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Using stable water isotopes to constrain ice cloud microphysics over Antarctica in CAM5

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Supersaturation with respect to ice (Si) determines the strength of isotopic fractionation during vapor deposition onto ice or snow, and therefore influences the isotopic composition of vapor and precipitation in cold environments, especially the deuterium excess ($d = \delta D - 8 \cdot \delta^{18}O$). Stable water isotopes in Antarctic precipitation therefore provide information about microphysical parameters that influence supersaturation (e.g., the concentration of ice nuclei or the rate of vapor deposition), and can potentially be used to constrain these often uncertain parameters in numerical models.

Historically, most general circulation models would apply saturation adjustment for the formation of both liquid and ice clouds, which means that no supersaturation was allowed to occur. For an accurate representation of the deuterium excess, Si in these models therefore had to be parameterized. Commonly this was done by assuming a linear dependence on temperature in the form of $Si = a + b \cdot T$. However, as fractionation during deposition was computed independently with this parameterization, isotopes could not be used as observational constraints for microphysical parameters.

The Community Atmosphere Model version 5 (CAM5) explicitly allows ice supersaturation and thus provides a physical link to the strength of fractionation during deposition. Here we use the recently developed isotope-enabled version of this model together with isotope measurements of Antarctic snow and ice cores to (i) evaluate the commonly used parameterization of Si as a linear function of temperature, and (ii) test the sensitivity of deuterium excess of Antarctic precipitation to microphysical parameters important for deposition.

Our results show that the parameterization of Si as a linear function of temperature is oversimplified, and that the wide range of Si during deposition is reflected in deuterium excess of Antarctic precipitation. Furthermore, the deuterium excess is highly sensitive to both the concentration of ice nuclei and the rate of vapor deposition in CAM5, highlighting the potential of stable water isotopes as observational constraints for cloud microphysical schemes in numerical models.