Atmos. Chem. Phys. Discuss., 2, S580–S582, 2002
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Atmospheric Chemistry and Physics Discussions

Interactive comment on "An exploration of ozone changes and their radiative forcing prior to the chlorofluorocarbon era" *by* D. T. Shindell and G. Faluvegi

D. T. Shindell and G. Faluvegi

Received and published: 5 November 2002

We thank referee #1 (Bram Bregman) for their constructive comments. We largely agree with the points raised by the referee, and believe that we will generally be able to modify the manuscript to take his suggestions into account.

Point-by-point response:

1) The reviewer suggests that we elaborate on the two sparse tropospheric ozone data sets when they are first mentioned at the end of section 2. We will now do so.

2) The reviewer asks what are the effects of uncertainties in water vapor trends in the upper and middle stratosphere (we explored the effect of uncertainties in the lower stratosphere only). It is true that the trends in those regions are also uncertain, and

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this leads to relatively large uncertainty in the percentage ozone change in those regions. However, the largest effects outside the lower stratosphere are seen in the upper stratosphere, which contributes so little to the total ozone column that we find the effects to be less than 0.5 DU even with a generous estimate for the water uncertainty (+- 50% of the HALOE 1992-2001 observations of +0.05 ppmv/yr). This is a tiny contribution to the 4.0 DU uncertainty arising from the lower stratospheric trend uncertainty (when added in quadrature, the resulting uncertainty is still 4.0 DU).

3) The reviewer notes that other studies show an opposite ozone response to temperature, and asks if this may be related to the chemistry scheme. As we noted, perhaps too briefly, in footnote c of Table 2, the difference between our results and those of some other studies is due to the behavior of the GCM rather than the chemistry. The calculated ozone change in response to increasing greenhouse gases is similar to other models in the middle and upper stratosphere where the temperature changes are similar. It is only different in the lower stratosphere, where our GCM shows an intrusion of the tropospheric warming while some others do not. Both features can be seen clearly in the comparison reported in the 1998 WMO Scientific Assessment of Ozone Depletion (Figure 12-23). It is not clear how to judge the temperature responses to increasing greenhouse gases, as observations show cooling even at the tropopause (where all the models find warming), but include all forcings and not just greenhouse gases.

4) The reviewer asks for more information on the transport within the model and how adequately the relatively coarse resolution GCM can simulate this. We apologize for not having adequately explained the ozone transport calculation, and will add this to the text. The parameterized stratospheric ozone chemistry calculates ozone anomalies, which are then added to the GCM's ozone climatology. The specified climatology implicitly includes an exact representation of stratospheric ozone transport. The GCM meteorology is used only to drive transport of the ozone anomalies. Climatological GCM fields were used for this, as changes in circulation were not considered here, and

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these fields are in reasonable agreement with observations. Since the ozone anomalies are small, biases in the GCM are unlikely to have much influence on the total ozone or on the chemical sensitivity, and thus the transport should not be a source of significant error due to our experimental setup. The reviewer is correct to point out that it is physically inconsistent to assume increased water due to circulation changes, and at the same time neglect circulation changes. We chose this setup, however, based on the observational constraints. For water, there are observed increases (albeit from sparse data) greater than what can be accounted for from increased methane oxidation, suggesting a circulation change. Unfortunately, there is no direct evidence yet to quantify the circulation change themselves.

5) We will clarify the distinction between our tropopause radiative forcing and that calculated in other GCMs.

6) Following the reviewers suggestion, we will separate the "Climate impacts and conclusions" section into two sections, "Climate impacts" and "Summary and conclusions".

7) The reviewer asks for an overview of how the final column change values are derived. We believe that this is already given in Figure 2, which presents all the calculations together in one place, and also shows how the individual values combine to yield the best estimate overall trend values. In that figure, observations and models are indicated by shading and box shape, and we hope that this graphic makes a complex arrangement of inputs to the final calculations easier to follow.

The referee also asks about the difference between the NH tropospheric ozone values and those shown in Table 4. The values in Table 4 are in fact total column ozone, which we will now state in the Table title.

Interactive comment on Atmos. Chem. Phys. Discuss., 2, 1371, 2002.