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Millennial and Sub-millennial Variability of Total Air Content from the WAIS Divide Ice Core

Jon Edwards (1), Edward Brook (1), John Fegyveresi (2), James Lee (1), Logan Mitchell (3), Todd Sowers (2), Richard Alley (2), Joe McConnell (4), Jeff Severinghaus (5), and Daniel Baggenstos (5)

(1) Oregon State University, College of Earth Ocean and Atmospheric Sciences, Corvallis, United States, (2) Penn State University, Department of Geosciences, College Station, Pennsylvania, United States, (3) University of Utah, Department of Atmospheric Sciences, Salt Lake City, Utah, United States, (4) Desert Research Institute, Nevada System of Higher Education, Reno, Nevada, United States, (5) University of California at San Diego , Scripps Institution of Oceanography, San Diego, California, United States

The analysis of ancient air bubbles trapped in ice is integral to the reconstruction of climate over the last 800 ka. While mixing ratios of greenhouse gases along with isotopic ratios are being studied in ever increasing resolution, one aspect of the gas record that continues to be understudied is the total air content (TAC) of the trapped bubbles. Published records of TAC are often too low in temporal resolution to adequately capture sub-millennial scale variability.

Here we present a high-resolution TAC record (10-50 year sampling resolution) from the WAIS Divide ice core, measured at Oregon State and Penn State Universities. The records cover a variety of climatic conditions over the last 56 ka and show millennial variability of up to 10% and sub-millennial variability between 2.5 and 3.5%. We find that using the pore close off volume parameterization (Delomotte et al., J. Glaciology, 1999, v.45), along with the site temperature derived from isotopes, our TAC record implies unrealistically large changes in surface pressure or elevation. For example, the TAC decreases by $\sim$10% between 19.5ka and 17.3ka, and would imply an elevation increase of nearly 800m. The total accumulation of ice over this period is just 280m (Fudge et al. Nature 2013), making the calculated elevation interpretation implausible.

To resolve this discrepancy, we investigate the millennial and sub-millennial variability in our TAC record as a function of changes in firn densification and particularly layering. The firn is the uppermost layer of an ice sheet where snow is compressed into ice, trapping ancient air. Thus firn processes are important for the interpretation of total air content as well as other gas records. We compare our TAC record with proxies for dust, temperature and accumulation to determine how processes other than elevation affect TAC.