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Quantifying the effects of mixing and residual circulation on trends of stratospheric mean age of air

Felix Ploeger (1), Marta Abalos (2), Thomas Birner (3), Paul Konopka (1), Bernard Legras (2), Rolf Müller (1), and Martin Riese (1)

(1) Institute of Energy and Climate Research, Stratosphere (IEK-7), Forschungszentrum Jülich, Jülich, Germany (f.ploeger@fz-juelich.de), (2) Laboratoire de Meteorologie Dynamique, UMR8539, IPSL, UPMC/ENS/CNRS/Ecole Polytechnique, Paris, France, (3) Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA

Trends in stratospheric mean age of air are driven both by changes in the (slow, large scale) residual mean mass circulation and by changes in (fast, locally acting) eddy mixing. However, to what degree both effects affect mean age trends is an open question. Here, we present a method that allows the effects of mixing and residual circulation on trends of mean age of air to be quantified. This method is based on mean age simulations with the Lagrangian chemistry transport model CLaMS driven by ERA-Interim reanalysis, and on the mean age tracer continuity equation integrated along the residual circulation.

CLaMS simulated climatological mean age in the lower stratosphere shows reliable agreement with balloon borne in-situ obsevations and with satellite observations by MIPAS (Michelson Interferometer for Passive Atmospheric Sounding). During 1990–2013, CLaMS simulated mean age decreases throughout most of the stratosphere, qualitatively consistent with results based on climate model simulations (e.g., Butchart et al., 2010). Remarkably, in the Northern hemisphere subtropics and mid-latitudes above about 24km CLaMS mean age trends are insignificant, consistent with published mean age trends from in-situ observations (Engel et al., 2009). Furthermore, during 2002–2012 CLaMS mean age changes show a clear hemispheric asymmetry in agreement with MIPAS satellite observations (Stiller et al., 2012; Ploeger et al., 2014) and HCl decadal changes (Mahieu et al., 2014).

We find that changes in the transit time along the residual circulation alone cannot explain the mean age trends, and including the effect of mixing integrated along the air parcel history is essential. Therefore, differences in mean age trends between models or between models and observations are likely related to differences in the integrated effect of mixing on mean age of air. Above about 550K, trends in the integrated mixing effect appear to be likely coupled to residual circulation changes.

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