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The GRIP ice core isotopic excess diffusion; new evidence for a possible cause

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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 smoothing depends on the wavelength and the diffusion length which is a function of both temperature and accumulation rate [*Johnsen et al.*, 2000] for the site. 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. In the cold GRIP ice the normal diffusion of water molecules is too slow to be responsible for any excess smoothing. Reduced accumulation rates through mid and early Holocene is also a possible explanation, but must be rejected based on the accurate dating of the core and time scale modeling. A diffusion process, operating through the water filled veins at crystal boundaries, was proposed as a possible explanation [*Johnsen and Andersen*, 1997]. This process has been further investigated by several authors [*Johnsen et al.*, 2000; *Nye*, 1998; *Rempel and Wettlaufer*, 2003].

Studies of the Holocene isotope data showed that the excess smoothing is related to increased diffusion lengths, which is either caused by an unknown diffusion process in the ice, as discussed above, or by warmer firn temperatures [*Vinther et al.*, 2005].

This suggests that the increased Holocene isotope smoothing is caused by several deg C warmer temperatures in the Holocene climatic optimum, as found by Monte Carlo borehole thermometry at the GRIP drill site [*Dahl-Jensen et al.*, 1998], rather than by the proposed crystal boundary diffusion process.

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