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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Quantifying uncertainty in projections of stratospheric ozone over the 21st century" *by* A. J. Charlton-Perez et al.

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Response to Reviewer 2: Quantifying uncertainty in projections of stratospheric ozone over the 21st century. A. J. Charlton-Perez, E. Hawkins, V. Eyring, I. Cionni, G.E. Bodeker, D. E. Kinnison, H. Akiyoshi, S. M. Frith, R. Garcia, A. Gettelman, J. F. Lamarque, T. Nakamura, S. Pawson, Y. Yamashita, S. Bekki, P. Braesicke, M. Chipperfield, S. Dhomse, M. Marchand, E. Mancini, O. Morgenstern, G. Pitari, D. Plummer, J.A. Pyle, E. Rozanov, J. Scinocca, K. Shibata, T.G. Shepherd, W. Tian, and D.W. Waugh

We thank the reviewer for their helpful comments, which we address as follows:

- We think that the confusion here stems from what is being quantified in our pa-

per. The purpose of the paper is to quantify the uncertainty itself and its source and not the date of return of ozone to a pre-defined value. In several figures, a numerical value is assigned to both the total uncertainty and it's breakdown by source (see for example Fig. 2 and 3). We do not choose to calculate the return date as an absolute number (which can be found in the companion paper, Eyring et al., 2010) but simply examine the fractional contribution to return date by internal variability, scenario and model uncertainty. However, since it seems our title may confuse readers in this way, and to make clear that our study is also a companion to Hawkins and Sutton 2009 and 2010 we change the title to 'The potential to narrow uncertainty in projections of stratospheric ozone over the 21st century.'

- We agree with the reviewer that the choice of return date to calculate is a thorny one and of course other authors do show return dates relative to 1960 values. Which of the dates (1960 or 1980 or something in between) has been argued about by many authors and it isn't clear to us that there is an obvious preference for either of the dates. A detailed discussion of the return of ozone to both 1960 and 1980 levels is included in the companion to this paper (Eyring et al, 2010, ACPD, in discussion). To avoid a complex discussion of the relative merits of the two choices we simply opted to choose 1980 as our milestone. The reviewer is correct that a choice of 1960 would have resulted in larger estimates for the uncertainty, but we don't regard our 1980 choice as 'hiding' uncertainty. Rather for our calculations in Fig. 5 we simply use 1980 as a guide to indicate the relative contributions of the different sources of uncertainty to a time period in which ozone amounts have returned to levels close to that of the pre-ODS period. Of course this is not the time of full recovery from ODS (as defined by the 2006 and 2010 ozone assessments) which can vary greatly from region to region given the different impacts of other stratospheric processes such as stratospheric dynamics. On a more practical note, in some regions (particularly the tropics) recovery

to 1960 levels does not occur before 2095 and hence calculations would be impractical if a 1960 return level were chosen.

- We certainly agree again with the reviewer that the analysis completed in Ch. 9 of the SPARC CCMVal (2010) Report is a useful step forward. However, we do not believe that substituting the TSAM for our own would lead to substantively different conclusions for our study. We therefore chose not to invest resources in implementing the TSAM method but rather to focus on designing a robust scheme for considering and assessing the different components of uncertainty. We would also like to point out that the advantage of the TSAM analysis is on the one hand the ability to make formal inference (e.g. calculation of confidence and prediction intervals what we are not using here), but on the other hand, as pointed out by Chapter 9 of the SPARC CCMVal (2010) Report, the formulation of multi-model mean estimates for the full period from model time series data that sampled only portions of it. While this is critical for the analysis of the CCMVal-1 time series data (with several model simulations already ending in 2019 or 2049), it is less critical for the CCMVal-2 time series data that are analysed here, as nearly all models in CCMVal-2 provided time series that spanned the full range of 1960-2099. Given a sufficient number of models that simulate the entire period, Chapter 9 shows that a straight multi-model average of the time series with a 1:2:1 filter applied produces very similar results to the TSAM (see Figures 9S.47 and 9S.48 in the supplementary material of Chapter 9). However, we have added a comment to the manuscript to mention the TSAM method on P8.

- We agree with the reviewer and present results for the period 1960-2010 in Fig. 2. However, since our goal is to assess how uncertainty in ozone projections might be narrowed it makes sense to us to focus on a period of projection rather than hindcast. The particular issue is the relative contributions of model and scenario uncertainty, which is a key determing factor for the development of CCMs and the use of computer time in future multi-model assessments.

- As we mention in the paper, our estimate of internal variability is drawn from an average of the residuals of the smooth fit to each model's evolution in time. Of course, this could be an over or underestimate of the actual internal variability in stratospheric ozone. Ideally, we would like to estimate this term directly from data, but we currently do not have large enough datasets to do so and so resort to estimating this term from models. The reviewer is correct to point out that there will always be internal variability in the system which is irreducible and will lead to prediction uncertainty. We add the sentence: 'Although we estimate the internal variability from the model simulations themselves (see below) it represents the irreducible component of the uncertainty associated with the natural, decadal variation in ozone.' on p8, l5.

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