# The study of air-ice $CO_2$ exchange emphasize the importance of gas bubble transport during sea ice growth

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## INTRODUCTION

Sea ice exchanges $CO_2$ exchanges with the ocean and the atmosphere. In the present study, we filled a tank with seawater and control the freezing of the room in order to reproduce ice growth and decay over 19 days experiment. The aims were to: (1) determine a gas transfer coefficient for $CO_2$ in sea ice, (2) understand the processes responsible for $CO_2$ transport between air and sea ice by comparing our results with a 1D biogeochemical model.

**Materials and Methods:** The air temperature above the tank was set to -15 °C the first 14 days, then to -1 °C the 5 last days. We measured continuously in situ ice temperature, underwater salinity and air-ice $CO_2$ fluxes. Ice cores were also collected regularly to measure biogeochemical variables.

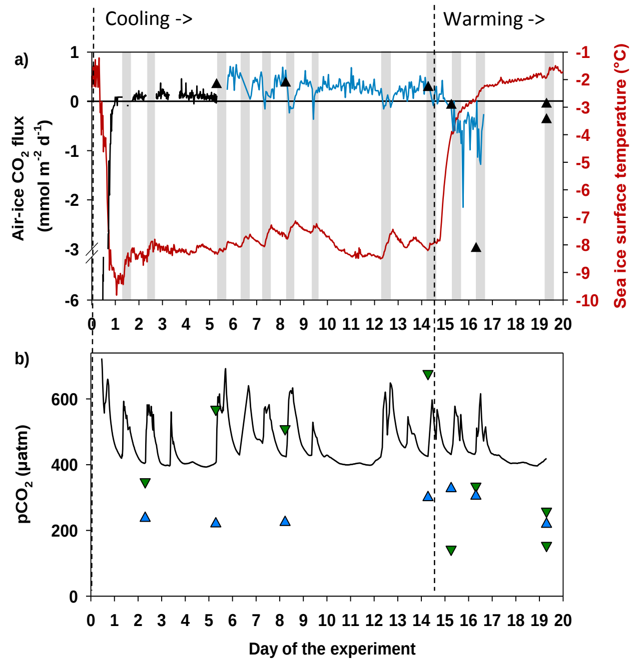
## F = air-ice $CO_2$ fluxes

We measured continuously temperature and air-ice $CO_2$ flux with an automated chamber over the ice. Sea ice shifts from:

(i) a sink during ice crystals formation,
(ii) a source during ice growth,
(iii) return to a sink during ice melt.

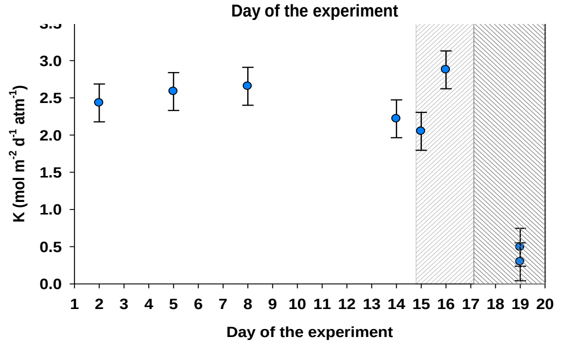
## dC = air-ice difference in $CO_2$ partial pressure

From the difference in partial pressure of $CO_2$ in the air and the ice, we calculated daily dC. The evolution of dC is consistent with measured flux (F), shifting from: (i) negative,
(ii) to positive and, finally
(iii) return negative.



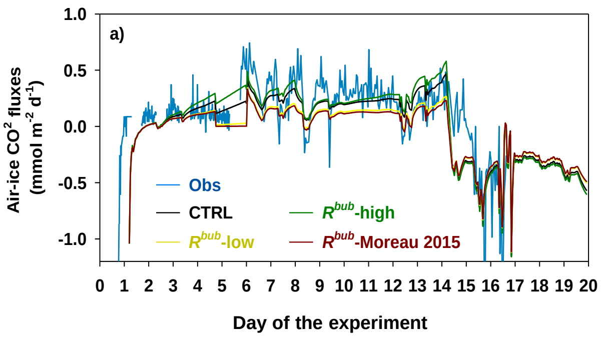

## Gas transfer coefficient for $CO_2$ : $K = F / (pCO_{2\,ice} - pCO_{2\,air})$

By combining F with dC, we determined gas transfer coefficients (K) for $CO_2$ at air-ice interface for growth and decay phases. K is 6 times higher during the growth phase compared to the decay phase. Transport of gas bubbles enhance dramatically transfer coefficient during ice growth, while only diffusion occurs during ice melt.




## 1D MODELLING EMPHASIZES THE ROLE OF BUBBLE

To mimic the observed air-ice $CO_2$ fluxes, we used the 1D model of Moreau et al. (2015). The inversion between outward $CO_2$ fluxes during ice growth and inward $CO_2$ fluxes during ice melt depicts well the observations. However, the model (M2015) strongly underestimates the fluxes during the cold phase if the formation rate of gas bubbles is low. Since ice is permeable throughout the cold phase, higher gas bubble formation rates are needed to reproduce high $CO_2$ fluxes during the growth phase.




## CONCLUSION:

- During sea ice growth, gas are transported by diffusion and buoyancy while convection is limited
- Gas transfer coefficients for $CO_2$ at air- ice interface differ for growth and decay : $K_{growth}$ **= 2,5** mol $m^{-2}\,d^{-1}\,atm^{-1}$ and $K_{decay}$ **= 0,4** mol $m^{-2}\,d^{-1}\,atm^{-1}$
- Our 1D model can simulate air-ice $CO_2$ fluxes and point to the role of gas bubbles in sea ice

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References: Moreau et al., 2015. Drivers of inorganic carbon dynamics in first-year sea ice : a model study. J. Geophys. Res. Ocean. 120, 471–495.