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 green house 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]

Introduction

As a first step to quantify the uncertainty in the the climate sensitivity of the **EGMAM** (**E**CHO-**G**[2] with **M**iddle **A**tmosphere and **M**essy Interface) model, the sensitivity of the model to perturbations of five relevant large-scale cloud-, convection- and precipitation parameters was tested. The five chosen parameters are known to be uncertain in their values and crucial for models climate. A 27 member perturbed-parameter-ensemble of EGMAM versions was generated by varying these parameters within the ranges specified by experts. This study is a first investigation of this ensemble.

Experimental setup

The EGMAM model used for the perturbation experiments is a coupled atmosphere-ocean model. The atmospheric component is the MA-ECHAM4 [3] model with a resolution of T30/L39. The oceanic component is the HOPE-G [3] primitive equation model with a T20/L42 resolution. Due to the relative complex model for perturbed 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]

Physical effect	Parameter	Component of GCM
Conversionrate from cloud water to rain	P	Cumulus convection
Entrainmentratefor shallow convection	ε	Cumulus convection
Overshooting of cumuli above the level of non-buoyance	β	Cumulus convection
Sedimentationrate of ice crystals in cold clouds	α	Stratiform clouds
Efficiency of rain formation	C_0	Stratiform clouds

Table 1 Overview of the perturbation parameters

The set of parameters is similar in other perturbed physics studies[6,7] allowing comparison of different models.
Perturbations were made as single and multi-parameter variations, but with an imperfect sampling of the underlying uncertainties. The resulting model versions were integrated over a period of ten years under constant present day conditions.

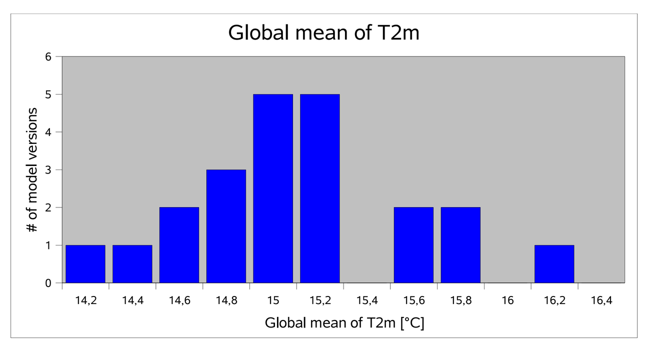

Fig. 1 The histogram shows the number of ensemble members in different categories of global mean of T2m

Here the parameter sensitivity is defined as the global mean of 2m temperature in the last five years in the integration of each model version.
The ensemble of perturbed EGMAM versions shows a distribution of global mean 2-meter-temperature centred around 15°C and a spread of 2°C for present day conditions.

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.

Parameter	stand. weight
P	0.275
ε	-0.303
β	0.196
α	-0.720
C_0	0.325

Table 2 The standardised pattern of weights determined with the MLR.

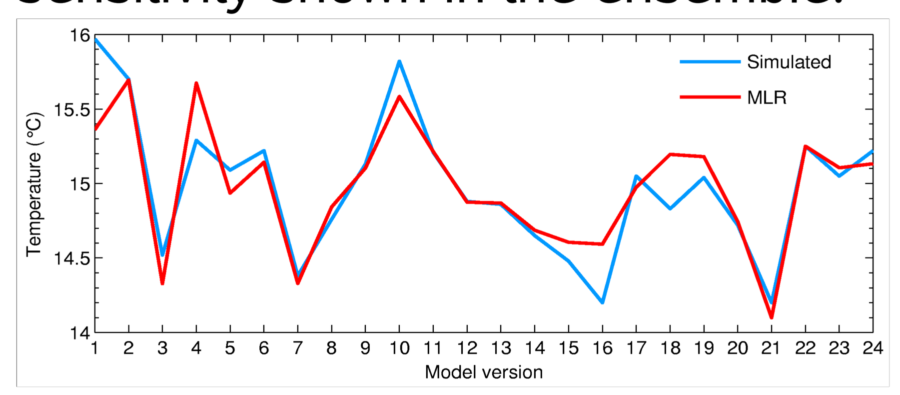

Fig. 2 The blue curve shows the temperature change in the different model versions. The red curve shows the reconstructed temperature with the results of the MLR.

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.

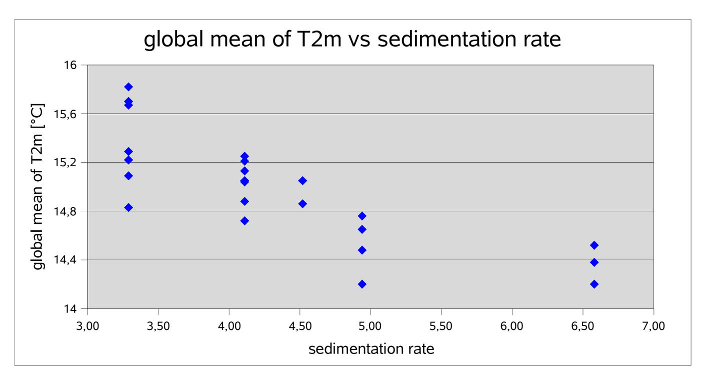

Fig. 3 The blue dots show the resulting global mean of of T2m for different values of the sedimentation rate of ice cristal in cold clouds.

Linear sensitivity of the model can be seen especially in the sedimentation rate of ice cristals in high cirrus clouds (Fig.3). This is one reason why the linear approach is succesful in explaining more than 79% of the variance in the ensemble.

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)

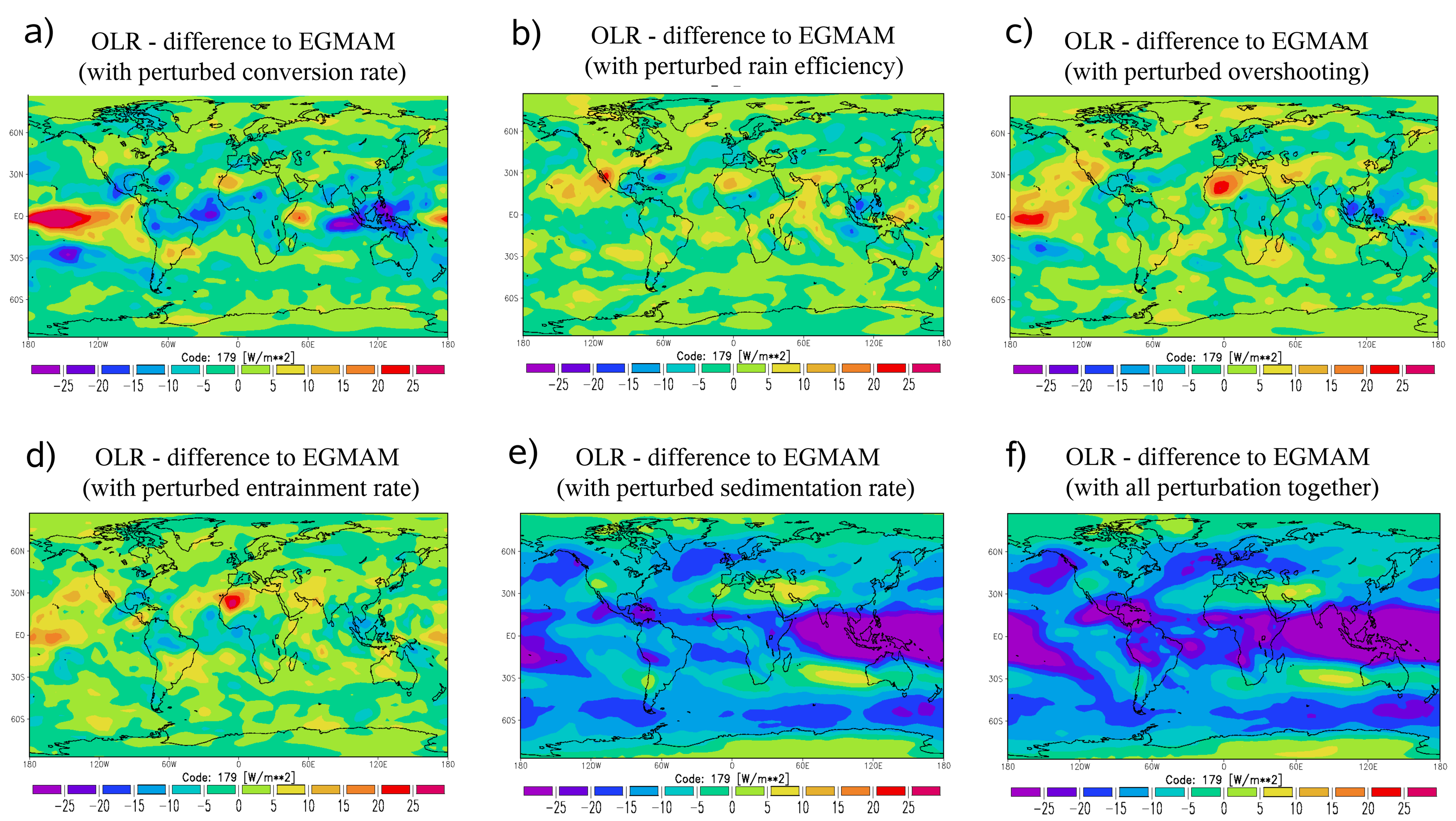

Fig. 4 Differences in the OLR between perturbed model versions and the unperturbed EGMAM model. Shown are the differences between a five year mean of the OLR in the ensemble member integrations and a 30 year mean of the OLR in the unperturbed EGMAM model.

The effects of single parameter perturbations [Fig. a)-e)] combine non-linear to an enhanced signal [Fig. f)] obtained in the perturbed sedimentation rate experiment [Fig. e)].

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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 CO_2 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.