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Carbon dioxide dynamics in Antarctic pack ice and related air-ice CO_2 fluxes

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There is increasing evidence that sea ice can exchange directly CO_2 with the atmosphere. These exchanges are driven by the evolution of the partial pressure of CO_2 (pCO_2) within sea ice and controlled by its permeability. Both these CO_2 fluctuations and permeability are linked to peculiar physical and biogeochemical processes such as sea ice temperature and texture, biological activity or precipitation of calcium carbonate minerals ($CaCO_3$). Among them, sea ice temperature was suggested as one of the main physical control of the pCO_2 dynamics and CO_2 transfer. Highest oversaturation of CO_2 (pCO_2 up to 915 ppmV) were encountered in coldest ice and result from winter processes (increased brine salinities, calcium carbonate precipitation, bacterial remineralization). However cold ice is generally not permeable either to gas or water transfer. As the temperature crosses the threshold of about -5°C, sea ice become permeable to gas, and sea ice begins to release CO_2 to the atmosphere (up to 1.9 $mmol.m^{-2}.d^{-1}$). However, at the same time brine convection develops bottom-up in the sea ice cover and by fuelling microalgae primary production in nutrients, triggers strong undersaturation of CO_2 (pCO_2 down to 30 ppmV). Sea ice therefore turns into a CO_2 sink with CO_2 fluxes ranging from 0 to -6 $mmol.m^{-2}.d^{-1}$ depending, among other parameters, on the ice texture. On the whole, spring and summer Antarctic pack ice appears to act as a CO_2 sink which magnitude could be of significant importance in the budgets of air-sea CO_2 fluxes over the Southern Ocean.