EGU22-12025
https://doi.org/10.5194/egusphere-egu22-12025
EGU General Assembly 2022

Oxygen in the trapped air: identifying primary atmospheric signals and secondary bubble close-off fractionation

Yuzhen Yan[1], Michael Bender[1,2], and John Higgins[1]
[1]Department of Geosciences, Princeton University, Princeton, NJ, USA
[2]School of Oceanography, Shanghai Jiao Tong University, Shanghai, China

Ice cores offer a unique opportunity to study past atmospheric composition because the trapped gases are ultimately derived from ancient atmosphere. This distinctive ability has motivated some pioneering efforts in the late 1980s to measure the elemental composition of the trapped air. The goal at that time was to reconstruct past atmospheric O_2 concentration variations (PO_2), the primary (atmospheric) signal. However, these measurements quickly revealed that oxygen, argon, and nitrogen concentrations in the ice (expressed as $\delta O_2/N_2$ and $\delta Ar/N_2$) are altered by gas-trapping processes. This is the secondary (and confounding) signal formation process.

Such alterations have long thwarted the application of ice core $\delta O_2/N_2$ to reconstruct true PO_2. Empirically though, $\delta O_2/N_2$ in the trapped air has a high coherency with local summer insolation, but the cause is not well understood. Presumably, the intensity of sunlight on the surface of the ice sheet determines the extent and nature of snow metamorphism, which in turn modulates the magnitude of O_2 and Ar losses relative to N_2 at the "bubble close-off depth" (typically 70-120 m in polar regions).

Here, we discuss recent efforts to identify the secondary signals in $\delta O_2/N_2$ and extract the primary, atmospheric PO_2 signals. First, using $\delta Ar/N_2$ as a proxy for insolation, we show that PO_2 remained stable prior to the Mid-Pleistocene Transition (MPT), the shift from 40- to 100-kyr glacial cycles. After the MPT, however, PO_2 began to decline, possibly linked to enhanced to weathering as a result of glacier expansion and, to a lesser degree, more exposed areas of the continental shelves.

Next, we proceed to exploit the secondary signal itself. That is, $\delta O_2/N_2$ and $\delta Ar/N_2$ could be used as a direct proxy of local insolation. By examining the relationship between elemental ratios and temperature proxies, we explore the relationship between high-latitude southern hemisphere insolation and Antarctic temperature in three time slices in the Pleistocene. The implications for the nature of 40-kyr glacial cycles will be discussed.