

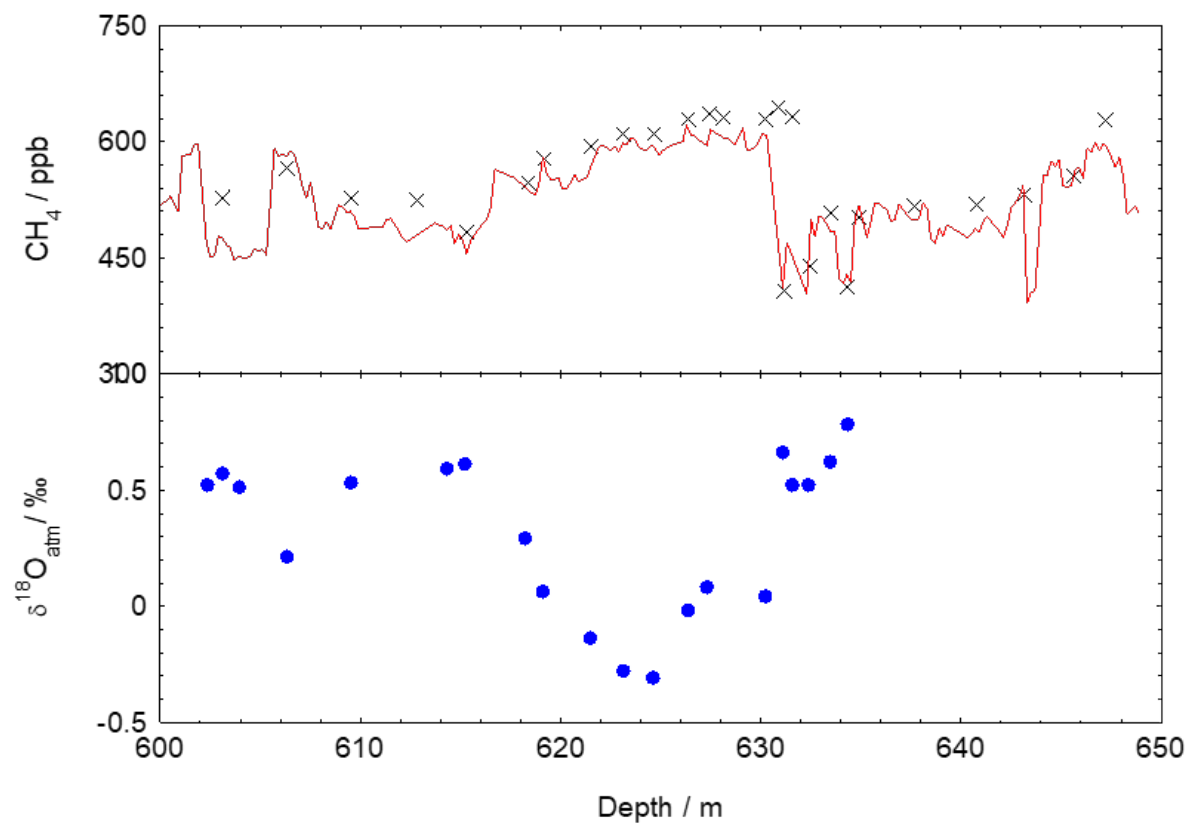
Supplementary Table S1. Values of methane concentration and $\delta^{18}\text{O}_{\text{air}}$ (and where available $\delta^{15}\text{N}$) for discrete analyses of the Skytrain Ice Rise core. The third tab of this table shows paired values of both measurements for adjacent samples.

Supplementary Table S2. Values of ^{10}Be measured on Skytrain Ice rise samples across the Laschamp Event.

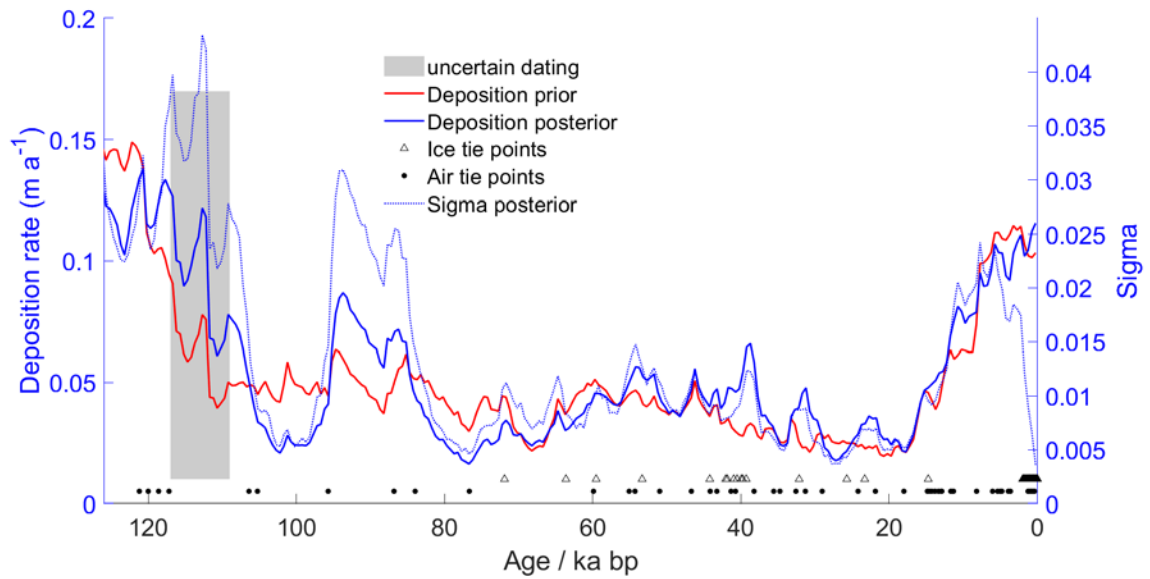
Supplementary Table S3. Gas age tie points for the Skytrain Ice Rise core.

Supplementary Table S4. Ice age tie points for the Skytrain Ice Rise core.

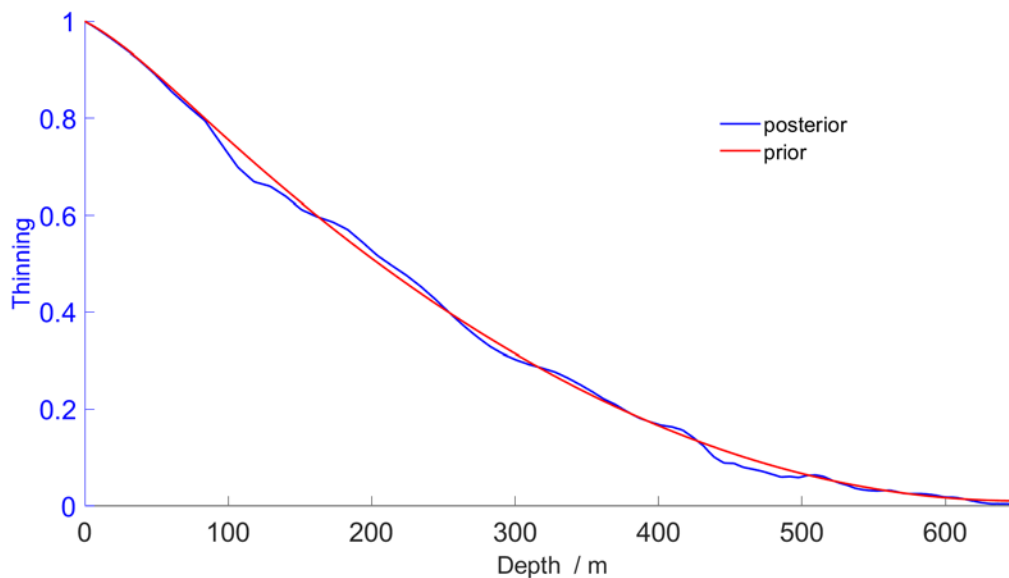
Supplementary Table S5. ST22 age model for the Skytrain Ice Rise core.



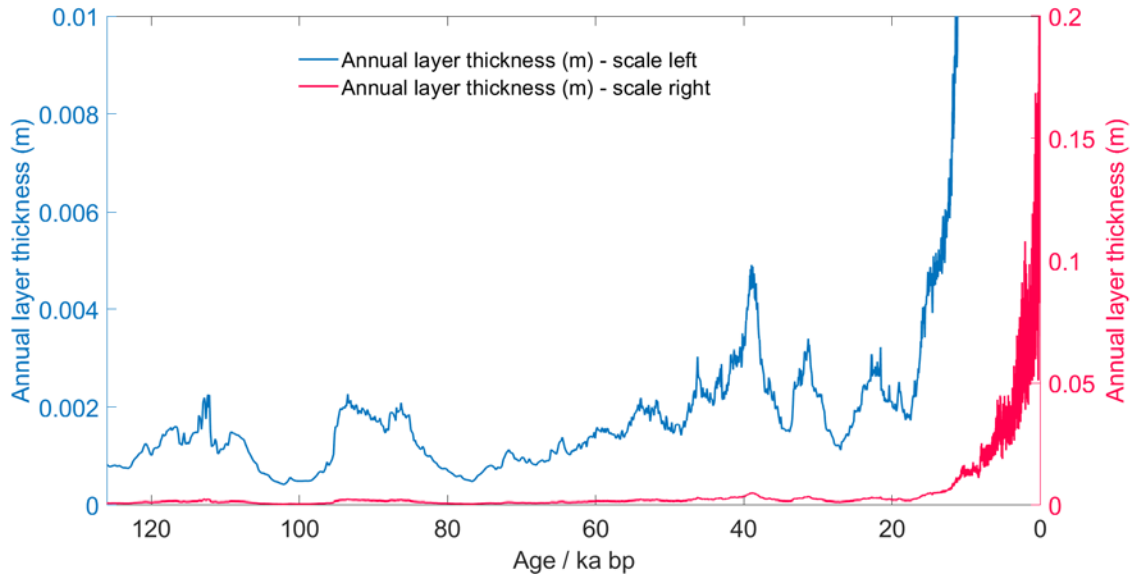
Supplementary Figure 1. Methane and $\delta^{18}\text{O}_{\text{atm}}$ on a depth scale between 600 and 650 m. Top: Continuous (CFA) methane (red), and data from discrete measurements (black crosses), after removal of occasional methane spikes as discussed in the text. This is a detail from main text Figure 3. Bottom: $\delta^{18}\text{O}_{\text{atm}}$ across the same depth range.



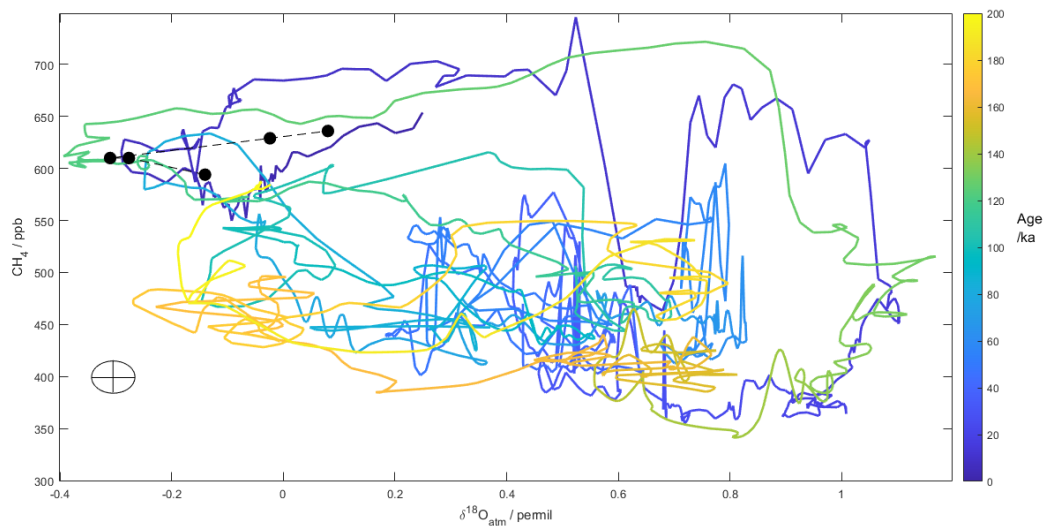
Supplementary Figure 2. Deposition rate at Skytrain Ice Rise: both the prior and the posterior (model output from PaleoChrono) are shown. Uncertainty is shown on the right hand axis. The markers on the x-axis show tie points used within PaleoChrono (dots are air age ties, triangles are ice age ties). The grey shaded area represents the ice (605-617 m) with unreliable ages due to flow disturbance (see section 9 of main text).



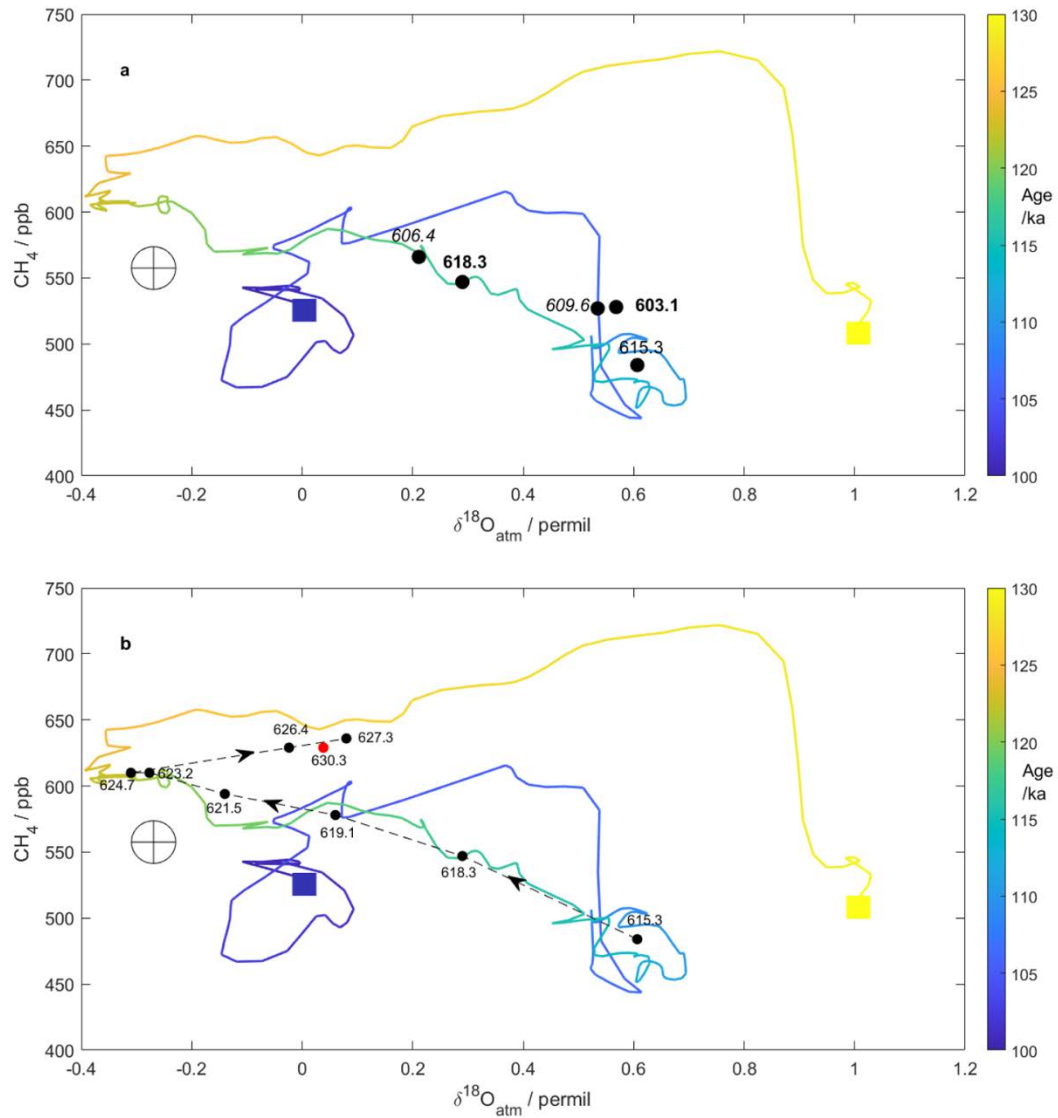
Supplementary Figure 3. Thinning function at Skytrain Ice Rise: both the prior and the posterior (model output from PaleoChrono) are shown.



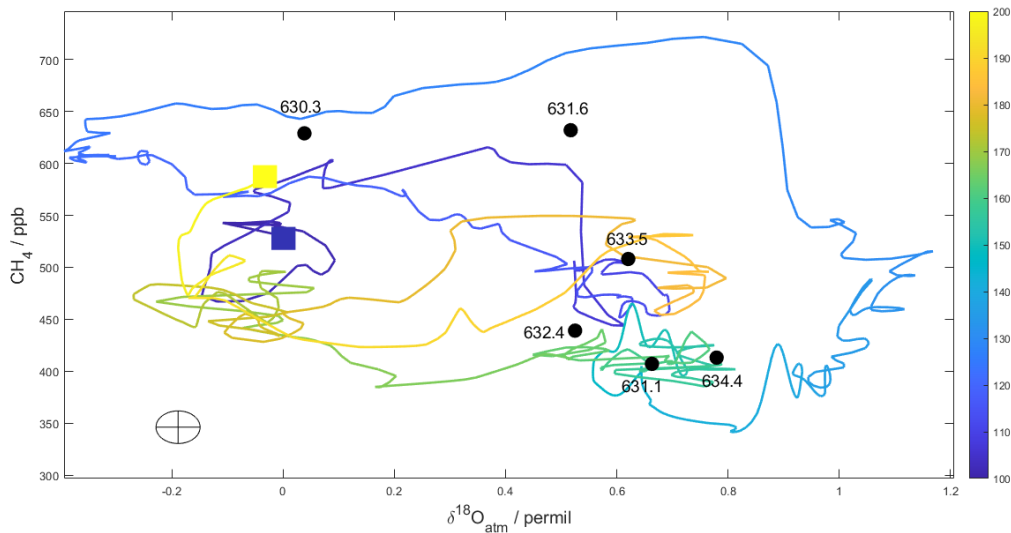
Supplementary Figure 4. Annual layer thickness as derived from PaleoChrono at Skytrain Ice Rise.



Supplementary Figure 5. An alternative visualisation (with different colour palette) of Fig 8b. Cross plot of CH_4 and $\delta^{18}\text{O}_{\text{atm}}$ reference data for CH_4 (Köhler et al., 2017; Loulergue et al., 2008) and $\delta^{18}\text{O}_{\text{atm}}$ (Extier et al., 2018) over the last 200 ka. Data are all on the AICC2012 age model. The colourbar indicates the age of the sample. The combined uncertainty is shown by the grey ellipse/cross. The black dots are data from Skytrain Ice Rise from 621.5 to 627.3 m (following the dashed line clockwise). On this plot unique LIG values are seen at the top in mid-green colours.



Supplementary Figure 6. An alternative visualisation (with different colour palette) of Fig. 9. Cross plots of CH_4 (Köhler et al., 2017) and $\delta^{18}\text{O}_{\text{atm}}$ (Extier et al., 2018) reference data for the period 100-130 ka, along with Skytrain Ice Rise data from (a) 603-618 m depth and (b) 615-628 m (black dots) and 630.3 m (red dot). The combined uncertainty (used to decide whether a match between the Skytrain and reference data is acceptable) is shown by the grey ellipse/cross. The start (130 ka) and end (100 ka) of the reference curve are marked by yellow and blue squares. Skytrain data points are marked with depths; in panel (a) the ones we later judge as being in disturbed ice are marked with italics, while the ones we consider well-dated are in bold. In panel b, the black dots are joined by dashed line with arrows pointing in order of increasing depth.



Supplementary Figure 7. An alternative visualisation (with different colour palette) of Fig. 10. Cross plot of CH_4 (Köhler et al., 2017; Louergue et al., 2008) and $\delta^{18}\text{O}_{\text{atm}}$ (Extier et al., 2018) reference data for the period 100-200 ka. The colourbar indicates the age of the sample. Also shown are the Skytrain data from 630 m downwards (black dots). The combined uncertainty (used to decide whether a match between the Skytrain and reference data is acceptable) is shown by the grey ellipse/cross. The start (200 ka) and end (100 ka) of the reference curve are marked by yellow and blue squares.

References

Extier, T., Landais, A., Bréant, C., Prié, F., Bazin, L., Dreyfus, G., Roche, D. M., and Leuenberger, M.: On the use of $\delta^{18}\text{O}_{\text{atm}}$ for ice core dating, *Quat. Sci. Rev.*, 185, 244-257, doi: <https://doi.org/10.1016/j.quascirev.2018.02.008>, 2018.

Köhler, P., Nehrbass-Ahles, C., Schmitt, J., Stocker, T. F., and Fischer, H.: A 156 kyr smoothed history of the atmospheric greenhouse gases CO_2 , CH_4 , and N_2O and their radiative forcing, *Earth Syst. Sci. Data*, 9, 363-387, doi: 10.5194/essd-9-363-2017, 2017.

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