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Finding the optimal arrangement of ice-core arrays for the reconstruction of past millennium Antarctic temperatures

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Stable oxygen and hydrogen isotope records from ice cores represent the major climate proxy archive for the reconstruction of past Antarctic temperatures. This is based on observed relations between variations in the isotopic composition of precipitation and variations in local air temperature, which arise from the temperature-dependent distillation and fractionation of the water vapour isotopic composition along its atmospheric trajectory. Additionally, other processes influence the isotopic composition recorded in ice cores, such as variable atmospheric circulation and moisture pathways, the intermittent nature of precipitation, and mixing and re-location of snow by wind drift. These processes lead to variable relationships between isotopes and temperature across sites and add noise to the temperature proxy record. Available key Antarctic temperature reconstructions of the last two millennia therefore rely on spatial averages of a large number of cores to reduce overall noise. However, the efficiency of the noise reduction in this averaging step depends on the spatial structure of the temperature signal and the other processes. While sound knowledge is available for the noise and its spatial structure in isotope records sampled on a local ($\sim$1 km) scale (Münch et al., 2016; Laepple et al., 2017), so far we lack sufficient information on the spatial structure of the processes important on the larger scales, e.g. precipitation intermittency and atmospheric circulation changes. Here, we analyse the millennium simulation of the ECHAM-wiso isotope-enabled general circulation model in order to learn about the spatio-temporal structure of the temperature-to-isotope relationship and its impact on the climate variability recorded in spatial arrays of ice-core isotope records. Using the climate model simulation output and our process model for the signal formation in ice cores, we estimate optimal core positions to reconstruct the temperature at a target location and also evaluate the best use of existing ice cores. Our results provide new insights into the ability of ice-core isotope records to reconstruct past regional temperature variability in Antarctica and into the spatial scales of the processes that drive the isotope variability depending on the topographic setting. Thereby, they lay the foundations for future ice-core drilling efforts in order to improve and extend present Antarctic climate reconstructions of the last two millennia.

Laepple, T., et al., The Cryosphere, 12(1), 169–187, doi: 10.5194/tc-12-169-2018, 2017.
Münch, T., et al., Clim. Past, 12(7), 1565–1581, doi: 10.5194/cp-12-1565-2016, 2016.