Anonymous Referee #2

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.

We thank the reviewer for reading the manuscript and providing helpful comments and suggestions. We address the raised issues in turn below.

Our answers to comments and suggestions are written in blue and manuscript changes are written in italic type within double quotes ("*like this*").

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).

We agree that neglecting the direct effect on heating rate should be considered carefully. To test the potential influence of the missing temperature feedback on ozone in our model setup, we performed additional analysis that we compared with recent model results of Sukhodolov et al. [2017] (see the answer to comment 2 for details). The manuscript has been revised at several places to discuss the effect of the neglect (see also answer to specific comments).

More specifically in section 2.3, we modified the text as follows:

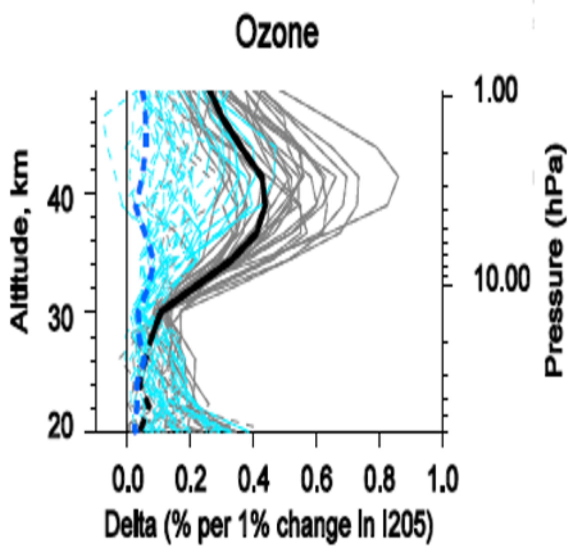
"Thus, the solar rotational cycle forcing is taken into account by using daily photolysis rates calculated by TUV in the photochemistry module of LMDz-Reprobus. *Note however that the direct effect on heating rates generated by UV variations associated with the 27-day rotational cycle is neglected: i.e. daily changes in the spectral irradiance are not considered by the model radiative scheme. As a consequence, part of the thermal and dynamical responses to the 27-day rotational cycle and hence their effect on ozone (through transport and temperature dependent chemical reactions, as described above) are missing. The impact of this approximation on our results seems to be small though, as discussed thereafter (sections 3 and 5). Note also that on timescales of the*

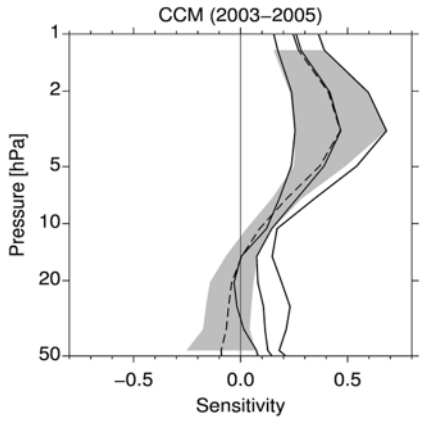
11yr cycle, Swartz et al. (2012) found that their photolysis-only simulation captured almost all of the solar cycle effect on ozone."

(2) Figure 6 compares the vertical profile of the ozone sensitivity to the solar UV (percent 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).

In a recent study, Sukhodolov et al. [2017] performed an ensemble of 30 simulations for the period 2003-2005 with the SOCOL CCM model. In their experimental setup, they considered both (i) the effects of UV changes on the photolysis rates and (ii) the direct radiative effects on temperature which feeds back on ozone. Hence, their CCM formulation allows accounting for all photochemical and radiative effects. Their large number of simulations and the fact that they simulated the period 2003-2005 using NRLSSI data (like us) allows comparing with our CCM ensemble results in a fair way. Their UV-ozone cross-correlation analysis (see their Figure 3b) reveal a negative lag of 1 to 2 days in the upper stratosphere (above 3 hPa) which is consistent with the one we found in our study (see our Fig. 7c,f). When performing the UV-ozone cross-correlation analysis over the same period (i.e. 2003-2005), we also found a negative lag of 1 to 2 days. We also compared the analysis of the ozone sensitivity to F205 index (see below) over the period 2003-2005. Their ozone sensitivity profiles (left) are shown at optimum lag and ours (right) at optimum lag (solid) and zero lag (dashed). Results from both models compare very well, showing a maximum slightly larger than 0.4 at 3-4 hPa and decreases down to 0.25 near the stratopause. The very good agreement between the two CCMs, despite their different formulation, suggest that omitting the direct radiative heating does not have a strong effect on the ozone response and is therefore an acceptable approximation in our case. Consequently, this model comparison suggests that the disagreement between the model and the observations in the upper stratosphere most likely comes from the dynamical variability, in line with our former interpretation. In 1991-1994, observational uncertainties (either in MLS or in the reanalysis used to nudge the model) may have an influence on the results. We will discuss this thoroughly in the revised version of the manuscript.

Nonetheless, we recognize that, ideally, the direct radiative heating should be considered. In its current version the LMDz-Reprobus radiative scheme has only 2 spectral bands resolved in the UV. Hence, this would lead anyway to an underestimation of the stratosphere temperature response to solar spectral variations (see also Figure 3.17 in chapter 3 of the CCMVal report). For the next version of LMDz-Reprobus, the radiative scheme spectral resolution in the UV range has been improved.





Globally, results and conclusions of the manuscript have been revised to discuss the CCM configuration => see answer to specific comments below (particularly comments 13, 15, 17, 18).

Specifically, discussion on results of Figure 6 (now Figure 7) has been extended as follows:

"We now analyse the CCM ensemble results. The ensemble mean ozone sensitivity profiles (Figs. 7c and f) markedly differ with ozone sensitivity profiles derived from observations (Figs. 7a and d) and CTM (Figs. 7b and e) at the corresponding periods. These differences are particularly pronounced in the upper stratosphere (above ~5 hPa). On the other hand, despite the two different periods, the ensemble mean ozone sensitivity profiles show very similar features with positive sensitivity from 15 hPa to the stratopause and a maximum sensitivity of 0.4 at ~3 hPa (Figs. 7c and f). This maximum tropical sensitivity value and its altitude level is in good agreement with previous CCM estimates (e.g. Rozanov et al., 2006; Austin et al., 2007; Gruzdev et al., 2009; Kubin et al., 2011). The CCM ozone sensitivity analysis has also been repeated for the period 2003-2005 (not shown) to be directly comparable with the CCM results of Sukhodolov et al. (2017): we found very similar ozone sensitivity profiles."

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.

Indeed, our study examines the photochemical ozone response, not the more general thermal and dynamical responses. We modified the manuscript as follows:

"A thorough understanding and accurate quantification of the UV variability effect on the middle stratosphere ozone are thus necessary."

(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

We are indeed using the NRL SSI model version 1. This is now clarified in the revised version of the manuscript in section 2.1:

"In our study, we use the solar spectral irradiance provided by the Naval Research Laboratory Solar Spectral Irradiance (NRLSSI) model version 1 (Lean, 2000; Wang et al., 2005)."

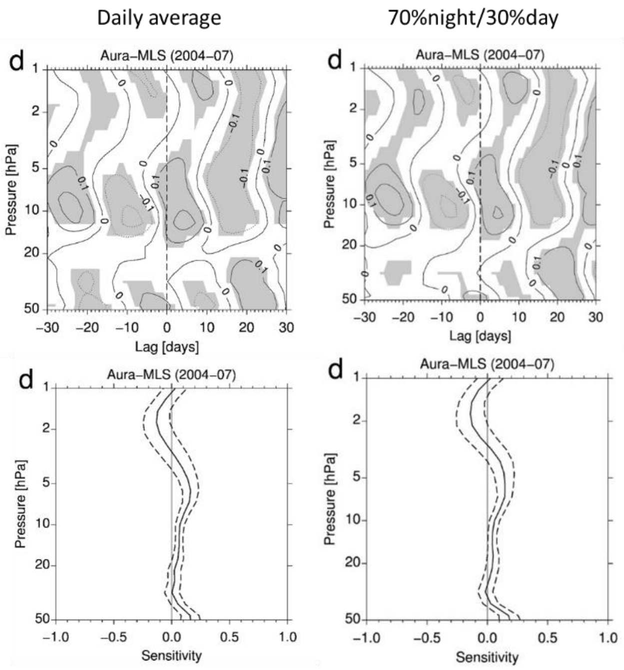
(5) Section 2.2, line 24. Please specify the pressure levels for ozone retrievals for the two MLS instruments. Which versions of the UARS MLS and AURA MLS data sets are being used for this analysis? Please reference more up-to-date descriptions of these data. The Version 5 UARS MLS data set is described 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.

We now clarified the pressure levels for ozone retrievals for versions 5 of UARS MLS and 4.2 of AURA MLS that are used in our study and give the references of the more up-to-date descriptions of the corresponding data (Livesey et al. 2003 for UARS MLS and Livesey et al. 2017 for AURA MLS). The URLs where data can be accessed are provided at the end of the paper section 6 (data availability).

Changes in the manuscript have been made in section 2.2:

"We used the version 5 UARS MLS dataset described Livesey et al., (2003). The ozone retrieval is based on 205 GHz radiances, provided onto 13 pressure levels in the range 100-1 hPa (100, 68.1, 46.4, 31.6, 21.5, 14.7, 10, 6.8, 4.6, 3.2, 2.2, 1.5 and 1 hPa) and has an average vertical resolution of 4 km in the stratosphere. The typical 1σ precision for ozone mixing ratio measurements is ~0.3 ppmv between 68 and 1 hPa."

(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.



We tested the influence of an uneven distribution of night/day time measurements (see figure above). To do so, we reproduced the 2004-07 analysis Aura-MLS data but by resampling the data with the ratio of 70/30 of night/day time measurements and compared it to the daily average (which has a ratio of roughly 50/50). The results are fairly similar, indicating a limited diurnal effect on the unbalanced day/night sampling. Note that we repeated the analysis by considering only nighttime or daytime measurements (not shown) and did not find any significant difference.

The ozone diurnal cycle issue is now mentioned in section 2.2 :

"*Furthermore, the ozone diurnal cycle becomes important in the upper stratosphere, so that the results may be affected by the imbalance in daytime and night-time measurements used to construct daily time series. This issue will be discussed in section 3.2.*"

(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.

As clarified previously, the UARS MLS (Aura MLS) vertical resolution for ozone retrieval is 4 (3) km in the stratosphere. In the LMDz-Reprobus, model, the vertical resolution slowly varies with altitude, from 1 km in the upper troposphere to 3 km in the middle and upper stratosphere (i.e. above 10 hPa). Between 10 hPa and 1 hPa – i.e. the region we are focusing on - MLS and LMDz-Reprobus have roughly the same vertical resolution (~3 km).

We now clarify this in section 2.3:

"The model uses a classical hybrid σ-P coordinate in the vertical, has 39 vertical levels and a lid-height at ~70 km*. The model vertical resolution slowly decreases with height. In the middle and upper stratosphere (30-50 km or ~10-1 hPa) - focus of our study – the model vertical resolution reaches 3 km which is similar to the vertical resolution of UARS-MLS and Aura-MLS measurements in this altitude range. The model is integrated with a horizontal resolution of 3.75° in longitude and 1.9° in latitude.* The equations are discretized on a staggered and stretched latitude-longitude Arakawa-C grid."

(8) Figure 1. The units should be $W/m_2/nm$.

This has been corrected.

(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?

For the version 5 of the UARS MLS measurements which is used in our study, the vertical retrieval grid over the stratosphere and lower mesosphere has been doubled compared to previous versions (i.e. v4 and before). Hence, the ozone measurements are provided at levels 2.2, 3.2, and 4.6 and not only 2.2 and 4.6 (see also Table 6 in Livesey et al. 2003). See also answer to comment #5.

(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 relatively weak solar rotational UV variations during the selected time periods.

We agree that the solar rotational signal should be more easily detectable during maximum phases of solar activity than during declining phases and this may contribute to the difficulty in the identification of a prominent peak in the power spectrum. Note however that we repeated the MLS power spectrum analysis during the maximum phase of solar cycle 24 (2012-2015) and we still did not identify a clear peak (over this period, the MLS sampling is large since almost 800 profiles are retrieved each day). Regarding daily zonal means of nadir-viewing backscattered ultraviolet measurements (like SBUV), it may be indeed easier to detect but we did not find any reference where this is clearly shown in power spectrum analysis (only in coherency as in our study).

We modified section 3.2 accordingly:

"*This illustrates the difficulty in detecting solar rotational signals in the observations, as well as in a single ensemble member over these 3year periods. Note that we additionally computed periodograms in observations during solar maximum phases (i.e. 2012-2015) where 27day fluctuations in the solar forcing are stronger than during the declining phase (not shown). The results were however similar and no clear peak at 27 days could be identified. Hence, the absence of a distinctive rotational signal suggests the presence of strong and rather random ozone variability of non-solar origin which makes the ozone rotational signal very difficult to detect and estimate*."

(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.

We made the choice not to provide the phase lag with the coherency since we calculate the cross-correlation afterwards which provides basically the same information and both are consistent.

The sensitivities are indeed shown at lag 0 and not at optimum lags. Optimum lags are in fact not simple to define as they may vary between observations and models results, between two different periods of observations, or between two ensemble members. Alternatively, we could choose one reference optimum lag vertical profile upon which the sensitivity would be calculated. But similarly, this poses the problem of defining the most accurate reference profile; shall we use observational or model results? Hence we opt for the lag 0 as a common reference. Finally, note that we tried both but it did not affect the results and conclusions as the sensitivity profiles shown in the answer to comment #2 reveal.

Section 3.2 has been modified accordingly:

"In previous studies, ozone sensitivity profiles were either calculated at optimum lags where the correlation coefficient maximizes (e.g. Hood and Zhou, 1998) or at zero lag (e.g. William et al., 2001; Austin et al., 2007). Both alternatives were tried but given the limited effect on the results and conclusions, we elected to show only ozone sensitivity profiles using a common time frame, hence at zero lag. Results are shown on Fig. 7."

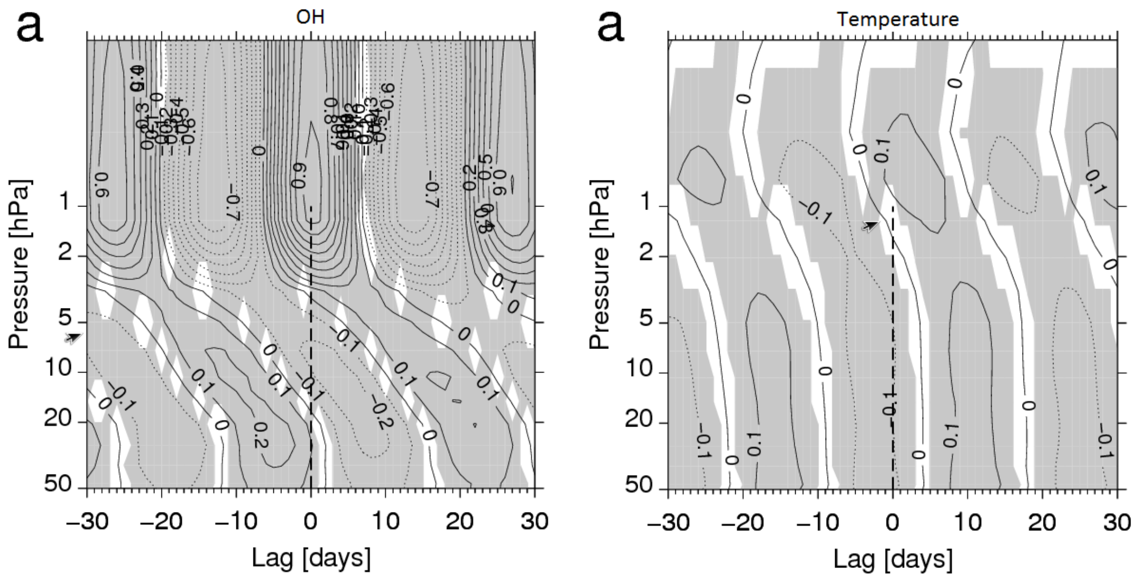
(12) P. 10, line 24. Typo: Seizing? Caption to Figure 3: from the runs ensemble?

We changed "*Seizing*" for "*Marked*" and corrected caption 3: "*The middle panels (b and e) represent the ozone Lomb-Scargle periodograms for CTM simulation and the bottom panels (c and f) the average periodogram of the CCM ensemble. The dotted envelop (c and f) indicates the 2σ standard deviation of the ensemble of CCM simulations."*

(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?

Below are shown the cross-correlation analysis (as in Fig. 5) for the hydroxyl and the temperature for the CCM ensemble mean. The hydroxyl response is highly consistent with the results of Sukhodolov et al. (2017) (see their Figure 3). The temperature response is also consistent. Thus even in absence of the direct UV heating, an "indirect" temperature response is produced by the ozone response. These two effects may thus contribute to the negative lags near the stratopause. Note the particularly good agreement in the upper stratosphere ozone phase lag with Sukhodolov et al. (2017) which suggests that the OH contribution is more important than the temperature one because in our case the temperature response is strongly reduced: the temperature sensitivity in our experiments yields a maximum of 0.035 in the upper stratosphere instead of 0.1 in Sukhodolov et al. (2017).



We modified the manuscript as follows:

- In the introduction, we added a short paragraph to describe the effect of HOx on ozone in the upper stratosphere and mesosphere: "*Fleming et al. (1995) further stressed the increasing importance with height of the solar-modulated HOx chemistry on the ozone response above 45 km. In the upper stratosphere and mesosphere, enhancement of HOx through photolysis of water vapour in Lyman-alpha line associated with an increasing solar irradiance contribute to destroy ozone. Above ~65 km and at zero-lag, the latter mechanism dominates over ozone production (i.e. by photolysis of oxygen) leading to a negative ozone-solar irradiance correlation. In the upper stratosphere and lower mesosphere (below 65 km), although ozone production dominates, increasing HOx at zero-lag contributes to the negative lag of the ozone response (Rozanov et al., 2006).*"
- We also mention this mechanism in section 3.2 when we discuss the cross-correlation analysis shown in Figure 5: "*Above 3 hPa (~40 km), CCM cross-correlations of both periods (Fig. 5c,f) show a maximum at negative time lag (-2 days). As mentioned in the introductory section, this negative time lag can be induced by temperature feedback on ozone and by increasing HOx with solar irradiance which contributes to destroy ozone. While our model configuration allows to fully account for the HOx effect, the solar-induced temperature response is limited since the direct radiative heating effect is not included. The temperature response to the 27-days cycle is thus solely controlled by ozone production in the photolysis scheme. Although a temperature signal is found (not shown), it is small, reducing the*

likelihood for the solar-induced temperature feedback to be prominent in our experiments. Despite the approximation made in our model configuration, we notice however that the upper stratosphere negative lags compare very well with those found in CCM experiments of Sukhodolov et al. (2017) (see their Fig. 3) in which both HOx and solar-induced temperature feedback effects are fully included. Hence, this suggests that neglecting the direct effect on heating rates generated by UV variations has a limited effect on the ozone response, at least at 27-days timescale. More sensitivity experiments are required however to quantify accurately the impact of this approximation."

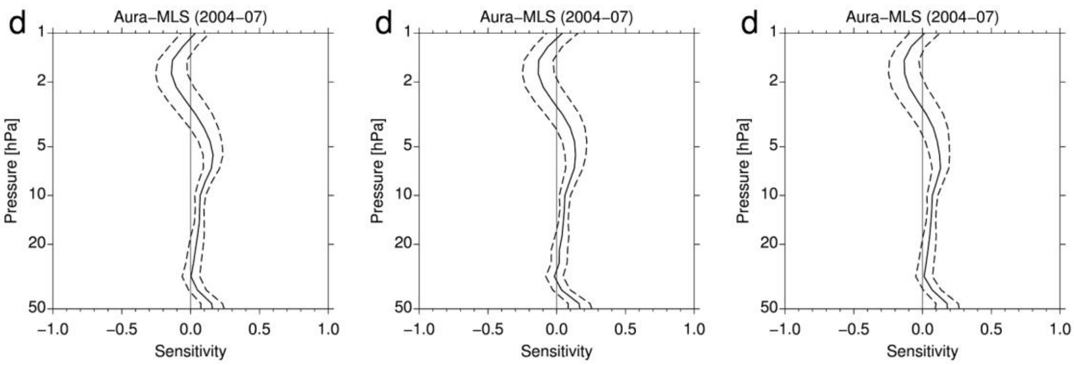
(14) P. 11, bottom of page. In addition to not mentioning the anomalously large CCM response in the upper stratosphere, there is also no mention here of the likely effect of the ozone diurnal cycle in reducing the ozone response in the upper stratosphere relative to that measured earlier from backscattered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

The CCM response is indeed anomalously large compared to observations and CTM results. It is however not anomalously large when comparing with Sukhodolov et al. (2017) (see also answer to comment 2). Section 3.2 has been modified accordingly.

Regarding the diurnal cycle, we tested its influence on the results over the period covered by Aura-MLS (i.e. 2004-2007). The Aura-MLS instrument measures in the tropics at one fixed night local time (~0142 LST) and one fixed day local time (~1342 LST). To mimic an irregular sampling with respect to the local time, we repeated the Aura-MLS analysis as follows:

1. We initially build the ozone time series using daytime measurements only (1095 days in total)
2. Out of these 1095 days, we select N days randomly where daytime measurements are replaced by nighttime measurements only.
3. We then compute the ozone sensitivity.

The procedure was repeated for N=100 (i.e. 91% of daytime measurements), N=500 and N=1000 (i.e. 9% of daytime measurements) (see figure below) and the results reveal very minor differences between the various sensitivity profiles. Hence this analysis suggests that the diurnal cycle has a small effect on the ozone solar rotational signal.



We added a paragraph to discuss ozone diurnal cycle at the end of section 3.2:

"*As mentioned in the section 2.2, the results based on UARS-MLS measurements may be affected by the imbalance between night and daytime sampling due to the ozone diurnal cycle becoming significant in the upper stratosphere. To test the influence of the ozone diurnal cycle, we repeated all the analysis performed in this section by mimicking an irregular sampling over the period covered by Aura-MLS (i.e. 2004-2007). Each day, ~800 ozone vertical profiles of the Aura-MLS instrument are evenly retrieved in the tropics [20S-20N] at two fixed local times: one at night (~0142 LST) and* *one during daytime (~1342 LST). We initially build the ozone time series using daytime measurements only (1095 days in total). Among these 1095 days, we selected N days randomly where daytime measurements were replaced by night time measurements. We then repeated the spectral, correlation and regression analysis. The procedure was performed for various values of N, from N=100 (i.e. 91% of daytime measurements) to N=1000 (i.e. 9% of daytime measurements). The results (not shown) revealed almost no dependence to N, suggesting that the diurnal cycle has a small effect on the ozone solar rotational signal*."

(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?

Regarding the suitability of the chosen configuration (see also answer to major comment #2), paragraphs have now been added at several places in section 3.2 where we discuss our results by comparing with previous independent CCM studies (i.e. Rozanov et al., 2006 ; Sukhodolov et al., 2017). We further mention this in the concluding paragraph of section 3:

"*Moreover, the fine correspondence of our results with those based on independent previous chemistry-climate modelling experiments (e.g. Rozanov et al., 2006; Sukhodolov et al., 2017) emphasizes the relevance of our experimental model setup (i.e. despite neglecting the direct effect on heating rates) to examine the ozone response to 27day solar variations.*"

Regarding the discussion of the length of the time window, we agree that it strongly depends on the amplitude of solar rotational fluctuations and, hence, the phase of the solar cycle. We examined this further with the solar maximum of cycle 23 with the model and found that choosing a 10year time window length still leads to the more accurate and robust estimates of the ozone sensitivity in comparison with restricting the analysis to one solar maximum period only. Of course, the strongest the solar maximum and its associated 27day solar fluctuations are, the shorter the time window size can be. But if a best option has to be given, our results seem to suggest that a long time window is preferable.

We modified the main text of section 4 to make this point clearer:

"*These uncertainty ranges also strongly depend on the amplitude of the solar rotational variations and hence the phase of the 11year solar cycle; we find that during solar maximum of cycle 23, minimum of cycle 22, a minimum time window size of 2, 5 years, respectively, is required for the standard deviation to drop under 50%. To obtain a standard deviation lower than 20%, we however found that randomly choosing a 10year time window length performs better than restricting the analysis to short but solar maximum period only (i.e. solar 23). These results suggest that long time series are preferable to estimate accurately the ozone sensitivity to solar rotational fluctuations in observations.*"

(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.

This has been corrected.

(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.

We added a full paragraph to discuss this aspect in section 5:

"In our CCM experimental design, the direct radiative effect of UV on heating rates has been neglected leading to an underestimated temperature response to the 27day cycle. As a consequence, this may affect the ozone response by reducing the magnitude of the solar-induced temperature feedback on chemical reaction rates. Nevertheless, a detailed comparison of the ozone response in our analysis with results from previous independent CCM studies (Rozanov et al., 2006 ; Sukhodolov et al., 2017) revealed a very good correspondence, despite the fact that their experimental design included the direct radiative heating effect. This suggests that the feedback exerted by the solar-induced temperature fluctuations on ozone is modest, at least at the 27day time scales. This is in fact not surprising. In their recent study, Sukhodolov et al. (2017) shown that the atmospheric internal variability largely dominates the variability of the stratospheric temperature on 27day time scales, making the temperature response to the solar forcing difficult to identify and, hence, the influence of its feedback on ozone secondary. Nonetheless, we recognize that to quantify properly the impact of the neglected solar-induced temperature feedback on our results, additional CCM experiments including the direct radiative effect of UV on heating rate should be performed."

(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.

See answer to comment #17.