Geophysical Research Abstracts
Vol. 13, EGU2011-2640, 2011
EGU General Assembly 2011

Impact of quasi-horizontal transport from the extratropics (in-mixing) on the seasonality of the trace gas composition in the TTL

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We analyse the impact of tropical upwelling and two-way quasi-horizontal transport from the extratropical lower stratosphere (in-mixing) on the seasonality of trace gas concentrations (e.g., H2O, O3, CO, N2O) in the tropical tropopause layer (TTL). Therefore, three-dimensional backtrajectory ensembles are released in the TTL throughout the year, based on ERA-Interim reanalysis data. Water vapour mixing ratios are predicted along the trajectories based on instantaneous freeze-drying, ozone based on photolytical production, CO based on chemical loss and N2O based on passive transport. The backtrajectory approach allows to separate the effects of tropical upwelling and of in-mixing on the TTL trace gas composition.

We find that horizontal in-mixing from each hemisphere shows a clear annual cycle with maximum contribution from the northern hemisphere during boreal summer and maximum contribution from the southern hemisphere during winter, both strongly related to monsoon anticyclonic circulations. For H2O in-mixing has no impact on the seasonality in the tropics, while the annual cycle of ozone in the TTL is largely affected by in-mixing, in particular from the northern hemisphere. The impact of in-mixing on the annual cycle of CO is larger than for H2O but, by far, not as large as for ozone. Consequently, the effect of quasi-horizontal transport from the extratropics on the TTL composition may not be neglected, in general. The sensitivity of tropical trace gas seasonality on the strength (e.g., amplitude) of the annual cycles of tropical upwelling and of quasi-horizontal transport is further studied using a conceptual one-dimensional tropical tracer model with in-mixing represented as linear relaxation to mid-latitude concentrations. If the species' meridional gradients are large enough, even a small amount of in-mixed mass significantly impacts the species' seasonality in the tropics.