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Atmospheric Chemistry and Physics Discussions

Interactive comment on "On the attribution of stratospheric ozone and temperature changes to changes in ozone-depleting substances and well-mixed greenhouse gases" *by* T. G. Shepherd and A. I. Jonsson

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We would like to thank reviewer 1 for his/her kind words and useful comments. Below we address his/her concerns.

SPECIFIC COMMENTS:

Page 12328, line 23: I think you should come up with more precise wording rather than just atmospheric conditions.

Answer: We disagree. This is a very generic statement to start off the Introduction. It is clearly specified later in the section that attribution of ozone and temperature changes

are meant.

Page 12329, lines 7 and 8: I am surprised to see a paper with Ted Shepherd's name on it that states that significant ozone depletion started only in 1979.

Answer: You're right, we'll have to remove that! Seriously, the phrase referred only to global ozone depletion. But apparently this qualifier is too subtle and could be missed. In any case the statement is not needed, and so we'll remove it.

Page 12330, lines 16 and 17: This is a key sentence in this manuscript i.e. in this formalism that you are developing in Section 2 you are assuming equilibrium conditions (I come back to this later). Anyway, at this point, when you say 'we are interested in long-term changes', you should say what you mean by 'long-term'. Is this decadal or many centuries?

Answer: The time scale we are considering is based on the observed global mean ozone depletion and the future predicted recovery. Hence, by 'long-term' we mean decadal or longer. We will insert "(i.e. decadal or longer)" following "long-term" for clarity.

Page 12330, Questions regarding equation (1).

Answer: Equation (1) is a Taylor expansion of the cooling rate in terms of perturbations in the major dependent variables: O3, CO2 and T.

As the reviewer underlines, the cooling rate depends on T – this is the Stefan-Boltzmann law! However, the term the reviewer is referring to, (c*deltaT*deltaCO2), is a second-order term in the Taylor expansion. Our 'c*deltaT' term is a first-order term, and refers to the change in cooling rate with temperature, at fixed CO2. The reviewer's suggested formulation

d(deltaT)/dt = 0 = a*deltaO3 - b*deltaCO2 - c*deltaT*deltaCO2

would imply that changing ozone alone (with fixed CO2) would not change temperature,

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and that's clearly incorrect. Thus Eq. (1) in its current form is indeed the correct way to linearize the problem.

The reviewer also asked: "ODSs (I am thinking specifically now of CFC-11 and CFC-12) don't themselves induce any radiative cooling of the stratosphere in the same way that CO2, CH4 and N2O do, do they?"

Answer: ODSs, in particular CFCs, do have a direct radiative effect but it's actually a warming, not a cooling (see e.g. the work of Forster and Joshi, 2005). However the impact is mainly limited to the upper troposphere and lower stratosphere. In the upper stratosphere, the direct radiative effect of the ODSs is insignificant compared to the temperature changes induced from CO2 and O3 changes.

Page 12335, lines 7 and 8: It is not clear to me what you mean by 'Note that changes in CO2 or ODSs at a single altitude are not physically realizable.'

Answer: What we meant was that since CO2 and ODSs are well-mixed, it is not physically sensible to think of a perturbation at a single altitude. But we agree that this sentence could be confusing. Since it's not needed, we'll omit it.

Page 12336, lines 7 and 8: All of the formalism developed in Section 2 was based on the assumption of the equilibrium response i.e. d(deltaT)/dt was zero and d(deltaO3)/dt was zero. Now it seems that you're going to be interpreting the TRANSIENT response in a CCM in terms of the Section 2 formalism. I am therefore a little worried. Should I be?

Answer: The 'transience' in question is multi-decadal, so the time tendency term is completely insignificant compared with the other terms in the equation. Over multi-decadal timescales, the ozone and temperature balances can be considered to be in a steady state. The point is that this steady state is slowly evolving over time. We make this statement in Section 2, but perhaps it is worth reiterating in Section 3. So, on p.12336, line 7 we suggest inserting the sentence: "Because these are long-term

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changes, we are looking at the change in the steady-state ozone and temperature balances over those periods."

Page 12338, lines 7 to 19: It is not clear to me whether these values have been derived within the formalism developed in Section 2 in anyway. If so, I would be worried for the same reason as outlined in the previous comment.

Answer: The values themselves are not derived according to the specific formalism used in Section 2, but they do rely on a steady-state assumption for the ozone and temperature balances, which as noted in the response to the previous comment is completely appropriate for multi-decadal changes.

Page 12341, line 8: The problem with moving to a multiple linear regression analysis is non-orthogonality of your basis functions. The CO2, CH4 and N2O time series would be very similar in shape and the regression will not partition the variance across these three in a very robust way.

Answer: Yes, we agree that such difficulties would limit the usefulness of multiple linear regression analyses. Yet, some IPCC projections of future CH4 changes differs fundamentally in shape from CO2 projections in the latter part of the 21st century, and while H2O behave very much like greenhouse gas in the troposphere (and lower stratosphere), in the upper stratosphere and mesosphere we expect H2O trends to primarily project into O3 changes via HOx chemistry. Hence ruling out the possible outcomes of multiple linear regression analyses completely would be somewhat too pessimistic.

MINOR GRAMMAR AND TYPOGRAPHICAL CORRECTIONS

Page 12329, lines 21 to 23: Remove the parenthesis around this sentence.

Answer: We disagree with this change.

Page 12336, line 14: Do you mean that the rate of increase in CO2 from 2010-2040 was approximately twice that from 1975-1995? If so, maybe just say that.

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Answer: No, we mean the total increase. We think that the present wording is quite clear in that respect. However, by mistake we quoted the wrong values for 'r' and 's'. The correct numbers should be r=3.0 and s=0.54. This will be corrected in the revised manuscript.

REFERENCES:

Forster, P.M.; Joshi, M. (2005) The role of halocarbons in the climate change of the troposphere and stratosphere, Climatic Change, 71, pp.249-266. doi:10.1007/s10584-005-5955-7

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