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Age of stratospheric air and aging by mixing in global models

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The Brewer-Dobson circulation is often quantified by the integrated transport measure age of air (AoA). AoA is affected by all transport processes, including transport along the residual mean mass circulation and two-way mixing. A large spread in the simulation of AoA by current global models exists.
Using CCMVal-2 and CCMI-1 global model data, we show that this spread can only in small parts be attributed to differences in the simulated residual circulation. Instead, large differences in the "mixing efficiency" strongly contribute to the differences in the simulated AoA. The "mixing efficiency" is defined as the ratio of the two-way mixing mass flux across the subtropical barrier to the net (residual) mass flux, and this mixing efficiency controls the relative increase in AoA by mixing. We derive the mixing efficiency from global model data using the analytical solution of a simplified version of the tropical leaky pipe (TLP) model, in which vertical diffusion is neglected. Thus, it is assumed that only residual mean transport and horizontal two-way mixing across the subtropical barrier controls AoA. However, in global models vertical mixing and numerical diffusion modify AoA, and these processes likely contribute to the differences in the mixing efficiency between models.

We explore the contributions of diffusion and mixing on mean AoA by a) using simulations with the tropical leaky pipe model including vertical diffusion and b) explicit calculations of aging by mixing on resolved scales.
Using the TLP model, we show that vertical diffusion leads to a decrease in tropical AoA, i.e. counteracts the increase in tropical mean AoA due to horizontal mixing. Thus, neglecting vertical diffusion leads to an underestimation of the mixing efficiency.
With explicit calculations of aging by mixing via integration of daily local mixing tendencies along residual circulation trajectories, we explore the contributions of vertical and horizontal mixing for aging by mixing.
The role of unresolved diffusion can then be derived from the residual of reconstructed AoA and AoA as simulated by the models.

A better understanding of the processes that control AoA will help to reconcile current discrepancies between simulated and observed AoA and its long-term changes.