Pan-Arctic simulation of coupled nutrient-sulfur cycling due to sea ice biology: Preliminary results

S. Elliott,[1] C. Deal,[2] G. Humphries,[3] E. Hunke,[1] N. Jeffery,[1] M. Jin,[2] M. Levasseur,[4] and J. Stefels[5]

[1] A dynamic model is constructed for interactive silicon, nitrogen, sulfur processing in and below Arctic sea ice, by ecosystems residing in the lower few centimeters of the distributed pack. A biogeochemically active bottom layer supporting sources/sinks for the pennate diatoms is appended to thickness categories of a global sea ice code. Nutrients transfer from the ocean mixed layer to drive algal growth, while sulfur metabolites are reinjected from the ice interface. Freeze, flux, flush and melt processes are linked to multielement geocycling for the entire high-latitude regime. Major element kinetics are optimized initially to reproduce chlorophyll observations, which extend across the seasons. Principal influences on biomass are solute exchange velocity at the solid interface, optical averaging in active ice and cell retention against ablation. The sulfur mechanism encompasses open water features such as accumulation of particulate dimethyl sulfoniopropionate, grazing and other disruptive releases, plus bacterial/enzymatic conversion to volatile dimethyl sulfide. For baseline settings, the mixed layer trace gas distribution matches sparging measurements where they are available. However, concentrations rise to well over 10 nM in remote, unsampled locations. Peak contributions are supported by ice grazing, mortality and fractional melting. The model bottom layer adds substantially to a ring maximum of reduced sulfur chemistry that may be dominant across the marginal Arctic environment. Sensitivity tests on this scenario include variation of cell sulfur composition and remineralization, routings/chemical time scales, and the physical dimension of water layers. An alternate possibility that peripheral additions are small cannot be excluded from the outcomes. It is concluded that seagoing dimethyl sulfide data are far too sparse at the present time to distinguish sulfur-ice production levels.

1. Introduction

[2] The aerosol precursor molecule dimethyl sulfide is distributed inhomogeneously through waters of the marginal ice zone, but may act as a strong source of reduced sulfur to the Arctic atmosphere under many circumstances (DMS) [*Ferek et al.*, 1995; *Lundén et al.*, 2007]. Production distributions for polar DMS have not been clarified, and must include contributions from both ice algae and phytoplankton in the water column [*Levasseur et al.*, 1994; *Matrai et al.*, 2007]. We demonstrate here by attaching multielement geochemical cycles to a dynamic/thermodynamic sea ice model that epontic ecosystems could play a significant role, on a regional and seasonal basis. Essential nutrient and sulfur flow are coupled in our computations through a set of porous bottom layer kinetics simulations, with radiation inputs arriving from above through geographically distributed columns of snow and ice. Optimization tests on ecodynamics of the major elements serve to reduce the number of broad biogeochemical scenarios, while variations in the model sulfur mechanism show that ice-derived peaks of greater than 10 nM are possible in remote areas. It becomes clear in the process, however, that measurement data are presently much too sparse and uncertain to permit a true quantification of error.

[3] Our development begins with individual descriptions of the program components. Some history and an overview of capabilities are provided for the dynamic sea ice model CICE [*Hunke and Lipscomb*, 2008; *Hunke and Bitz*, 2009]. Since the biogeochemistry involved becomes quite detailed whether regarding nutrients or the sulfur compounds,

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[1]Climate Ocean Sea Ice Modeling, Computational Sciences Division, Los Alamos National Laboratory, Los Alamos, New Mexico, USA.

[2]International Arctic Research Center, Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

[3]Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

[4]Department of Biology, Laval University, Quebec, Quebec, Canada.

[5]Laboratory of Plant Physiology, Center for Life Sciences, University of Groningen, Groningen, Netherlands.