Atmos. Chem. Phys. Discuss., 8, S6457–S6460, 2008
www.atmos-chem-phys-discuss.net/8/S6457/2008/

Atmospheric Chemistry and Physics Discussions

ACPD

8, S6457–S6460, 2008

Interactive Comment

Interactive comment on "On the diagnosis of climate sensitivity using observations of fluctuations" *by* D. Kirk-Davidoff

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Received and published: 28 August 2008

Kirk-Davidoff (hereafter DKD) used a simple climate model and analyses of archived coupled climate model output from the IPCC AR runs to test the utility of an approach proposed by Schwartz (2007, hereafter SES, see references in DKD). Schwartz's approach is based on observational data. It consists of the estimation of the pertinent global heat capacity C (from regression of ocean heat content to global mean surface temperature), the estimation of the relaxation time constant τ of the climate system (from autocorrelation of the global mean surface temperature), and the derivation of the climate sensitivity S using the relation $S = \tau / C$. The latter rests on the fluctuation dissipation theory (FDT). The resultant equilibrium climate sensitivity is 0.3 K/(Wm^{-2}), which corresponds to a temperature increase of only 1.1^{o}C under a doubling of CO2.

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DKD showed that when applying to archived IPCC AR data, S calculated using Schwartz' approach is slightly negatively correlated to, and hence does not match, the modeled climate sensitivity. DKD further showed, with the aid of his simple climate model, that 100yr time series are too short for reliable estimation of the relaxation time constant. In particular, 100yr time series underestimate the true relaxation time. Furthermore, the existence of multiple heat capacities in a climate system introduces systematic errors to the estimation of relaxation time scale. In particular, a simple model with high climate sensitivity and a weak coupling between two heat reservoirs has shorter relaxation time scale than a model with low sensitivity and a single heat reservoir. DKD arrived at, amongst others, the conclusion that 'the FDT is poorly suited to the evaluation of model sensitivity in practice'.

DKD jointed other three comments on Schwartz' approach (Foster et al. 2008, Knutti et al. 2008, and Scafetta 2008, see references in DKD). Somewhat different from the earlier comments, which were more focused on the problems related to the estimation of the relaxation time τ due to inappropriate AR(1)-assumption and single-time-scale assumption, DKD put forward the role of multiple heat capacities on the relaxation time.

DKD's analysis is important, since it could help to improve our understanding of climate sensitivity. It is also well motivated, as Schwartz' approach is indeed inaccurate in various aspects. In this sense, I recommend the publication. The paper could however be futher improved and the conclusions could be more convencing, if the following two inconsistencies in the analysis can be removed.

The first inconsistency is found in the validation of the FDT using the IPCC runs. The goal is to compare the climate sensitivity produced by $S = \tau/C$ with those produced by model simulations, or equivalently to check the FDT using model simulations. FDT predicts that the change in the *equilibrium mean* temperature $\Delta\mu_T$ is determined by the change in the external forcing ΔF in units K/s times constant τ in units of time. τ equals the integral of the auto-correlation function. When introducing a heat capacity C in units Ws/(m^{2}K), $\Delta\mu_T$ is determined by the change in the external forcing $\Delta F^* = \Delta F \times C$

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in units W/m^2 times constant $S = \tau/C$ in units K/(Wm^{-2}), or equivalently the climate sensitivity equals $S = \tau/C = \Delta\mu_T/\Delta F^*$. Note that ΔF^* could be different in different models due to different radiation schemes. If the FDT is checked consistently, one should compare $S = \tau/C$ obtained from τ and C using model data with the *equilibrium* sensitivity $\Delta\mu_T/\Delta F^*$ produced by the equilibrium simulations. This means, first, that the equilibrium response $\Delta\mu_T$, rather than transient responses ΔT, should be considered. Secondly, S should be compared with the ratio $\Delta\mu_T/\Delta F^*$, not just $\Delta\mu_T$. Unfortunately, both aspects were ignored. DKD considered transient responses in IPCC runs (his Fig.3) and compared S with the transient temperature changes ΔT (his Fig.4d). Generally, the mismatch between S and ΔT, as found by DKD, does not directly imply the invalidity of the FDT. It is possible that the FDT is indeed 'poorly suited to the evaluation of model sensitivity'. But this needs to be shown explicitly by comparing S with $\Delta\mu_T/\Delta F^*$.

The second inconsistency is found in the applications of the simple climate model. The problem here is that the fluctuations in the model are generated by the forcing of the model (the red noise included in the solar constant). Such a simple model cannot be used to test the FDT, since FDT rests on *inherent* fluctuations (e.g. those arising from internal instabilities), rather than externally forced fluctuations. Apart from other parameters in the model, the auto-correlation functions of the model outputs depend crucially on the temporal characteristic of the fluctuating forcing. The time constant τ that is derived from the simple model driven by prescribed fluctuations in the forcing has nothing to do (at least not in the sense of the FDT) with the simple-model response, induced by changing the forcing from one constant value to another. The result that the simple model with high climate sensitivity has shorter relaxation time scale than a model with low sensitivity is hence indifferent to the value of τ, which should result from inherent fluctuations.

The paper would also be more readable when edited with greater care. As an example, I mention here only some errors / typos regarding the figures:

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- Fig.1: There are no red and blue curves, which are mentioned in the text.
- Fig.3: between the years 2000 (instead 2100) and 2100 in the SRESa1b runs.
- Fig.5: delete 'and' in the second last line.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 12409, 2008.

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