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Lagrangian transport of water vapor and CFCs in a coupled Chemistry Climate Model

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We describe the implementation of a Lagrangian transport core in a chemistry climate model (CCM). Thereby we address the common problem of properly representing trace gas distributions in a classical Eulerian framework with a fixed model grid, particularly in regions with strong trace gas gradients. A prominent example is stratospheric water vapor, which is an important driver of surface climate change on decadal scales. In this case, the transport representation is particularly important in the tropical tropopause layer (TTL), where tropospheric air enters into the stratosphere.

We have coupled the Chemical Lagrangian Model of the Stratosphere (CLaMS) with the ECHAM-MESSy Atmospheric Chemistry Model (EMAC). The latter includes the ECHAM5 climate model, and the MESSy interface, which allows for flexible coupling and switching between different submodels. The chemistry transport model CLaMS provides a fully Lagrangian transport representation to calculate constituent transport for an ensemble of air parcels that move along trajectories. To facilitate the calculation of long time-series a simplified chemistry scheme was implemented. Various studies show that the CLaMS model is particularly suited to properly represent dynamics and chemistry in the UT/LS region.

The analysis of mean age of stratospheric air gives insight into the different transport characteristics of the Eulerian and the Lagrangian transport schemes. Mean age of air, calculated in both frameworks, is compared regarding the representation of important processes, i.e. descent in the polar vortex, upwelling in the tropical pipe, and isentropic in-mixing in subtropical regions.
We also compared the zonal mean distributions and photochemical lifetimes of CFC-11 and CFC-12 with climatologies from different satellite experiments (ACE-FTS, HIRDLS, and MIPAS).

CLaMS stratospheric water vapor distributions show remarkable differences compared to the stratospheric water vapor simulated by ECHAM, especially in the Northern hemisphere in summer. The results are compared to statellite water vapor mesurements. Qualitatively, Lagrangian CLaMS data are in better agreement with the satellite climatologies. It can be expected that the more accurate representation of the UT/LS region with the CLaMS model likely yields to improved climate predictions.