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Ice-vapor equilibrium fractionation factor of hydrogen and oxygen isotopes: Experimental investigations and implications for stable water isotope studies

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Stable water isotopes have been used in climate research for several decades. The differences in vapour pressure of the different isotopic species give rise to fractionation during phase changes. The water isotopic composition in the precipitation therefore depends on the condensation history of the air mass and source region evaporation. Through ice cores in Greenland and Antarctica containing archived precipitation, knowledge about past variations in the hydrological cycle and climate can therefore be obtained. The ice-vapor equilibrium fractionation factor α controls the magnitude of the isotope fractionation during phase changes, which makes it a core component in isotope models e.g. used to interpret ice core data for palaeoclimate studies. In this work we successfully designed and built an experimental setup with the purpose of investigating the temperature dependency of α and extend the temperature range of earlier work. In our experimental setup we used both a Picarro cavity ringdown spectrometer and a conventional TC/EA-IRMS system. Comparing the results from the two systems revealed good reproducibility. The results of the experiments show fractionation factors for δD and δ^{18}O, with a temperature dependency well in accordance with theory for equilibrium fractionation, for temperatures between 0°C and -40°C. The expressions for the results are: $\ln\alpha_{\delta D}$= 0.2133-203.10/T+48888/T^2 and $\ln\alpha_{\delta^{18}O}$= 0.0831-49.192/T+8312.5/T^2. Compared to previous experimental work, a significantly larger α for δD is obtained while for δ^{18}O α is larger for temperatures below -20°C and slightly lower for temperatures above this. Sensitivity tests with the latest generation isotope enabled general circulation model are preformed to show the differences in model performance using the α of earlier work and this work. The model output is compared to observations of the deuterium excess signal in both Greenland and Antarctica, in order to assess the effect of the α in this work on the annual cycle and spatial distribution of the deuterium excess. These preliminary tests provide guide lines for the future use of the α in this work to investigate the present and past climates.