Impacts of sea ice on the iron cycle and marine ecosystems

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with

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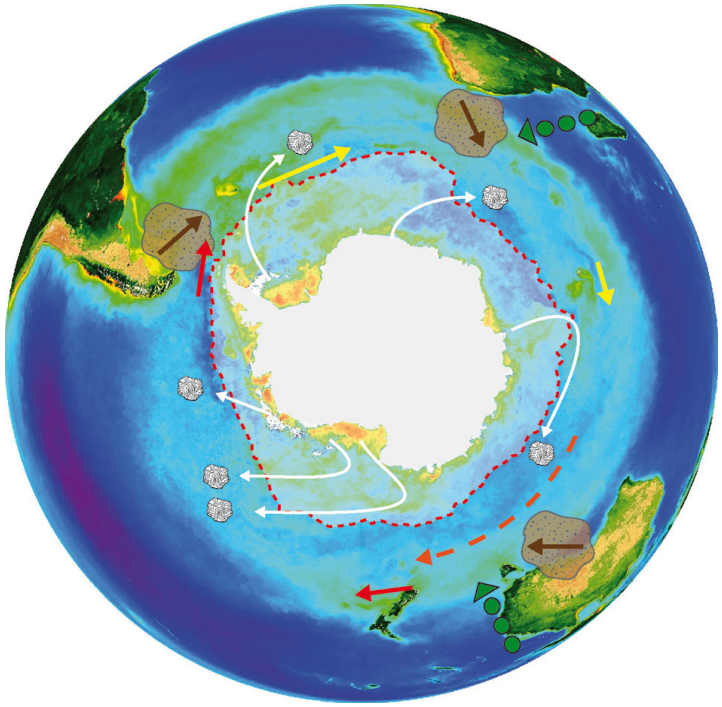
Motivation

- Iron (Fe) is an essential nutrient for phytoplankton growth
- Growing evidence for sea ice transport of iron (Arctic and Antarctic)
- Sea ice Fe concentrations can be two orders of magnitude higher than seawater (Tovar-Sanchez et al., 2010)
- Fe from sea ice fuels Bering ice-edge blooms (Aguilar-Islas et al., 2008)



(from Boyd and Ellwood, 2010)

Dust deposition

Lateral transport of iron-rich sediments

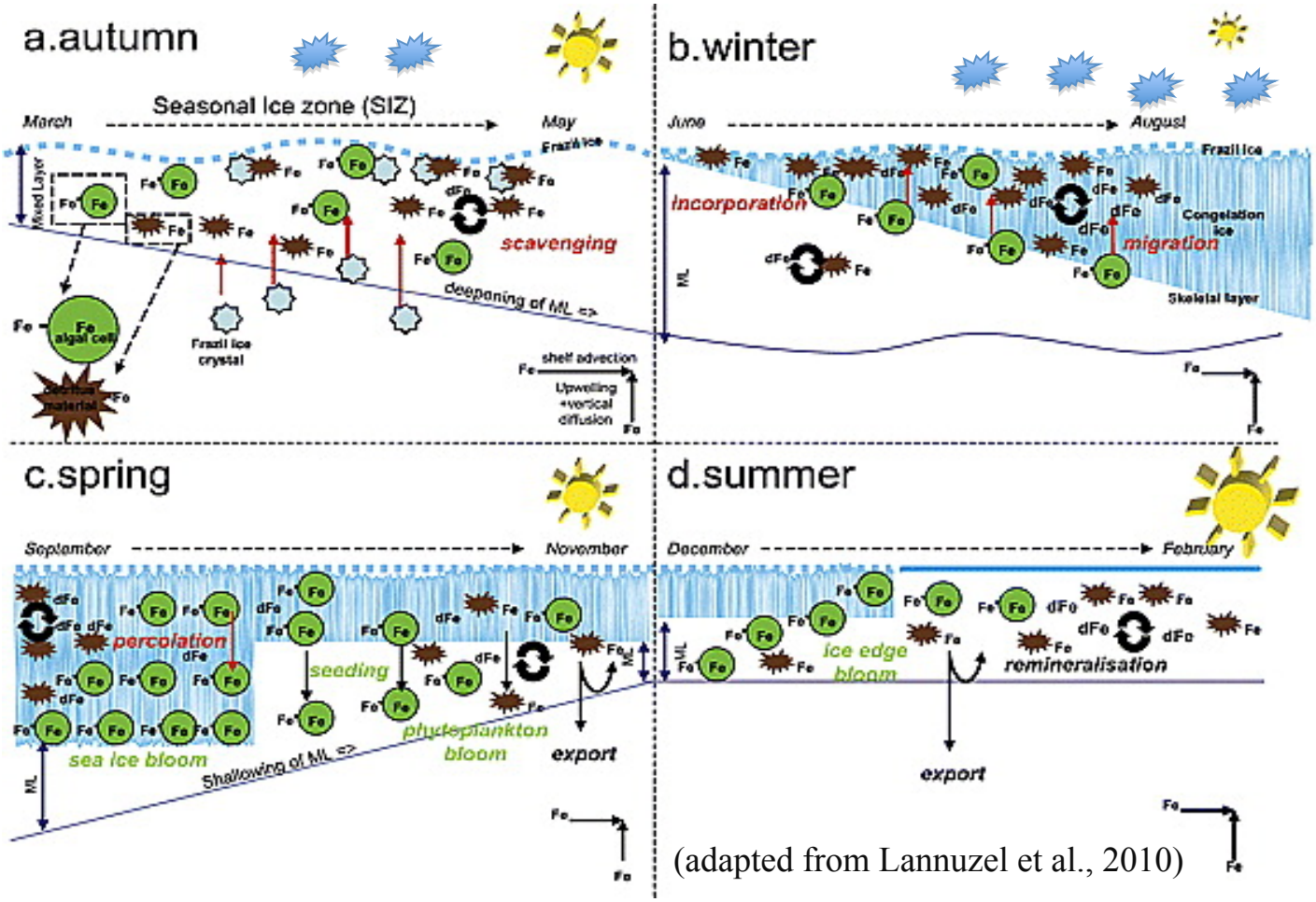
Eddy shedding/sediment entrainment

Bathymetric interactions

Iceberg drift and melt

Seasonal ice-melt

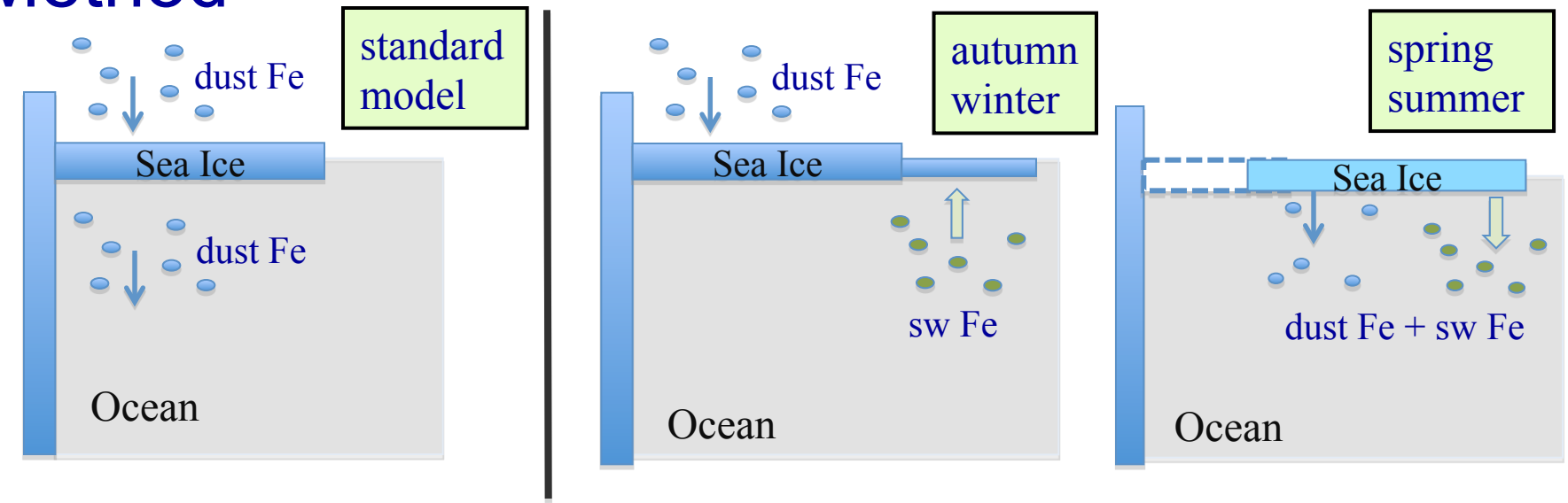
Impacts of sea ice on the iron cycle

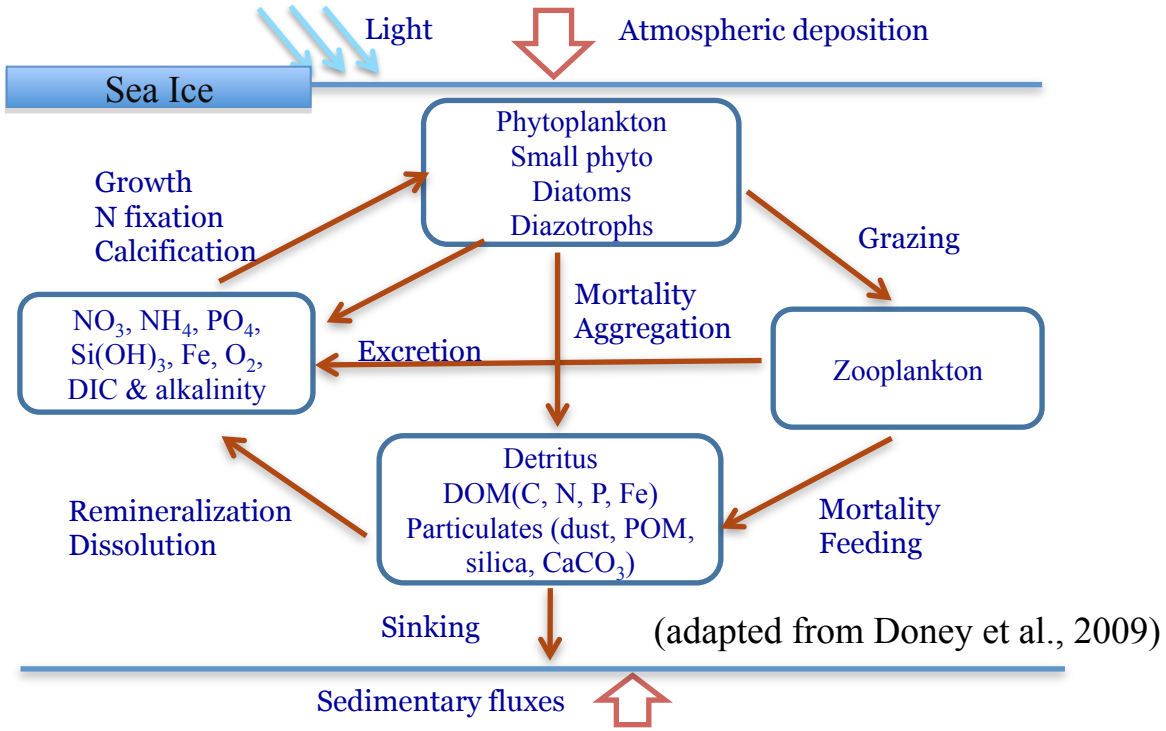


(adapted from Lannuzel et al., 2010)

- Iron is captured from atmospheric deposition and during ice formation, transported by ice, and released during ice melt.
- How does sea-ice iron transport affect marine ecosystems?

Method



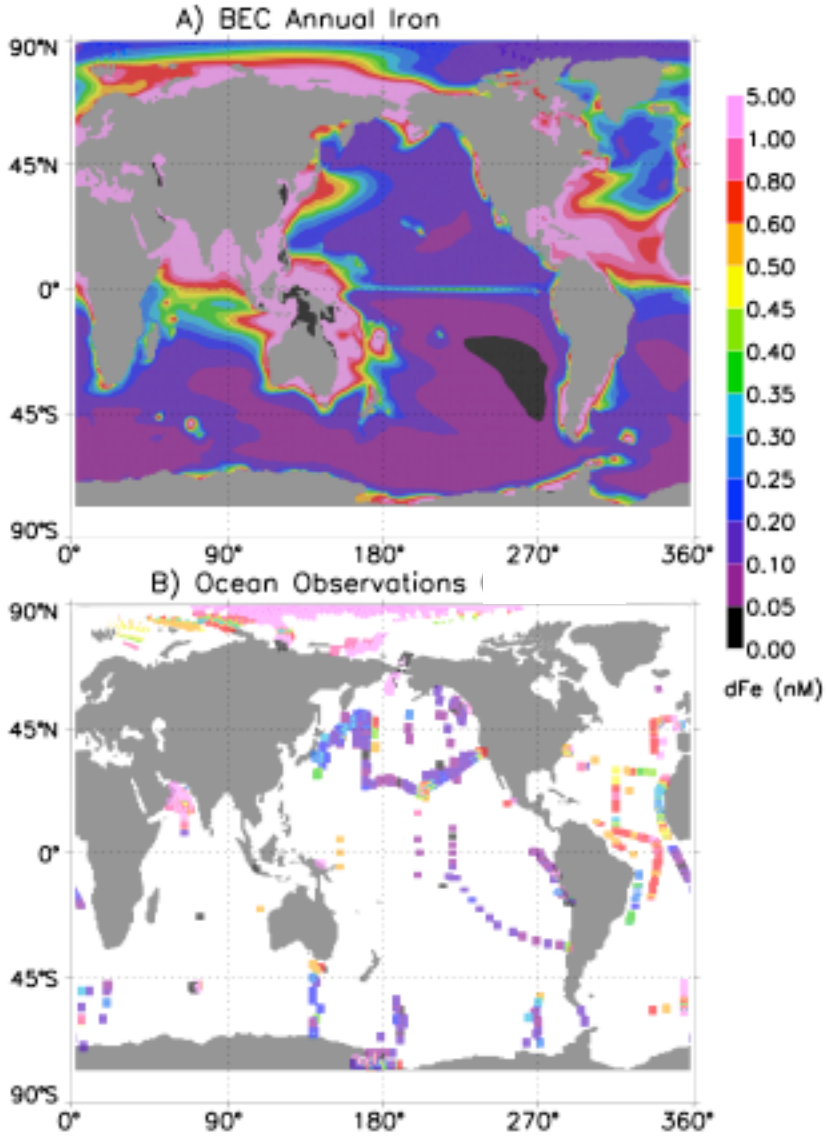


(adapted from Doney et al., 2009)

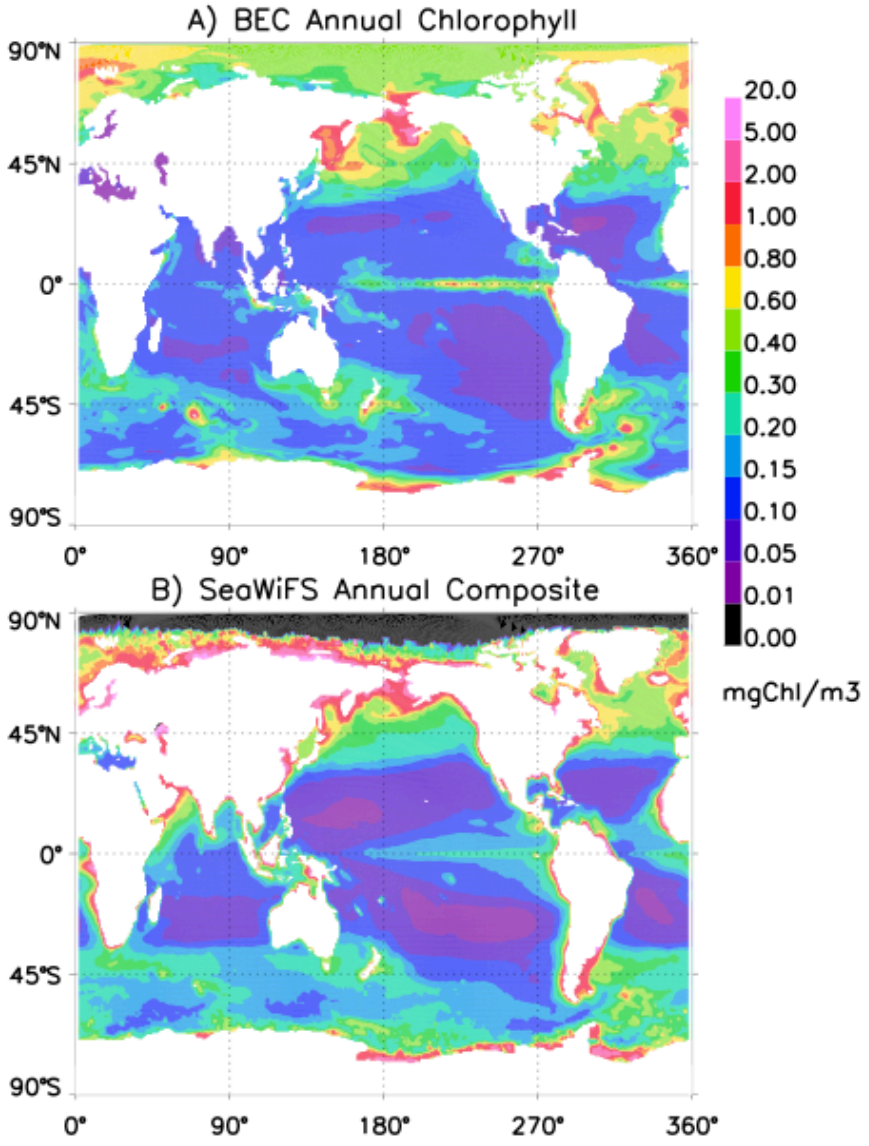
- NCAR CESM1, ~1 degree resolution, GIAF-eco
- Sedimentary source of dissolved iron by Moore and Braucher (2008).
- Atmospheric iron deposition from Mahowald et al.(2008), includes combustion sources and dust.

Model vs. observation

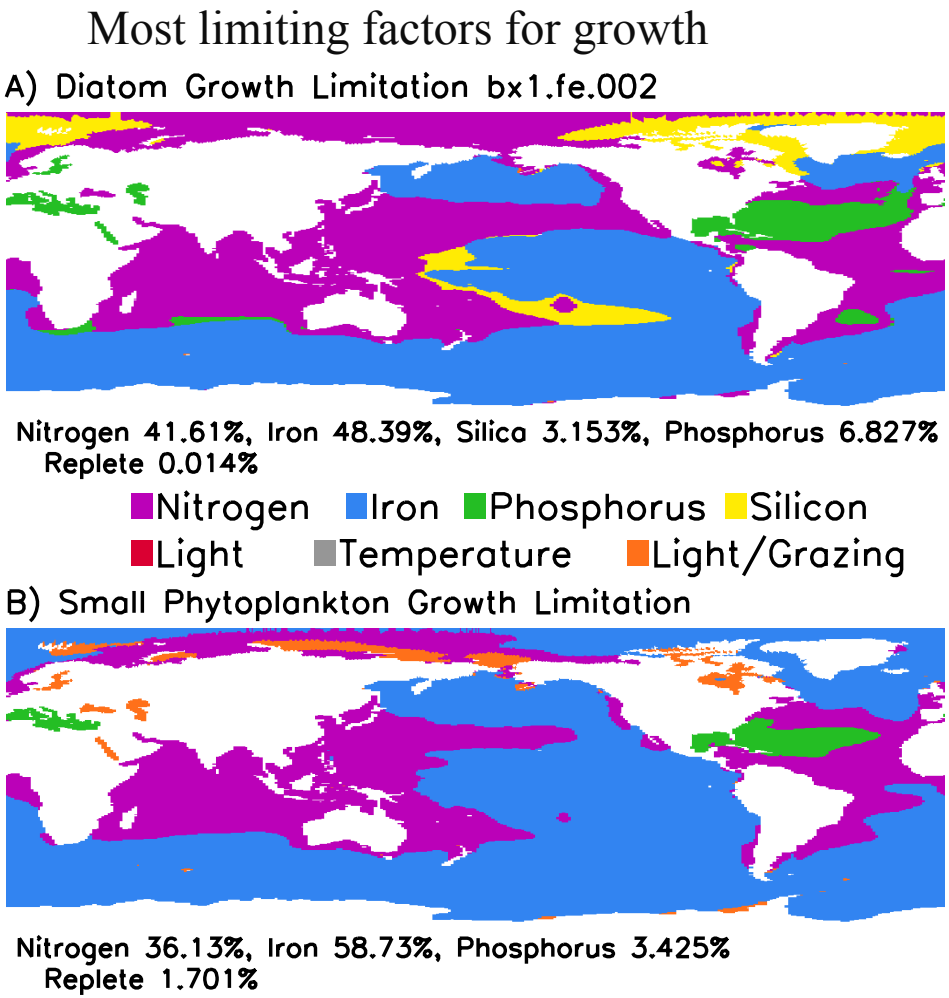
Iron concentration (upper ~100m)



Surface Chlorophyll



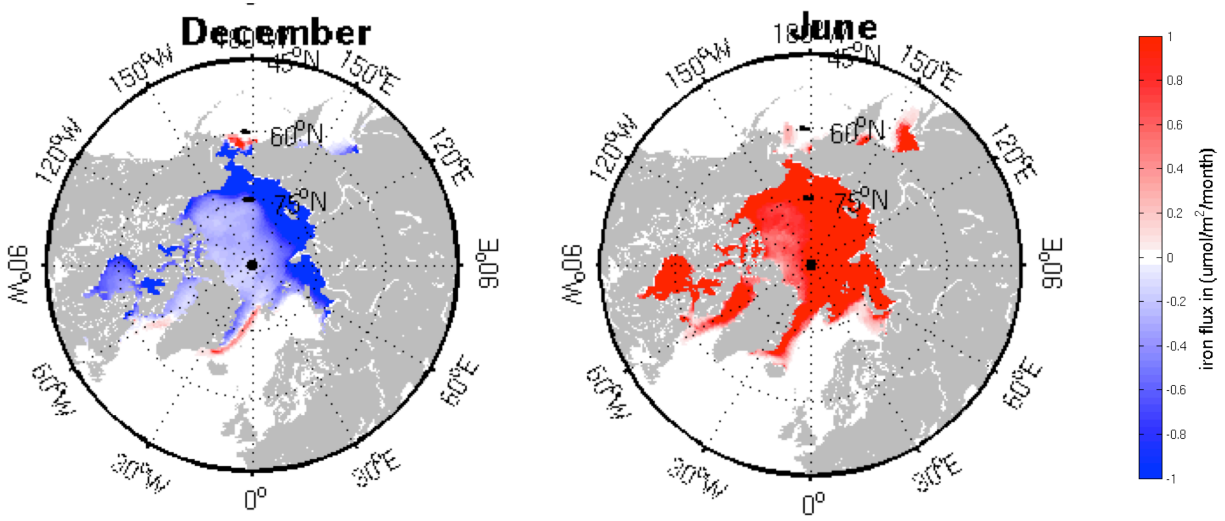
Model Results



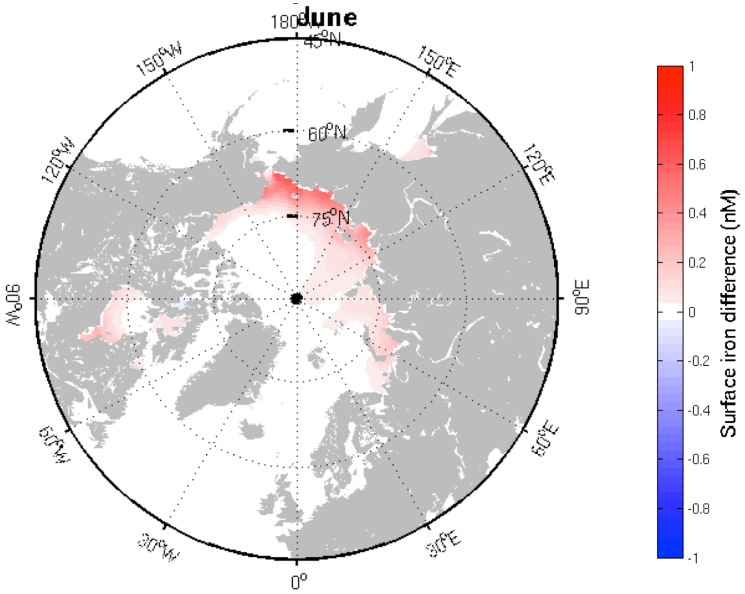
- Phytoplankton growth is mostly limited by iron in large areas of the Southern Ocean.
- Primary production is strongly diatom-dominated in Arctic.
- Most limiting factors for diatom growth in Arctic are N and Si.

Impacts of sea ice

Differences in iron influx (control: no iron sequestration in ice)

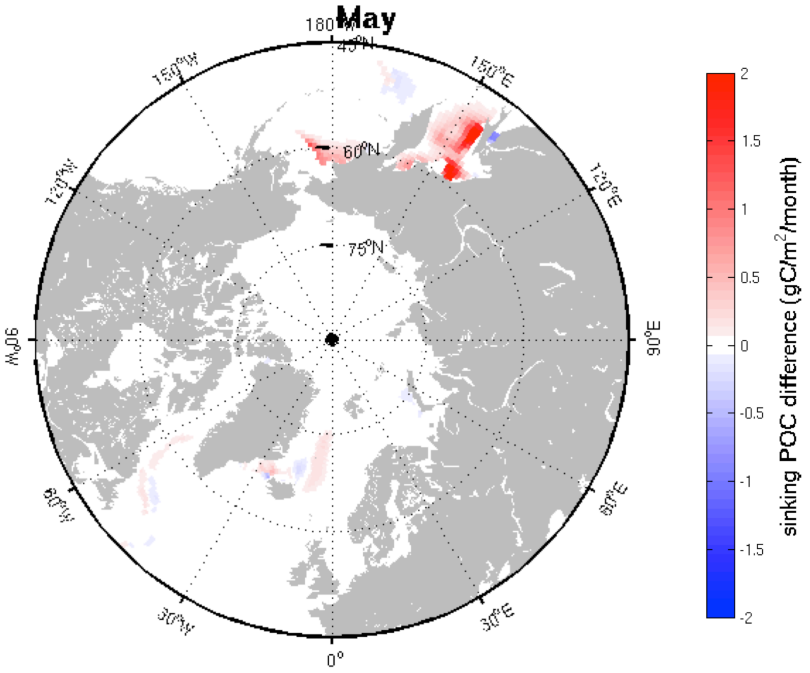


Differences in surface iron concentrations

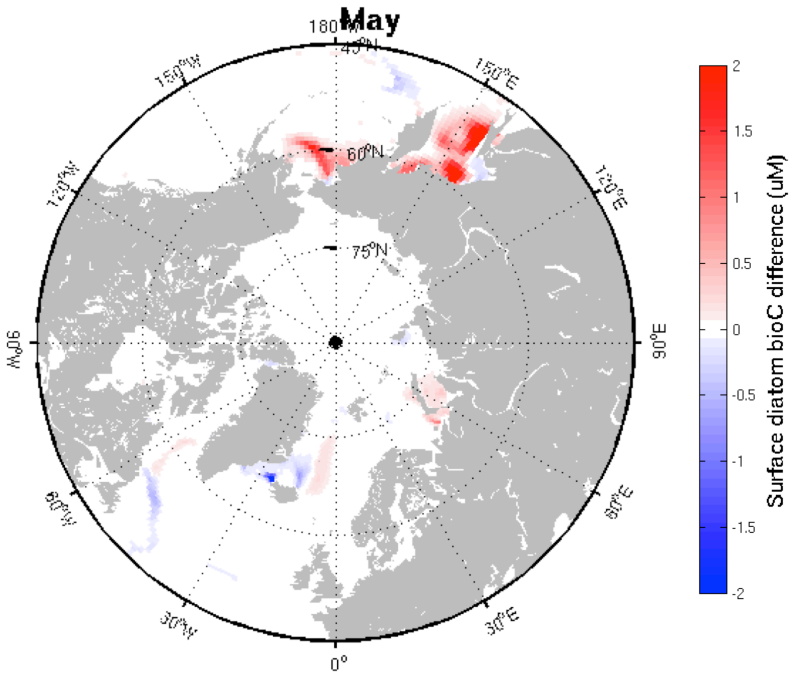


- The seasonal sea ice dynamics can alter the timing and magnitude of iron fluxes into the ocean.
- Iron concentrations elevate in the Transpolar Drift

Differences in diatom biomass

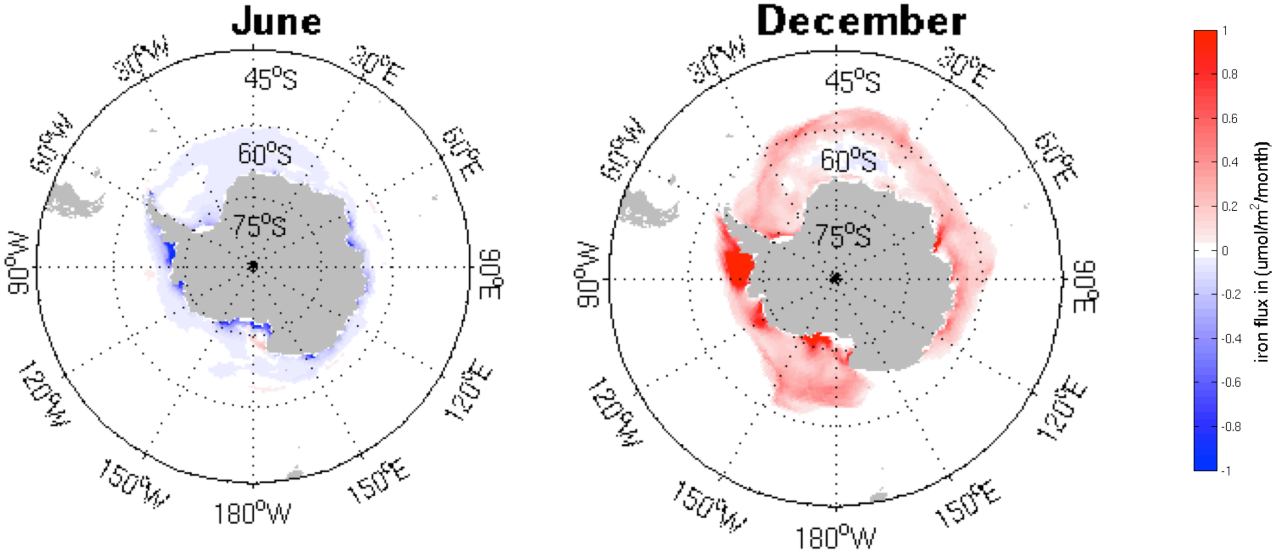


Differences in sinking POC

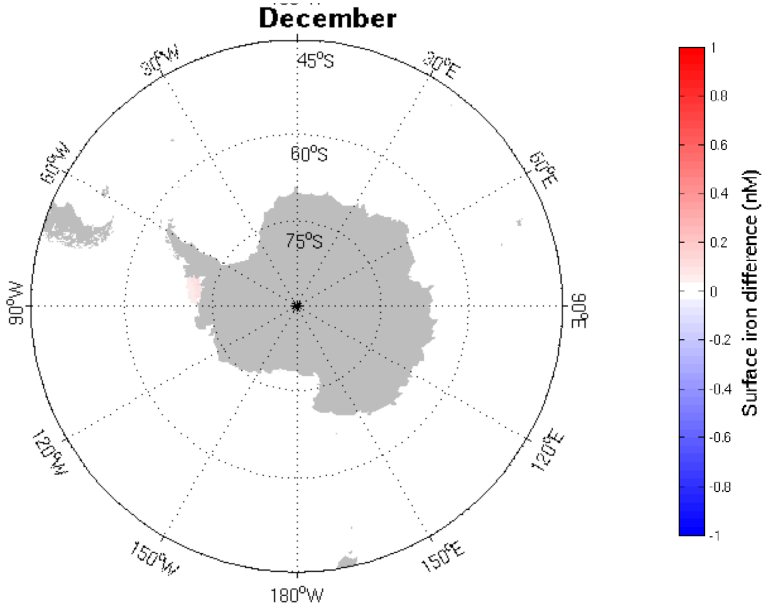


Additional iron from melting sea ice leads to an increase in diatoms biomass and export production in the Bering Sea and the Sea of Okhotsk

Differences in iron influx (control: no iron sequestration in ice)

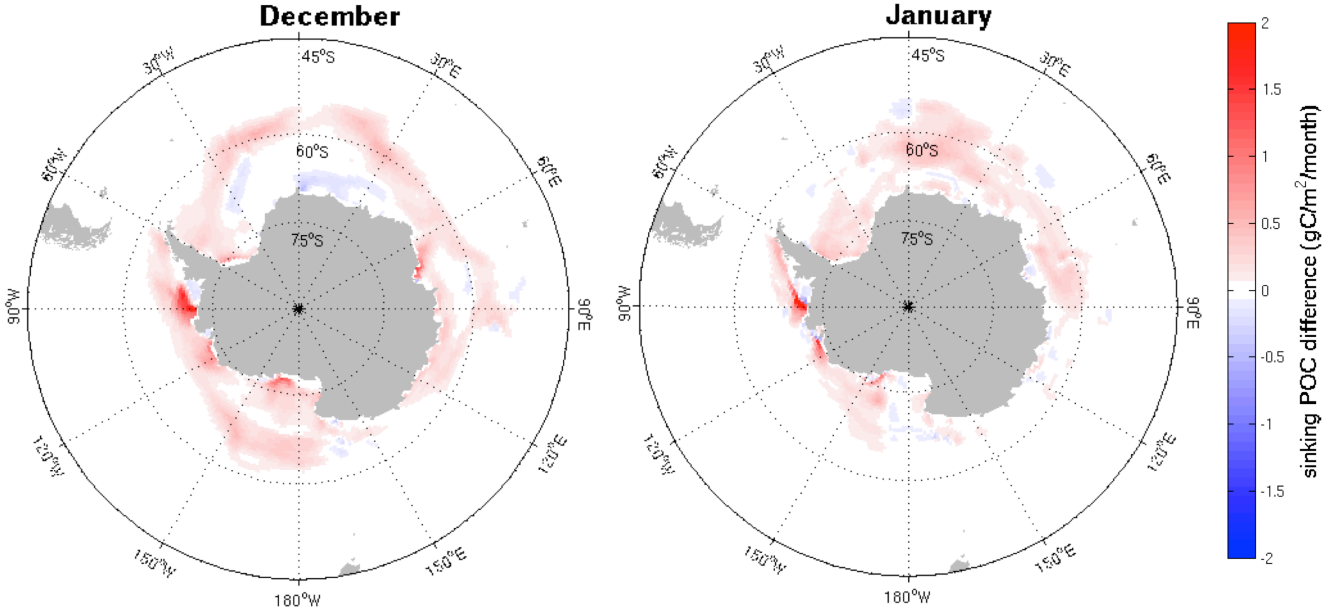


Differences in surface seawater iron concentrations



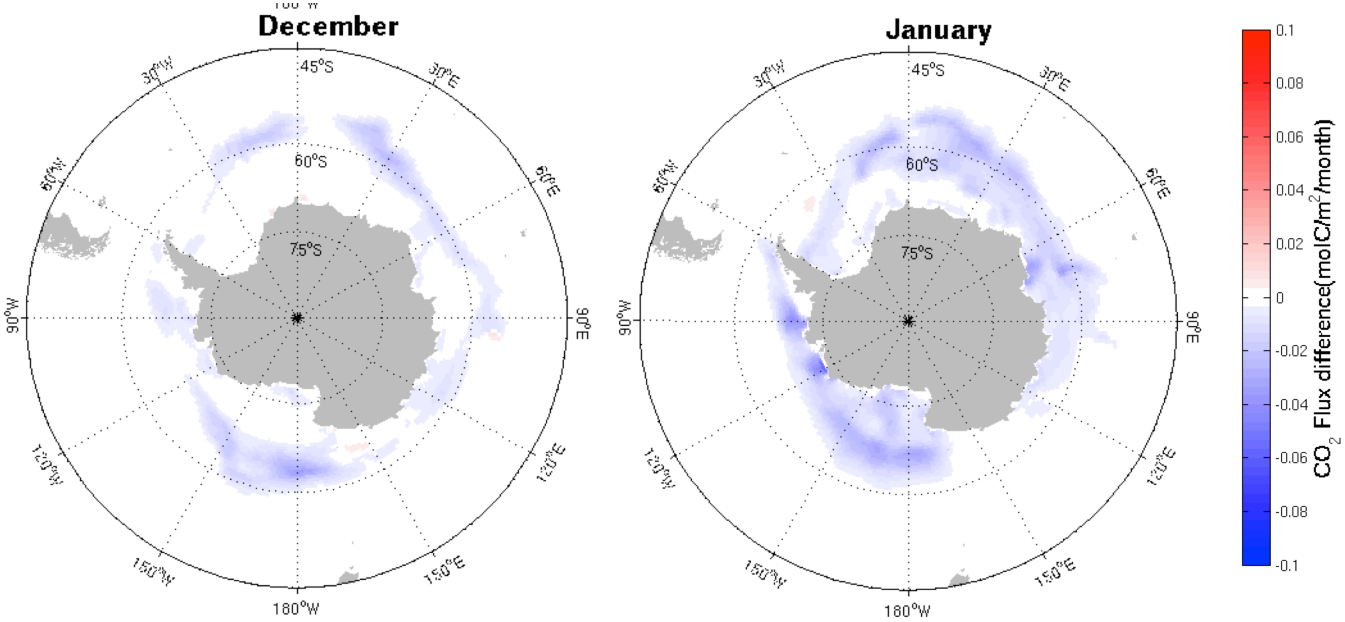
- The timing and magnitude of iron fluxes into the ocean also changed.
- Surface iron concentrations are controlled by biological uptake.

Differences in sinking POC



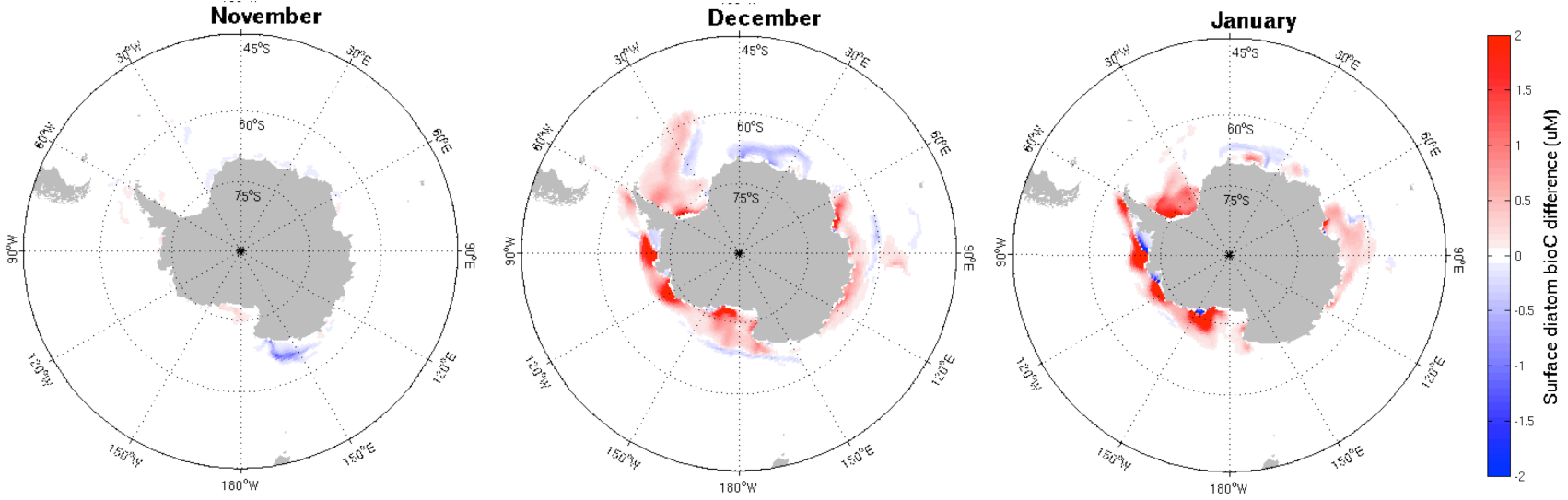
- Altered iron input due to sea ice changes affects phytoplankton production.

Differences in monthly CO_2 flux

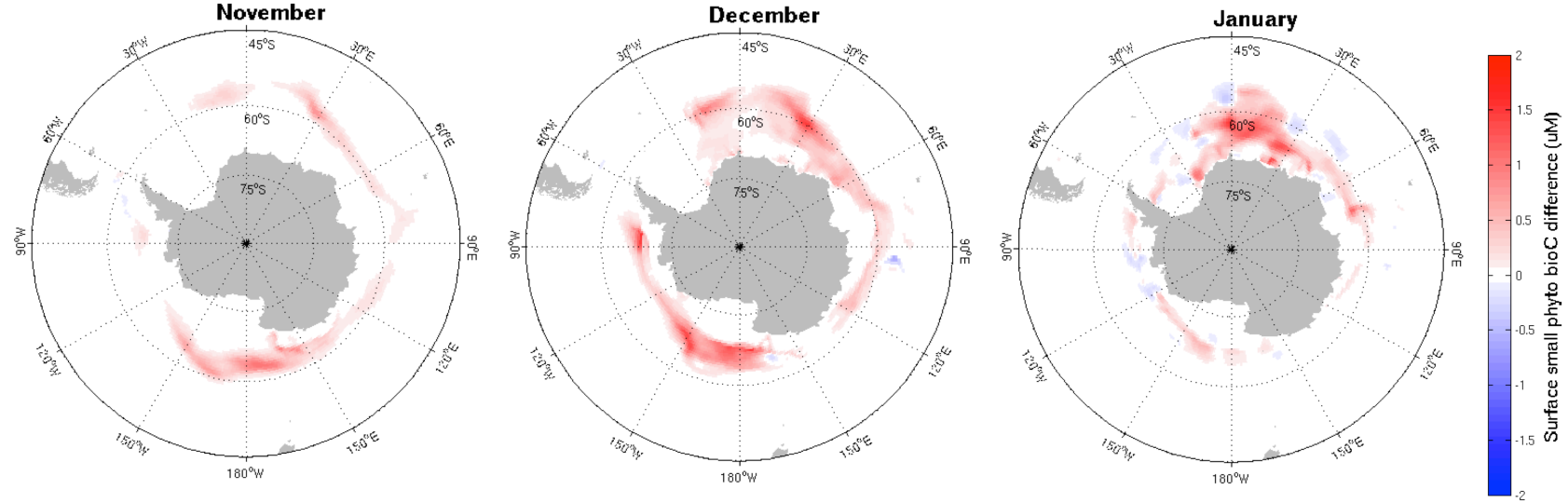


- CO_2 uptake increased, or CO_2 outgassing decreased.

Differences in diatom biomass



Differences in small phytoplankton biomass



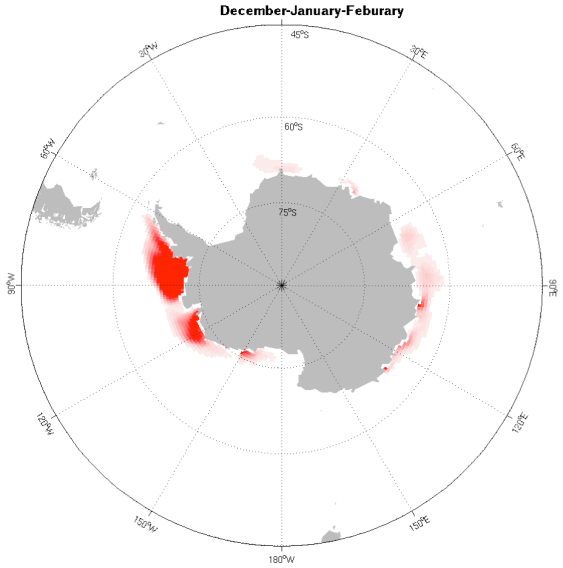
- Diatom biomass (>60S) change by 3% and 11% in Dec and Jan, respectively.
- Small phytoplankton biomass (>60S) increase 3% and 9% in Nov and Dec, respectively.

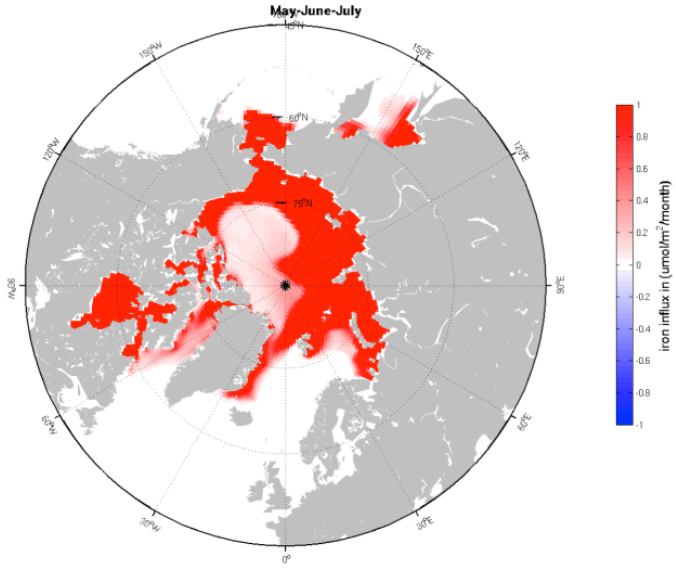
Dirty ice…

- Ice-iron experiment: includes uptake and transport of dissolved iron by sea ice.
- Sed-iron experiment: additional dissolved iron is added to sea ice forming in shallow areas to account for sediment incorporation. Here “shallow” is defined as < 200m (on coarse model grid) and iron source is increased X10.

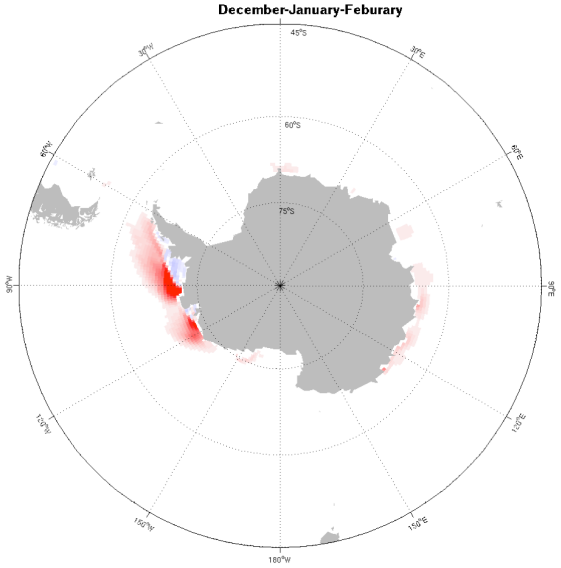
http://www.crrel.usace.army.mil/sid/personnel/perovichweb/HotraxWeb/index.htm

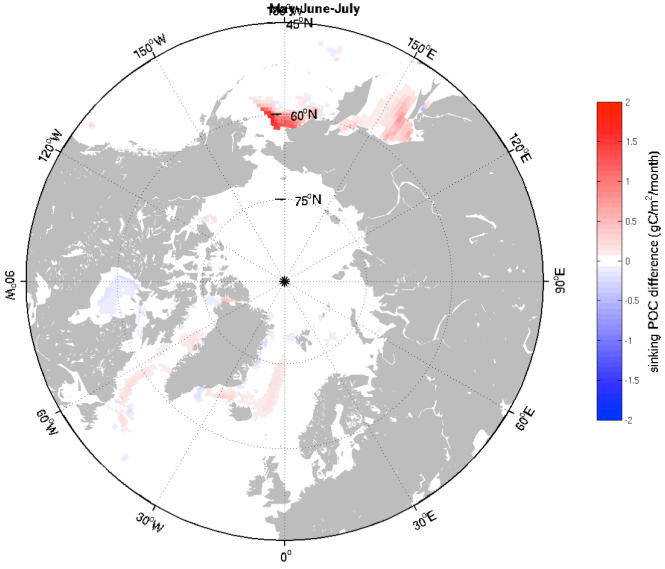
Differences in summer season Fe flux into the ocean





Differences in sinking POC during growth season



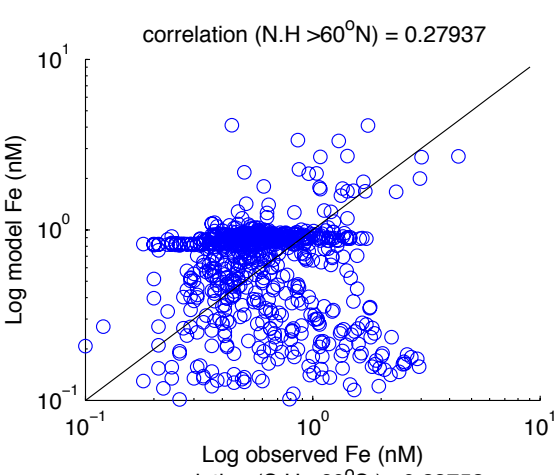


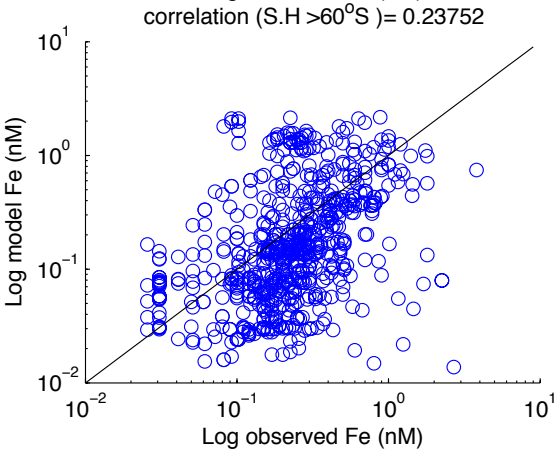
Summary

- Seasonal sea ice dynamics alter the timing, location, and magnitude of iron fluxes into the ocean.
- Iron from sea ice can affect phytoplankton production.
- Community composition may be influenced by iron released during ice melting. Small phytoplankton and Diatoms have different responses to iron released from melting sea ice.
- There are still many uncertainties in the ice-related iron cycle.

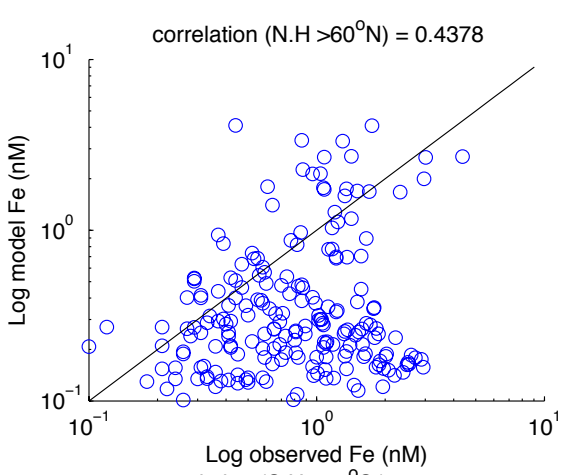
Thank you!

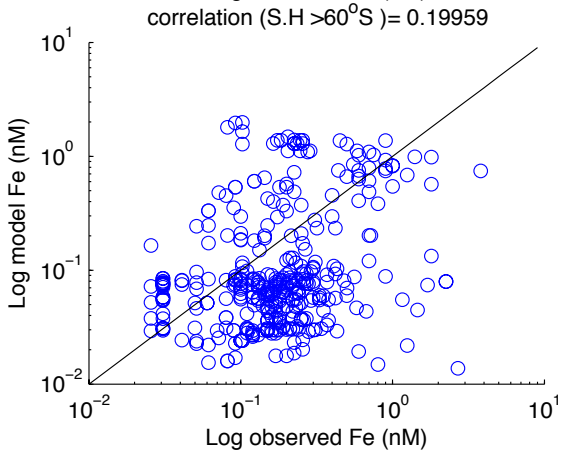
Simulation of Fe



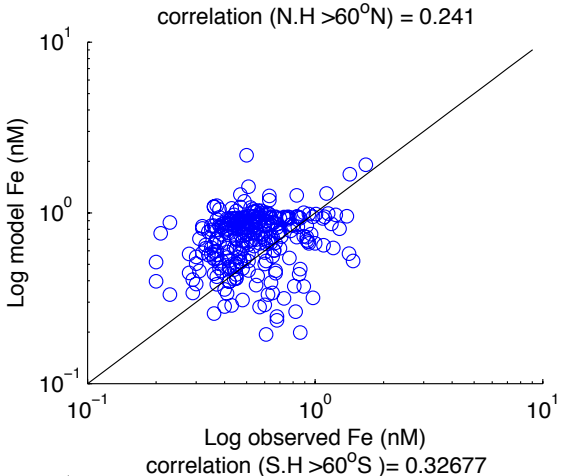


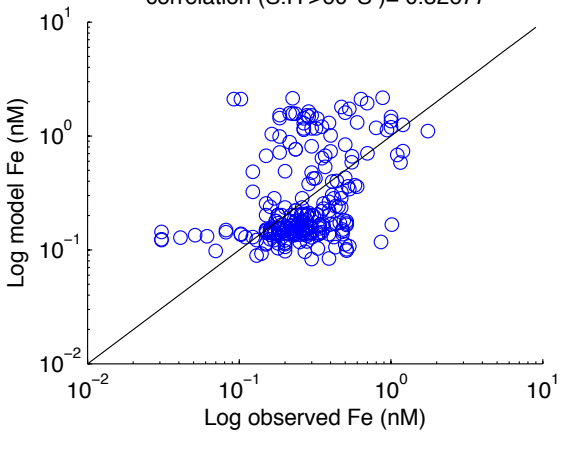
(from all depth)





(upper 100m)





(100m – 1000m)

A core of Arctic sea ice with algae visible at the bottom.

http://nature.ca/education/cls/lp/lpasi_ph01_e.cfm