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# Evolution of Maud Rise Polynya during the last 250 years – a multiproxy ice core reconstruction from coastal Dronning Maud Land, Antarctica

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## S1. Effect of water isotope diffusion

Polar ice core water isotope data are naturally smoothed by molecular diffusion processes in the top 60–80 m of the ice sheet (Johnsen et al., 2000). Diffusion in the firn attenuates high-frequency water-isotope information in ice cores. Diffusion length quantifies the statistical vertical displacement of water molecules from their original position and is based on accumulation rate, temperature, surface pressure, and strain rate at the drilling site (Johnsen, 1977; Johnsen et al., 2000). Our 122-m-long IND36/B9 core has experienced limited surface melt, with annual melt proportion varying between 0 and 4.4%, with a median melt proportion of 0.25% (Dey et al., 2023). We used diffusion-correction code developed by S. Johnsen, University of Copenhagen (Johnsen et al., 2000; Vinther et al., 2003) and made publicly available in Jones et al. (2023) which uses maximum entropy methods to invert an observed power-density spectrum. The determination of diffusive attenuation and correction arises from the observed frequency spectra themselves and therefore is entirely independent of firn diffusion and densification models. After diffusion correcting the isotopic data, the winter minima and summer maxima (used to define mid-winter and mid-summer) in the diffusion corrected data can be shifted slightly in depth as compared to the raw isotopic record. In our corrected record, this shift is less than 5 cm, which is within the sampling interval of 5 cm and therefore making it insignificant in altering the accuracy of the chronology. The diffusion corrected water isotope record is then further used for developing an age-depth model for the ice core.

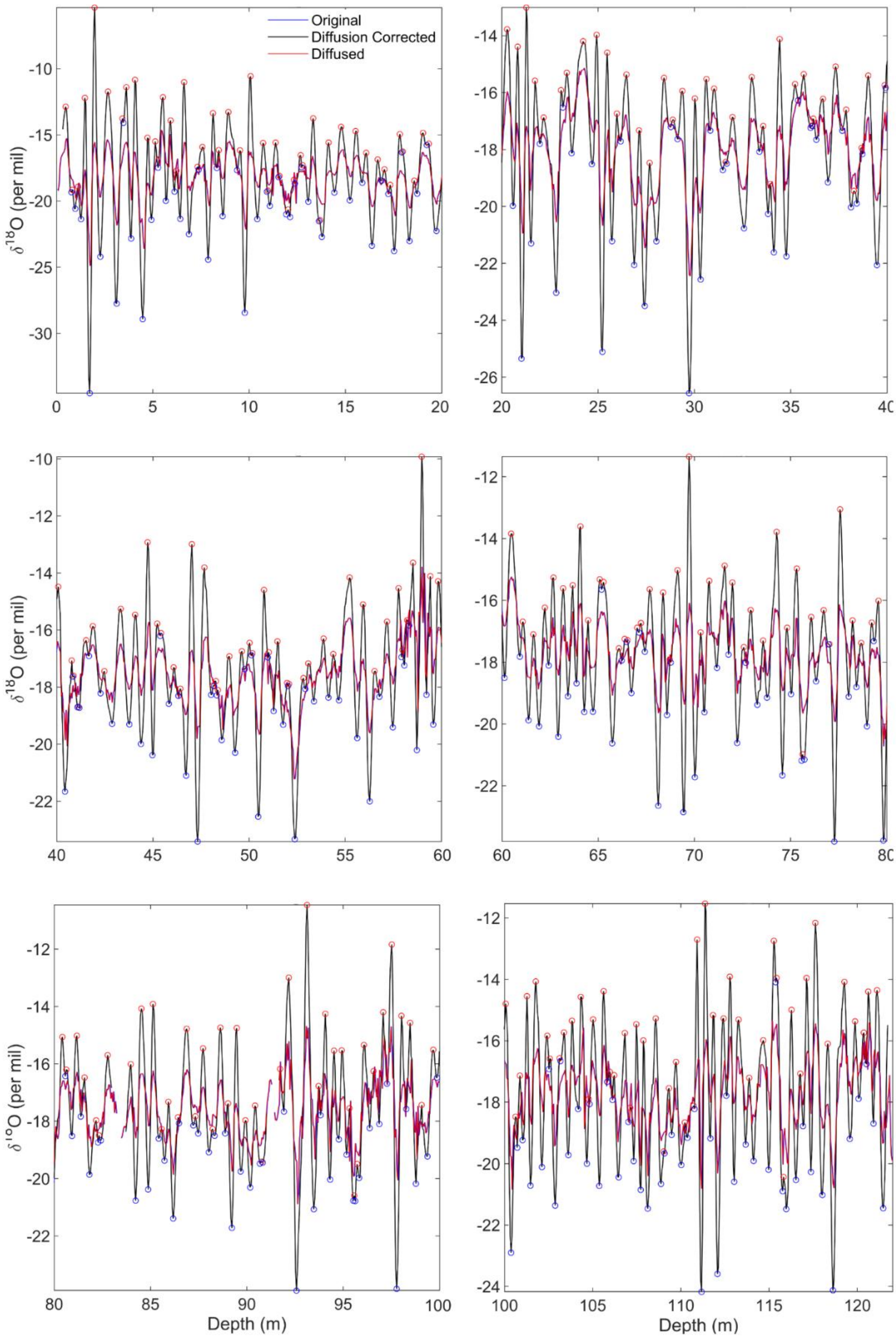


**Figure S1 | Diffusion correction of water isotopes.** Diffusion correction of $d^{18}O$ records (raw: blue curve; corrected: black curve) for the Djupranen ice core. Algorithmically identified annual maxima (red circle) and minima (blue circle) from the diffusion corrected record.

## S2. Ice core proxies and polynya index

We used four proxies for developing our polynya indices: sea-salt sodium (ssNa), deuterium excess (d-excess), $\delta^{18}O$, and snow accumulation. The justification for selecting these proxies is in Section 3.3.1 of the main manuscript while the method of calculating the indices is detailed in Section 3.3.2.

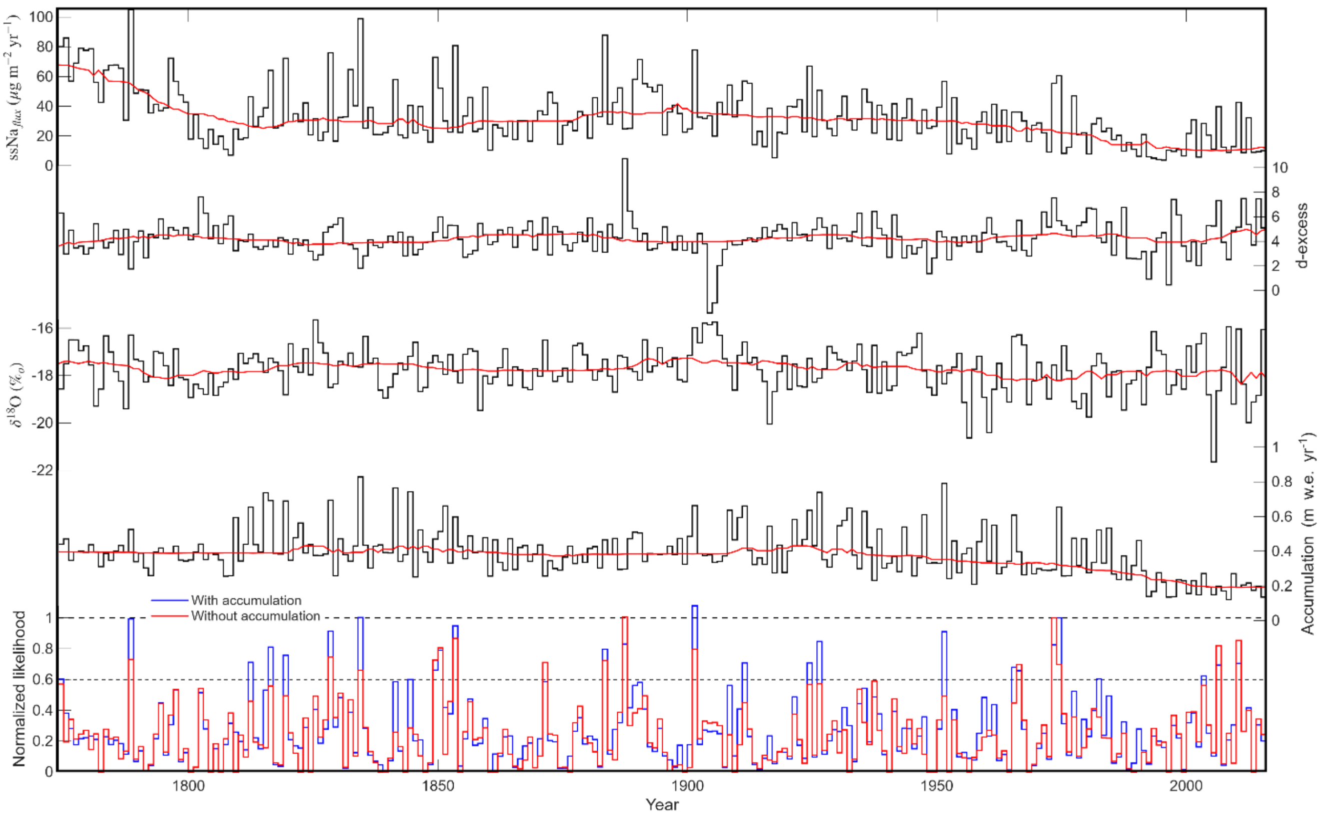


**Figure S2 | Ice core proxies and polynya identification.** Annual variability of selected ice core proxies and polynya index from 1774 – 2016. The red curve is the moving median over a 30-year window.

## S3. Comparison of polynya indices

A direct annual correlation of the polynya indices from this study and those from Goosse et al., 2021 is statistically limited by the independent age-scale uncertainties, typically ± 1–2 years, inherent in all ice core records. These chronological offsets cause high-magnitude events to appear out of phase between two indices/studies, which artificially degrades linear correlation coefficients despite clear physical synchronization in the raw signals. To provide a more robust and physically meaningful assessment, we used a binary presence-absence matrix assuming a ±2 years lead/lag window at threshold levels of 0.6, 0.7, 0.8, 0.9 and 1. Therefore, we look for polynya events at different threshold levels in our record and then look for polynya events with a threshold of 0.6 from the polynya index from Goosse et al. (2021) within a ±2 years window. For simplicity, we focus on only one index from each study, simple average of the standardized time series (Stat) from Goosse et al. (2021) and polynya index including accumulation from this study. We find that nine polynya years (threshold = 0.6) in our index that are also corroborated by the Goosse et al. (2021) record (Figure S3a). Similarly, seven polynya years are corroborated at a threshold of 0.7 and three at 0.8. At the threshold of 0.9 and 1, only the polynya event of 1974 is corroborated, which is expected as both studies use this event as an assumed truth and normalize all event to it. Similarly, when we repeat the same process for polynyas identified in Goosse et al. (2021) (Figure S3b), we find that 17 polynya years are corroborated at 0.6 threshold, 12 polynya years at 0.7, 9 polynya years at 0.8, eight at 0.9 and seven polynya years with a threshold of 1 are also identified in our polynya index.

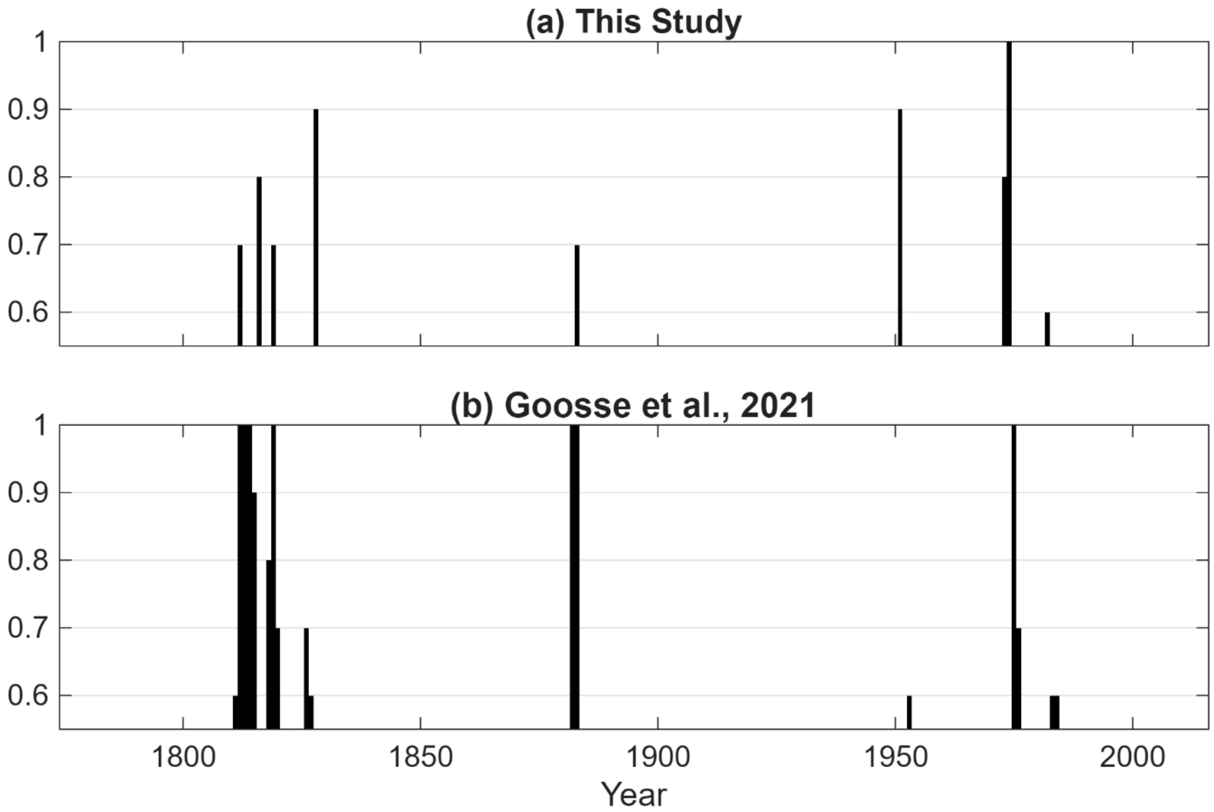


**Figure S3 | Comparison of synchronous polynya events.** Binary presence-absence analysis comparing the reconstructed polynya index from this study and the index from Goosse et al. (2021) across five threshold levels (0.6, 0.7, 0.8, 0.9, and 1.0) and assuming a lead/lag of ±2 years. (a) Temporal distribution of polynya events identified at different threshold in this study and corroborated by the Goosse et al. (2021) record (threshold ≥ 0.6). (b) Distribution of polynya events from Goosse et al. (2021) at different threshold corroborated by this study (threshold ≥ 0.6).

## References

Dey, R., Thamban, M., Laluraj, C. M., Mahalinganathan, K., Redkar, B. L., Kumar, S., and Matsuoka, K.: Application of visual stratigraphy from line-scan images to constrain chronology and melt features of a firn core from coastal Antarctica, Journal of Glaciology, 69, 179-190, https://doi.org/10.1017/jog.2022.59, 2023.

Goosse, H., Dalaiden, Q., Cavitte, M. G. P., and Zhang, L.: Can we reconstruct the formation of large open-ocean polynyas in the Southern Ocean using ice core records?, Clim. Past, 17, 111-131, https://doi.org/10.5194/cp-17-111-2021, 2021.

Johnsen, S., 1977. Stable isotope homogenization of polar firn and ice.

Johnsen, S.J., Clausen, H.B., Cuffey, K.M., Hoffmann, G., Creyts, T.T., 2000. Diffusion of stable isotopes in polar firn and ice: the isotope effect in firn diffusion.

Jones, T. R., Cuffey, K. M., Roberts, W. H. G., Markle, B. R., Steig, E. J., Stevens, C. M., Valdes, P. J., Fudge, T. J., Sigl, M., Hughes, A. G., Morris, V., Vaughn, B. H., Garland, J., Vinther, B. M., Rozmiarek, K. S., Brashear, C. A., and White, J. W. C.: Seasonal temperatures in West Antarctica during the Holocene, Nature, 613, 292-297, https://doi.org/10.1038/s41586-022-05411-8, 2023.

Vinther, B.M., Johnsen, S.J., Andersen, K.K., Clausen, H.B., Hansen, A.W. NAO signal recorded in the stable isotopes of Greenland ice cores. Geophysical Research Letters 30, https://doi.org/10.1029/2002GL016193, 2003