University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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"Modelling Carbon Exchange in the Air, Sea, and Ice of the Arctic Ocean"

School of Earth and Ocean Sciences

Friday, May 3, 2019
2:00 P.M.
Clearihue Building
Room B017

Supervisory Committee:
Dr. Adam Monahan, School of Earth and Ocean Sciences, University of Victoria (Co-Supervisor)
Dr. Nadja Steiner, School of Earth and Ocean Sciences, University of Victoria (Co-Supervisor)
Dr. Deborah Ianson, School of Earth and Ocean Sciences, UVic (Member)
Dr. Lisa Miller, Institute of Ocean Sciences (Outside Member)

External Examiner:
Dr. Frédéric Maps, Department of Biology, Université Laval

Chair of Oral Examination:
Dr. Randy Scharien, Department of Geography, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

The purpose of this study is to investigate the evolution of the Arctic Ocean's carbon uptake capacity and impacts on ocean acidification with the changing sea-ice scape. In particular, I study the influence on air-ice-sea fluxes of carbon with two major updates to commonly-used carbon cycle models I have included. One, incorporation of sea ice algae to the ecosystem, and two, modification of the sea-ice carbon pump, to transport brine-associated Dissolved Inorganic Carbon (DIC) and Total Alkalinity (TA) to the depth of the bottom of the mixed layer (as opposed to releasing it in the surface model layer). I developed the ice algal ecosystem model by adding a sympagic (ice-associated) ecosystem into a 1D coupled sea ice-ocean model. The 1D model was applied to Resolute Passage in the Canadian Arctic Archipelago and evaluated with observations from a field campaign during the spring of 2010. I then implemented an inorganic carbon system into the model. The carbon system includes effects on both DIC and TA due to the coupled ice-ocean ecosystem, ikaite precipitation and dissolution, ice-air and air-sea carbon exchange, and ice-sea DIC and TA exchange through a formulation for brine rejection to depth and freshwater dilution associated with ice growth and melt. The 1D simulated ecosystem was found to compare reasonably well with observations in terms of bloom onset and seasonal progression for both the sympagic and pelagic algae. In addition, the inorganic carbon system showed reasonable agreement between observations of upper water column DIC and TA content. The simulated average ocean carbon uptake during the period of open water was 10.2 mmol C m^{-2} day^{-1} (11 g C m^{-2} over the entire open-water season).

Using the developments from the 1D model, a 3D biogeochemical model of the Arctic Ocean incorporating both sea ice and the water column was developed and tested, with a focus on the pan-Arctic oceanic uptake of carbon in the recent era of Arctic sea ice decline (1980 – 2015). The model suggests the total uptake of carbon for the Arctic Ocean (north of 66.5°N) increases from 110 Tg C yr^{-1} in the early eighties (1980 – 1985) to 140 Tg C yr^{-1} for 2010 – 2015, an increase of 30%. The rise in SST accounts for 10% of the increase in simulated pan-Arctic sea surface pCO_2. A regional analysis indicated large variability between regions, with the Laptev Sea exhibiting low sea surface pH relative to the pan- Arctic domain mean and seasonal undersaturation of Ω_{arag} by the end of the standard run.

Two sensitivity studies were performed to assess the effects of sea-ice algae and the sea-ice carbon pump in the pan-Arctic, with a focus on sea surface inorganic carbon properties. Excluding the sea ice-carbon-pump showed a marked decrease in seasonal variability of sea-surface DIC and TA averaged over the Arctic Ocean compared to the standard run, but only a small change in the net total carbon uptake (of 1% by the end of the no ice-carbon-pump run). Neglecting the sea ice algae, on the other hand, exhibits only a small change in sea-surface DIC and TA averaged over the pan-Arctic Ocean, but a cumulative effect on the net total carbon uptake of the Arctic Ocean (reaching 4% difference from the standard run by the end of the no-ice-algae run).