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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Sensitivity of the tropical stratospheric ozone response to the solar rotational cycle in observations and chemistry-climate model simulations" *by* Rémi Thiéblemont et al.

Anonymous Referee #2

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Overall, this is a valuable comparison study of the ozone response to short-term solar UV variations in both observations and a state-of-the-art chemistry climate model. The analysis is detailed and the results offer plausible explanations for differing results obtained in observations covering different time periods. Final publication is certainly expected in ACP. However, I have some important comments that will require some revision.

Main Comments:

(1) In the description of the adopted CCM configuration in section 2.3 (p. 7), the authors say: "We do not take into account the direct effect on heating rates generated by UV variations because previous modelling studies have already shown that the stratospheric ozone response to solar variations is almost entirely driven by the effects of UV changes on the photolysis rates, in particular the photolysis of molecular oxygen (Swartz et al, 2012)." Even on the 11-year time scale when a steady-state approximation is allowed and both photolysis and radiative heating are accounted for, temperature feedback reduces the ozone response in the upper stratosphere at 2 hPa by about 30% compared to that calculated by considering changes in photolysis only (see Figure 2 of Swartz et al.). 30% is still a fairly large fraction and should not be neglected. On the 27-day time scale, it is more important to include radiative effects on temperature and their feedbacks on the ozone response for two reasons. First, on this time scale, the temperature response peaks at a positive phase lag. As reviewed in the Introduction (lines 5 to 14 on p. 3), the lagged temperature response significantly alters (reduces) the ozone response and shifts it to a negative phase lag in the upper stratosphere. Second, as also reviewed there, a dynamical component of the response is produced in the upper stratosphere which feeds back into the temperature response resulting in a larger effect on the ozone response than would be predicted by a 1D radiative-photochemical model. Therefore, please modify section 2.3 to note and discuss these issues and whether the neglect of the modeled temperature response (and its accompanying dynamical response) may lead to errors in the CCM results that would not be present in simulations done in the CTM mode (forced using observed dynamics and temperatures).

(2) Figure 6 compares the vertical profile of the ozone sensitivity to the solar UV (per cent change in ozone for a 1 per cent change in solar UV at 205 nm) as derived from observations for two time periods, from the model using specified temperatures and dynamics (CTM), and from the model in a free-running mode (CCM). While the observational and CTM results agree fairly well, the mean CCM results show a much larger

response in the upper stratosphere than is seen in either the observations or the CTM results. There is apparently no mention of this disagreement in the manuscript. In view of comment (1) above, it seems possible that part or all of the disagreement is due to neglect of the UV-induced temperature response in the CCM, which would modify both the amplitude and phase lag of the modeled ozone response. The sensitivity calculation is apparently at zero lag so it does not take into account the actual phase lag of the ozone response. Therefore, please modify the results and conclusions sections to consider the possibility that the chosen CCM configuration does not accurately simulate the net ozone response in the upper stratosphere (taking into account both the radiatively and the dynamically induced temperature response).

Other Comments:

(3) Introduction, first paragraph, last sentence. “A thorough understanding and accurate quantification of the UV variability effect on the middle stratosphere from which the “top-down” theory stems, are thus necessary.” If so, then why is the CCM configuration limited to only the photochemical ozone response? The thermal response and its associated dynamical response are the main components of the top-down mechanism for solar influences on the troposphere.

(4) Section 2.1, line 11. Are you using the NRL SSI version 1 or version 2? It is fine if you are still using version 1 but it should be clarified. Version 2 is available from https://data.noaa.gov/dataset/ noaa-climate-data-record-cdr-of-solar-spectral-irradiance-ssi-nrlssi-version-2

(5) Section 2.2, line 24. Please specify the pressure levels for ozone retrievals for the two MLS instruments. Which versions of the UARS MLS and AURA MLS data sets are being used for this analysis? Please reference more up-to-date descriptions of these data. The Version 5 UARS MLS data set is described by Livesey et al., JGR, v. 108, doi:10.1029/2002JD002273, 2003. Please give URLs where readers who wish to

repeat the analysis can download the data. For example, the UARS MLS data are at https://mls.jpl.nasa.gov/uars/data.php.

(6) Section 2.2, line 31. If only 30% of the measurements are in the daytime, another problem arises, which is the ozone diurnal cycle. This cycle becomes important at roughly 2 hPa and above. Including 70% of measurements at night will therefore have the effect of reducing the estimated ozone response to solar UV variations at 2 hPa and above. This will not affect comparisons with the CTM and CCM provided that the model “measurements” also include both day and night data. Ideally, there should be 70% night and 30% day model data to allow an exact comparison. Please add text to explain this.

(7) Section 2.3, line 24. 39 levels and 70 km lid means a resolution of less than 2 km. This is much better than the MLS vertical resolution, which is about 6 km. One should mention this before making direct comparisons in the following sections.

(8) Figure 1. The units should be W/m^2/nm.

(9) Section 3.2, Figure 3. The periodogram of the MLS ozone measurements (Figure 3a,d) is done at 3.2 hPa. But, according to Livesey et al. (2003), the UARS MLS measurements were not retrieved at this level, only at 2.2 and 4.6 hPa. So, how are data obtained at 3.2 hPa?

(10) Section 3.2, lines 10-12. Please note that the lack of an obvious solar rotational signal in the MLS data considered here is partly because the measurements were obtained during the declining phases of solar activity using a limb sounding instrument, whose measurements are spatially and temporally sparse. The ozone signal is more easily detectable and repeatable in daily zonal means of nadir-viewing backscattered ultraviolet measurements under solar maximum conditions when solar UV variations are stronger and more coherent. The CTM simulations are also affected by the rela-

tively weak solar rotational UV variations during the selected time periods.

(11) P. 9, Figure 4. Normally, a cross-spectral analysis should yield phase estimates as well as coherency estimates. There is no mention of phase on p. 9 so it must be assumed that the coherency estimates are at zero lag. But the cross-correlation functions in Figure 5 show that the phase lags are not constant with altitude and are not always zero. They tend to be somewhat negative in the upper stratosphere and become positive in the middle and lower stratosphere. The ozone-UV sensitivities shown in Figure 6 are also presumably at zero lag. This differs from previous observational studies (e.g., Hood and Zhou, 1998) which calculated sensitivities at the so-called optimum lag, i.e., the lag where the correlation maximizes. Please add text to explain that these calculations are being done at zero lag and why this lag is chosen.

(12) P. 10, line 24. Typo: Seizing? Caption to Figure 3: from the runs ensemble?

(13) P. 11, top of page. The CCM results shown in Figure 5c,f are characterized by negative lags near the stratopause. What is the cause of these negative lags? Is it feedback from a temperature response caused only by increased radiative heating associated with the ozone response (holding direct UV heating changes constant)? Or, is it increased photolysis of water vapor in the lower mesosphere and resulting destruction of ozone by odd hydrogen? Or both? Can this be diagnosed?

(14) P. 11, bottom of page. In addition to not mentioning the anomalously large CCM response in the upper stratosphere, there is also no mention here of the likely effect of the ozone diurnal cycle in reducing the ozone response in the upper stratosphere relative to that measured earlier from backscattered ultraviolet instruments, which operated only in the daytime. This difference is emphasized in Hood and Zhou [1998] for example.

(15) Section 4. While it is useful to carry out these analyses, one must question whether

the CCM in its chosen configuration (no direct solar UV heating changes) is ideal for this purpose. Also, a time window with a length of 10 years includes both solar maximum periods (when 27-day UV variations are strong and numerous) as well as solar minimum periods (when these variations are weak and sparse). Could it therefore be possible that a shorter time window of 3 years centered on a strong solar maximum (e.g., that in 1979-82) could yield more reliable results than a 10-year window which includes mostly non-maximum solar conditions?

(16) Minor corrections: In the abstract, lines 23-24, neither nor should be either or. P. 13, line 10. anti-correlation should be inverse correlation.

(17) P. 15, lines 11,12: “Applying the same spectral analysis to the average of the CCM ensemble simulations allows reducing the ‘masking’ effect by random dynamical variability, so that the rotational signal in ozone can be more easily identified and estimated.” However, the negative aspect of this approach is that the CCM may not perfectly simulate the actual ozone response to short-term UV variations, partly because of the neglect of the direct radiative effet of the UV variations in the model, and their secondary dynamical effects.

(18) P. 15, lines 18-21: “Analysis of the CCM ensemble simulations suggest that the differences mostly originate from the dynamical variability.” Usually, internal dynamical variability in a model is larger than in observations so it is not clear that a single model run is equivalent to a single sample of observations (or a single run of the CTM). The large spread in the ensemble mean sensitivity profile could also reflect a less complete simulation of the upper stratospheric dynamical response to short-term solar UV variations.

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