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The GRIP ice core isotopic excess diffusion explained

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Stable isotope profiles in cold ice caps are being smoothed due to diffusion of water molecules in the open pore space of the firn. The degree of smoothing depends on the wavelength and the diffusion length which is a function of both temperature and accumulation rate for the site [*Johnsen et al.*, 2000]. The GRIP ice core from Summit Greenland suffers from this smoothing which today reduces the annual δ^{18}O amplitude from 5 per mille to 0.4 per mille at pore close off. Further down in the core this smoothing apparently increases through the Holocene ice with δ^{18}O annual amplitudes becoming as low as 0.15 per mille. This excess smoothing is not observed in the deeper glacial ice but is observed together with longer diffusion lengths in the Holocene ice. In the cold GRIP ice the normal diffusion of water molecules is too slow to be responsible for any excess smoothing. In order to understand the anomalous high diffusion lengths a diffusion process, operating through the water filled veins at crystal boundaries, was proposed as a possible scenario [*Johnsen and Andersen*, 1997]. This process has been further investigated by several authors [*Johnsen et al.*, 2000; *Nye*, 1998; *Rempel and Wettlaufer*, 2003].

The stronger than expected Holocene smoothing can also be explained by warmer firn temperatures in the past, resulting in longer firn diffusion lengths [*Vinther et al.*, 2005].

This suggests that the higher than expected Holocene isotope smoothing can be explained by several deg C warmer temperatures in the Holocene climatic optimum, as observed by Monte Carlo borehole thermometry at the GRIP drill site [*Dahl-Jensen et al.*, 1998], rather than by the proposed crystal boundary diffusion process in the glacier ice.

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