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Isentropic transport of water vapor into the extra-tropical lower stratosphere

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Water vapor is one of the most important greenhouse gases in the Earth's atmosphere. Due to the high sensitivity of atmospheric radiative forcing to changes in greenhouse gases in the cold upper troposphere and lower stratosphere (UTLS) region, even small variations in water vapor in the lower LS are an important source of the decadal variability of the surface temperature. This implies the need for a detailed understanding of the observed water vapor variability in the UTLS and their underlying processes.

Isentropic transport of water vapor due to planetary waves and their breaking provides a mechanism for bringing moist tropical tropospheric air into the dry lower extra-tropical stratosphere (exLS, see e.g. McIntyre and Palmer, 1983). Uplifted moist air masses by the Asian and American monsoons at the sub-tropical jet generate maximum water vapor concentrations in the summer/fall season. This water vapor maximum coincides with a maximum in planetary wave breaking in the northern hemisphere lower stratosphere and thus subsequent horizontal poleward transport. This transport serves as the dominant pathway to moisten the exLS in boreal summer (e.g. Ploeger et al., 2013 , Rolf et al. 2018).

We investigate this transport pathway with measurements to better understand the water vapor distribution and their annual cycle in the exLS. Here, we use in-situ measurements of water vapor obtained with the FISH instrument (Fast In-situ Stratospheric Hygrometer) during the aircraft field campaigns TACTS in August/ September 2012 and WISE in September/October 2017. Water vapor observations with the AURA MLS satellite instrument encompassing the entire exLS are used to put the temporal and spatial limited in-situ observations into a larger perspective. A very good agreement between the median of the in-situ water vapor distribution and the satellite observation is found, which shows that the in-situ observations are representative for the water vapor distribution of the exLS. Isentropic transport is shown to be dependent on the planetary wave activity by using the divergence of the Eliassen-Palm flux. Together with an extensive backward trajectory analysis we show that the isentropic transport is the dominant pathway of moistening the exLS up to 420 K potential temperature.

References

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