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Oxygen-to-nitrogen ratios in 1.5-million-year-old ice cores from Allan Hills Blue Ice Areas: implications for the long-term atmospheric oxygen concentrations

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Gases preserved in ice cores provide a potential direct archive for atmospheric oxygen. Yet, oxygen-to-nitrogen ratios in ice cores (expressed as $\delta O_2/N_2$) are modified by a number of processes related to gas trapping and gas losses in the ice. Such complications have long hindered the use of ice core $\delta O_2/N_2$ to derive true atmospheric oxygen concentrations. Recently, a persistent decline in $\delta O_2/N_2$, observed in four different ice cores (GISP2, Vostok, Dome F, and EDC), is interpreted to reflect decreasing atmospheric O_2 concentrations over the late Pleistocene (Stolper et al., 2016). The rate of $\delta O_2/N_2$ change is -8.4±0.2 ‰/Myr (1σ). Using new measurements made on EDC samples stored at -50 °C and therefore free from gas loss, Extier et al (2018) confirms the decrease in $\delta O_2/N_2$ with a slope of -7.0±0.6‰/Myr (1σ).

Here, we present new $\delta O_2/N_2$ measurements made on 1.5-million-year-old blue ice cores from Allan Hills Blue Ice Areas, East Antarctica. We use argon-to-nitrogen ratios ($\delta Ar/N_2$) in the ice to correct for the fractionations during bubble close-off and gas losses. In those processes, $\delta Ar/N_2$ is fractionated in a fashion similar to $\delta O_2/N_2$ (Huber et al., 2006; Severinghaus and Battle, 2006). Paired $\delta O_2/N_2$-$\delta Ar/N_2$ values measured from the same sample were classified into three different time slices: 1.5 Ma (million years old), 950 ka, and 490 ka. Between 950 ka and 490 ka, we observe a decline in $\delta O_2/N_2$ similar to that observed in the aforementioned deep ice cores. This observation gives us confidence in the validity of the Allan Hills blue ice $\delta O_2/N_2$ records. Between 1.5 Ma and 950 ka, however, there is no statistically significant trend in ice core $\delta O_2/N_2$. Our results show a surprising lack of variability from 1.5 to 0.95 Ma; even during the past ~0.9 Ma, the rate of decline was very slow.