Comparing Cloud Feedbacks in Perturbed-Physics Ensembles from two different GCMs

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In order to quantify uncertainties in cloud feedbacks arising from cloud parameterization schemes a 32-member perturbed-physics ensemble is generated by perturbing the values of key parameters in the corresponding cloud schemes of the fully coupled climate model EGMAM. To analyse parametric uncertainty, climate change experiments are carried out for the ensemble of models. To estimate cloud feedbacks, it is important to simulate the change in sea surface temperature in a physically consistent way. Thus, a key development for this study is an effective method to estimate the equilibrium change due to a doubling of the CO_2 concentration for an ensemble of climate models with a comprehensive ocean component. Results of these climate change experiments are presented for quantities indicative for cloud feedbacks and parametric uncertainty for different climate signals are quantified. Two main drivers for the simulated cloud feedbacks can be identified: (i) an increase in cloud height enhances the greenhouse effect of clouds (a positive feedback) and (ii) an increase in liquid water content especially of marine low-clouds in the tropics results in an increase of cloud albedo (a negative feedback).

An analysis of the contribution of individual perturbation parameters to parametric uncertainty shows that the entrainment rate for turbulent entrainment and the conversion rate from cloud water to rain in updrafts play an important role in determining the simulated cloud feedbacks. Nevertheless, independent of the choice of parameter values, all ensemble members show positive longwave and negative shortwave cloud feedbacks. As an important result, an anti-correlation between longwave and shortwave cloud feedbacks is found within the ensemble of model versions which leads to low variance in (negative) total cloud feedback and a low climate sensitivity in the EGMAM ensemble.

A comparison of results from perturbed physics ensemble with the HadSM3 climate model shows substantial differences in the simulation of climate feedbacks as well as the relationships between them. These differences to the EGMAM results lead to different estimates of climate sensitivity. This indicates a model dependence of perturbed physics results and leads to the conclusion that parametric uncertainty is different from structural uncertainty in climate models. Therefore, a comprehensive quantification of uncertainties in simulations of future climate change has to include the analysis the analysis of multi-model and perturbed-physics ensembles.