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Age of air and heating rates

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The age of air in the stratosphere is often used as a test for atmospheric models and chemistry models strongly depend on the good representation of the Brewer-Dobson circulation for long-lived species. It is often advocated that using heating rates for vertical transport in the stratosphere performs better that standard analysed velocities from weather centers.

This work is based on an extensive study of the age of air using 5 years of heating rates from the ERA-40 reanalysis and a more recent reanalysis made with 4D-Var assimilation. It is shown that heating rates provide a much better representation of the Brewer-Dobson circulation and preserve transport barriers and polar vortex confinements. The circulation is modulated at the top and the bottom of the stratosphere by seasonal isentropic mixing and variations of the vertical motion at mid and high latitudes, resulting into a monotonic but nonlinear distribution of the age of air in the vertical.

It is also shown that heating rates alone predict much too large age of air due to unsufficient heating in the lower tropical stratosphere and trapping of parcels. This effect is usually corrected by an empirical correction which can exceed in some regions the calculated heating rate in magnitude, with opposite sign. We relate this correction to the assimilation temperature increment that is required to compensate the bias of the model, notably the excessive negative heat transport due to the noisy vertical velocities.

We propose an optimal correction combining heating rates and a filtered version of the assimilation increment to be used for vertical transport in the stratosphere. We study the effect of restoring the mass conservation by recalculating a mass divergence balancing the modified heating rates. The new velocity dataset generated in isentropic coordinates is then used to study the interranual variability of the Brewer-Dobson

and of heating rate, in relation with the QBO cycle. Improvements due to 4D-Var assimilation and increased vertical resolution are also discussed.