Model-based analysis of sea ice algal photophysiology and export processes

Antoine Haddon (University of Victoria)
Nadja Steiner (DFO,CCCma), Adam Monahan (University of Victoria)
Eva Leu (Akvaplan-Niva, Norway), CJ Mundy (University of Manitoba)

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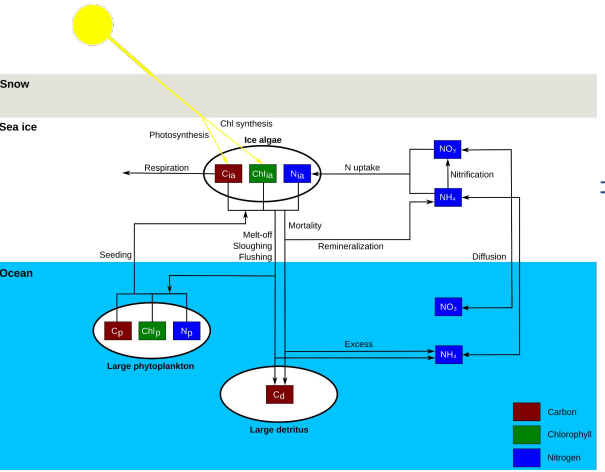
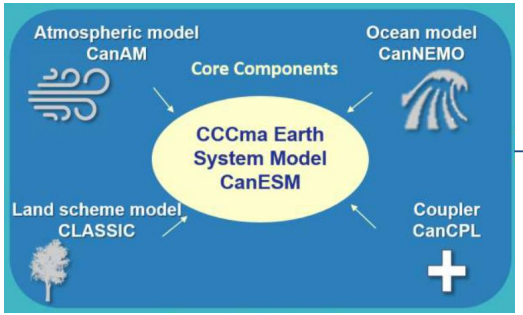
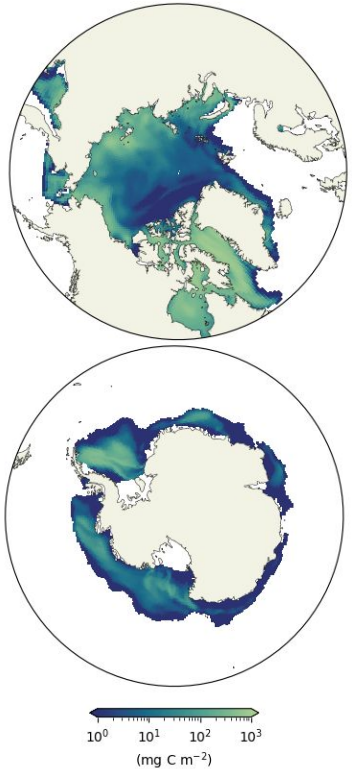
Canadian Sea Ice Biogeochemistry (CSIB) model



Canadian Earth System Model



1D sea ice + ocean model

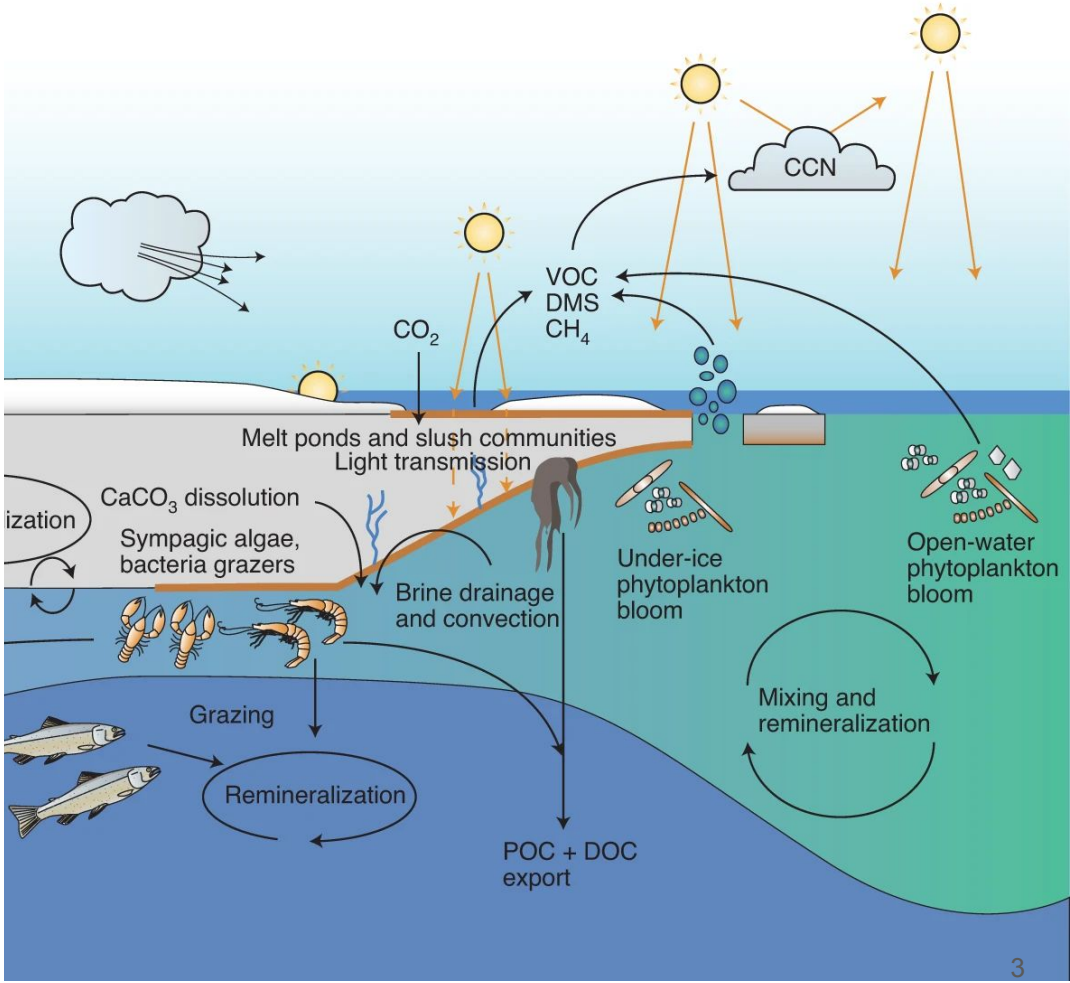


How to evaluate large scale simulations of our sea ice biogeochemistry model?

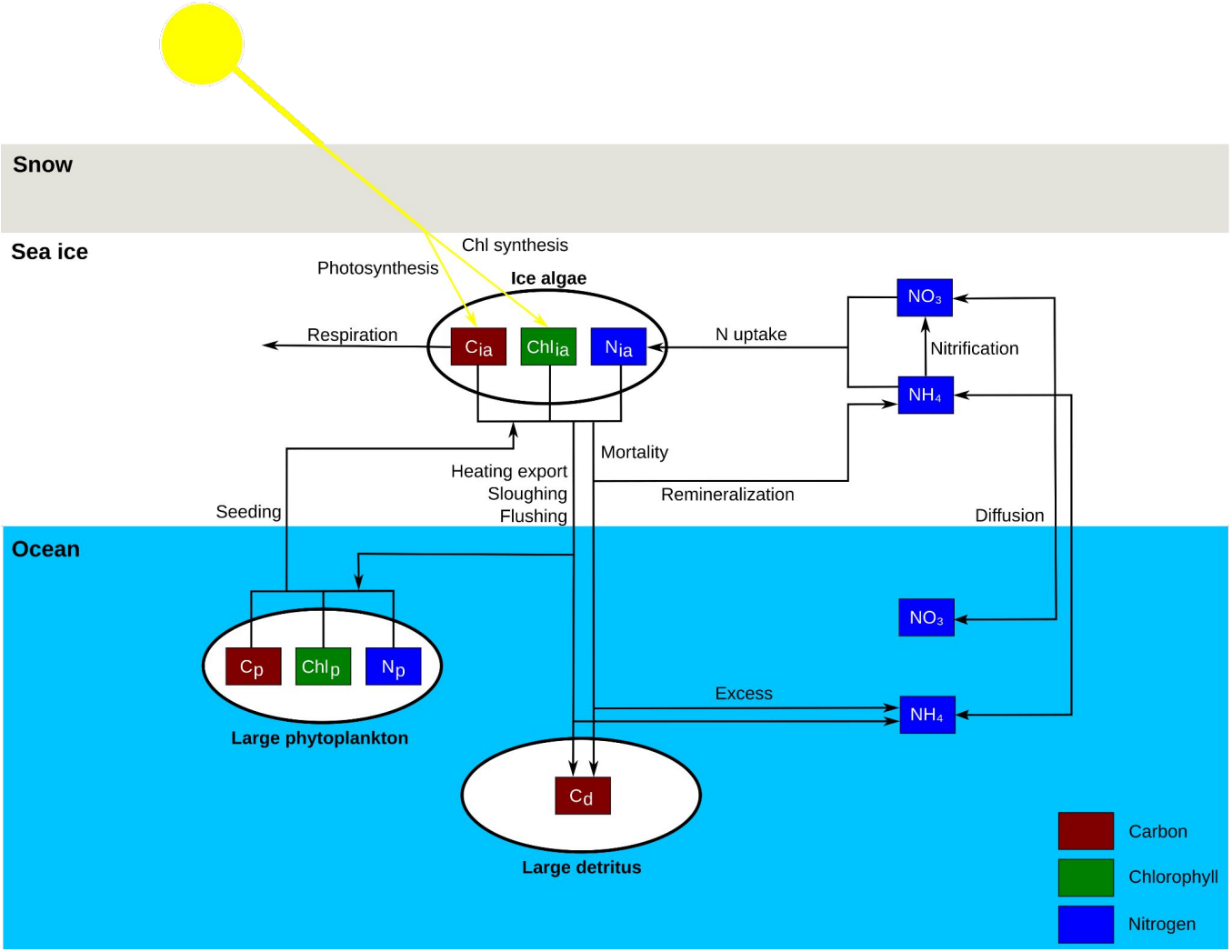
- No remote sensing under ice ➡ comparison with direct observations
- Focus on qualitative features of model & process based analysis

How do environmental conditions impact sea ice algal blooms?

1. Sea ice and snow, light and ice algal photophysiology
2. Turbulent nutrient input to sea ice and N ice algal uptake
3. Sea ice melt and export processes



Lannuzel et al. (2020) *The future of Arctic sea-ice biogeochemistry and ice-associated ecosystems*



Canadian Sea Ice Biogeochemistry (CSIB)

Bottom ice

- Ice algal carbon, chlorophyll (Chl) and nitrogen
- Inorganic nitrogen (NO_3 & NH_4)

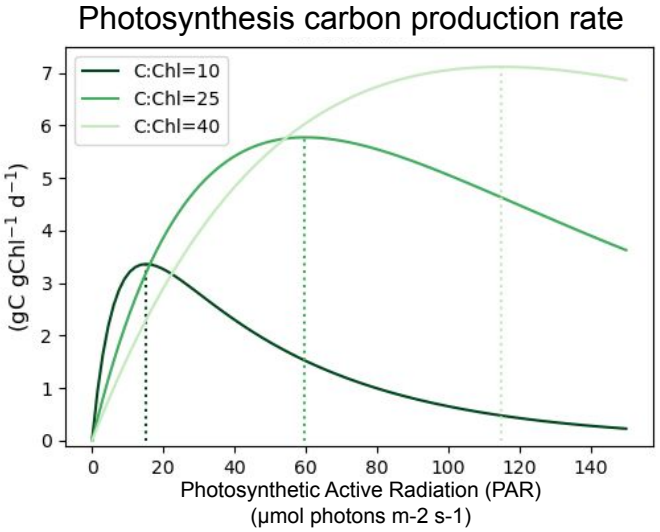
coupled with

Canadian Ocean Ecosystem (CanOE)

- 2 phytoplankton
- 2 zooplankton
- 2 detritus
- C chemistry
- Nutrients: N & Fe

(not all ocean biogeochemistry shown)

Modelling photo-acclimation



- Variable C:Chl
  - Chl synthesis dependent on PAR
- Variable production-irradiance relation
  - C:Chl indicative of photo-acclimation status
  - Light affinity (initial slope) inversely proportional to C:Chl

$$\alpha = \alpha_{ref} \frac{Chl_{ia}}{C_{ia}}$$

  - Max production rate proportional to C:Chl

$$P_{\max} = P_{ref} \frac{C_{ia}}{Chl_{ia}}$$

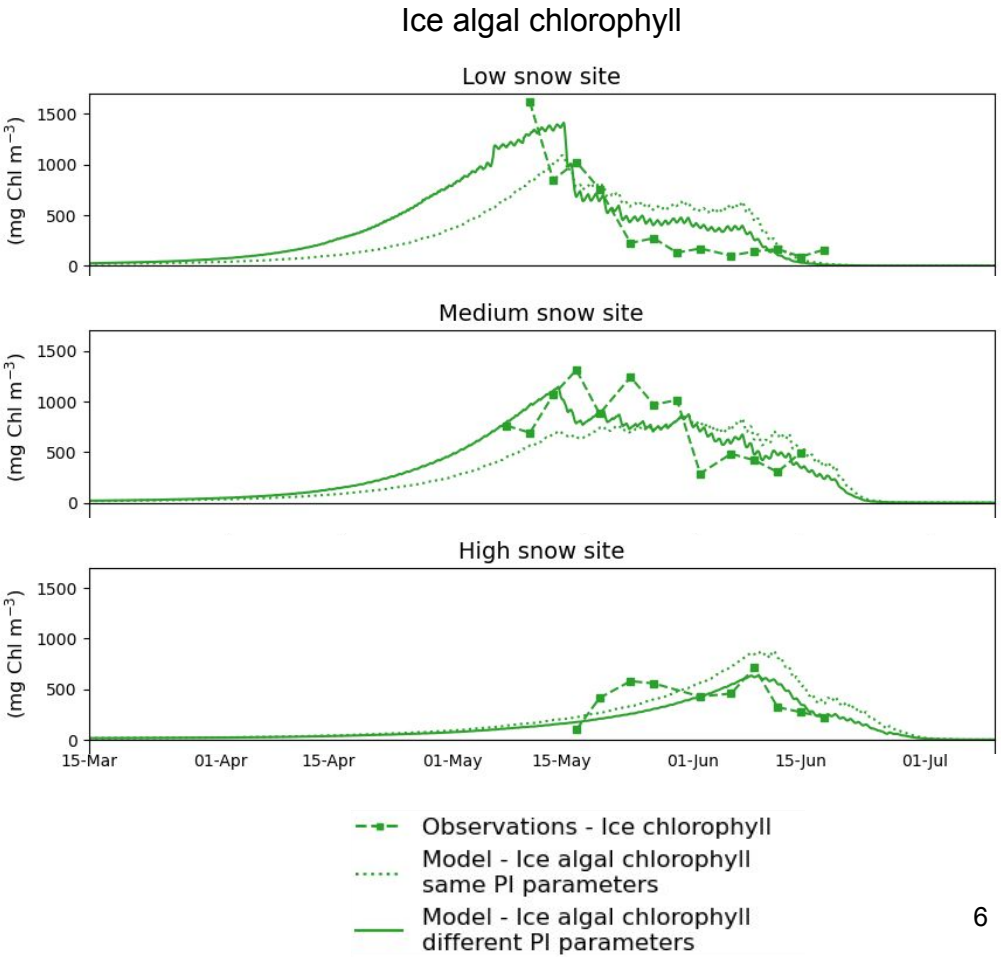
  - Photoinhibition inversely proportional to C:Chl
    - ➢ Stronger photoinhibition when acclimated to low light

Modeled ice algal blooms

- Observations:
  - ➢ May-June 2010
  - ➢ Resolute passage, Canadian Arctic Archipelago
  - ➢ Landfast ice

- 3 snow depth sites
  - ➢ Differences in timing and magnitude of ice blooms

- Better fit with different photophysiology parameters for each sites
  - ➢ Strong differences in photophysiology between sites
  - ➢ Elements of photo-acclimation not included in model



Nitrogen dynamics

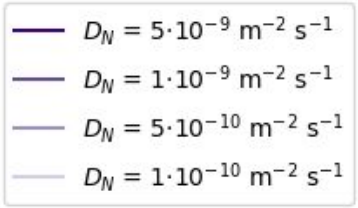
- N input to sea ice : diffusion at sea-ocean interface

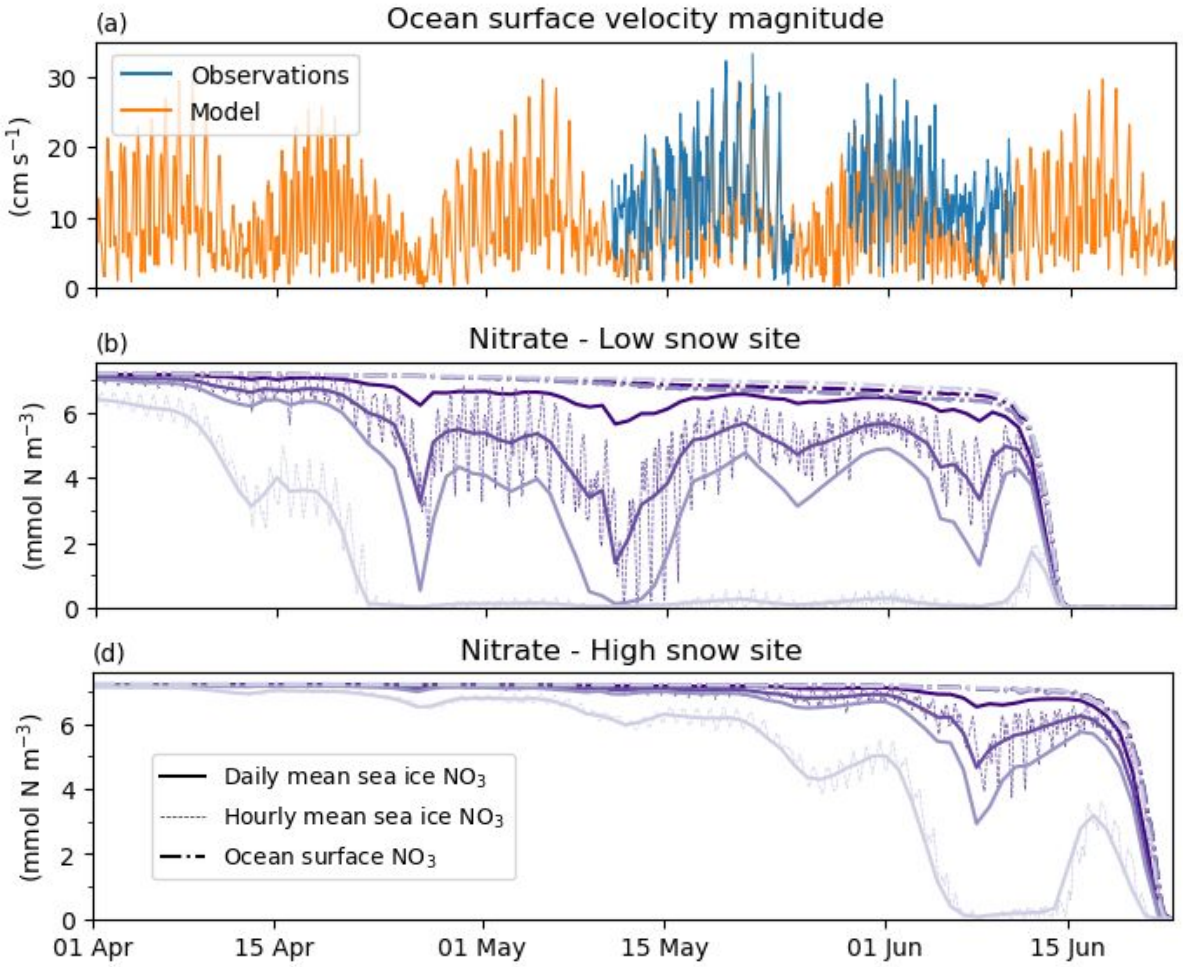
$$F_D = \frac{D_N}{h_\nu}\left(N^{ice} - N^{sw}\right)$$

h_ν : molecular sublayer thickness, depends on the friction velocity

➢ Impacts of turbulence and tides

- Uncertainty in diffusion parameter

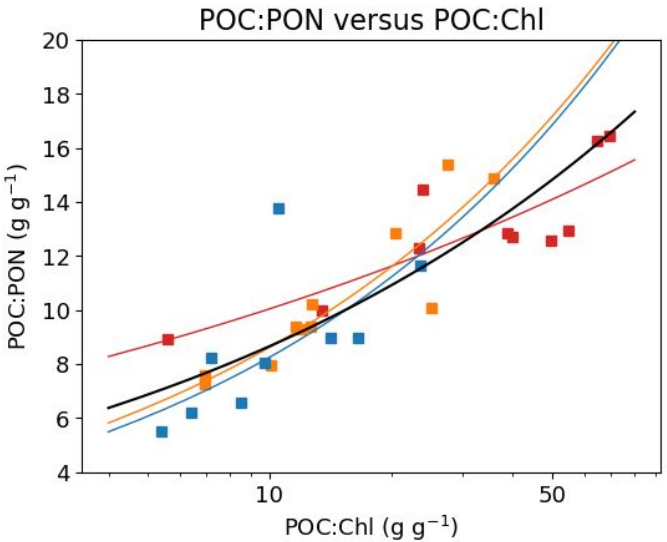


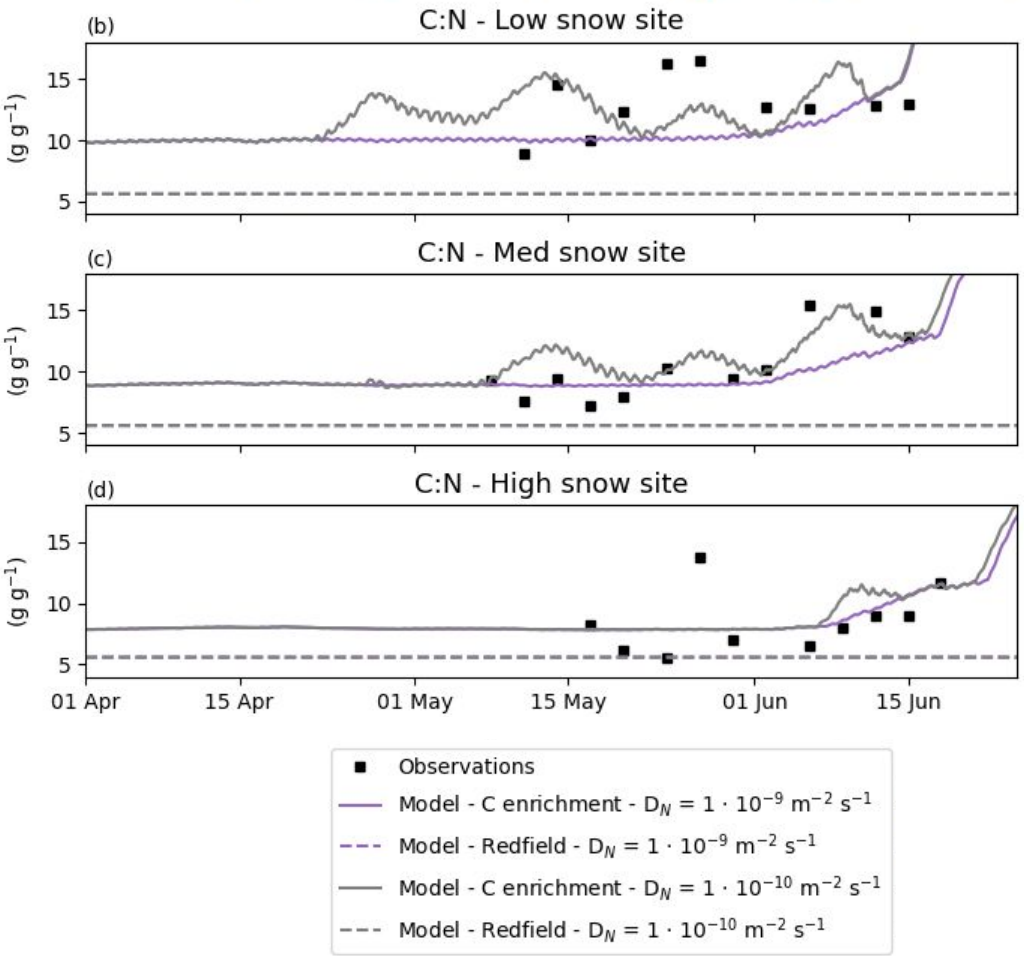


Ice algal N uptake

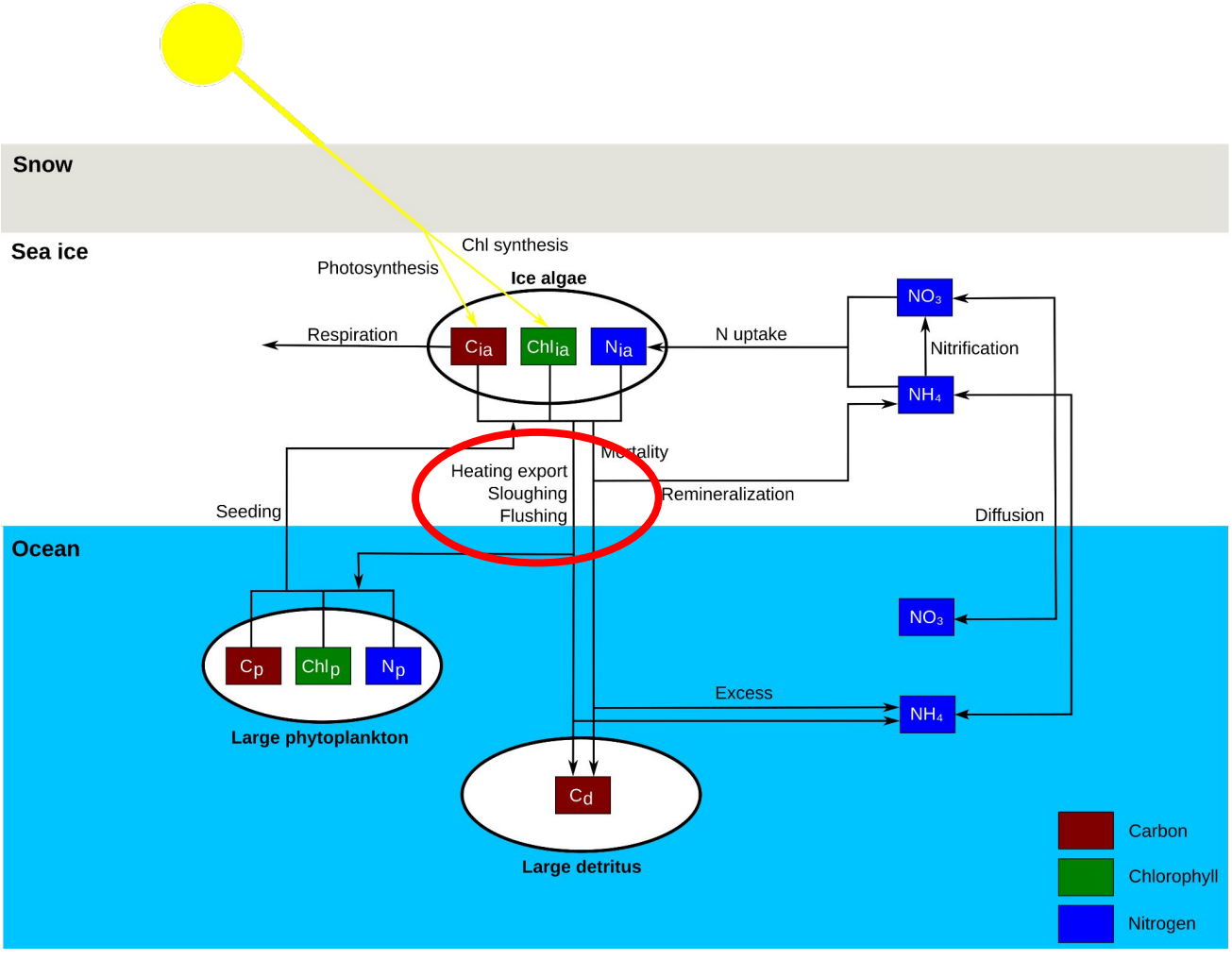
- Maintain ice algal C:N at target ratio
  - Redfield ratio C:N = 5.6 gC gN^{-1}
- Ice algae: high lipid content
  - High C:N without N limitation
  - C enrichment parameterization

    C:N = f(C:Chl)





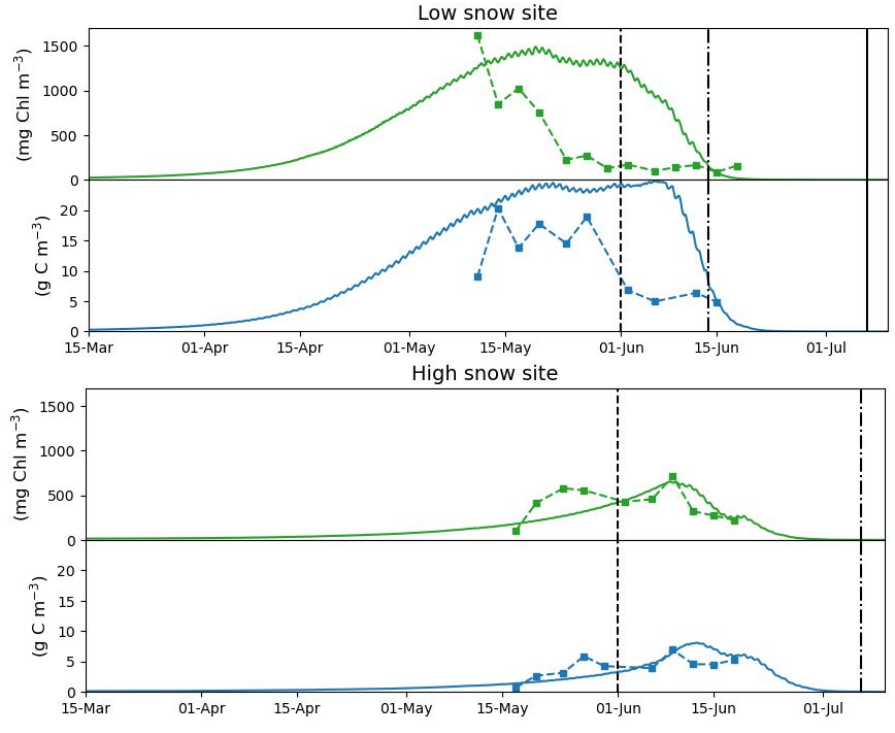
Export processes

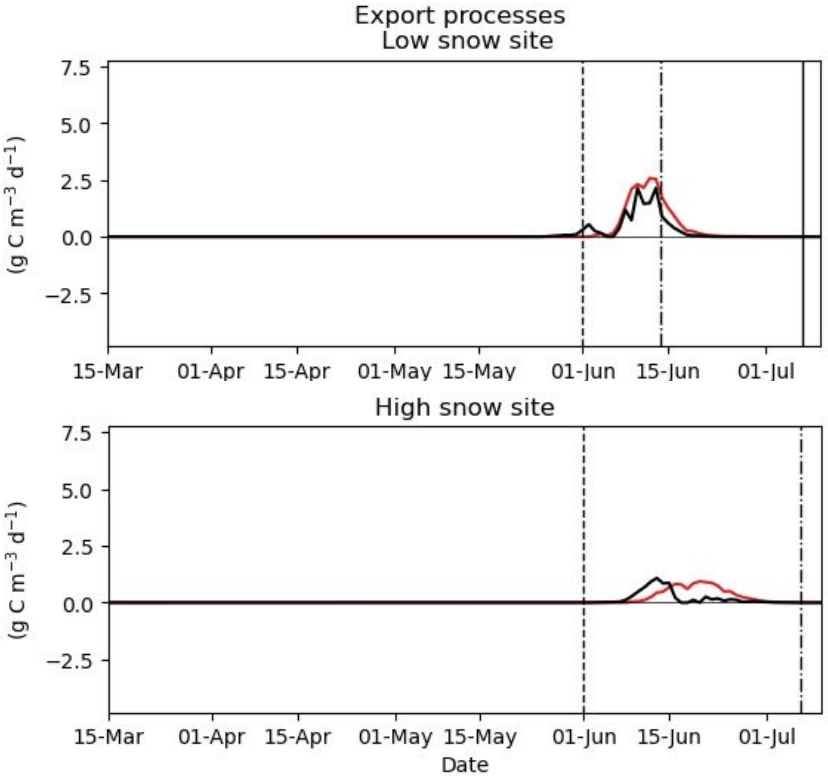


- Flushing
  - Snow and ice surface melting + melt pond drainage
- Sloughing
  - Ocean heat flux melting bottom ice layer

➢ Parametrized with sea ice melt rate

Flushing + Sloughing



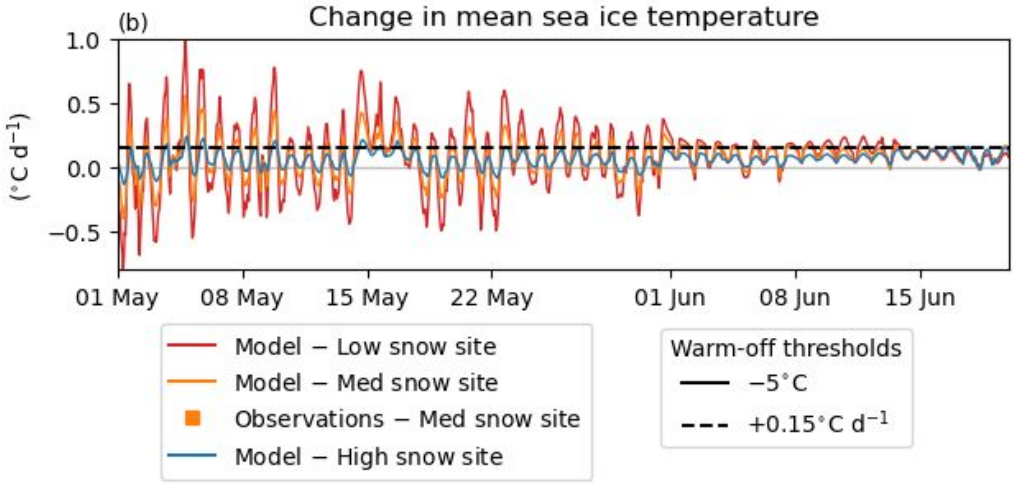


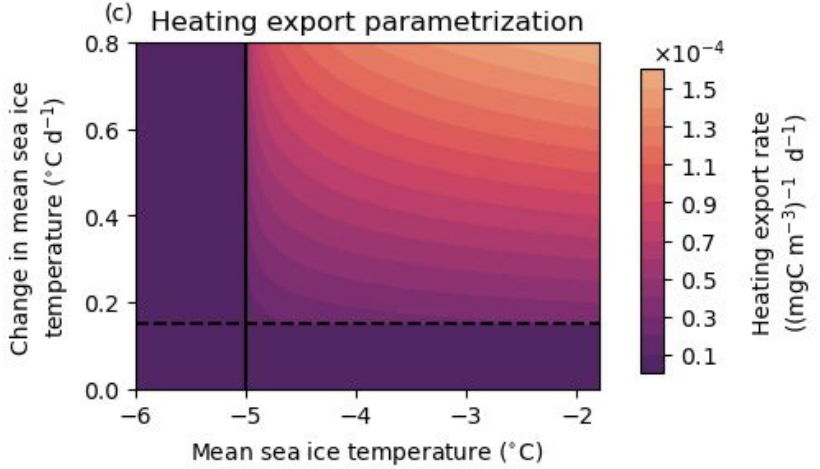
Model - Snow melt onset
Model - Snow melt end
Model - Sea ice break-up

Heating export

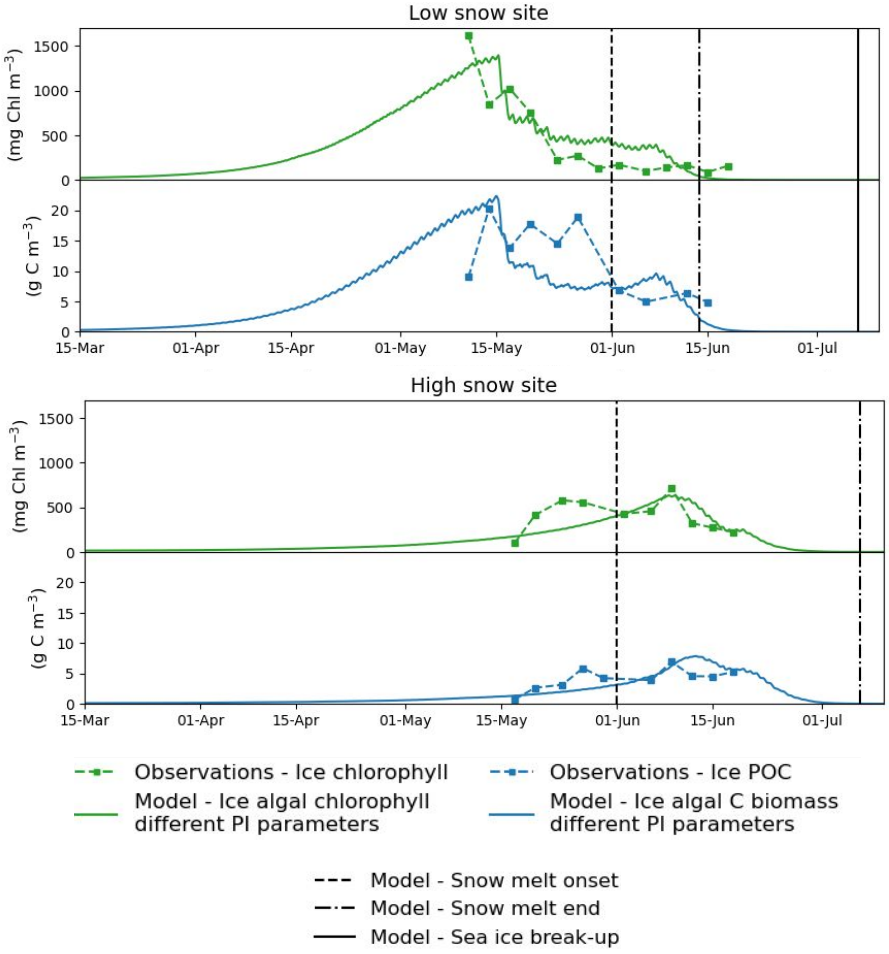
- Export due to sea ice warming
  - ➢ Brine gravity drainage
  - ➢ Increase of brine volume
    - ○ Detachment of ice algae from sea ice
    - ○ Increased diffusive exchange with ocean

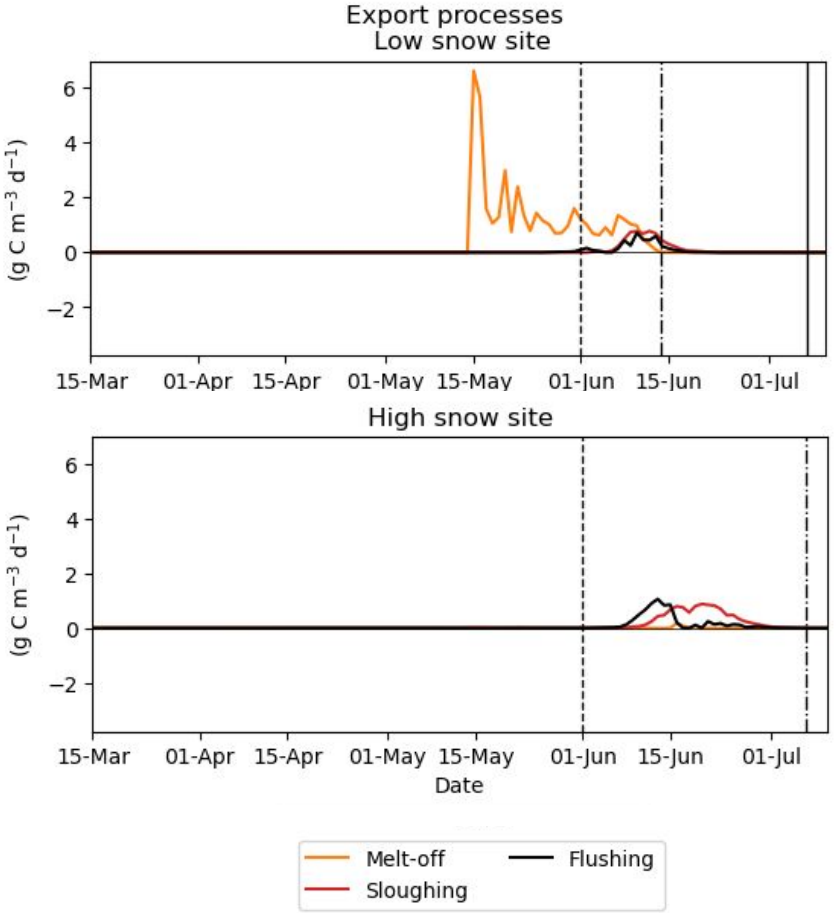
- Only active when sea ice temperature > -5℃ when brine channels connected



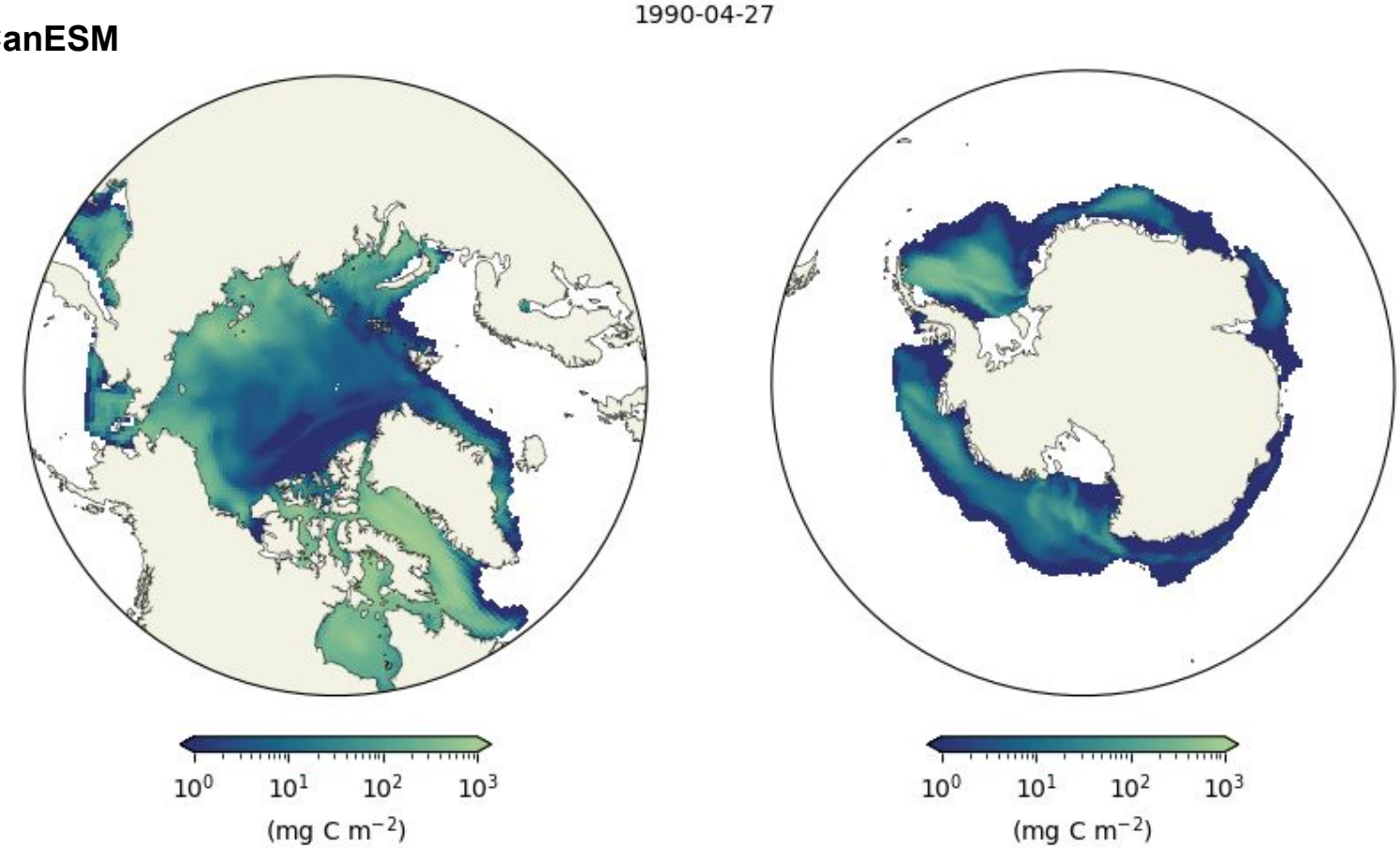


Flushing + Sloughing + Melt-off





CSIB in CanESM



Thank you for your attention!

ahaddon@uvic.ca