pCO_2 dynamics and related air-ice CO_2 fluxes during sea ice growth and decay in a ice tank experiment

B. Delille[1], D.N. Thomas[2], G. S. Dieckmann[3], S. Papadimitriou[2], H. Kennedy[2], M. Fischer[3], K.-U. Evers[4] J.-L. Tison[5]

[1] Unité d'Océanographie Chimique Université de Liège – Belgium (Bruno.Delille@ulg.ac.be)
[2] School of Ocean Sciences, Bangor University - UK
[3] Alfred Wegener Institute - Germany
[4] Ice & Offshore Technology, Hamburgische Schiffbau-Versuchsanstalt GmbH (HSVA), Germany
[5] Glaciology Unit, Université Libre de Bruxelles - Belgium

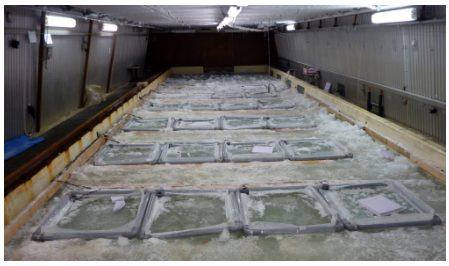
www.co2.ulg.ac.be

CO_2 uptake by sea-ice

For decades, sea ice has been considered by the scientific community as an inert and impermeable barrier to air-sea gas exchanges. However, this assumption is not supported by studies on the ice permeability to gases and liquids, which show that sea ice is permeable at temperatures above -5°C. Recently, uptake of atmospheric CO_2 over sea-ice cover has been reported supporting the need to further investigate pCO_2 dynamics in the sea-ice realm and related CO_2 fluxes

The experiment

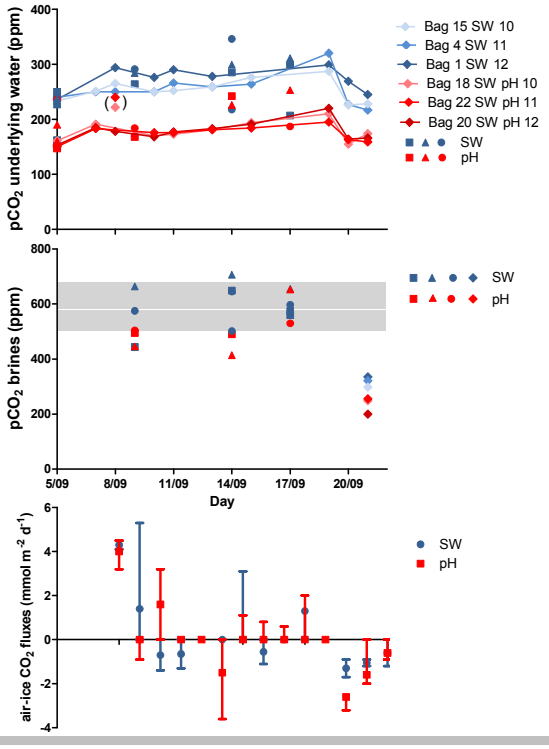
The INTERICE 4 project run at the Arctic Environment Test basin of Hamburgische Schiffbau-Versuchsanstalt GmbH (HSVA) in September 2009. It addressed fundamental questions on the biogeochemistry of carbon during ice formation with an emphasis on precipitation of $CaCO_3$. In the course of the experiment, we followed the pCO_2 changes within brines and underlying water of several ice mesocosms, together with physical parameters of the ice. In addition we measured air-ice CO_2 fluxes with the chamber method



24 polyethylene enclosures were filled with North Sea water. 12 were treated to increase phosphate concentration and decrease pH. The experiment was designed to simulate an ice growth phase during 12 days followed by a melt phase of 4 days. Ice growth was about 2 cm d^{-1}. Underlying water of 6 of the bags were sampled every 1~2 days. Ice samples were collected during 4 main sampling session. 6 bags were sampled for ice at each main sampling system. Each bag were sampled for ice only one time. We collected ice for salinity and temperature vertical profile, and we carried out direct measurement of the partial pressure of CO_2 (pCO_2) of brines and underlying water, and air-ice CO2 fluxes with the chamber method.

pCO_2 changes and related air-ice CO_2 fluxes

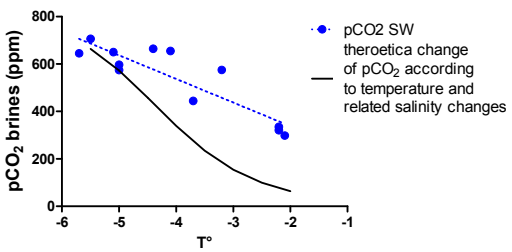
We observed steady sea ice growth during the first 8 days of freezing, with a slight slowing down of the sea ice growth during the next 6 days of freezing conditions. This phase was followed by the final phase of ice decay in warm conditions. The pCO_2 in the brines increased during the first 4 days of the ice growth phase and ranged from 444 to 706 ppm. During the ice decay phase, the pCO_2 of the brine decreased dramatically and ranged from 200 to 335 ppm. At the beginning of the ice growth, all mesocosms released CO_2 to the atmosphere. As the ice temperature and permeability decreased further, the flux of CO_2 to the atmosphere decreased. During most the ice growth phase, air-ice CO_2 fluxes were low or below the detection limit of the measurement. At the beginning of ice decay phase, we measured significant uptake of atmospheric CO_2 by the ice in accordance with the observed sharp decrease of the pCO_2 of brines well below the mean air pCO_2 in the ice tank room. However, this uptake decreased significantly afterwards.



SW and pH denotes none treated and treated bags for phosphate and pH, respectively. Negative fluxes correspond to influx from the atmosphere to the ice. Grey area correspond to pCO2 of the atmosphere inside the tank room.

Driving processes

pCO_2 of brines (none treated bags) appears to be tightly linked to temperature changes. However, there is a strong discrepancy between observed changes and theoretical changes predicted by temperature changes and related salinity changes (predicted by Cox and Weeks 1975). Other temperature-related processes are likely to influence pCO_2.



CO_2 fluxes are controlled by permeability of the ice at the air-ice interface. During the experiment the threshold of permeability for air-ice CO_2 transfer was a brine volume of 0.95% almost twice the value predicted by Golden et al. 1998.

Université de Liège
PRIFYSGOL BANGOR UNIVERSITY
AWI
HSVA
ULB

IGS Tromsø 31/05 – 4/06 2010 57A189