Stratospheric Residence Time Inferred from Trajectory Model Driven by Modern Reanalyses

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Stratospheric mean residence time (τ) is a useful quantification of the Troposphere-Stratosphere exchange. We use Lagrangian trajectories driven by modern reanalyses (MERRA, MERRA-2, CFSR, ERA-Interim, and JRA-55) to investigate the τ and its variability in three decades. The results show systematic consistency among the MERRA, MERRA-2, and CFSR, but differ in ERAi and JRA-55. Starting from the 370-K isentrope, it takes ~3 months for tracers to transport through the Tropical Tropopause Layer (TTL, upper boundary 425-K) when driven by MERRA, MERRA-2, and CFSR, while it only takes 2.5 and 2 months when driven by JRA-55 and ERAi, respectively. In middle to upper stratosphere (450–1500K) the accumulated differences could be up to one year. The discrepancies are mainly caused by uncertainties in total heating rates that are subject to changes by temperature, ozone, and clouds (especially cirrus) assimilated differently in reanalysis system. The residence time varies spatially and is shorter over frequent convection region and over the Asian summer monsoon where persistently strong upwelling ascends parcels faster. Despite the discrepancies, the interannual variability of τ shows common features that are linked to the stratospheric quasi-biennial oscillation (QBO) and to the El Nino–Southern Oscillation (ENSO) events. While excluding the impact from QBO and ENSO, we found a negative trend of -1–4%/decade of residence time throughout the TTL, indicating a faster transport from strengthened upwelling in the stratosphere.

Keywords: stratospheric residence time, troposphere-stratosphere exchange, trajectory model, reanalysis

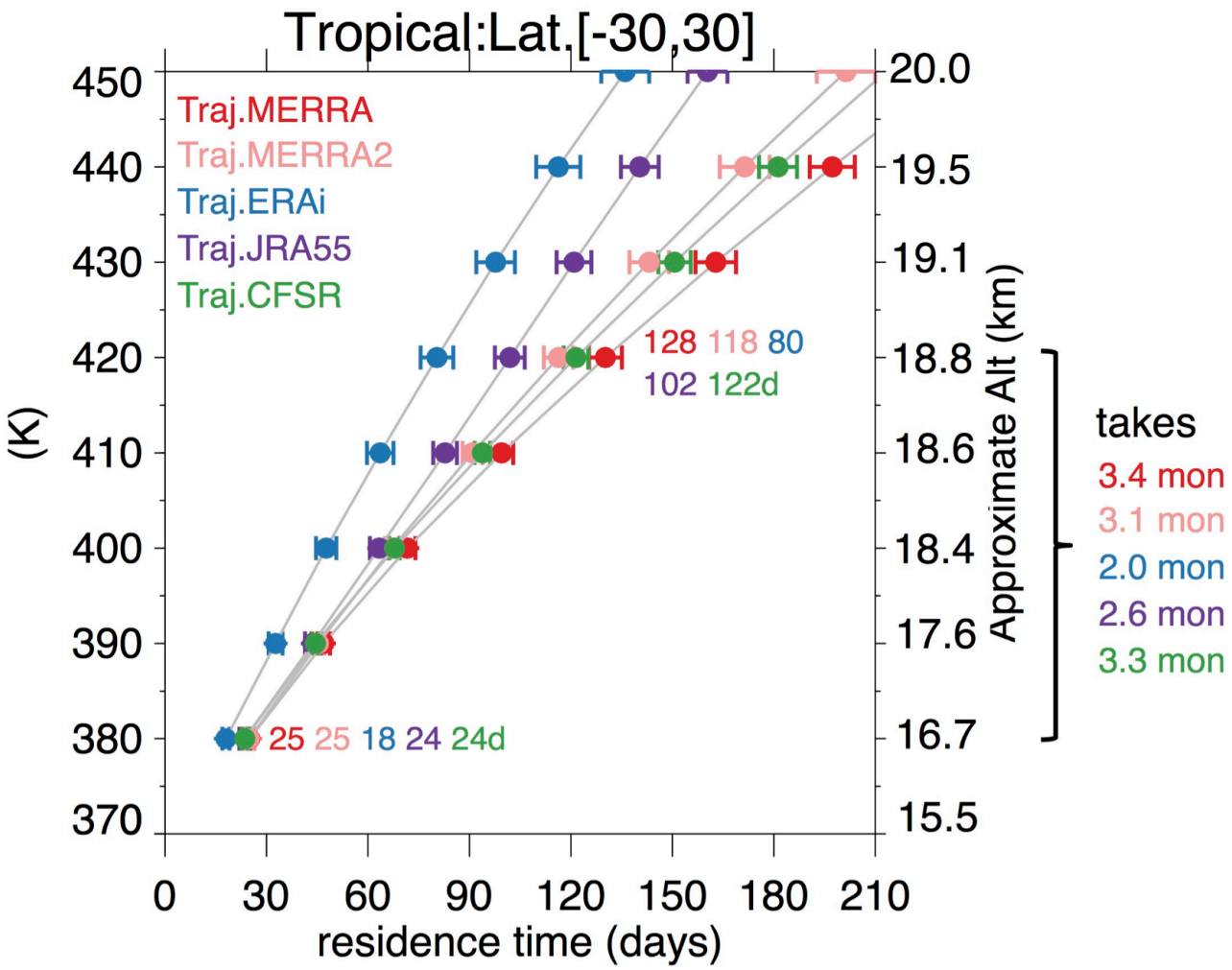

Figure 1. The residence time (days) within the lower stratosphere inferred from diabatic trajectories driven by circulations from MERRA, MERRA2, ERAi, JRA55, and CFSR. Trajectories are initiated at 370 K within 30° N-S and being advected upward by total diabatic heating rates Q_{tot} (vertical velocity $d\theta/dt = Q_{tot} \bullet (P/P_0)^{-R/Cp}$).

