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Lagrangian simulation of the water vapour in the lower stratosphere

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Water vapour in the upper troposphere and lower stratosphere (UTLS) plays an important role for global radiation. A realistic representation of Water vapour is critical for climate model predictions of future climate change. Here, we investigate the effects of current uncertainties in tropopause temperature, horizontal transport and small-scale mixing on simulated water vapour in the lower stratosphere.

To assess the sensitivities of simulated water vapour, we use the Chemical Lagrangian Model of the Stratosphere (CLaMS). First, we examine CLaMS driven by two different reanalysis, ERA-Interim and Japanese 55-year (JRA-55) reanalysis, to investigate the robustness with respect to the meteorological dataset. Second, we carry out CLaMS simulations with transport barriers along latitude circles (at the equator, 15°N/S and 35°N/S) to assess the effects of horizontal transport. Third, we vary the strength of parametrized small-scale mixing in CLaMS. Also, we relate a change in simulated water vapour to the change in vertical diffusivity.

Our results show significant differences (about 0.5 ppmv) in simulated stratospheric water vapour due to uncertainties in the tropical tropopause temperatures between current reanalysis datasets. The JRA-55 based simulation is significantly moister when compared to ERA-Interim, due to a warmer tropical tropopause in JRA-55 reanalysis. Through barrier sensitivity simulations, we have introduced artificial transport barriers in the model to suppress certain horizontal transport pathways. Such transport experiments demonstrate that the Northern Hemisphere subtropics have a strong moistening effect on global stratospheric water vapour. Interhemispheric exchange shows only a very weak effect on stratospheric water vapour. Small-scale mixing mainly increases troposphere-stratosphere exchange, causing an enhancement of stratospheric water vapour, particularly along the subtropical jets and in the Asian monsoon region. Above around 430 K, increased small-scale mixing causes a complex interplay between vertical and horizontal mixing, which results in both moistening or drying of the stratosphere depending on the mixing strength.

The sensitivity studies presented here provide new insights into the leading processes that control stratospheric water vapour, important for assessing and improving climate model projections.