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Estimating the differential diffusion length of the stable water isotope signals obtained from ice core records.

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Stable water isotope signals retrieved from polar ice core records are smoothed by diffusion in the firn stage. The total amount of diffusion a layer has experienced can be quantified in terms of the diffusion length, which is the average displacement of a molecule due to diffusion. This length is a function of the firn temperature and the accumulation rate which makes it a valuable proxy for past local temperatures (Johnsen et al, 2000, Simonsen et al, 2011). In principle this proxy can be derived from either of the individual isotope signals (Oxygen-18 or Deuterium), but it is much better constrained when the difference in diffusion length between the two isotopes is used.

The individual diffusion lengths and the differential diffusion lengths are commonly calculated using the power spectral densities (PSD) of the isotope data. The Maximum Entropy Method (MEM) is often used for the calculation of the PSD, but other methods such as the fast fourier transform or ones based on the autocorrelation series of the isotope data can also be used. However, in all these methods a parameter has to be chosen, for example the auto regression order in the MEM. Additionally, it is necessary to define a cut off frequency in order to use only the red part of the power spectrum. These choices can significantly influence diffusion length obtained with these methods.

We present a new method which circumvents these issues, based on the correlation between the Oxygen-18 and Deuterium records. The measured Deuterium record is numerically diffused, after which the correlation between this record and the measured Oxygen-18 record is calculated. The correlation reaches a maximum when the diffusion lengths of the two records are equal. This allows us to reconstruct the differential diffusion length.

A large number of synthetic data sets were created to (1) test this correlation method and (2), for the MEM, find the optimum values for the parameters in this method. The values found by the correlation method need to be corrected for offsets resulting from the finite sampling resolution and measurement uncertainty. The two methods yield results with comparable precision.

References:

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