Carbon flux in sea ice: Implementation of Sea Ice Algae in a 1D Biogeochemical Ecosystem Model

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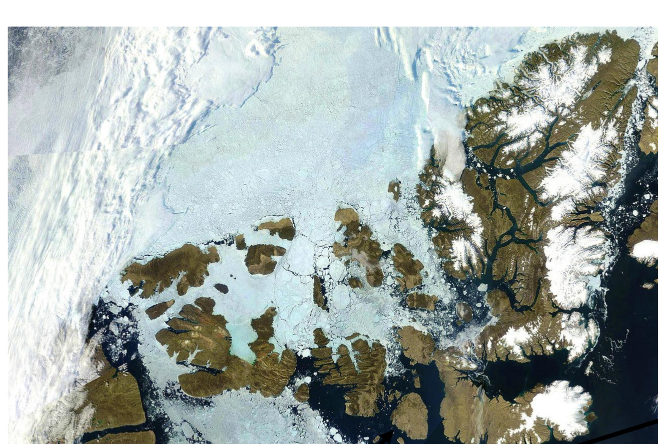
Introduction

Air-sea gas exchange is an essential process in determining the amount of carbon in the atmosphere, and primary producers in the euphotic zone play an important role in the oceanic uptake of carbon. One area of particular interest is the Arctic ocean, where in addition to the pelagic ecosystem, first-year sea ice provides an environment for ice algae to contribute to this exchange. In the past it had been assumed that sea ice acts as a cap to air-sea gas exchange, but recent studies have shown that carbon in the ice is taken up or released into both the atmosphere and ocean through chemical and biological processes during ice formation and melting. These processes need to be included in a representative air-sea-ice model of carbon exchange in the Arctic. The purpose of this study is to incorporate sea ice algae into a working ecosystem model set to conditions in Arctic sea ice formation and melting regions.

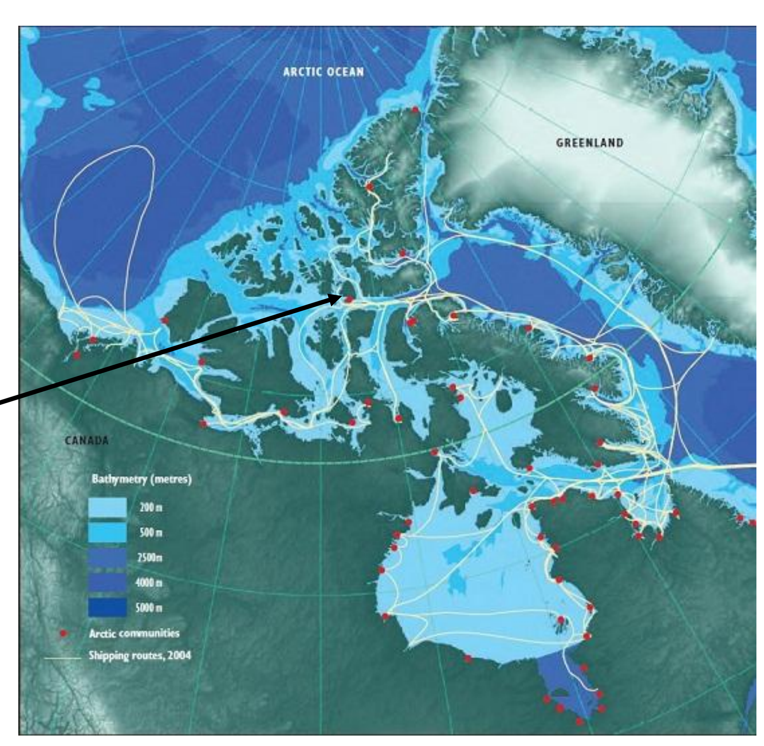
Background (Field Observations)

Arctic sea ice is a unique environment strongly dependent on the seasons. In areas of melting ice in the Arctic, ice algae blooms are typically observed in late spring or early summer when nutrients have not yet been depleted in the lower ice layer, and snow and ice melt to allow light to the bottom of the ice.

Observations of biogeochemical data for the Arctic sea ice environment are limited in both space and time. Resolute Bay, however, is located near a scientific research station where long term measurements of sea ice provide a basis for model testing.



Resolute Bay,
Nunavut

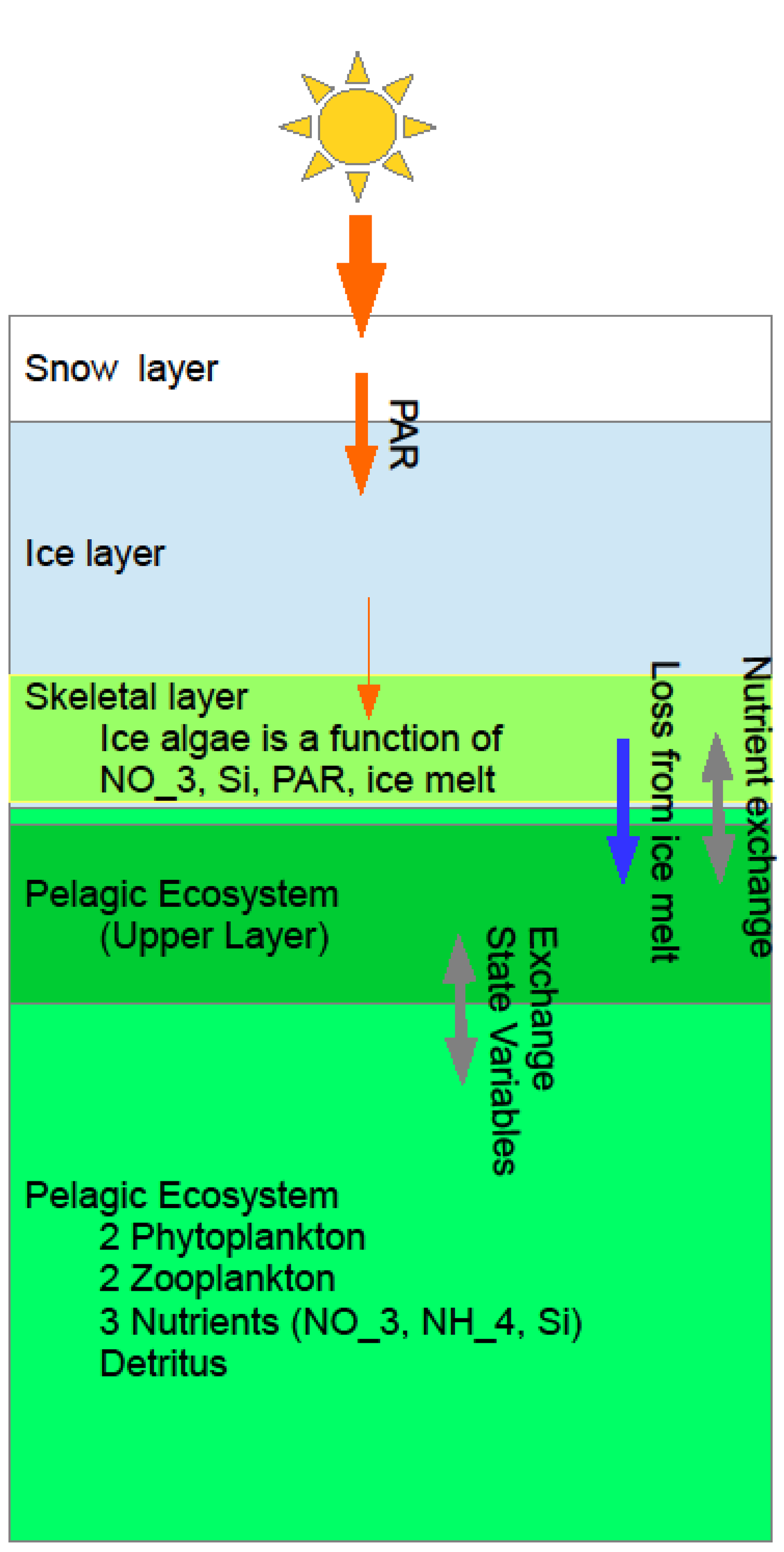


Sources:
NASA/GSFC, MODIS (above)
Transport Canada (right)

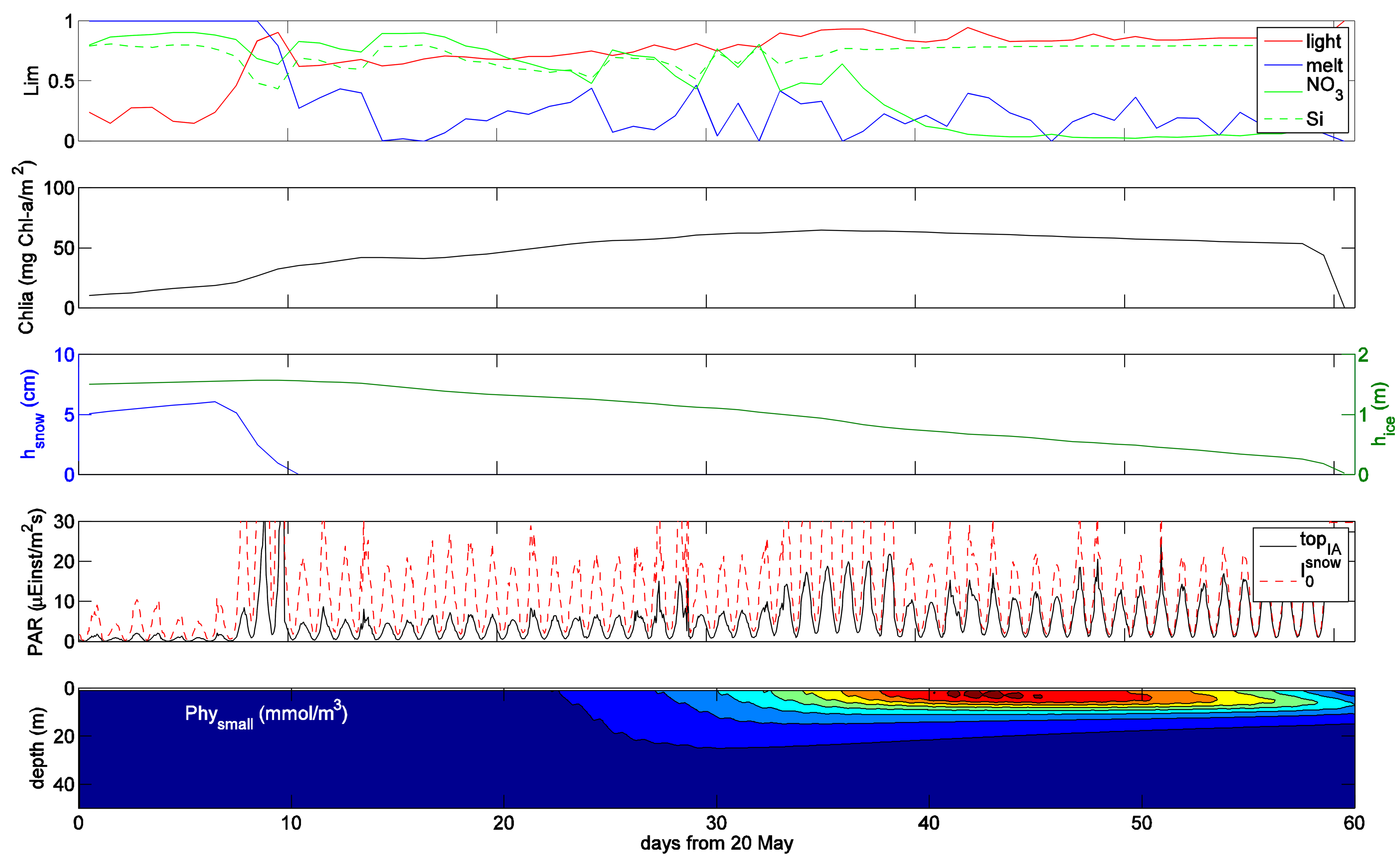
Model Description

The 1D General Ocean Turbulence Model is used for physical forcing along with sea ice implementation. The nitrogen-conserving ecosystem component is comprised of **two phytoplankton groups, two zooplankton groups, bacteria, detritus, nitrate, ammonium, and silicate**.

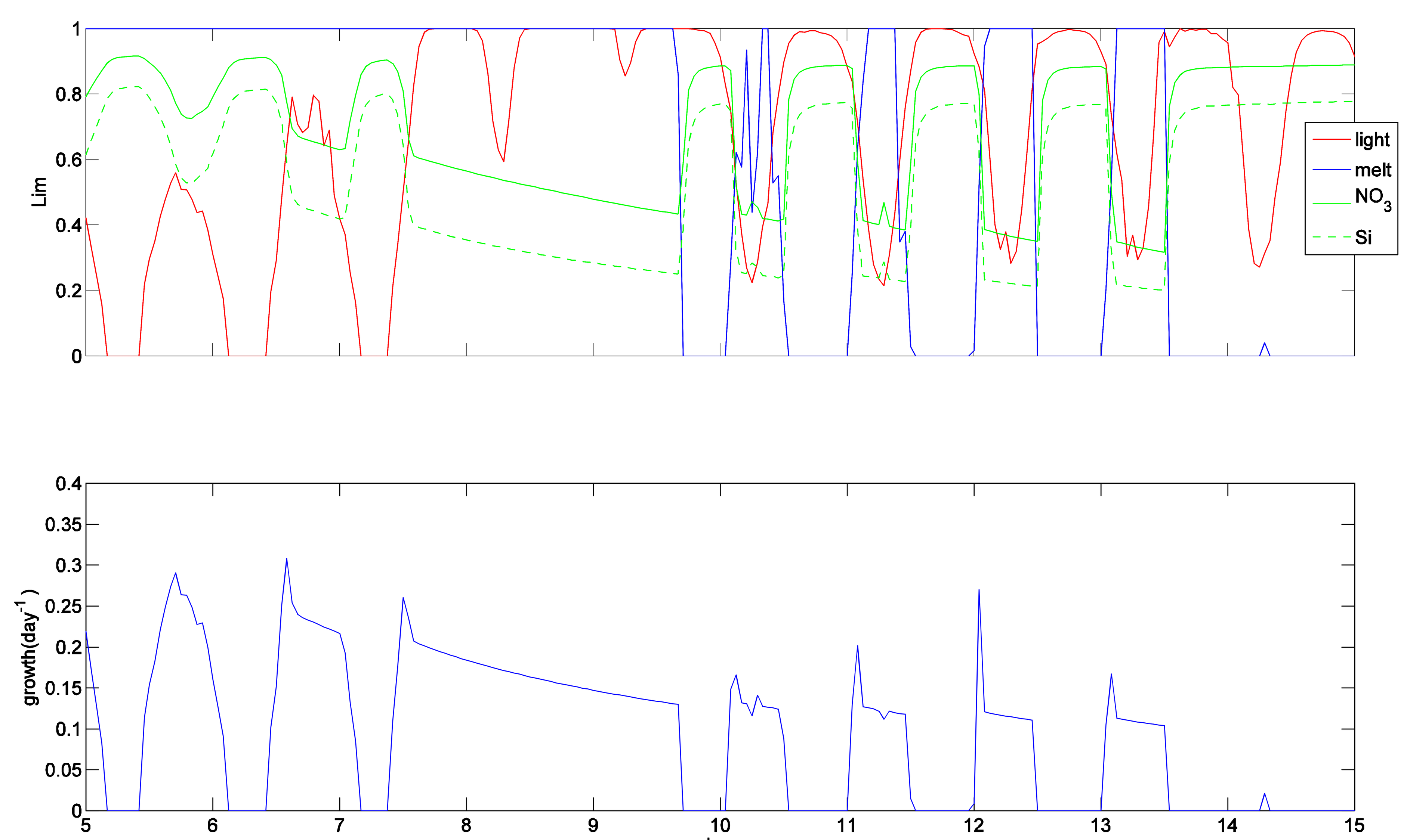
Modeled sea ice algae are limited by nutrients (both NO_3 and Si), light and ice melt rate. The limiting nutrients are fed into the skeletal layer from the upper meter of the 1D modeled water column of the nitrogen-conserving ecosystem model.



Preliminary Results and Discussion



Daily averaged growth limitations, ice algal biomass, snow and ice depth, hourly light at the base of snow and ice during a spring thaw and bloom, and small phytoplankton biomass show the effects of light, nutrients, and melt on the ice algae population.



Ice algal growth in the skeletal layer provides a sink to nutrients, which when depleted limits further growth. The upper plot shows daily cycles in limitation functions over a 10 day period during the ice algal bloom. Both nitrate and silicate increase at night, when growth is limited by light and the skeletal layer is replenished by mixing with the upper ocean.

Conclusions

In this project, ice algae have been incorporated into a 1D turbulence and ecosystem model. The preliminary results demonstrate that the modeled ice algae have physically representative reactions to limitation functions relevant to an Arctic marine environment.

Future Work

Fine tuning of the turbulent mixing and the oceanic heat flux are in progress.

Model development, validation, and sensitivity analyses are ongoing in order to compare the timing and magnitude of the spring bloom for the simulated ice algae to those from observations at key sites including Resolute Bay. Ultimately, the aim is to incorporate parameterisations from this 1D model into a coupled ocean-atmosphere regional model for the Arctic to better represent carbon fluxes.

Referencees

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