Fractionation of O_2/N_2 and Ar/N_2 in polar ice cores during bubble formation, bubble-clathrate transition, and gas loss during storage from precise gas measurements of the Dome Fuji ice core, Antarctica

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Air trapped in polar ice sheets provides various information on past climatic and atmospheric changes. The major atmospheric gases (N_2, O_2 and Ar) trapped in the ice sheet originate in the past atmosphere. However, O_2/N_2 and Ar/N_2 in the ice sheets, after correcting them for gravitational settling in firn, are significantly lower than the original atmospheric ratios due to selective loss of smaller molecules during the bubble formation process (e.g., Severinghaus and Battle, 2006), which in turn is controlled by the variation of local summer insolation through its effects on snow metamorphism (Bender, 2002; Fujita et al., 2009). The O_2/N_2 records have been used as the local insolation proxy for precise orbital dating of the Dome Fuji and Vostok deep ice cores (Kawamura et al., 2007; Suwa and Bender, 2008). The fractionations of O_2/N_2 and Ar/N_2 also occur during bubble-clathrate hydrate transition in the bubble-clathrate hydrate transition zone (BCTZ) (e.g., Ikeda-Fukazawa et al., 2001), and during coring and storage of ice cores (artifact gas-loss) (Bender et al., 1995; Severinghaus et al., 2009). Better understanding of the fractionation of O_2/N_2 and Ar/N_2 under the various processes is important for the deep-ice-core dating and eventual reconstruction of the past atmospheric O_2 concentration from ice cores.

In this work, we have been analyzing the first Dome Fuji core, drilled in the mid-1990s and kept at -50 ˚C, with a newly developed method to reconstruct the O_2/N_2 and Ar/N_2 ratios as originally recorded in the ice sheet. The average value of O_2/N_2 and Ar/N_2 are approximately -10 and -5 ‰, respectively. Our new O_2/N_2 data agree well with the previous data (Kawamura et al., 2007) that was corrected for gas-loss during the core storage at -25 ˚C, suggesting successful reconstruction of O_2/N_2 and Ar/N_2 without post-coring gas-loss. The variations of O_2/N_2 and Ar/N_2 from the bubbly ice zone (112 – 450 m) and upper BCTZ (450 – 800 m) are similar to the local summer insolation curve. In the lower BCTZ (800 – 1200 m), short-term scatters becomes extremely large, possibly due to layered (vertically inhomogeneous) distribution of highly fractionated (O_2-rich) air hydrates. Below BCTZ (> 1200 m), the short-term scatters gradually decrease toward deeper depths, and the similarities of O_2/N_2 and Ar/N_2 variations with the summer insolation curve is re-established. In the presentation, we will discuss gas fractionations associated with the bubble-close off, transformation of bubbles to clathrate hydrates, and post-coring gas loss.

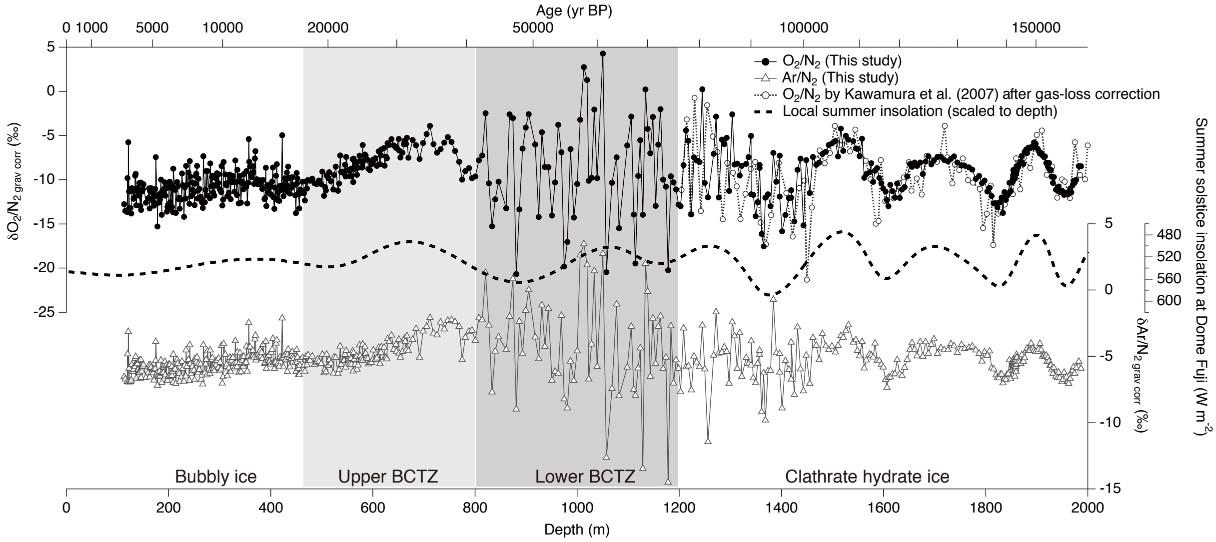

Figure: O_2/N_2 and Ar/N_2 data analyzed in this study, together with the previous O_2/N_2 data by Kawamura et al. (2007) and local summer insolation curve scaled to depth.

References: Bender, M. et al., *Geophys. Res.*, 1995., Bender, M. L., *Earth Planet. Sci. Lett.*, 2002.; Fujita, S. et al., *J. Geophys. Res.*, 2009.; Ikeda-Fukazawa, T. et al., *J. Geophys. Res.*, 2001.; Kawamura, K. et al., *Nature*, 2007.; Severinghaus, J. P., & Battle, M. O., *Earth Planet. Sci. Lett.*, 2006.; Severinghaus, J. P. et al., *Science*, 2009.; Suwa, M., & Bender, M. L., *Quat. Sci. Rev.*, 2008.