Chemical feedbacks in climate sensitivity studies

Simone Dietmüller (1,2), Michael Ponater (1), and Robert Sausen (1)
(1) Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Germany
(simone.dietmueller@dlr.de), (2) now at: Institut für Meteorologie, Freie Universität Berlin, Germany

Interactively coupled climate chemistry models extend the number of feedback mechanisms in climate change simulations by allowing a variation of several radiatively active chemical tracers that are prescribed in conventional climate models. Different perturbation experiments including chemical feedbacks were performed using the chemistry-climate model system EMAC coupled to the mixed layer ocean model MLO. The influence of the chemical feedbacks O$_3$, CH$_4$ and N$_2$O on climate response and climate sensitivity is quantified for a series of CO$_2$-perturbation simulations: Equilibrium climate sensitivity is dampened, if chemical feedbacks are included. In case of a CO$_2$ doubling simulation chemical feedbacks decrease climate sensitivity by -3.6% and in case of a 4*CO$_2$ simulation by -8.1%. Analysis of the chemical feedbacks reveals, that the negative feedback of ozone, mainly the feedback of stratospheric ozone, is responsible for this dampening. The radiative feedbacks of CH$_4$ and N$_2$O are negligible, mainly because the model system does not allow interactive emission feedbacks at the Earth’s surface for these gases. The feedback of physical parameters is significantly modified by the presence of chemical feedbacks. In case of the CO$_2$-perturbation experiments the negative stratospheric ozone feedback is accompanied by a negative stratospheric H$_2$O feedback change of the same order of magnitude. So the dampening effect of the direct O$_3$ radiative feedback is enhanced. A non-linearity in the damping is found with increasing CO$_2$ concentrations. Reasons are the nonlinear feedbacks of ozone, temperature, and stratospheric water vapor. Additional 6*CO$_2$ simulations with and without chemical feedbacks included show, that the presence of chemical feedbacks helps to prevent a runaway greenhouse effect, as the O$_3$ distribution can react to the upward shift of the tropopause. Also experiments driven by anthropogenic NO$_x$- and CO-emissions were performed, where chemically active trace gases act both as radiative forcing and radiative feedback. The comparison to CO$_2$-perturbation experiments shows, that the variation of the perturbation type induces different feedback processes resulting in a different influence on climate sensitivity.