

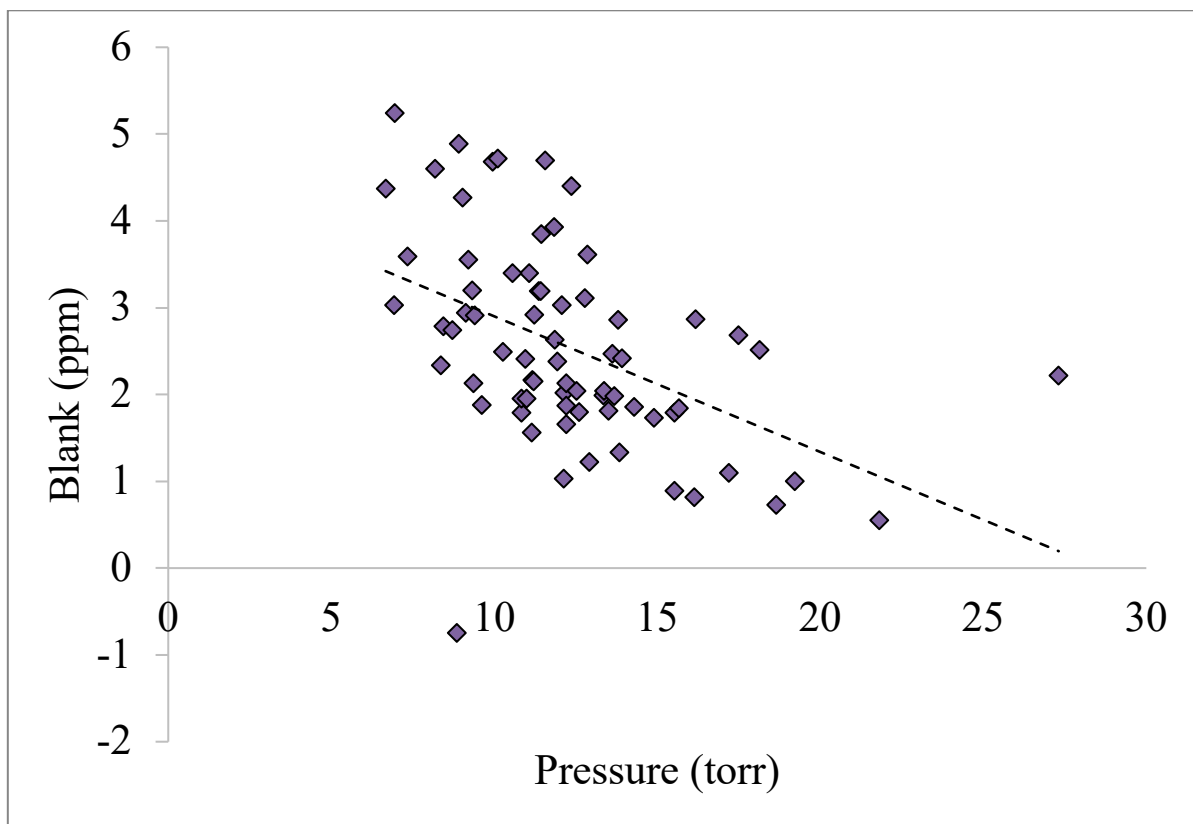
Supplement of

5

A high-resolution Termination II trace gas record and chronology for a continuous ice core from the Allan Hills Blue Ice Area, Antarctica

10 Julia Marks-Peterson et al.

Correspondence to: Julia Marks-Peterson (peterju2@oregonstate.edu)



15 **Figure S1. Instrumental “blank” values for the CO₂ measurement system plotted against pressure. For pressures from 6 to 30 torr, a negative correlation exists with blank values. The linear regression ($R^2=0.27$, $p<<0.01$) was used to correct CO₂ measurements.**

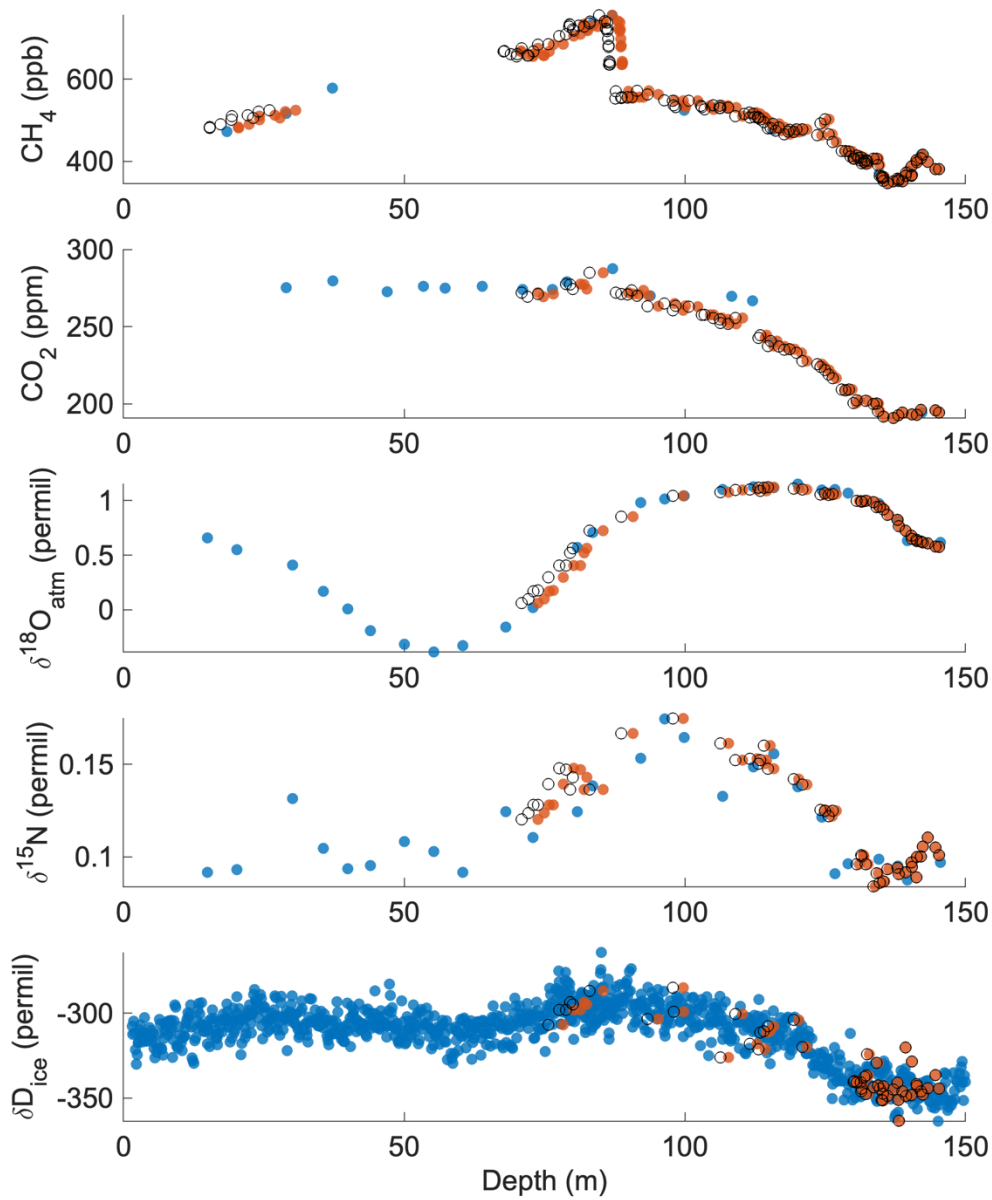


Figure S2. Alignment of gas and ice records from the ALHIC1903 (this study, Carter et al., 2024) and S27 (Spaulding et al., 2013; Yan et al., 2021) ice cores (from top to bottom: CH₄, CO₂, δ¹⁸O_{atm}, δ¹⁵N-N₂, and δD_{ice}) plotted on depth. ALHIC1903 measurements plotted on original depths (open circles) and on adjusted depth (orange) to fit with S27 records (blue, Yan et al., 2021).

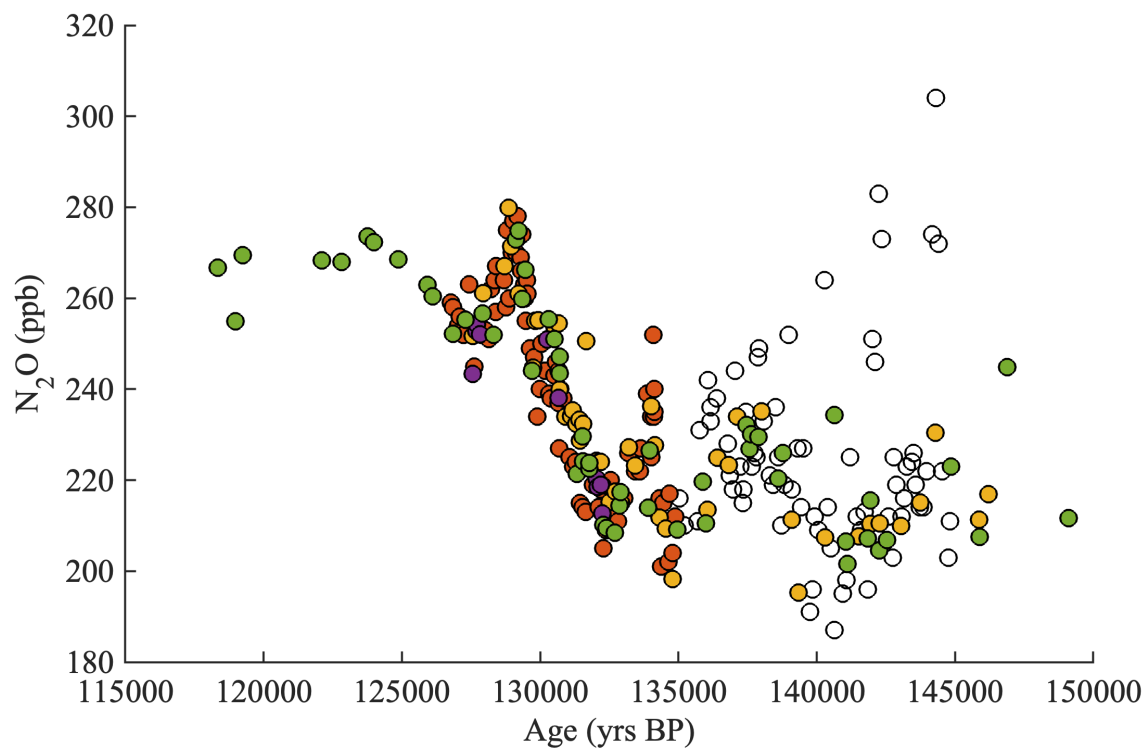


Figure S3. N₂O records from ALHIC1903 and EDC (red, Schmidely et al., 2021). ALHIC1903 measurements from three analytical systems: dry extraction at OSU (yellow), wet extraction at OSU (purple) and dry extraction at UCI (green). EDC measurements excluded from record due to *in situ* production shown in open circles.

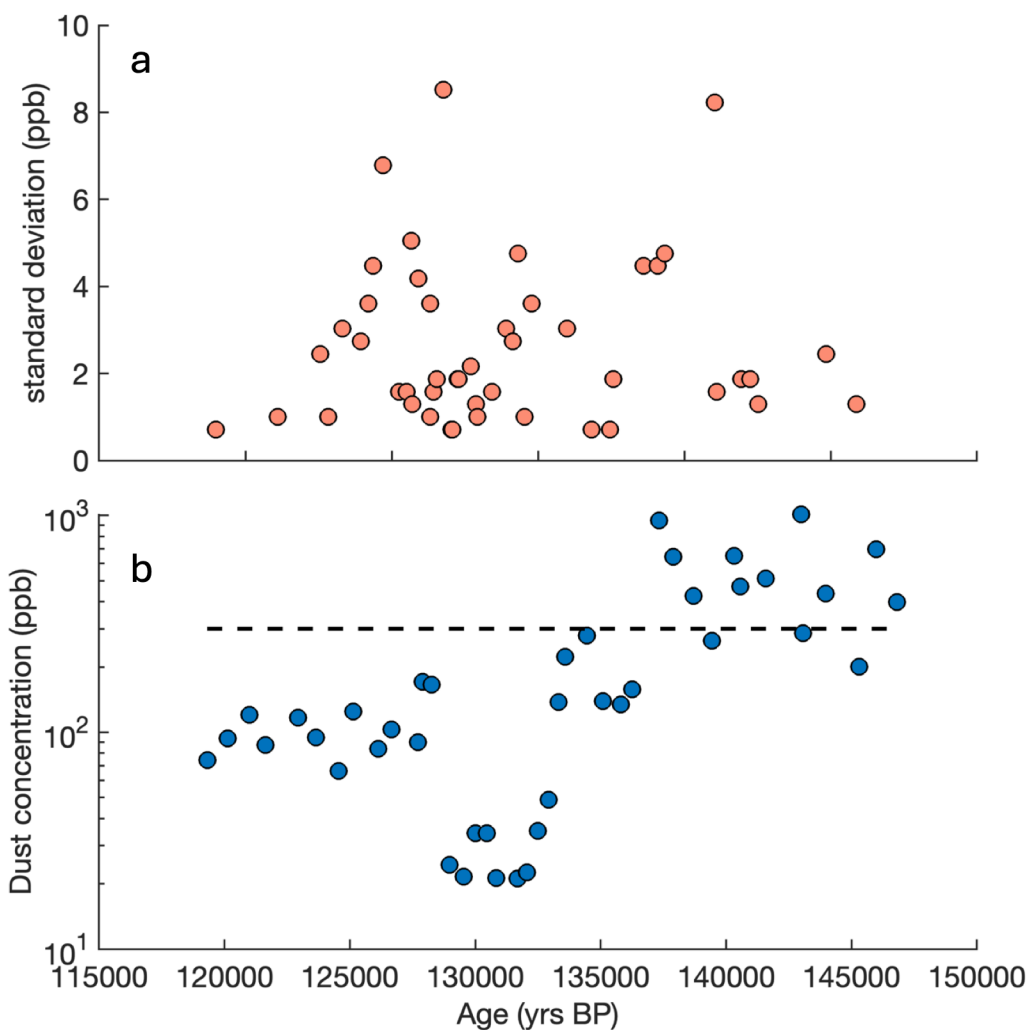


Figure S4. S4a: The standard deviation between adjacent N_2O concentrations in ALHIC1903 for samples <600 years apart. All three N_2O datasets from Oregon State University and University of California Irvine are included. **S4b:** ALHIC1903 dust concentration record from Carter et al., 2026 across a diameter range of 1-20 μm . Glacial-level samples are above the 300-ppb threshold (black dashed line) identified in Schilt et al., 2010 and Flückiger et al., 2003 and used to exclude N_2O concentrations affected by dust-related reactions.

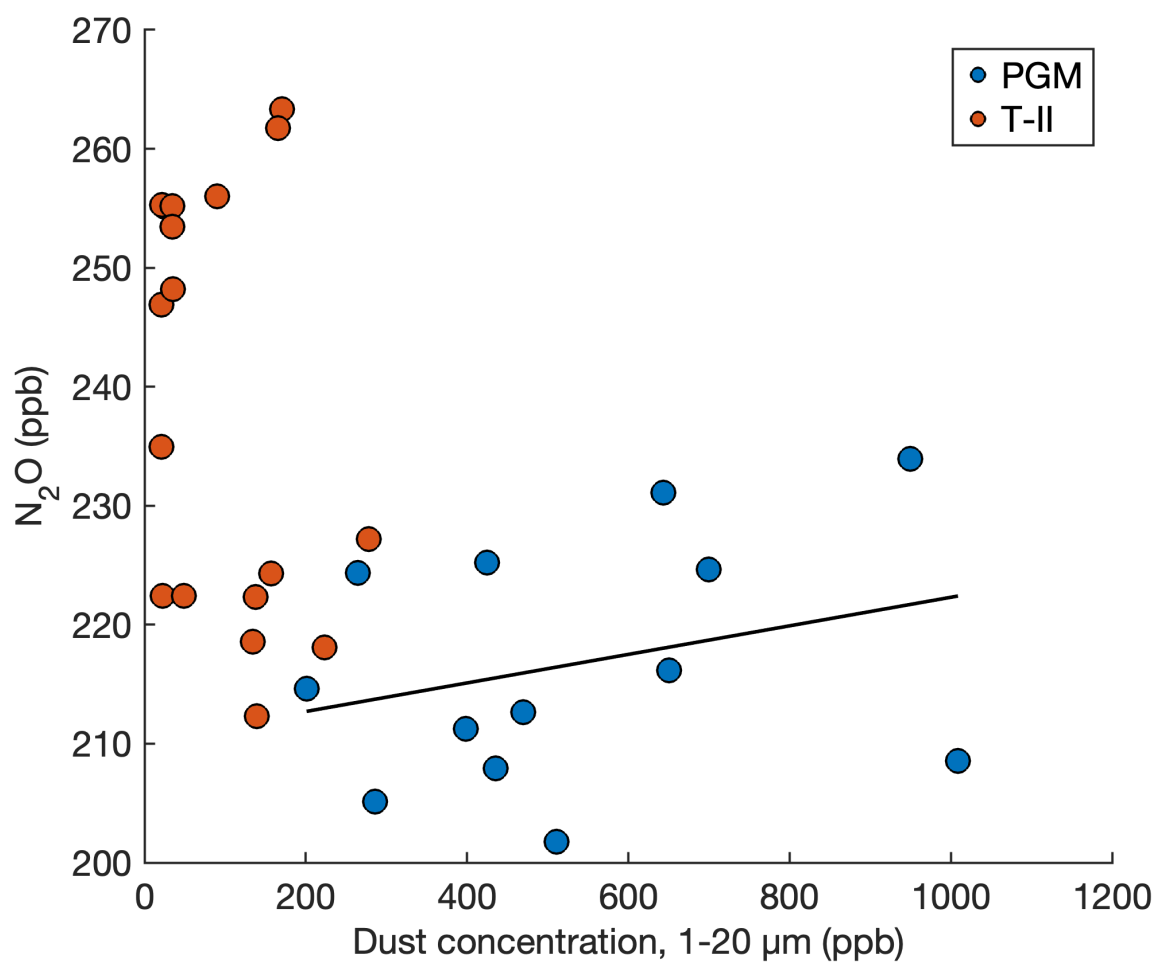


Figure S5. Cross plot of dust concentration from Carter et al., 2026 and N₂O concentration separated by time interval (PGM in blue, T-II in red). Though many PGM dust concentrations are above the 300-ppb threshold identified in Schilt et al., 2010 and Flückiger et al., 2003, the correlation between dust and N₂O is not statistically significant ($R^2 = 0.08$, $p \gg 0.05$).

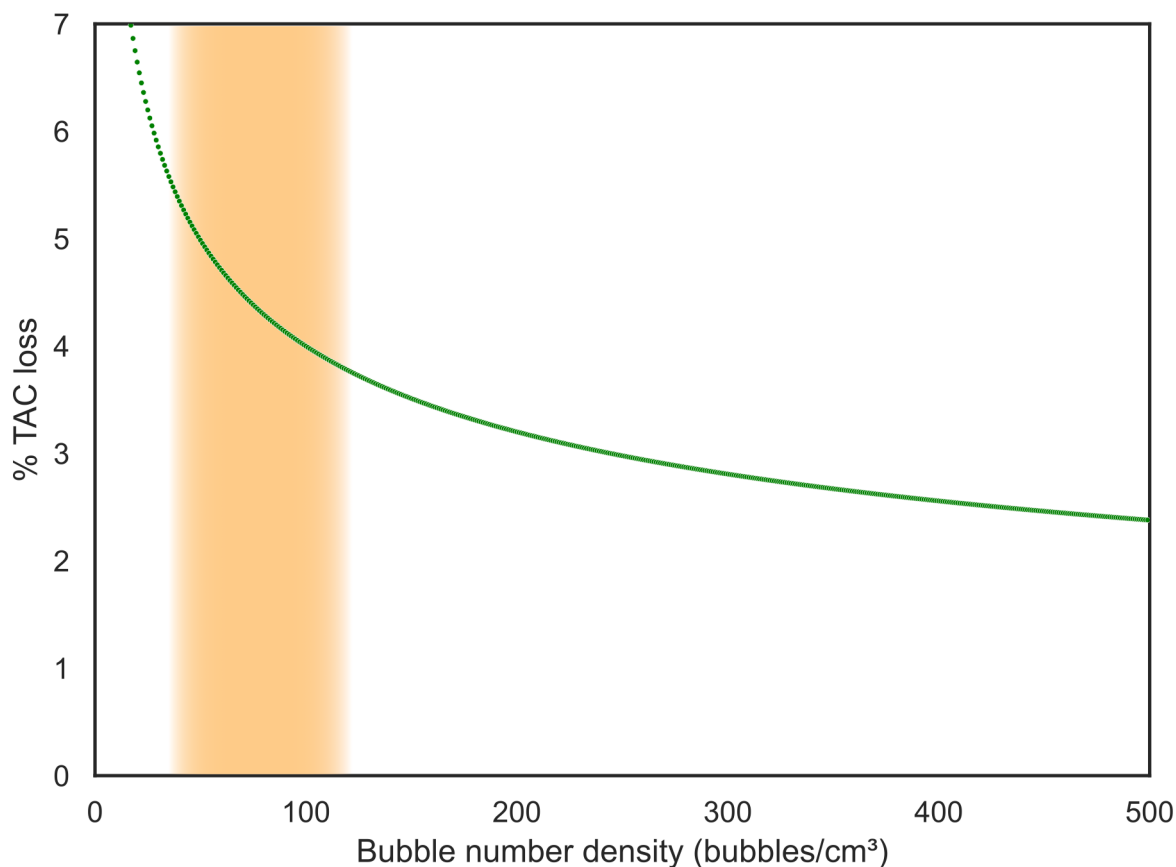


Figure S6. Dependence of the fraction of TAC loss from the cut-bubble effect on bubble number density. Densities range from ~200-500 bubbles/cm³ for typical polar ice cores, in contrast to the low densities measured in the ALHIC1901 ice core (tan bar) of 35-120 bubbles/cm³ (Stoll et al., 2026). We applied a 4.7% TAC loss for both Allan Hills ice cores.

Cut-bubble correction

Using the statistical relationships between bubble characteristics and the magnitude of the cut-bubble effect derived by (Martinerie et al., 1990), we constructed a computer model for predicting the cut-bubble effect based on bubble number density.

Our computer model randomly populates a rectangular prism sample (with dimensions s_1, s_2, s_3) of ice with spherical bubbles.

Each of the x, y, and z coordinates of the center of each bubble is randomly chosen from the interval $\left(-\frac{s_i}{2} - r, \frac{s_i}{2} + r\right)$, where s_i is the sample length in the corresponding dimension. For each bubble, the computer program checks to see if the bubble is cut based on the distance of each coordinate from the side of the sample; a bubble is cut if for at least one coordinate of the

bubble's center, x_i , $\left|\frac{s_i}{2} - x_i\right| \leq r$ or $\left|x_i + \frac{s_i}{2}\right| \leq r$. The program then calculates the percentage of bubbles that are cut.

50 Assuming that bubbles are on average cut through their centers (and so on average, half of a given cut bubble was contained in the sample), the percentage of TAC loss can be written as half the percentage of bubbles cut.

Building on this basis, we modified the computer model to accept bubble number density, rather than bubble radius, as an input from which to run trials. From a given bubble number density, mean bubble size was determined by relating bubble
55 volume, bubble number density, and porosity using Equation S1.

$$\text{Mean bubble volume (cm}^3\text{/bubble)} = \frac{\text{porosity}}{\text{bubble number density (bubbles/cm}^3\text{)}}, \quad (\text{S1})$$

In this relation, we assumed a porosity of 0.45%, which is mean value observed in ALHIC1901 (Stoll et al., 2026). Assuming
60 ice samples were uniform dimensions (2.4cm x 2.4cm x 9cm, the typical sample size for TAC measurements conducted at OSU), we ran three trials for each bubble number density between 10-500 bubbles/cm³.

In addition to using the computer model, we also derived a probability-based equation for percent TAC loss based on the sample dimensions and bubble size. First, we calculate the probability that any given bubble is not cut. We assume, as in the
65 computer model, that a bubble is not cut if its center is further than a distance of r from any side of the sample, i.e. for coordinate x_i , $x_i \in \left(-\frac{s_i}{2} + r, \frac{s_i}{2} - r\right)$. Using the fact that the bubble's coordinates are randomly chosen from the range $\left(-\frac{s_i}{2} - r, \frac{s_i}{2} + r\right)$, we can say that for each dimension, the probability that a bubble's coordinate is within this inner interval is

$$P_{\text{not cut}} = \frac{\frac{s_i}{2} - r - \left(-\frac{s_i}{2} + r\right)}{\frac{s_i}{2} + r - \left(-\frac{s_i}{2} - r\right)} = \frac{s_i - 2r}{s_i + 2r}, \quad (\text{S2})$$

70

Because the bubble coordinates are independent and must each fall in a specific range, the overall probability that a bubble is not cut can be written and rearranged as

$$P_{\text{cut}} = 1 - \left(\frac{s_1 - 2r}{s_1 + 2r}\right) \left(\frac{s_2 - 2r}{s_2 + 2r}\right) \left(\frac{s_3 - 2r}{s_3 + 2r}\right), \quad (\text{S3})$$

75

The actual percentage of cut bubbles in a sample is close to the probability of any individual bubble being cut. To get from percentage of bubbles cut to percent TAC loss, we again use the assumption that bubbles are on average cut through their center, which yields the final equation

$$\% \text{ TAC loss} = \frac{1}{2} \left[1 - \left(\frac{s_1 - 2r}{s_1 + 2r} \right) \left(\frac{s_2 - 2r}{s_2 + 2r} \right) \left(\frac{s_3 - 2r}{s_3 + 2r} \right) \right],$$

(S4)

A comparison of the computer model, the equation derived here, and the statistical relation given by Martinerie et al. (Martinerie et al., 1990) show strong agreement (Figure S6).

Table S1. A list of tie points used for chronology development with associated tie point uncertainty.

Original ALHIC1903 Depth (m)	Adjusted Depth (m)	AICC2023 Age (yrs)	Tie point uncertainty (yrs)	Tie point variable	Tie point Reference
15.37	20.48	116745	797	CH ₄	Loulergue et al., 2008
26.04	30.72	118014	772	CH ₄	Loulergue et al., 2008
67.725	70.73	126774	751	CH ₄	Schmidely et al., 2021
70.93	73.80	127557	766	δ ¹⁸ O _{atm}	Bouchet et al., 2023
73.84	76.60	127929	763	δ ¹⁸ O _{atm}	Bouchet et al., 2023
77.61	80.21	128485	735	δ ¹⁸ O _{atm}	Bouchet et al., 2023
80.07	82.58	128943	718	δ ¹⁸ O _{atm}	Bouchet et al., 2023
86.435	88.74	129517	770	CH ₄	Schmidely et al., 2021
106.36	108.32	130818	796	δ ¹⁸ O _{atm}	Bouchet et al., 2023
115.71	116.78	132282	852	CH ₄	Schmidely et al., 2021
124.96	125.66	134320	933	CH ₄	Schmidely et al., 2021
126.31	126.96	134790	985	CH ₄	Schmidely et al., 2021
134.185	134.51	139307	1101	CH ₄	Schmidely et al., 2021
136.12	136.37	141067	1237	CH ₄	Schmidely et al., 2021
140.42	140.50	144172	2894	δ ¹⁸ O _{atm}	Bouchet et al., 2023
142.345	142.35	144537	1234	CH ₄	Schmidely et al., 2021
145.28	145.16	146215	1697	δ ¹⁸ O _{atm}	Bouchet et al., 2023

References

Carter, A., Aarons, S., Schnaubelt, J., Tabor, C., Higgins, J., Shackleton, S., Epifanio, J., Morgan, J., Koornneef, J., Davies, G. R., Gabrielli, P., Choi, A., Severinghaus, J. P., Brook, E. J., Introne, D. S., Marks Peterson, J., and Sutter, J.: Evidence for diminished Ross Ice Shelf and West Antarctic Ice Sheet during the Last Interglacial from ice cores at the Allan Hills, Antarctica, in Review, 2024.

Martinerie, P., Lipenkov, V. Y., and Raynaud, D.: Correction Of Air-content Measurements In Polar Ice For The Effect Of Cut Bubbles At The Surface Of The Sample, Journal of Glaciology, 36, 299–303, <https://doi.org/10.3189/002214390793701282>, 1990.

Schmidely, L., Nehrbass-Ahles, C., Schmitt, J., Han, J., Silva, L., Shin, J., Joos, F., Chappellaz, J., Fischer, H., and Stocker, T. F.: CH₄ and N₂O fluctuations during the penultimate deglaciation, Climate of the Past, 17, 1627–1643, <https://doi.org/10.5194/cp-17-1627-2021>, 2021.

- 100 Spaulding, N. E., Higgins, J. A., Kurbatov, A. V., Bender, M. L., Arcone, S. A., Campbell, S., Dunbar, N. W., Chimiak, L. M., Introne, D. S., and Mayewski, P. A.: Climate archives from 90 to 250 ka in horizontal and vertical ice cores from the Allan Hills Blue Ice Area, Antarctica, *Quat. res.*, 80, 562–574, <https://doi.org/10.1016/j.yqres.2013.07.004>, 2013.
- 105 Stoll, N., Shaya, M., Kirkpatrick, L., Freitag, J., Hishamunda, V., Manos, J.-M., Jansen, D., Weikusat, I., Fegyveresi, J., Lipovsky, B. P., Brook, E., Shackleton, S., Higgins, J., and Fudge, T. J.: Fabric, Texture, and Bubble Characteristics of the Million-Year Old Allan Hills Blue Ice Core ALHIC1901, *Journal of Geophysical Research: Solid Earth*, 131, e2026JB033890, <https://doi.org/10.1029/2026JB033890>, 2026.
- Yan, Y., Spaulding, N. E., Bender, M. L., Brook, E. J., Higgins, J. A., Kurbatov, A. V., and Mayewski, P. A.: Enhanced moisture delivery into Victoria Land, East Antarctica, during the early Last Interglacial: implications for West Antarctic Ice Sheet stability, *Climate of the Past*, 17, 1841–1855, <https://doi.org/10.5194/cp-17-1841-2021>, 2021.