Supplement of

Isotopic diffusion in ice enhanced by vein-water flow

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Movie S1. Influence of the vein-water flow velocity $w$ on the pattern of $\delta$ in the ice–vein system and on the amount of excess diffusion at $T = -32$ °C, for a signal with wavelength $\lambda = 0.02$ m. These simulations show how the isotopic “shear layer” described in Sect. 3 evolves and transitions between the sheet regime and tail regime as $w$ changes in small steps from $-50$ m yr$^{-1}$ to $50$ m yr$^{-1}$ and back, for the model parameters $a = 1$ $\mu$m, $b = 1$ mm and $\alpha = 1$. (a) $\delta$-variations at the vein (red curve) and in the grain interior at $r = b$ (black curve). (b) Colour map of the pattern of $\delta$ in the ice. (c) The corresponding decay-rate enhancement factor $f$ (white dot), located on the surface of $f(\lambda, w)$ in Fig. 7a.

Movie S2. Influence of vein-water flow velocity $w$ on the pattern of $\delta$ in the ice–vein system and on the amount of excess diffusion at $T = -32$ °C, for a signal with wavelength $\lambda = 0.08$ m. The simulation scheme and layout of panels are the same as in Movie S1.

Movie S3. Compressional scaling of the surfaces of (a) signal decay-rate enhancement factor $f$, (b) $\log_{10} f$ and (c) signal migration velocity $v$, over the $\lambda$–$w$ parameter space, as temperature decreases from $-20$ °C to $-60$ °C. Some axis ranges are updated at $-35$ °C and $-47$ °C to focus on relevant variations.
Figure S1. Computed curves of signal decay-rate enhancement factor \( f \), \( \log_{10} f \) and signal migration velocity \( v \) versus signal wavelength \( \lambda \), at (a–c) \( T = -32 \, ^\circ C \) and (d–f) \( T = -52 \, ^\circ C \), for different vein-water flow velocities \( w \) (curve labels in m yr\(^{-1}\)) and assuming the deuterium–hydrogen fractionation coefficient, \( \alpha = 1.021 \). These curves differ negligibly from those in Fig. 6, where \( \alpha = 1 \) is assumed. Results based on the \( ^{18}\text{O}–^{16}\text{O} \) fractionation coefficient, \( \alpha = 1.0029 \), are still closer to those in Fig. 6.
Figure S2. Surfaces of the signal decay-rate enhancement factor $f$, $\log_{10} f$ and signal migration velocity $v$ over the $\lambda$–$w$ parameter space, computed for (a–c) $T = -32 \, ^\circ$C and (d–f) $T = -52 \, ^\circ$C and assuming the deuterium–hydrogen fractionation coefficient, $\alpha = 1.021$. These surfaces differ negligibly from those in Fig. 7, where $\alpha = 1$ is assumed. Results based on the $^{18}$O–$^{16}$O fractionation coefficient, $\alpha = 1.0029$, are still closer to those in Fig. 7.
**Figure S3.** A study of the ice contribution to the differential diffusion length at the (a–c) GRIP and (d–f) EPICA ice-core sites, in model runs using constant grain radius $b = 2$ mm and different vein-water flow velocities $w$ (curve labels in m yr$^{-1}$). Depth profiles of (a, d) the ice diffusion lengths $\sigma_{\text{ice}}(O)$ and $\sigma_{\text{ice}}(D)$, (b, e) the square differential $\Delta \sigma_{\text{ice}}^2 = \sigma_{\text{ice}}^2(O) - \sigma_{\text{ice}}^2(D)$, and (c, f) the differential $\Delta \sigma_{\text{ice}}$. 