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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Solar cycle variations of stratospheric ozone and temperature in simulations of a coupled chemistry-climate model" *by* J. Austin et al.

J. Austin et al.

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Response to Reviewer 2's comments

We would like to thank the Reviewer for the comments which have significantly improved the paper.

Preamble. As emphasised throughout the text, and recognised by the reviewer, our's are the only results so far analysed in this detail which show the tropical minimum response for the 11-year cycle. As mentioned in the text, results from other models now support our calculations. Uncertainties in observations are present certainly, but nonetheless we argue that as a result of this qualitative difference alone our results are an advance on previous work. The longer datasets alluded to by the Reviewer do not add significantly to the observations presented here, which were considered sufficiently comprehensive to be acceptable for publication elsewhere (Soukharev and Hood, 2006). The main purpose of the current paper is not to produce another observation paper, with the database extended by another year or two, but to analyse model simulations.

Abstract. In the revised paper, further results are included to show the model solar cycle as a function of latitude and compared briefly with observations. However, extensive comparisons with observations are not made, as the uncertainties in the data are comparable with the observed signal. The paper focuses on the tropical regions where the uncertainties are smaller, and the results are averaged over a latitude band to lower the uncertainties further. As the Reviewer indicates, it has not been possible to establish the cause of the minimum response. The simulations are climate model simulations and do not cover the full range of simulations needed to address this issue. The likely possibilities have already been discussed in the paper. The abstract is revised slightly to emphasise the tropics and to indicate the additional discussion on tropical upwelling.

P12122, L23/24. This has been clarified in the revised text. The statement refers to indirect climate effects. Haigh (1994) was the first to simulate this, as far as we are aware.

P12123, L4. 24 years' data constitute 2.2 cycles, covered by the phrase 'about two'. In the text 'about two' has been changed to 'two complete'.

P12123, L11. The suggested change has been made.

P12123, L12. The Introduction naturally refers to published material. It is legitimate for us to include later in the paper further information that has become available in a rapidly developing field. No change has been made.

P12123, L18-21. No change has been made. Resources are a moving feast. In 2003

JA carried out a coupled simulation of 40 years, almost 4 solar cycles, longer than the observational database. JA did not have the foresight to include a varying solar cycle in that simulation. Neither has 2-D modellers. The community has for some time thought that fixed phase runs were good enough, as did JA.

P12123, L23ff. The reason for highlighting NOx and EEPs is that some works suggested that these were the missing processes responsible for poor simulations of the 11-year solar cycle. The Introduction contrasts this approach with our simpler approach in which only ‘standard’ processes are included.

P12125, L2. Further information has been supplied and the reader is referred to Anderson et al. for full details.

P12125, L8/9. That is correct, but the lookup table is for specific fluxes, corresponding approximately to solar maximum and solar minimum. The parameterisation is explained in Eqs. 1-3. For the variable phase experiments F10.7 is taken as the monthly average value as a function of time and for the fixed phase simulations, F10.7 is fixed for the duration of each simulation.

P12126. The numbers the reviewer quotes refers to typical monthly or even annually averaged values. The F10.7 values corresponding to 69.6 and 154.3 were specific values on given days during the solar cycle with data from SOLSTICE. This allowed a full spectral variation to be made available to compute the phtolysis rates. The paramterisation has been described in more detail in the revised paper.

P12129. It is unclear where the changes come from and we prefer not to speculate. In principle, as the model results are from a transient simulation, the model chemistry should evolve consistently with the atmosphere.

P12129, L29. Comments have been added about the O3 zero lag results.

P12130, L19. Technical changes are needed to the model climate model to carry out these sensitivity runs and these are beyond the current understanding of the first

ACPD

6, S6556–S6560, 2007

Interactive Comment

author.

Comparisons with the Rozanov et al. paper are included in the revised paper. The units of temperature sensitivity were incorrectly plotted as K/%, instead of %/%. We are thankful to the Reviewer for spotting this oversight. Figure 5 (left panel) has been redrawn and the associated text has been revised.

P12131, L1. We have no explanation for the seasonal differences, such as they are. These are likely to be related to the underlying photochemical and dynamical processes. Rather than concentrate on their differences, we prefer to concentrate on their similarities and in particular during each season there is a minimum in ozone response in the middle stratosphere, albeit with different levels of statistical significance.

P12132, L2-4. This has been reworded. It is not a major issue, so has not been developed further.

P12132, L14-18. As explained earlier in the paragraph, results from 8 individual years are analysed to consider whether the ozone response might be nonlinear in the solar forcing. Comparison with measurements is not appropriate here, as in that case there are 24 years' observations that are typically used, and no attempt that we are aware of has been made to use data just for the solar cycle extreme values.

P12132, L19. This has been clarified.

P12133, L9. The section has been retitled.

P12133, L20. The upward flux region changes little with altitude and is not material to the discussion. The response of the upwelling to the solar flux is presented for the pressure range 0.3 - 100 hPa

P12133, L26. The upwelling is subject to a considerable amount of interannual variability driven by chaotic processes. The preliminary analysis presented here suggests that these other processes are dominating any solar signal. The seasonal changes indicated were not statistically significant and this has now been stated. Presentation of these results in a coherent manner is problematic and in view of the statistical uncertainty, we believe that it is not very meaningful to show the seasonal results.

P12134, L6. Some speculation concerning the impact of upward motion on ozone and temperature have been included in the revised paper.

P12137, L1/2. A range of possibilities is suggested to explore the sensitivity of the solar cycle to the tropical upwelling.

Caption Figure 6. A similar model is applied, and the software is different. A suitable comment has been added to the description of the regression equation.

Figure 10, left panel. The axis range for the abscissa has been reduced to match that of Figure 6.

P12128, L18 'in to' has been changed to 'into'.

Figs. 2, 3. The contour intervals have been specified.

Fig. 4. The typo has been corrected.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 12121, 2006.