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Drivers of inorganic carbon dynamics in first-year sea ice: A model study

Sébastien Moreau (1), Martin Vancoppenolle (2), Bruno Delille (3), Jean-Louis Tison (4), Jiayun Zhou (4), Marie Kotovich (4), David Thomas (5,6), Nicolas-Xavier Geilfus (7), and Hugues Goosse (1)

(1) Université catholique de Louvain, Louvain-la-Neuve, Belgium, (2) Sorbonne Universités, UPMC/CNRS/IRD/MNHN, LOCEAN, IPSL, Paris, France, (3) Université de Liège, Belgium, (4) Université Libre de Bruxelles, Belgium, (5) Bangor University, Wales, (6) Finnish Environmental Institute (SYKE), Helsinki, Finland, (7) Aarhus University, Denamark

Sea ice is an active source or a sink for carbon dioxide (CO_2), although to what extent is not clear. Here, we analyze CO_2 dynamics within sea ice using a one-dimensional halo-thermodynamic sea ice model including gas physics and carbon biogeochemistry. The ice-ocean fluxes, and vertical transport, of total dissolved inorganic carbon (DIC) and total alkalinity (TA) are represented using fluid transport equations. Carbonate chemistry, the consumption and release of CO_2 by primary production and respiration, the precipitation and dissolution of ikaite ($CaCO_3$•$6H_2O$) and ice-air CO_2 fluxes, are also included. The model is evaluated using observations from a 6-month field study at Point Barrow, Alaska and an ice-tank experiment. At Barrow, results show that the DIC budget is mainly driven by physical processes, wheras brine-air CO_2 fluxes, ikaite formation, and net primary production, are secondary factors. In terms of ice-atmosphere CO_2 exchanges, sea ice is a net CO_2 source and sink in winter and summer, respectively. The formulation of the ice-atmosphere CO_2 flux impacts the simulated near-surface CO_2 partial pressure (pCO_2), but not the DIC budget. Because the simulated ice-atmosphere CO_2 fluxes are limited by DIC stocks, and therefore < 2 mmol m-2 day-1, we argue that the observed much larger CO_2 fluxes from eddy covariance retrievals cannot be explained by a sea ice direct source and must involve other processes or other sources of CO_2. Finally, the simulations suggest that near surface TA/DIC ratios of $\sim$2, sometimes used as an indicator of calcification, would rather suggest outgassing.