Atmos. Chem. Phys. Discuss., 8, S477–S483, 2008
www.atmos-chem-phys-discuss.net/8/S477/2008/

Atmospheric
Chemistry
and Physics
Discussions

Interactive comment on "Radiative forcing from modelled and observed stratospheric ozonechanges due to the 11-year solar cycle" *by* I. S. A. Isaksen et al.

Anonymous Referee #2

Received and published: 3 March 2008

This paper presents both data analyses and model calculations to estimate solar cycle changes in stratospheric ozone. It is stated that there is a general agreement between the satellite data estimates and the model estimates, especially at middle and high northern latitudes, and that the peak ozone increases occur at about 40 km altitude. The estimated ozone profile changes are then used to calculate the change in radiative forcing, including the effect of stratospheric temperature changes under the fixed dynamical heating approximation. The increases in longwave thermal radiation due to ozone increases in the stratosphere are found to be nearly offset by decreases in short-wave radiation resulting from greater absorption by ozone. The sign of the net forcing change is found to depend most sensitively on ozone changes in the lower stratosphere. For example, the authors' analyses of SAGE data yield smaller ozone changes in the lower stratosphere and corresponding negative net forcing while analyses of SBUV data yield larger ozone changes in the lower stratosphere and corresponding positive net forcing.

Although the work reported in the manuscript is a useful exercise, a series of important problems prevent me from recommending publication. Major revisions are needed.

Main Problems:

(1) A major problem is that the statistical data analyses of ozone changes over a solar cycle are poorly documented, no error estimates are provided, and the results do not agree well with several much more detailed studies published during the last few years (Tourpali et al., JGR, 2007; Soukharev and Hood, JGR, 2006). Publication of this part of the paper, especially the solid colored curves in Figure 2, is not recommended. The only results that might be characterized as documented are the blue curves in Figure 2 that are "based on the analysis (of SAGE I and II data) in Randel and Wu (2007)." However, it is not clear what was done to produce the blue curves since they do not agree well with the annual solar regression coefficients given by Randel and Wu (their Figure 12a) and no error estimates are given. In any case, the Randel and Wu paper was mainly oriented toward constructing an ozone profile data set (based partly on climatology) for use by modelers and was not specifically oriented toward investigating the solar cycle ozone variation. In contrast to the authors' data analyses, Tourpali et al. reported a detailed multiple regression statistical analysis of both the longest available satellite data record (25 years of SBUV(/2) version 8 ozone profile data) and available ground-based Umkehr measurements (up to 50 years in length). Soukharev and Hood reported detailed multiple regression analyses of three different long-term satellite data records (the SBUV(/2) record, the SAGE II record, and the UARS HALOE record). Both the Tourpali et al. study and the Soukharev and Hood study concluded that the ozone response consists of a strong maximum (+2-3%) in the upper stratosphere, a very

weak or negligible response in the tropical middle stratosphere, and a second strong ($\sim$ 2%) response in the tropical lower stratosphere. At middle latitudes, the response did not show such a strong minimum in the tropical middle stratosphere. It is important to note that ground-based Umkehr results were consistent with the satellite-based results in showing a second response maximum in the lower stratosphere. Furthermore, the Randel and Wu analysis of the SAGE I and II data also yielded a statistically significant (but smaller) secondary response in the tropical lower stratosphere near 25 km. The lack of a significant response in their analysis at levels below $\sim$ 20 km can be attributed to sparsity of the SAGE measurements in the tropics (see also Figure 6 of Soukharev and Hood) and interference from Pinatubo aerosols (e.g., Cunnold et al., JGR, 1996). The Soukharev and Hood study further applied the HALOE data to argue that the increase in tropical column ozone approaching the 2000 maximum occurred primarily in the lower stratosphere below the 30 hPa level. A mainly dynamical origin for this lower stratospheric ozone variation was suggested. Finally, the latter study also showed that a similar vertical structure of the ozone response is obtained for separate time intervals with a minimum response always near 10 hPa. It was argued that this characteristic was hard to explain by random interference from the QBO and volcanic eruptions in their statistical analysis (as previously suggested by Lee and Smith, JGR, 2003).

Given the fact that these two much more detailed analyses have already been published, the best solution in this reviewer's opinion is to adopt their results as the most reliable basis for the radiative forcing calculations. I am sure that the authors of these two studies (one of which, Tourpali, is also a co-author of the present manuscript) would be happy to provide the necessary solar cycle ozone change estimates with associated error bars.

(2) A second problem is that the two model calculations of the ozone profile change (peaking near 40 km, decreasing with decreasing altitude) do not agree well with the

observed solar cycle ozone change, at least in the tropics. The main disagreement occurs in the tropical lower stratosphere where, as discussed above, observations show a second positive maximum while the two models simulate a continuously decreasing amplitude with decreasing altitude. As the authors point out, ozone changes in the lower stratosphere are most important for determining the net radiative forcing so this is a large problem. In contrast to the two model calculations presented here, several recent simulations using coupled chemistry climate models do produce a significant positive solar cycle ozone variation in the tropical lower stratosphere. Specifically, J. Austin et al. (ACP, 2007) find a strong secondary ozone response maximum in the lower stratosphere centered near 50 hPa in transient simulations of a CCM with no QBO but using observed SST's. The need for transient simulations rather than time-slice simulations was suggested. K. Matthes et al. (paper in preparation or submitted) finds a secondary ozone response maximum in the tropical lower stratosphere in a 110-year simulation of the NCAR WACCM3 CCM using fixed SST's but relaxing to observed QBO winds. Also, Schmidt and Brasseur (Space Science Reviews, 2006) obtain a secondary response maximum in the tropical lower stratosphere (although it is difficult to see in their Figure 1) using the HAMMONIA CCM.

These other model simulations should be referenced and the effect of the larger modeled ozone change in the lower stratosphere on the net radiative forcing should be assessed.

(3) Significant temperature increases (0.5-0.8 K near 50 hPa) are observed in the tropical lower stratosphere from solar minimum to maximum that may be partly or mainly dynamical in origin (Crooks and Gray, J. of Climate, 2005; Labitzke, JASTP, 2004; Hood and Soukharev, JAS, 2003; Scaife et al., Q. J. R. Met. Soc., 2000). The longwave component of the solar cycle radiative forcing change may therefore be larger than would be estimated using only the observed ozone change together with a fixed dynamical heating approximation. This possibility should at least be noted. Some estimate of the effect of such dynamical temperature increases on the net radiative forcing should be

provided.

More Specific Comments:

(4) P. 2, next to last para. of sect. 1: Here references are given for solar effects on total ozone but not for the ozone profile. The observational studies mentioned in comment (1) should be also referenced and discussed here along with that of Randel and Wu (2007), although the latter paper was again mainly oriented toward developing an ozone profile data set by combining regression analysis of SAGE data, ozonesonde data, and an ozone climatology.

(5) P. 2, last para. of sect. 1: The physical causes of the longwave and shortwave components of the radiative forcing are not explained very well here. An ozone increase in the stratosphere increases the thermal infrared (longwave) radiation reaching the troposphere by increasing the emission by ozone. Simultaneously, a decrease in (shortwave) ultraviolet and visible radiation reaching the troposphere occurs because of increased absorption by ozone in the stratosphere. I am not sure what the authors mean by “enhanced atmospheric trapping of longwave radiation”. Finally, it would help to define what the term radiative forcing is for non-climate modelers (e.g., the net energy flux reaching the troposphere or surface). Please revise the paragraph.

(6) P. 3, last few paragraphs of sec. 2: I know of one observational analysis of UARS HALOE data that directly constrains the solar cycle variation of NOx (Hood and Soukharev, GRL, 2006). In particular, evidence is obtained for a decrease in NOx from solar minimum to maximum near the tropical stratopause of order 10%. This agrees roughly with the modeled NOx reductions of 5 to 10% in the upper stratosphere estimated by the authors. However, they attribute this mainly to “increased photolysis of NO near solar maximum”. Also, their study found no significant evidence for NOx increases in the lower stratosphere.

(7) P. 4, Sec. 3.2. As already discussed in comment (1), this section is far too brief and the methods of analysis are not documented sufficiently. Since several much more detailed studies of these data sets have been published in the last few years, the best solution is to replace the subsection with a brief summary of these published studies and adopt their results as input to the radiative forcing calculations. This is especially true since the first author of one of these studies is a co-author on this manuscript. The SBUV record analyzed by Tourpali et al. is the longest available continuous intercalibrated record (see Goddard Space Flight Center web site). The SAGE I and II record, while having better vertical resolution has issues because of the very limited global sampling, large gap between SAGE I and II, intercalibration problems between SAGE I and II, and, most importantly, big effects of volcanic aerosols in the data. So, while there are intercalibration problems in the SBUV data, this data set analyzed by Tourpali et al. may be the best available at the moment.

(8) P. 4, sec. 3.3. The general theme of this paragraph seems to be that there is an overall good agreement between observations and the two model calculations, except perhaps for the SBUV data, which may be anomalous. However, as discussed in comments (1) and (2), this is not really the case. As recommended in comment (1), the observational (solid colored) curves in Figure 2 should be replaced using the more well-documented ozone solar cycle regression coefficients and error estimates given in detailed statistical analyses published during the last few years (Soukharev and Hood, 2006; Tourpali et al., 2007). As already mentioned in comment (2), the two model calculations presented here do not simulate the increase in lower stratospheric ozone that is observed using both satellite and ground-based (Umkehr) data (Tourpali et al., 2007; Hood and Soukharev, 2006). This is an important disagreement and it should be discussed. The recent model simulations that have begun to simulate the lower stratospheric ozone signal should also be referenced and discussed here. It would be useful to add model curves from one or more of these papers, e.g., that of Austin et al. (their Figure 6).

(9) P. 6, sec. 4.2: Unless I missed it, there is no mention of the latitude range over which the radiative forcing calculations are done. Is it the tropics or some average of the three latitude bands? It would help to put the latitude range in the descriptions of the tables also. A discussion of the effect of an increased ozone response in the lower stratosphere (e.g., 2% centered near 50 hPa) on the radiative forcing results should be added to this section. Also, a discussion of the effect of dynamically induced temperature increases from solar minimum to maximum (e.g., 0.8 K centered near 50 hPa) on the radiative forcing results should be added.

(10) P. 7, sec. 5, Conclusions. The conclusions relating to the solar cycle impact on ozone (first paragraph) should be revised after the changes in the analysis as suggested above. The net radiative forcing resulting from stratospheric ozone and temperature changes (including the dynamical component) will probably be somewhat larger than estimated in the present manuscript. However, it may still be small compared to the TSI change of 0.23 W m^{-2}. So, the basic conclusions of the paper with respect to radiative forcing of the troposphere may not change greatly. However, it should be emphasized more in the last paragraph that the ozone change may influence tropospheric climate in other ways, specifically through changes in stratospheric dynamics (e.g., propagation of planetary waves). The probable existence of a lower stratospheric ozone and temperature response is one evidence that these changes in stratospheric dynamics are significant. This is noted briefly near the beginning of section 4.2 but it should be emphasized also in the Conclusions section.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 4353, 2008.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper