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Age of air and heating rates: comparison of ERA-40 with ERA-Interim

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The age of air in the stratosphere is often used as a test for the good representation of the Brewer-Dobson circulation by atmospheric models. This is a critical requirement to modelize the distribution of long-lived species in chemical models. 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 comparison of the age of air using 5 years of heating rates from the ERA-40 reanalysis and from the new ERA-interim reanalysis built with 4D-Var assimilation.
The ERA-40 exhibits both too young ages with analyzed velocities and too old ages with heating rates.
The reason for too young ages is spurious transport associated with too noisy wind, as a result of 3D-Var assimilation. Heating rates provide a much less noisy meridional circulation and preserve transport barriers and polar vortex confinement. However, excessive cooling near 30 hPa in the tropics blocks the ascending motion within the tropical pipe over extended periods of time inducing very old ages. 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 and the lack of mass conservation in the isentropic frame.
The new ERA-interim exhibits much reduced noise in the vertical velocity and is ten times less diffusive than the ERA-40 in the tropics. Age of air is then found to be slightly older than given by the observations.
The biases in the heating rate have also been considerably reduced with respect to ERA-40 and the assimilation increment is now only a fraction of the heating rate. The age of air is in fairly good aggreement with the observations at 20 km and higher altitudes.
Further improvements combining heating rates and a filtered version of the assimilation increment for vertical transport in the stratosphere are discussed. 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.