Geophysical Research Abstracts
Vol. 15, EGU2013-4044, 2013
EGU General Assembly 2013

Chemical feedbacks in climate sensitivity studies

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Interactively coupled climate chemistry models extend the number of feedback mechanisms in climate change simulations by allowing a variation of several radiatively actice 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_2O 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_2O 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_2O 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 chemic 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.