Atmospheric Chemistry and Physics
An Interactive Open Access Journal of the European Geosciences Union

Atmos. Chem. Phys., 5, 1257-1272, 2005
www.atmos-chem-phys.net/5/1257/2005/

Simulation of stratospheric water vapor trends: impact on stratospheric ozone chemistry

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Abstract. A transient model simulation of the 40-year time period 1960 to 1999 with the coupled climate-chemistry model (CCM) ECHAM4.L39 (DLR)/CHEM shows a stratospheric water vapor increase over the last two decades of 0.7 ppmv and, additionally, a short-term increase after major volcanic eruptions. Furthermore, a long-term decrease in global total ozone as well as a short-term ozone decline in the tropics after volcanic eruptions are modeled. In order to understand the resulting effects of the water vapor changes on lower stratospheric ozone chemistry, different perturbation simulations were performed with the CCM ECHAM4.L39 (DLR)/CHEM feeding the water vapor perturbations only to the chemistry part. Two different long-term perturbations of lower stratospheric water vapor, +1 ppmv and +5 ppmv, and a short-term perturbation of +2 ppmv with an e-folding time of two months were applied. An additional stratospheric water vapor amount of 1 ppmv results in a 5–10% OH increase in the tropical lower stratosphere between 100 and 30 hPa. As a direct consequence of the OH increase the ozone destruction by the HO_x cycle becomes 6.4% more effective. Coupling processes between the HO_x-family and the NO_x/ClO_x-family also affect the ozone destruction by other catalytic reaction cycles. The NO_x cycle becomes 1.6% less effective, whereas the effectiveness of the ClO_x cycle is again slightly enhanced. A long-term water vapor increase does not only affect gas-phase chemistry, but also heterogeneous ozone chemistry in polar regions. The model results indicate an enhanced heterogeneous ozone depletion during antarctic spring due to a longer PSC existence period. In contrast, PSC formation in the northern hemisphere polar vortex and therefore heterogeneous ozone depletion during arctic spring are not affected by the water vapor increase, because of the less PSC activity. Finally, this study shows that 10% of the global total ozone decline in the transient model run can be explained by the modeled water vapor increase, but the simulated tropical ozone decrease after volcanic eruptions is caused dynamically rather than chemically.

Final Revised Paper (PDF, 641 KB) Discussion Paper (ACPD)

Citation: Stenke, A. and Grewe, V.: Simulation of stratospheric water vapor trends: impact on stratospheric ozone chemistry, Atmos. Chem. Phys., 5, 1257-1272, 2005. Bibtex EndNote Reference Manager