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Effects of residual transport and mixing on the simulation of stratospheric Age of Air

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The stratospheric Brewer-Dobson circulation is often quantified by the integrated transport measure stratospheric age of air (AoA). AoA is influenced by mean transport along the residual circulation, by two-way mixing and by vertical and local diffusion. Therefore, AoA is a good measure of the overall capabilities of a global model to simulate stratospheric transport. Currently, a large spread in the simulation of AoA by global models is found. A better understanding of the processes that control AoA might help to understand this spread and to reconcile discrepancies between modelled and observed long-term changes in AoA.

We seek to untangle the effects of different processes on the simulation of AoA in global models. The effects of residual transport and two-way mixing on AoA are calculated from global model data from CCMVal-2 and CCMI-1. To do so, we calculate the residual circulation transit time (RCTT), i.e. the age air would have if it was only transported by the residual circulation. The difference of AoA and RCTT is interpreted as the additional aging by mixing. However, as vertical diffusion or any numerical uncertainties are included in this difference, we further calculate the effect of aging by mixing directly by integrating the daily local mixing tendencies numerically along the trajectories. Comparing these two methods of calculating aging by mixing allows for separating the effect of vertical and numerical diffusion in the different models.

A “mixing efficiency” is defined as the ratio of the two-way mixing mass flux across the subtropical barrier to the net (residual) mass flux. This mixing efficiency controls the ratio of tropical mean AoA to RCTT, and thus the relative increase in AoA by mixing. We find that the spread in AoA is caused both by differences in the residual circulation strength and in mixing. The mixing efficiency varies strongly between models, and the spread in AoA between models is strongly correlated to their mixing efficiency.