Quantification of model uncertainties: Parameter sensitivities of the coupled model EGMAM

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Motivation
One aim of the European project ENSEMBLES is to quantify model uncertainties in the projections of future climate change. Beside the uncertainties in the initial conditions and the external forcings, another source of uncertainty are poorly constrained model parameters. These are leading to uncertainties in models climate response to changing levels of greenhouse gas concentrations. Recently many studies and projects concentrate on systematic approaches to estimate the ‘model error’ and conclude that the ‘model uncertainty’ is contributing even about equally to the uncertainty in projected change at the end of the twenty-first century as the uncertainty in the emissions of green house gases does.¹

Experiment setup
The EGMAM model used for the perturbation experiments is a coupled atmosphere-ocean model. The atmospheric component is the MA-ECHAM³ model with a resolution of T30/L39. The oceanic component is the HOPE-G³ primitive equation model with a T20/L42 resolution. Due to the relative complex model for perturbations physics experiments, the ensemble size of 27 is small. But it can be used to study also regional effects and compare regional patterns found in similar studies.⁵

A linear approach to asses multi-variate parameter sensitivity
With a multi-variate linear regression approach (MLR) we try to explain the parameter sensitivity shown in the ensemble.

Table 1 Overview of the perturbation parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Component of GCM</th>
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<tr>
<td>P</td>
<td>Cumulus convection</td>
</tr>
<tr>
<td>f</td>
<td>Cumulus convection</td>
</tr>
<tr>
<td>g</td>
<td>Stratiform clouds</td>
</tr>
<tr>
<td>C_z</td>
<td>Stratiform clouds</td>
</tr>
</tbody>
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The result of the MLR is the gradient for the sensitivity in the 5-dimensional parameter space. The most sensitive parameter is found to be the sedimentationrate of ice crystals. All others are less sensitive (Table 2).

The T2m reconstructed from the parameter settings is close to the simulated T2m in the ensemble (Fig.2). The two curves are highly correlated with a coefficient of 0.89.

Nonlinearities in combined perturbations of different parameters
Despite the linear response pattern in the temperature signal, it can be seen in several radiative quantities, for example the outgoing longwave radiation, that the effects of single parameter perturbations combine non-linear in multi parameter perturbation experiments. (Fig. 4)

Conclusions and future prospects
On the global scale the sensitivity in terms of temperature response of the model can be explained with a multi-variate linear regression approach. This is due to the strong linear behaviour in the sensitivity of the model to the sedimentation rate of ice crystals in high cirrus clouds. A non-linear behaviour of the model can be seen especially in radiative quantities. Effects in multi-parameter variation experiments are non-linear combinations of effects in single parameter variations.

In a next step the ensemble will be enhanced by an improved sampling of the underlying uncertainties. The experiments will be extended to doubling CO₂ to give a probabilistic estimate of the climate sensitivity of the model. This will also allow a deeper look on the relationship between the parameter- and the climate sensitivity.

References:
7. Murphy,A.J. et al. ‘Quantifying uncertainties in climate change from a large ensemble of general circulation model predictions’ Nature Vol. 430(2004), 768-772