Tropical dehydration processes constrained by the seasonality of stratospheric deuterated water

Jörg Steinwagner[1], Stephan Fueglistaler[2], Gabriele Stiller[3], Thomas von Clarmann[3], Michael Kiefer[3], Peter-Paul Borsboom[1], Aarnout van Delden[1] and Thomas Röckmann[1]

[1]*Institute for Marine and Atmospheric research Utrecht, Utrecht University, Utrecht, The Netherlands*

[2]*Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, UK*

[3] *Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research, 76021 Karlsruhe, Germany*

Stratospheric water vapour affects Earth's radiative budget and plays a key role in stratospheric chemistry, importantly for processes that permit ozone depletion. Air largely enters the stratosphere in the tropics, but the processes that bring water through the cold tropopause into the stratosphere are not well understood. Isotope measurements have the potential to identify the underlying processes, but previously reported measurements lack the spatio-temporal coverage necessary to fully exploit this potential. We present 19 months of $\delta D(H_2O)$ data in the tropical stratosphere from remote sensing measurements with the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS). The data show a clear seasonal cycle in isotopic composition that propagates upward in the tropical stratosphere. The seasonal HDO and H_2O variations provide constraints on processes controlling stratospheric humidity. The slope of the HDO-H_2O correlation of water entering the stratosphere in the tropics is close to, but slightly steeper than expected from Rayleigh fractionation. This points to a key role for gradual dehydration via *in-situ* formed cirrus clouds. A seasonally varying contribution from evaporation of convectively lofted ice steepens the HDO-H_2O slope relative to Rayleigh fractionation. The dataset provides a benchmark for the accuracy of the hydrological cycle in numerical models used for climate predictions.