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The effect of post-depositional diffusion on seasonal estimates of stable water isotopes in firn cores from Greenland

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The stable water isotopes in firn cores provide a unique archive of past climate on annual to centennial time scales, which can be used, for example, for the evaluation of general circulation models with isotope physics. For this evaluation, time series of summer and winter δ^{18}O are often used. We show, using model data, that post-depositional diffusion significantly affects the interannual isotopic signal in firn cores for typical conditions as observed in Greenland: the correlation (r^2) between diffused and undisturbed time series of summer and winter δ^{18}O is on average 0.30. Hence, our results suggest that more than half of the interannual variability in ice cores is not related to the actual interannual variability in summer and winter δ^{18}O. Furthermore, our results show that explicitly mimicking the effect of post-deposition diffusion can be beneficial for the evaluation of isotope estimates from climate models.

We obtained these results by comparing model data with homogenized seasonal δ^{18}O estimates from 11 ice cores and two ice cores stacks (Vinther *et al.*, 2010). For these 13 sites, daily output of the regional climate model RACMO2, driven by the ERA-40 reanalysis, is converted into δ^{18}O using a simple fractionation model. Undisturbed seasonal estimates are derived as the precipitation weighted averages for the months JJA (summer) and NDJFM (winter). For diffused estimates, daily data are cumulated as if it becomes an ice core, and diffused until the ratio between interannual variability and the mean seasonal amplitude equals the ratio as observed in the ice core data. For summer and winter, the standard deviation of δ^{18}O is derived; the average standard deviation for these two seasons is used as a measure for the interannual variability. The correlations (r^2) between ice core data and diffused model estimates are on average 0.23 and 0.17 for summer and winter estimates, respectively. The root mean square error (RMSE) of the modeled seasonal amplitude in δ^{18}O is 0.64‰; the RMSE of the interannual variability of summer and winter δ^{18}O is 0.22‰. Furthermore, the undisturbed modeled seasonal amplitudes are on average 10‰, comparable with observations. Although simplified isotope physics is used, the model estimates of δ^{18}O agree reasonably well with the ice core data, giving credibility to the results presented.

Vinther, B.M. *et al*, 2010: Climatic signals in multiple highly resolved stable isotope records from Greenland, *Quart. Sc. Rev.* **29**, 522-538.