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Fractionation of O2/N2 and Ar/N2 in the Antarctic ice sheet during bubble formation and bubble-clathrate hydrate transition from precise gas measurements of the Dome Fuji ice core

Content

The variations of δO2/N2 and δAr/N2 in the Dome Fuji ice core were measured from 112 m (bubbly ice) to 2001 m (clathrate hydrate ice). Our method, combined with the low storage temperature of the samples (-50 ℃), successfully excludes post-coring gas-loss fractionation signals from our data. From the bubbly ice to the middle of the bubble-clathrate transition zone (BCTZ) (112 – 800 m) and below the BCTZ (>1200 m), the δO2/N2 and δAr/N2 data exhibit orbital-scale variations similar to local summer insolation. The data in the lower BCTZ (800 – 1200 m) have large scatters, which may be caused by mm-scale inhomogeneity of air composition combined with finite sample lengths. The insolation signal originally recorded at the bubble close-off remains through the BCTZ, and the insolation signal may be reconstructed by analyzing long ice samples (more than 50 cm for the Dome Fuji core). In the clathrate hydrate zone, the scatters around the orbital-scale variability decrease with depth, indicating diffusive smoothing of δO2/N2 and δAr/N2. A simple gas diffusion model was used to reproduce the smoothing and thus constrain their permeation coefficients. The relationship between δAr/N2 and δO2/N2 is markedly different for the datasets representing bubble close-off (slope ~0.5), bubble-clathrate hydrate transformation (~1), and post-coring gas-loss (~0.2), suggesting that the contribution of the mass-independent and mass-dependent fractionation processes are different for those cases. The method and data presented here may be useful for improving the orbital dating of deep ice cores over the multiple glacial cycles and further studying non-insolation-driven signals (e.g., atmospheric composition) of these gases.

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