

2.7-million-year-old ice from Allan Hills Blue Ice Areas, East Antarctica reveals climate snapshots since early Pleistocene

YUZHEN YAN^{1*}, JESSICA NG², JOHN HIGGINS¹, ANDREI KURBATOV³, HEATHER CLIFFORD³, NICOLE SPAULDING³, JEFFREY SEVERINGHAUS², ED BROOK⁴, PAUL MAYEWSKI³, AND MICHAEL BENDER¹

¹Department of Geosciences, Princeton University, Princeton, NJ (*correspondence: yuzheny@princeton.edu)

²Scripps Institution of Oceanography, University of California, San Diego, CA

³University of Maine, Climate Change Institute, Orono, ME

⁴College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR

A tight coupling between atmospheric CO₂ and global climate over the last 800 thousand years (kyr) has been established by analyzing ancient air trapped in Antarctic ice cores. 1-million-year-old (Ma) ice has been found in Allan Hills Blue Ice Areas (AH BIAs), East Antarctica [1], a region where old ice flows along the rising bedrock and approaches the surface. Although the blue ice core is stratigraphically disturbed, it provides the first direct observations of *p*CO₂ before 800 kyr as “climate snapshots”.

Here we report the discovery of clean, ancient, bubbly ice as old as 2.7±0.3 Ma at shallow depth from AH BIAs. The ice is dated by precisely measuring the isotopic composition of argon in the trapped air. Radiogenically produced by ⁴⁰K in the solid Earth, ⁴⁰Ar accumulates over time in the atmosphere. By contrast ³⁸Ar and ³⁶Ar are primordial and have constant atmospheric burdens. A further benefit of our analytical procedures is the ability to measure Xe/Kr ratios in the same aliquot of extracted ice core gas, allowing the reconstruction of past mean ocean temperature.

The old ice can be binned into three age groups: 1 Ma, 1.5 Ma, and 2+ Ma, disturbed by layers of ≤800 ka ice. This age-depth relationship indicates large-scale disturbance in the ice stratigraphy, reinforcing the concept of climate snapshots instead of time-series. Three climate proxies (Xe/Kr, δD_{ice}, and *p*CH₄) fall within the range of variations in the recent 100-kyr glacial cycles, but with reduced variability.

[1] Higgins, J.A., Kurbatov, A.V., Spaulding, N.E., Brook, E., Introne, D.S., Chimiak, L.M., Yan, Y., Mayewski, P.A. and Bender, M.L., 2015. Atmospheric composition 1 million years ago from blue ice in the Allan Hills, Antarctica. *Proceedings of the National Academy of Sciences*, 112(22), pp.6887-6891.