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Atmospheric Chemistry and Physics Discussions

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

D. Kirk-Davidoff

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Author Comments

I thank both reviewers for their careful reading and for their many helpful comments, criticisms and suggestions. My replies to their comments follow:

Reviewer 1, A. Gritsun

1. The reviewer suggests that the definition of the sensitivity as "a surface temperature response to CO2 doubling" should be given somewhere in the Introduction.

Response: I have added a new first sentence of Introduction: "An accurate determination of the earth's climate sensitivity, the expected mean surface temperature response to a doubling of carbon dioxide concentration, has been the outstanding problem in climate dynamics for the last several decades. "

2. The reviewer suggests the discussion of a number of additional references in the Introduction.

Response: We have added many of the suggested references to the Introduction, including the following paragraph: "These concerns suggest that the FDT should be applied to the climate system using a large state vector, containing many climate relevant variables. Indeed Dymnikov and Gritsun (2005) and Majda et al. (2005) have shown that the FDT applies well to the fully non-linear systems represented by climate models, and Gritsun and Branstator (2007) have confirmed that the response of a GCM to a spatially constrained climate forcing can be predicted in detail using the FDT on a large state vector (approximately 1800 variables). In this work we focus on the ability of the FDT to diagnose climate sensitivity using a single global temperature variable so that we can focus on the data requirements for this diagnosis, and especially on the role of an unknown heat capacity as an obstacle to accurate diagnosis."

3. The reviewer notes that others have considered the length of the time series necessary for accurate diagnosis of a model's response matrix using observations of fluctuations.

Response: I have inserted this sentence in the Introduction: "Gritsun and Branstator (2007) also found that very long data sets (O(100) years) were necessary for accurate prediction of climate model responses (in their case to localized heating anomalies) using the FDT."

4. The reviewer notes the missing red/blue curves referred to in the text, but not present in Figure 1.

Response: I have removed the reference to red and blue curves in text.

5. The reviewer suggests that references to "relaxation time constant" be changed to "decorrelation time scale".

Response: I have made this change.

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6. The reviewer suggests that the applicability of linear system to climate is impuned by the sensitivity of the decorrelation time scale with respect to lag.

Response: We have added the following sentence to the discussion of Figure 1b: "The variability of the decorrelation time scale as a function of lag for each model, and for the observed data are due to a combination of random error associated with the relatively short time series involved, and deviations from linearity of the models. In the absence of much longer runs for each model, we cannot distinguish the role of each."

7. The reviewer points out that "linear theory ... should work for all forcings."

Response: I agree, but the point of this section is that since feedbacks might depend on the current state, we should expect the FDT to work best at predicting climate sensitivity for small changes from the mean state. I've added the phrase "such that state-dependent feedbacks are functioning near the unperturbed initial state" to the sentence in question.

8. The reviewer suggests that after "we can define climate sensitivity..." I should change "the response" to "the response of the global mean surface temperature".

Response: I have made this change.

9. The reviewer asks that I be clear about the definition of the "equilibrium climate sensitivity" that is shown in figure 5a.

Response: I have made this change in the text.

10. Be clear that "temperature" referred to in Figure 3. "we show that these sensitivities... " is the surface air temperature (Ta (or is it Ts? Better check!)).

Response: I have made this change.

11. Use a single term for "adjustment time scale" "response time", etc. referring to 90% adjustment time in figure 5.

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Response: I have made this change.

12. The reviewer suggests toning down the conclusion that "The FDT is poorly suited to the evaluation of model sensitivity in practice." Response: I have changed the first conclusion to read: "Although methods based on the FDT can produce precise, accurate estimates, given sufficient time, the time required for accurate evaluation of model sensitivity is in general several times longer than a model would require to come to equilibrium with a step-change in forcing. "

13. The reviewer suggests a number of additional explanations for the poor performance of the FDT in estimating the climate sensitivity of the coupled climate models.

Response: We have added the following paragraphs to our conclusion: "There is some prospect that improved diagnostic techniques based on the FDT may allow accurate estimation of climate sensitivity from climate fluctuations. Gritsun (2008) points out that an estimate of a more complete response vector of the climate system, obtained by analyzing a much larger state vector, might give better results. Alternatively, better results might be obtained using a different method to deal with the non-stationarity of the observed and modeled time series, for instance by concentrating on shorter time scale fluctuations during the winter season."

Reviewer 2: J.-S. von Storch:

1. The reviewer notices the incorrect description of figure 1 in the text. Response: I have corrected the text to agree with the figure.

2. The reviewer noticed that the caption of Figure 5 is incoherent. Response: I've fixed this caption.

3. The reviewer argues that it is more appropriate to compare the prediction of model sensitivity based on the FDT to the full equilibrium response of doubled CO2 experiments.

Response: I have changed figure 4 and the accompanying discussion to use the ap-

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proximately equilibrated results of the runs with CO2 increasing at 1% per year to doubling. I have only used the runs with a full two hundred years of data, and have taken the mean temperature difference between first and last ten years of the runs to be the equilibrium climate sensitivity. As in the results shown previously, the predicted and observed model climate sensitivities are poorly correlated.

4. The reviewer points out that our simple model cannot be used to test the applicability of the FDT to climate, since its fluctuations are externally, rather than internally driven.

Response: Although the model is driven by red noise, and it is true that the autocorrelation of the temperature is partially dependent on the autocorrelation of the forcing, in our experiments we have held the autocorrelation of the forcing fixed such that the autocorrelation at one year is about 0.6. The autocorrelation of the model temperature is in fact an excellent predictor of climate sensitivity, provided heat capacity is held fixed, and a sufficiently long time series is available. For a wide range of climate sensitivities, and a time series of 1600 years, the inverse log of the 1-year lag autocorrelation is itself correlated with model climate sensitivity with r = 0.98. I have included a discussion of this point in the model disription, and an additional panel showing the inverse lag autocorrelation in Figure 5, also discussed in the text.

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

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Interactive Comment