Measurement of the partial pressure of CO_2 in bulk sea ice

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Why measuring the partial pressure of CO_2 (pCO_2) in sea ice ?

The impact of sea ice on the physical interactions between the atmosphere, the ocean and the biosphere is well known in the polar area. However, sea ice was assumed to be an impermeable and inert barrier to air-sea exchanges.
But Golden et al (1998) showed that sea ice is a highly permeable medium for liquids in warm conditions (T= -5°C, Salinity = 5).
Accordingly, uptake of atmospheric CO_2 over the sea ice cover in the Arctic and Southern oceans were recently reported.

Development of a new analytical method

Data on gas composition in sea ice are scarce. Unfortunately, conventional analytical methods cannot be applied for CO_2 in sea ice since CO_2 is mainly found in seawater media in the carbonate (CO_3^{2}) and bicarbonate (CO_3^{2-}) forms that cannot be measured by a simple extraction.

We use a new method that overcomes this issue. The backbone idea is that the ice sample is equilibrated with a standard atmosphere of known concentration in CO_2 (*fig.1*).

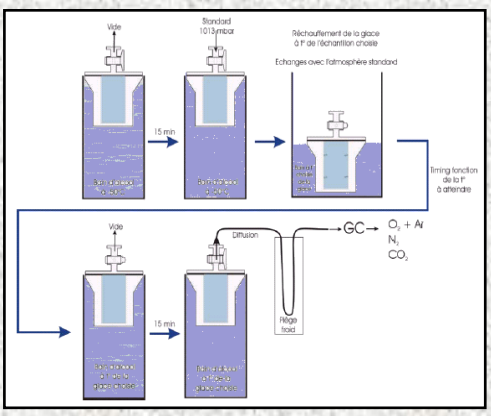


fig. 1 – New analytical method.
The ice sample is equilibrated with a standard atmosphere at a selected temperature (Verbeke 2005).

Manufacture of standard ice

We aimed to assess the reproducibility of the method. A prerequisite was to find a method to produce a standard ice with reproducible and homogeneous physical properties. We use an ice-cream maker to create a slush. During this process the slush is equilibrated with the external atmosphere to keep the pCO_2 of this ice constant. This slush is eventually squeezed with an hydraulic press in a cold room. Measurements of pCO_2 are carried out on this standard sea ice and compared to assess the reproducibility of the measurement.

Results

Above -8°C, the measures are linearly correlated with the temperature within 14% . Measurement carried out at the same temperature on the same block of standard sea ice are consistent. pCO2 measurements carried out on different sea ice blocks are also consistent (*fig. 2*).
At temperature lower than -8°C, we observed a large scattering of pCO_2, probably due to an insufficient equilibration.
We then tried to equilibrate the ice sample for longer time with the standard (*fig. 3*). The pCO_2 appears to increase with equilibration time.

Conclusions

The reproducibility of the method is lower than 14% at temperature above -8°C, giving some confidence in the overall method. However, at temperature lower than -8°C, longer equilibration times are required likely due to the low permeability of sea ice to gases. The optimal equilibration time still need to be assessed.

fig. 2 - pCO_2 vs Temp

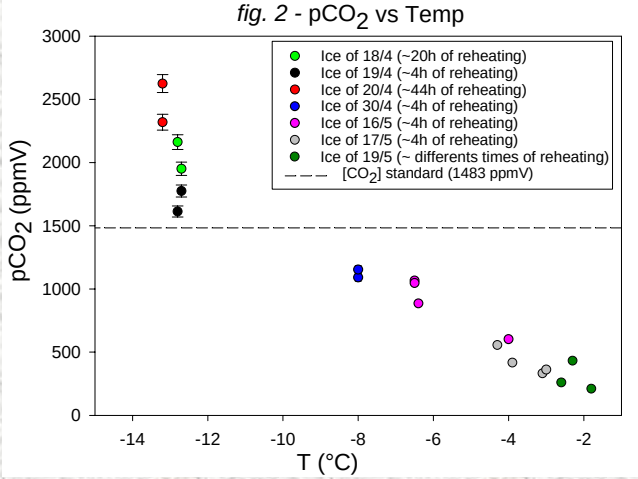
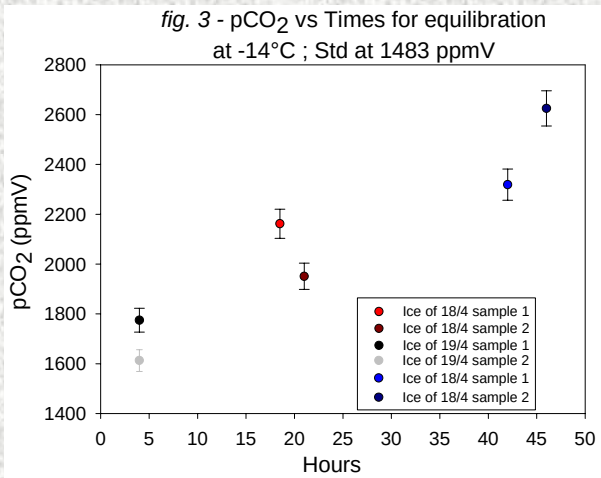


fig. 3 - pCO_2 vs Times for equilibration at -14°C ; Std at 1483 ppmV



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