Composition of firn air collected at H128, a coastal site in East Antarctica

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Ice cores contain air bubbles, which allow us to reconstruct past atmospheric histories. One difficulty is that trapped gas is younger than surrounding ice (the age difference is called Δage) because gas trapping occurs at several tens to ~100m below surface. To accurately estimate Δage, understating of past firn thickness and accumulation rate are necessary. Also, it is important to understand gas fractionation in open pores in firn and during bubble close off. One approach to study these processes is to measure air withdrawn from modern firn under various climatic conditions. We present the results of firn air at H128 in coastal area of East Antarctica, ~80 km from Syowa Station. The firn air was measured for $\delta^{15}N$, $\delta^{18}O$, $\delta^{40}Ar$, $\delta O_2/N_2$, $\delta Ar/N_2$, $\delta^{86}Kr$ and $\delta Xe/Ar$ at National Institute of Polar Research using two mass spectrometers, and CH_4, CO_2, N_2O and SF_6 concentrations at Tohoku University using a non-dispersive infrared spectrometer and two gas chromatographs.

Our results show that $\delta^{15}N$, $\delta^{18}O$, $\delta^{40}Ar$, $\delta O_2/N_2$, $\delta Ar/N_2$, $\delta^{86}Kr$ and $\delta Xe/Ar$ linearly increase with depth as expected for gravitational fractionation. There are offsets between the observed depth profiles and barometric line with the mean temperature at the site (δ (‰)≅Δmgz/RT*1000)[1], suggesting the existence of a convective zone. We estimate the convective zone thickness to be 5-6 m, by fitting a line with the barometric slope to the $\delta^{15}N$ and $\delta^{18}O$ data in the deep firn (37.48 –40.55 m). The convective zone is deeper than most sites in Greenland and Antarctica (mostly 0-2 m). A deep convective zone (~14 m) has been found at YM85, a middle-elevation site in Antarctica (Kawamura et al., 2006[2]), probably due to strong katabatic wind over surface topography. Wind at H128 is probably weaker than at YM85 but stronger than at most (or all) studied sites having shallow convective zones.

Positive and negative anomalies from the barometric line are seen around 0-10 and 20-35 m, respectively. These anomalies are the result of thermal diffusion due to varying seasonal temperature gradients in the top few meters in firn since the previous winter before the sampling.

Increases in $\delta^{15}N$, $\delta^{18}O$, $\delta^{40}Ar$, $\delta^{86}Kr$ and $\delta Xe/Ar$ cease below 40.55m. On the other hand, $\delta O_2/N_2$ and $\delta Ar/N_2$ strongly increase below this depth. Depth range between 40.55m and bubble close off depth is called “lock-in zone” where vertical air exchange due to molecular diffusion is impeded by impermeable layers (high density, early closed-off layers). The thickness of lock-in zone at H128 is estimated to be 7-8m from the data. Concentrations of CH_4, N_2O, SF_6 and CO_2 strongly decrease in the lock-in zone. Because lock-in zone has impermeable (or nearly impermeable) layers, the age of each layer becomes old with depth at approximately the same rate as the surrounding firn. The strong decreases are the result of rapid increases of these greenhouse gases in the atmosphere over the last few decades. By comparing CH_4 concentration with direct observation and previous works of firn and ice-core gas measurements (summarized in ref. 3), the age of the deepest firn air (at 47.69 m) is estimated to be about 1970 C.E.

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