Sea ice dynamics and related air-sea CO_2 fluxes during a flood-freeze cycle (Bellingshaussen Sea, Antarctica)

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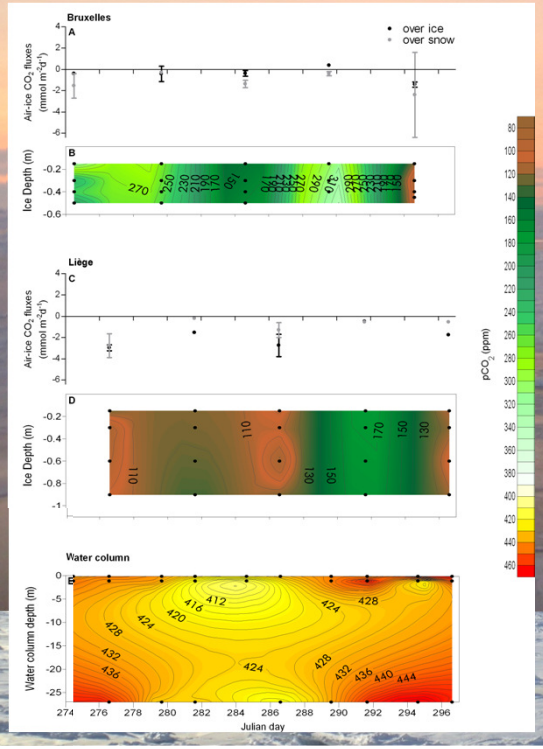
Sea ice, a barrier to air-sea exchange of CO_2 ?

Sea ice covers about 7% of the Earth surface at its maximum seasonal extent. For decades sea ice was assumed to be an impermeable and inert barrier for air-sea exchange of CO_2 so that global climate models do not include CO_2 exchange between the oceans and the atmosphere in the polar region. However, uptake of atmospheric CO_2 over sea ice cover has been recently reported raising the need to further investigate pCO_2 dynamics in the marine cryosphere realm and related air-ice CO_2 fluxes.

Measurements

We carried out a 4 weeks' survey of temporal changes of the partial pressure of CO_2 (pCO_2) within brines and related air-ice CO_2 fluxes of Antarctic first year pack ice during the "Sea Ice Mass Balance in Antarctica – SIMBA" drifting station experiment on board the N.B. Palmer in September and October 2007 in the Bellingshausen Sea, Antarctica (69 – 71 °S; 90 – 95°W). The survey was carried out at two contrasted sites ("Bruxelles" and "Liège"). pCO_2 of brines and air-ice CO_2 fluxes were measured using the equilibration and chambers methods respectively.

fig.1. – accumulation chamber for air-ice CO_2 fluxes measurements



Results

The underlying water was supersaturated in CO_2 with respect to the atmosphere, with CO_2 values ranging from 404 to 464 ppm (*fig. E*).

In contrast, sea ice was undersaturated in CO_2, with CO_2 values ranging from 77 ppm at "Liège" to 377 ppm at "Bruxelles" (*fig. D, B*). The overall temporal evolution was roughly similar at both site. The maximum of pCO_2 (day 289) was observed when negative freeboard allowed flooding and mixing of brines with seawater with high pCO_2 values.

At "Liège", CO_2 fluxes between the atmosphere and sea ice ranged from -0.5 to 3 mmol $m^{-2}d^{-1}$. Temporal evolutions of the CO_2 fluxes were consistent with the changes in pCO_2 of brines. Snow reduced air-sea fluxes because of the formation of solid snow and ice lenses that precluded gas transfers (*fig. C*).

At "Bruxelles", the magnitude of fluxes was generally lower than in "Liege" partly due to lower pCO_2 gradients at the air-ice interface. On 3 occasions, the CO_2 fluxes over snow was higher than over the ice. This might due to surface biological communities in the air-snow interface and enhance CO_2 flux (*fig. A*).

Conclusions

Sea ice brines exhibited high temporal variability of pCO_2 that appeared to be related to a major sea ice physical process (flooding event). This underlines the large role of physical processes in pCO_2 dynamics in sea ice environment in addition to the chemical and biological processes previously reported.

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