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The millennium water vapour drop in the stratosphere in chemistry-climate model simulations

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This study investigates the strong water vapour decline in the stratosphere beginning in year 2000, by means of various simulations using the Chemistry-Climate Model (CCM) EMAC. Since the beginning 1980s, balloon borne stratospheric water vapour measurements and corresponding satellite measurements starting in the early 1990s indicated a long-term steady increase of water vapour concentrations.

However, the multi-year data sets also show significant fluctuations on different time scales. In the year 2000, an extraordinary sudden drop of stratospheric water vapour concentration has been observed followed by persistent low values for several years. Solomon et al. (2010) showed that this drop slowed down the rate of increase in global surface temperature over the following decade by about 25%.

So far, the stratospheric water vapour variations observed by satellite from 1992 to 2012 are not reproduced by CCM simulations forced by observed changes in sea surface temperatures, greenhouse gases and ozone-depleting substances (Gettelman et al., 2010, Randel and Jensen, 2013).

However, the CCM EMAC is able to reproduce the signature and pattern of the water vapour disturbances in agreement with those derived from observations. We found periods, where large water vapour drops occured after preceding El Nino/La Nina events. Strong El Nino/La Nina events in connection with the west phase of the quasi-biennial oscillation seem to trigger large amplitudes in stratospheric water vapour.

In this paper we present results of a hierarchy of simulations with the CCM EMAC, demonstrating that it is possible to retrace the observed water vapour fluctuations in the stratosphere (incl. the millennium drop), if suitable inner and outer boundary conditions are applied.