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Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft
Institut für Physik der Atmosphäre

Cloud Radiative Feedback and Climate Sensitivity: Experiences from the ECHAM Global Model

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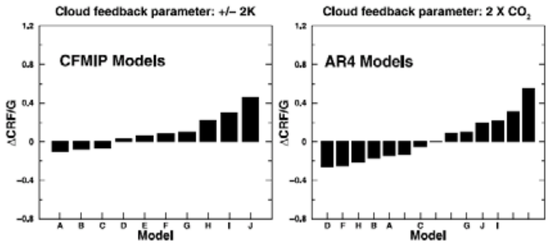
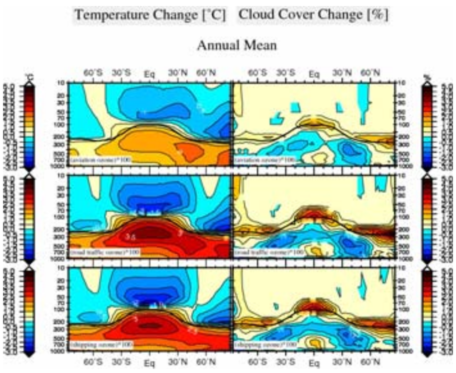
The Problem

The importance of the cloud radiative feedback in climate models for simulated global warming has well been acknowledged. Global cloud feedback may contribute positive or negative in global warming simulations, leading to a distinct model dependency of the climate sensitivity parameter $\lambda = \Delta T_{surf}/RF$ (see example figure from Ringer et al., 2005). Main experience on the subject is originating from sea surface temperature change simulations and CO_2 doubling simulations (with mixed layer ocean). On this poster we add some experiences from simulations using as an input more "exotic" perturbations that are connected with the climate response to radiative forcings caused by transport systems.



Cloud feedback in simulations using scaled ozone perturbations

In the framework of the FP7 project QUANTIFY equilibrium climate change simulation were performed using ozone change pattern from aviation, road traffic, and shipping as input. The model chosen was ECHAM4/ATTILA (Stenke et al., 2008) which uses the Sundqvist cloud scheme. Heavy scaling had to be applied to the ozone perturbations in order to yield a statistically significant temperature change for estimating climate sensitivity differences.



Temperature and cloud cover response in this type of simulations seems to be not substantially different to CO_2 experiments (figure), yet at closer look at the cloud feedback (table) shows its own peculiarities:

Beyond a threshold of the primary radiative forcing the cloud feedback is no longer negative (as it is at moderate forcing) but changes sign to positive. The threshold seems moreover, to depend on the particular pattern of the forcing perturbation.

Perturbation	ΔT_{surf}	RF_{adj}	λ_{adj}	ΔCRF	λ^*_{adj}
CO2 (1W/m2)1	0.694	1.010	0.687	−0.127	0.786
CO2 (doubling)	2.726	3.792	0.714	−0.340	0.790
CO2 (tripling)	4.543	6.160	0.736	−0.355	0.783
Ozone_avia (50)	0.617	0.862	0.712	−0.082	0.791
Ozone_avia (100)	1.167	1.593	0.733	−0.160	0.814
Ozone_avia (200)	2.201	2.849	0.773	−0.085	0.769
Ozone_avia (500)	4.832	5.730	0.843	+0.562	0.769
Ozone_road (100)	2.032	2.646	0.768	−0.034	0.778
Ozone_road (150)	2.900	3.689	0.786	+0.129	0.760
Ozone_road (500)	8.586	9.051	0.949	+3.262	0.697
Ozone_ship (100)	1.925	2.679	0.719	−0.018	0.723
Ozone_ship (150)	2.833	3.743	0.757	+0.155	0.727
Ozone_ship (500)	8.793	9.261	0.949	+3.888	0.669
	[K]	$[Wm^{-2}]$	$[K/ Wm^{-2}]$		$[K/ Wm^{-2}]$

Resolution dependency of the climate sensitivity parameter

	CO_2	Solar
ECHAM4/T30.L39	0.73	0.74
ECHAM4/ATT/T30.L39	0.71	0.71
ECHAM5/T42.L41	0.75	0.70
	K/Wm^{-2}	K/Wm^{-2}

Within the ECHAM family a basic assumption of the climate sensitivity concept is generally fulfilled: The climate sensitivity parameter is similar (or equal) in simulations with CO_2 or solar constant increase.

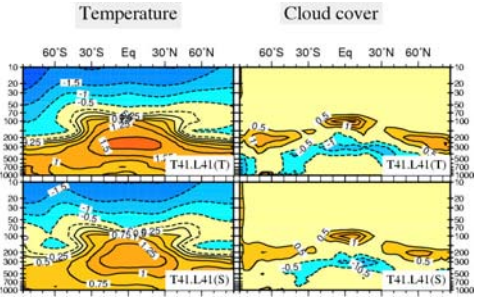
Reso	RF_a	ΔT_{surf}	ΔCRF	λ	λ^{cs}
	CO_2		cloud fb		clear-sky
T31.L19	1.00	1.95	+1.38	1.95	0.82
T42.L19	1.00	1.55	+0.84	1.55	0.85
T42.L31	0.99	1.21	+0.37	1.23	0.89
T42.L41	1.01	0.98	+0.19	0.97	0.82
T63.L31	0.99	1.06	+0.23	1.07	0.87
T31.L19	0.99	0.93	-0.04	0.94	0.99
T42.L41	1.01	0.75	-0.24	0.74	0.97
T63.L31	0.98	0.71	-0.21	0.72	0.93
	W/m^2	K	W/m^2	K/Wm^{-2}	K/Wm^{-2}

The ECHAM5 cloud radiative feedback is positive when run with the Tompkins cloud scheme, while it's negative when run with the Sundqvist cloud scheme.

Using the Tompkins scheme results in an undesirable resolution dependency of the climate sensitivity as the cloud feedback for coarse resolution versions gets extremely positive. ECHAM5 with the Sundqvist scheme appears to be less sensitive to resolution changes.

The reason of the change in cloud feedback sign for the two model versions is not immediately evident: Looking superficially only at the cloud cover changes, both version seem to respond consistently.

The global mean radiative feedback receives so many contributions of different sign that is it very hard to detect crucial or dominating effects, let alone to assess whether they are correctly represented.



Preliminary Conclusions

On many occasions nonlinearities in cloud radiative feedback occur in climate change simulations, and sometimes feedback regime changes from one sign to the other are possible.

The critical threshold may be resolution dependent, thus it is essential to understand its origin for assessing the reliability of the respective models.

The threshold may depend on the particular character of the primary forcing, and the way it affects the static stability of the atmosphere. Hence, differences in forcings may lead to differences in feedbacks and explain part of the known variability of the climate sensitivity parameter for different models as well as for different perturbations.

It is necessary to analyze observations in order to develop ideas how global cloud radiative feedback is composed by local contributions (both with respect to latitude and with respect to altitude). Self-consistent observations over periods as long as possible are needed for this purpose, as we are looking for a small residual of large regional components.

In extension of current efforts to validate climate models in this respect (like CFMIP, e.g., Bony et al., 2005) more attention than hitherto should be directed to the specifics of model response patterns to non-CO_2 forcings.

References

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