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Chemistry–Climate Interactions of Stratospheric and Mesospheric Ozone in EMAC Long-Term Simulations with Different Boundary Conditions for CO2, CH4, N2O, and ODS

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To evaluate future climate change in the middle atmosphere and the chemistry–climate interaction of stratospheric ozone, we performed a long-term simulation from 1960 to 2050 with EMAC. In addition to this standard simulation we performed five sensitivity simulations from 2000 to 2050 using. For these sensitivity simulations we used the same model setup as in the standard simulation but changed the boundary conditions for CO_2, CH_4, N_2O, and ozone-depleting substances (ODS). In the first sensitivity simulation we fixed the mixing ratios of CO_2, CH_4, and N_2O in the boundary conditions to the amounts for 2000. In each of the four other sensitivity simulations we fixed the boundary conditions of only one of CO_2, CH_4, N_2O, or ODS to the year 2000.

In our model simulations the future evolution of greenhouse gases leads to significant cooling in the stratosphere and mesosphere. Increasing CO_2 mixing ratios make the largest contributions to this radiative cooling, followed by increasing stratospheric CH_4, which also forms additional H_2O in the upper stratosphere and mesosphere. The simulated ozone recovery leads to warming of the middle atmosphere.

In EMAC the future development of ozone is influenced by several factors. 1) Cooler temperatures lead to an increase in ozone in the upper stratosphere. 2) Decreasing ODS mixing ratios lead to ozone recovery, but the contribution to the total ozone increase in the upper stratosphere is only slightly higher than the contribution of the cooling by greenhouse gases. In the polar lower stratosphere a decrease in ODS is mainly responsible for ozone recovery. 3) Higher NO_x and HO_x mixing ratios due to increased N_2O and CH_4 lead to intensified ozone destruction. In comparison to the increase in ozone due to decreasing ODS, ozone destruction caused by increased NO_x is of similar importance in some regions. 4) In the stratosphere the enhancement of the Brewer-Dobson circulation leads to a change in ozone transport (Kirner et al., 2015).