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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol lifetime and climate change" *by* G.-J. Roelofs

Anonymous Referee #1

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This manuscript examines simple relations, which describe the global mean lifetimes of water vapor and aerosols and the sensitivity of these lifetimes to temperature change. These are rather back-of-the-envelope type calculations, which attempt to provide a simple characterization of a complex system. The author shows that previous global model simulations exhibit a wide range of simulated aerosol lifetime sensitivities to temperature change (with sign differences). The simple relations yield an aerosol lifetime sensitivity to temperature of 5.3%K-1, which is in the upper range relative to previous studies. The author uses these relations to show that water vapor and aerosol lifetime are coupled since they depend on the same cloud parameters, and that the ratio of their lifetimes is proportional to the ratio of scavenging and condensation efficiencies.

The analysis related to the temperature sensitivity of aerosol and water vapor lifetimes is scientifically interesting. However, there are certain points that are not clearly presented and certain conclusions that are not well supported. These issues should be

satisfactorily addressed prior to publication and are outlined below. Also, many of the relations presented are a review of already published work. For example, all of the equations presented in Section 2.1 are from Pruppacher and Jaenicke (1995). The figure and table in the manuscript are also a summary of data taken from previous studies. While a review of previous work is useful for the discussion, I was not sure if there was enough new scientific development in this manuscript.

Specific Comments: 1) A recurrent term in the analysis is (fccUc), could the author provide a clearer physical meaning for this term earlier in the text, other than simply calling this the 'cloud response'? The derivative of this term with respect to temperature is approximated to be -5.3%K-1.There is a discussion at page 16499, line 15-20 that this result is consistent with a negative correlation between sea surface temperature and low-level cloud cover. It is not clear that this relation should be expected since the term also includes f, which is the volume fraction of clouds that produce precipitation – thus the derivative of the term with respect to temperature could be negative while sea surface temperature and cloud cover were positively correlated, if the volume fraction of cloud that produced precipitation decreased with increasing temperature. Also, I am not sure if 'cloud response' is the best terminology to use to describe the physical meaning of this term.

2) The calculations in Section 2.2 are based on the work of Held and Soden (2006). So in many respects the first line in Table 1 might reference that publication. Could the author comment on how the 5.3%K-1 sensitivity calculated in Section 2.2 relates to Figure 5b) in Held and Soden, which also shows a roughly 5%K-1 temperature sensitivity related to moisture transport?

3) Could the author state more clearly what is meant at page 16500, line 4, by the 'tendency of models to maintain relative humidity' and why this is expected?

4) The last paragraph of Section 2.2 is a useful discussion about the precipitation sensitivity term and how there is considerable uncertainty related to this term, such that

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even the sign of the 'cloud response' term is in question as a result. Thus I was not clear why the author chose to present the 5.3%K-1 result in the Table 1 as the only result of this study - a range of values between -0.5 K-1 and 6.0 K-1 results when Eqn. 7 is applied using the precipitation sensitivities given in Section 2.2, paragraph 2 (and under the assumption that the water vapor concentration sensitivity is roughly constant as noted at page 16500, line 4).

5) The last paragraph in Section 2.3 discusses a potential feedback mechanism under the assumption of constant scavenging efficiency (ea). I think that the author should acknowledge more clearly here that this assumption of constant ea with temperature change is highly uncertain and perhaps not very likely. This makes the conclusion about the relative importance of emissions versus climate change on the aerosol burdens a highly uncertain result. Thus I am not sure how meaningful this feedback discussion is here, given this uncertainty. Also, could the author provide a clearer list of the assumptions underlying this analysis? This paragraph also references Eq. (5), which is not the correct equation number.

6) Section 3 first sentence, perhaps 'water vapor lifetime' could be used to be more specific as opposed to water vapor lifetime.

7) Table 1 presents quite a limited selection of previous studies (only 4) – is this enough to draw the conclusions about the sign of the simulated sensitivity of aerosol lifetimes as related to the climate sensitivity of models? The ideas examined by this study would be suitable for a model intercomparison project involving a greater number of global models.

8) Page 16503, line 12 states that 'more likely that increased precipitation frequency is responsible' for the negative temperature sensitivity of aerosol lifetime – could not other factors also contribute to this result? Can the author better justify this conclusion?

9) Figure 1 is a plot of data from Soden and Held (2006). Could the author provide a less cursory discussion of the figure to make the paper more accessible to a reader that

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is not as familiar with this previous study? Perhaps there could be a brief discussion of what is meant for cloud radiative, water vapor and lapse rate feedbacks and why the author has chosen to present the feedbacks in this way. Also perhaps a clearer statement of the main conclusion that the figure supports.

10) Page 16504, line 25 states that when the temperature response of the term fccUc is negative, this is consistent with a positive cloud radiative feedback. Could the author provide a clearer discussion about how cloud radiative feedback relates to the term fccUc?

11) Page 16505, lines 22-23 – could the author be more specific about what is meant by 'cloud response'? Also in that paragraph, could the author be clear about the assumptions that underlie the derived 'cloud response'

12) Page 16506, line 2, I am not sure that cloud cover observations alone can provide an indication about the estimate of the 'cloud response' term, given that this term also includes f, the fraction of clouds that produce precipitation. Also in this paragraph, I think that presenting the range of aerosol lifetime temperature sensitivities would be helpful.

13) Page 16506, line 2 states that atmospheric transport is not included – would this not be implicit in term 2 if the results are based on estimates for the other terms in Eq. 7, which come from global models that include transport processes (taken from the Held and Soden (2006) compilation of models)? Likewise for some of the remaining list of not included processes.

14) Page 16506, line 14-16, could the author add a reference here?

15) Could the author provide a clearer reference to the evidence from this study that supports the tentative conclusion of page 16506, line 19?

16) Table 1 – it is not clear what the term 'average' means, and also add units for CS.

17) Abstract – I think the abstract should mention that even the sign of the aerosol and

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water vapor lifetime temperature sensitivity is not certain. Also perhaps mention that nature of the forcing (LW) for the derived value of 5.3%K-1 and be clear that these were not model simulations conducted in this study.

18) Abstract – I find that the argument about the distribution of water vapor and aerosol between the lower and upper troposphere as related to climate sensitivity and temperature sensitivity of aerosol lifetime was not clearly developed in Section 3.2 and had frequent use of the words 'may' and 'probably' - so I was not sure how much confidence to place in this analysis. The last 2 sentences of the abstract seem to be rather general and not a strong conclusion based on evidence provided by this study.

19) Introduction page 16495, line 10, wet deposition efficiency is noted to depend on the efficiency of air processing by precipitating clouds and uptake of aerosol in cloud water – should this not also depend on rates of conversion of cloud water to precipitation (autoconversion, aggregation, accretion)?

20) Introduction page 16495, line 15-16, lifetime and burden should be positively correlated – do you mean removal efficiency and burden are anticorrelated?

21) Page 16495, line 25-30, are these studies for changes to stratiform scavenging only? Could the lifetime changes be greater for changes to convective scavenging processes? Is this evidence enough to indicate the significant influence of the simulated hydrological cycle alone?

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 16493, 2012.