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Insight from water vapour and ozone on transport in the TTL

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Chemistry transport models and chemistry climate models are suitable tools to understand the chemical and dynamical processes in the tropical tropopause layer (TTL), which controls the amount of radiatively active species like water vapour and ozone in the stratosphere. However, model results are subject to uncertainties arising from the representation of vertical transport. We use three-dimensional backtrajectory calculations in the TTL, based on ERA-Interim reanalysis, to study the sensitivity of transport and predicted H2O and O3 distributions to the choice of a diabatic or kinematic transport representation. Diabatic transport uses potential temperature as vertical coordinate and vertical cross-isentropic motion deduced from diabatic heating rates. Kinematic transport uses pressure as vertical coordinate and pressure tendency as vertical velocity. H2O concentrations along the backtrajectories are predicted based on instantaneous freeze-drying, O3 concentrations based on photolytical production.

We find significant transport differences between diabatic and kinematic representations with a much higher trajectory dispersion and frequent regions of mean downwelling in the upper TTL for kinematic compared to mean upwelling for diabatic transport. The water vapour predictions are similar for both transport representations, but predictions for ozone are systematically higher for kinematic transport. Compared to global ozone observations from HALOE, the diabatic model prediction underestimates the vertical ozone gradient. Comparison of the kinematic prediction with in-situ observations from the tropical SCOUT-O3 campaign shows a large high bias in the upper TTL. We show that ozone predictions and vertical dispersion of the trajectories are highly correlated, rendering ozone an interesting tracer for aspects of transport to which water vapour is not sensitive. Furthermore, we show that dispersion and mean upwelling have similar effects on ozone profiles, with slower upwelling and larger dispersion both leading to higher ozone concentrations. Analyses of tropical upwelling based on mean transport characteristics and model validation have to take into account this ambiguity between tropical ozone production and in-mixing from the stratosphere.