- ✓ Bio-optical params: $|S_p| < 0.01$

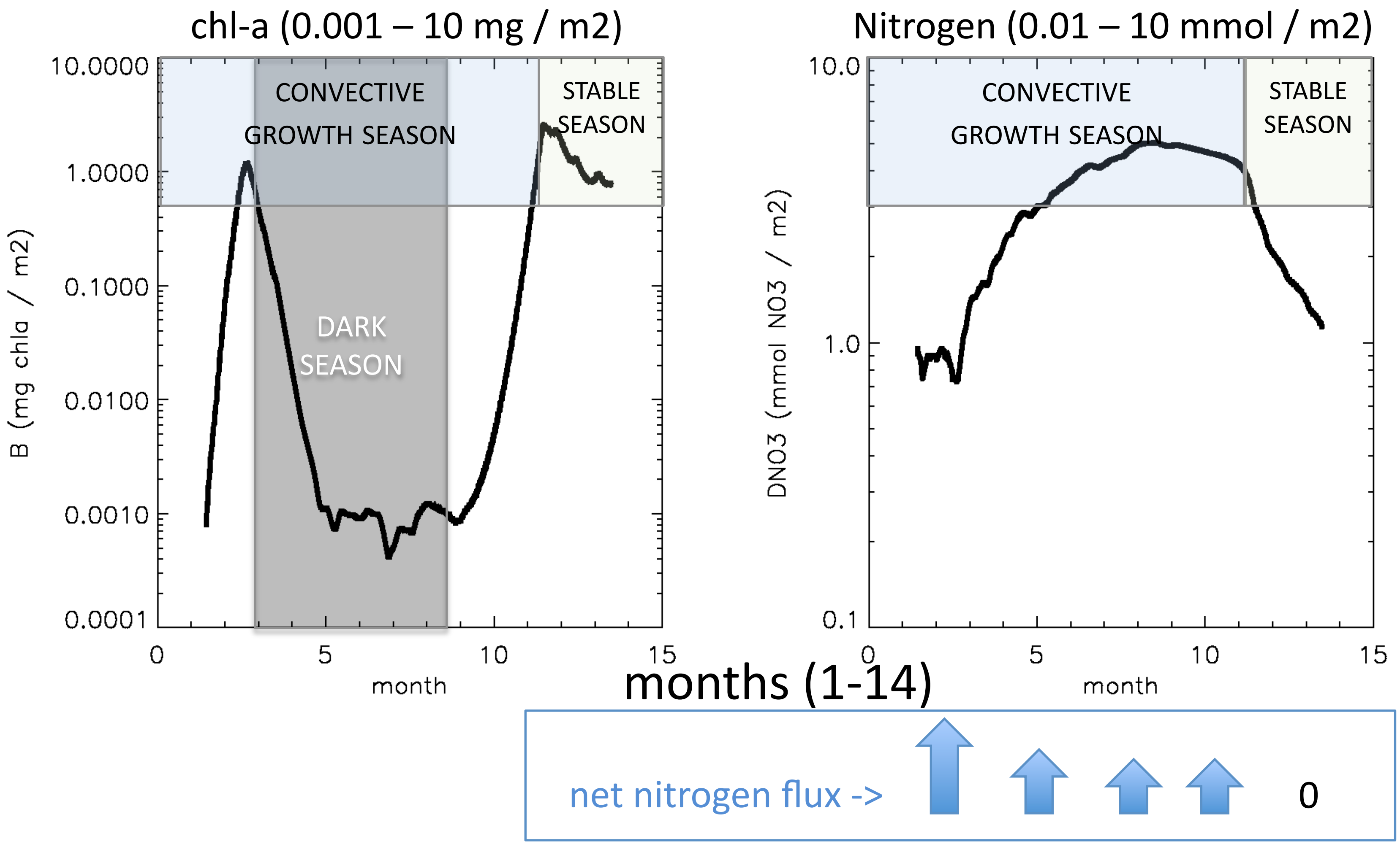
μ_m	2.2	Maximum growth rate (s^{-1})
λ	-1.9	Decay rate (s^{-1})
E_k	-1.8	Light saturation (µE/m^2/s)
r_C^N	-0.94	N-C ratio in diatoms (mol/mol)
R_G	-0.25	Temperature response param (°C).
w_σ	0.14	Salinity response param (‰).
f_R	0.10	Remineralization param.
k_N	-0.01	Half-saturation for N uptake (mmol)
r_C^{chl-a}	1.00	Chl-a – C ratio (g/mol)
a^*	-0.003	Specific attenuation coeff (µE/m^2/s/mg)
f_{det}	-5.0×10^{-4}	Fraction of detrital organic matter

Brine stability rules nutrient supply



- Ra is a function of porosity and stability (*Notz and Worster*, 2008)
- Describes intensity of vertical mixing in the model
- 3 periods
  1. Winter: convection near the base
  2. Spring: convection everywhere
  3. Summer, stable network

Nutrient supply governs algal growth



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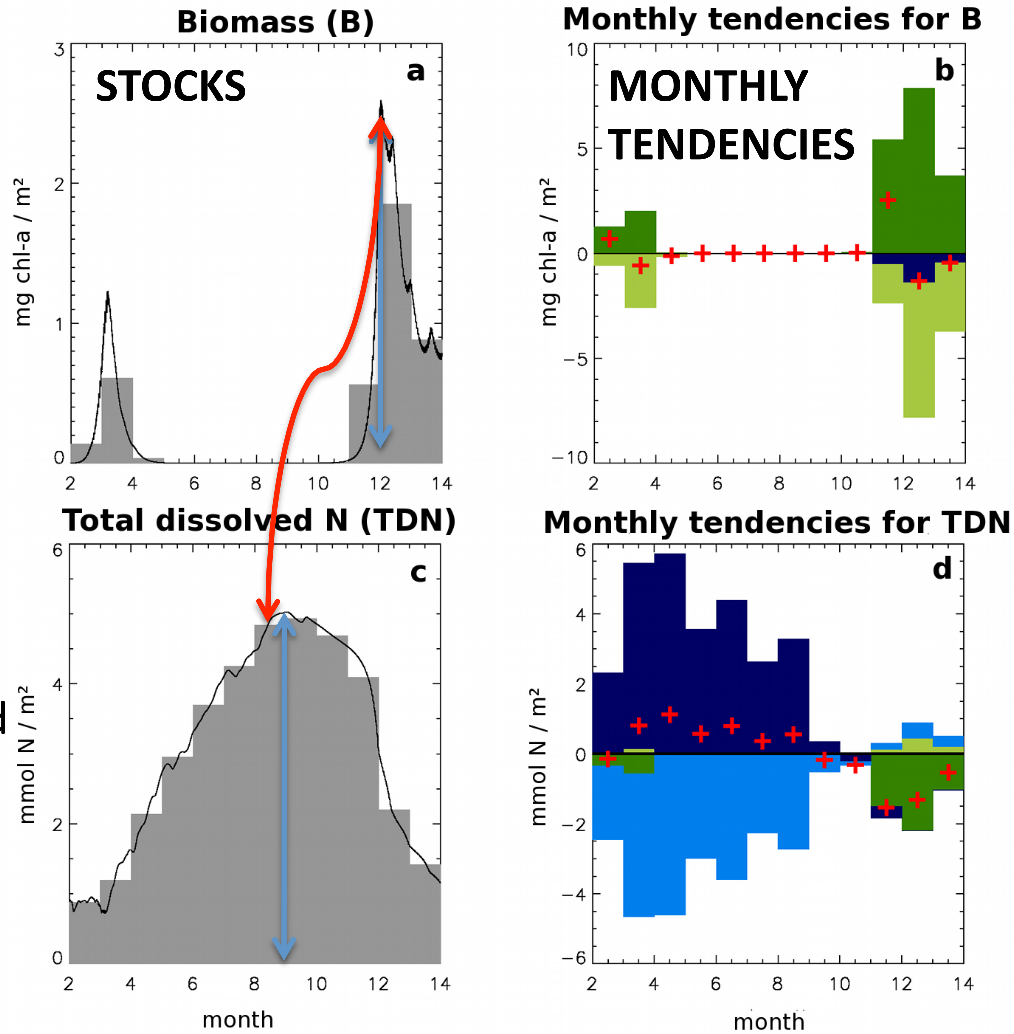
Introduction | Methods | **Results** | Conclusions

A winter nutrient control on summer biomass

Vertically integrated chl-a

Vertically integrated nitrogen



biogeochemical processes

physical processes

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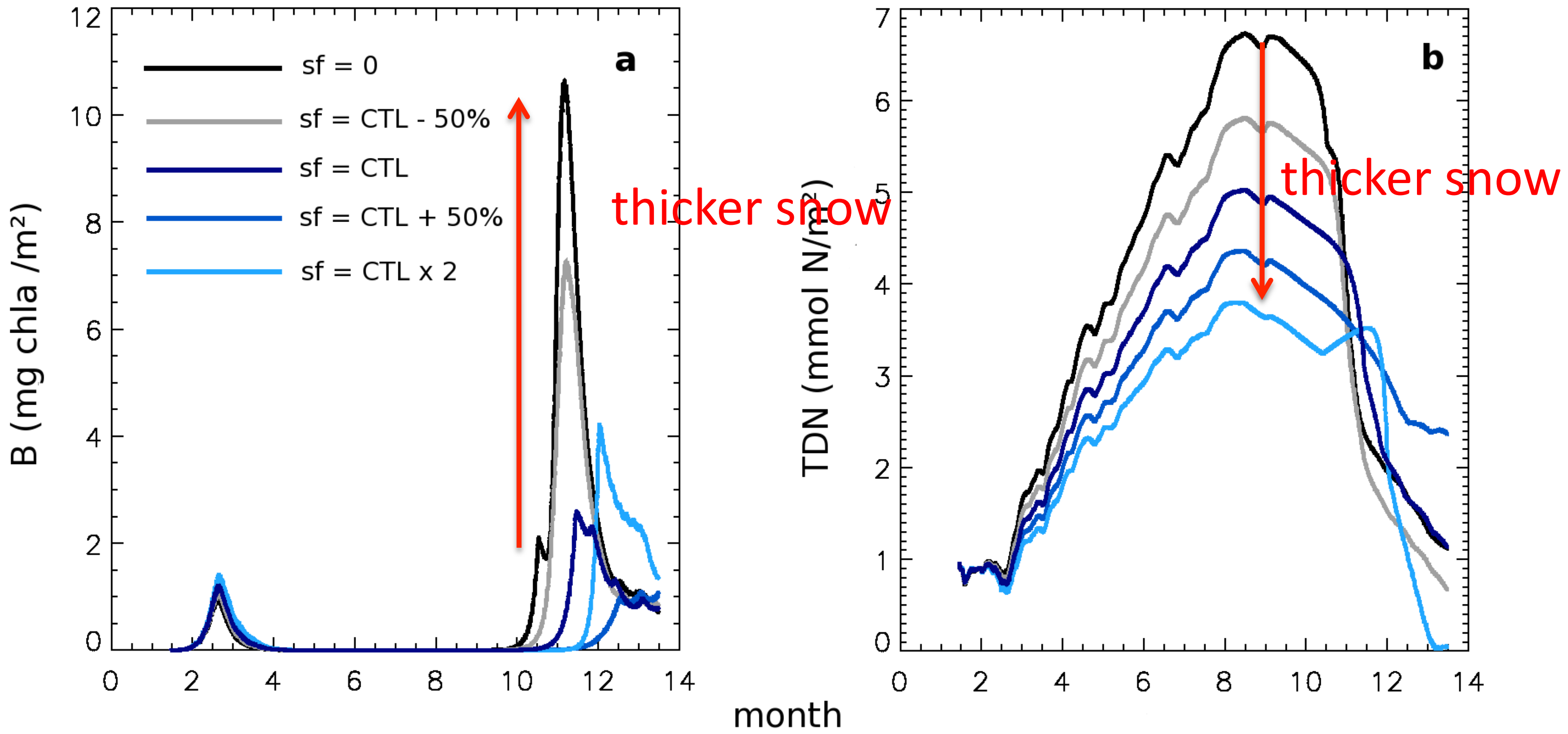
Control of the winter nutrient uptake by snow depth



Summary and conclusions

« Brine dynamics shape the location and seasonality of micro-algal developments in sea ice. »

- ✓ Model spontaneously generates communities at the ice base or near the surface
- ✓ After calibration, chl-a is well simulated

- ✓ Brine stability rules nutrient supply
- ✓ Nutrient supply rules rules nutrient stocks and algal growth rates
- ✓ There is a winter control of nutrient stock on summer biomass due to the seasonality of brine dynamics
- ✓ This mechanism partly explains why there is more biomass under thin snow