Geophysical Research Abstracts, Vol. 9, 05158, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-05158

CO_2 diffusion in polar ice: Observations from the Siple Dome ice core, Antarctica

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CO_2 in air trapped in polar ice cores provides important information about past changes in the global carbon cycle. One common assumption in interpreting ice core CO_2 records is that diffusion in the ice does not affect the concentration profile. However, this assumption remains untested because the CO_2 diffusion coefficient in ice has not been accurately determined in the laboratory. In this study we take advantage of high levels of CO_2 associated with refrozen layers in ice core from Siple Dome, Antarctica, to study CO_2 diffusion rates. We use noble gases (Xe/Ar and Kr/Ar), electric conductivity, and Ca^{2+} ion concentration to show that substantial CO_2diffusion occurs in the ice on timescale of thousand of years. We estimate the permeation coefficient for CO_2 in ice (product of the diffusion constant and the solubility) as an order of 10^{-21} to 10^{-20} m^2s^{-1} mol CO_2 m^{-3} ice Pa^{-1} CO_2 at –23 ^oC. This diffusion smoothes rapid changes of the CO_2 record. However, the smoothing of the CO_2 record by diffusion is one or two orders of magnitude smaller than the smoothing produced by the gas age distribution in our samples. Further studies should include estimation of (1) the permeation coefficient in different depths and temperatures and (2) the change of CO_2 mixing ratio during storage with permeation coefficients for the main air gases such as O_2 and N_2.