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Lagrangian and Eulerian Transport: Comparison through Agespectrum Analysis

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Modern climate models have a number of robust stratospheric features, some of which are not robust within observations or even conflict with them. Most notably among these are Brewer-Dobson circulation trends, which show a robust and global acceleration within climate models but have a more complicated form in observation-based inferences (although few of these exist). Also notable is the well-known model wet bias, where climate models show approximately double the amount of stratospheric water vapor as is observed.

Previous work has shown that model transport schemes could contribute to the stratospheric wet bias, raising suspicion that other model features - particularly in the stratosphere - could have baises caused by the model transport scheme. A very common transport scheme in current climate models is the flux-form semi-Lagrangian (FFSL) scheme. Understanding the effects of the FFSL transport scheme is the goal of this work, which is sought through comparison of climate model age spectra These spectra differ only due to the transport scheme used to produce the age spectra.

Precisely, in this work age spectra were produced by a standard EMAC run and by a version of EMAC which is coupled into CLaMS - the Chemical Lagrangian Model of the Stratosphere. This latter model is a chemical transport model with a purely Lagrangian transport scheme and a robust parameterization of mixing, and is coupled into EMAC in that the EMAC winds drive CLaMS parcel transport. The CLaMS parcels only carry agespectra information, and thus two agespectra results are produced while the only difference between them is the transport scheme used.

The age spectrum, in both models, is produced by a series of tracers pulsed at the surface over the course of a month, which are dispersed to the global atmosphere. Forty tracers are used, and once every three months one of these tracers is pulsed. The amount of each tracer present in a parcel of air therefore indicates an amount of air in the parcel which is of a certain age, which can be used to produce a spectrum of air age within the parcel. By construction, these multi-pulse tracer age spectra contain the full time-dependent transport information. Thereby, the spectrum is a metric which can be used to diagnose the strength of transport including both mean and seasonal effects, and is therefore a powerful method of condensing a variety of transport information. A particular focus of our analysis is the comparison of cross-tropopause transport between the standard FFSL scheme and the Lagrangian transport scheme of CLaMS, and especially the search for potential relations to common climate model biases in the stratosphere.