Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2019-38-RC1, 2019

May 12, 2019

Authors' response to anonymous referee #1 of manuscript titled

Interactive comment on "Ozone and temperature decadal solar-cycle responses, and their relation to diurnal variations in the stratosphere, mesosphere, and lower thermosphere, based on measurements from SABER on TIMED" by Frank T. Huang and Hans Mayr

Anonymous Referee #1
Received and published: 19 April 2019

1a) Referee #1: Overall this paper has some intriguing information but it is presented in a confusing way and does not go far enough in showing the reader the changes in diurnal ozone & temperature values on a global scale. This reviewer recommends that the changes measured between solar max and minimum be plotted as a function of latitude. We believe that the diurnal changes are different at different latitudes (fig 6 of Diurnal ozone variations in the stratosphere revealed in observations from the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) on board the International Space Station (ISS) by Sakazaki et al) and that the maximum diurnal cycle occurs at 60 degrees latitude in the summer months so the question that needs to be addressed is: does the solar cycle affect ozone and temperature differently at different latitudes?

Response 1a): Before responding to specifics, we wish to note the intended length and scope of the manuscript.

As it stands, at different latitudes, the variation of the responses to the decadal solar cycle can be seen in Figure 3(4ºlat), Figure 5 (32º, 16º), Figure 6 (16º), and Figure 7 (Equator).

In response to the reviewer for more figures, we added an Appendix with 4 plots/2 figures, corresponding to Figure 7 of the manuscript, but at 32ºN and 44ºN latitude.

Also in response to the reviewer, we have added errors bars to Figures 6, 7, 8, and to the added Figures A1 and A2 in the Appendix. However, we did not add error bars to other figures, as they seem to only make the plots busier, and sometimes can make the details more difficult to discern. Besides, the errors are quite consistent from figure to figure because the SABER data are extremely stable, with few dropouts.

The revised and new figures are included below at the end of this response.

As for adding even more figures, the manuscript is already long, more than 20 pages, and adding more of what the reviewer suggests would be well outside the scope.

To explain why the manuscript is already long, we note the following:

1) Unlike previous results, there is the added variable of local time in addition to latitude and altitude.

2) In addition to the extra variable of local time, there have been essentially no previous studies on the effects of diurnal variations, over the 24 hrs of local time, on the responses of ozone and temperature to the decadal solar cycle (~11 years),. Because nearly all relevant results are new, and we need to spend space to substantiate the validation and reality of the results.

3) We derive responses to the solar cycle for

a) both ozone and temperature

b) in the stratosphere, mesosphere, and lower thermosphere,

Usually, previous results by others in this area (even without regard to diurnal variations), cover the stratosphere and mesosphere in separate papers, and often ozone and temperature in separate papers.

For example, we compare various results with results based on HALOE data with Beig et al., [2012] and Fadnavis and Beig [2006], who separated their studies into two papers.

In addition to latitude, our higher priorities are also the variations of the responses to the solar cycle as a function of altitude, because the diurnal variations of ozone and temperature themselves are relative small in the stratosphere, and can dominate in the upper mesosphere and lower thermosphere. As expected, the effects due to diurnal variations on the responses can be large at high altitudes. What was unexpected, at least to us, was that the diurnal effects were not negligible even at low altitudes in the stratosphere.

The point here is that much of the results and discussion can only be basic, limited by space and scope.

Concerning the diurnal variations themselves, we agree that the diurnal variations themselves are a function of latitude, as shown by our previous papers (e.g., Huang et al, 2010b), in addition to the results by Sakazaki et al.,[2013]. We have added the Sakazaki et al., [2013] reference to the manuscript.

In item 11) below, Referee#1 states "… a more comprehensive paper showing different latitudes in 10, 20 or 30 degree bands would be useful and enlightening.

We agree.

This is our point as well, and we could readily write a more comprehensive paper, concentrating on details and variations with latitude. However, that should be for another day.

1b) Referee #1: If there is no difference in the changes vs latitude, then this needs to be explicitly stated early in this paper. If there is, then plots for zonal averages (10, 20 or even 30 degrees) is necessary. This could be very useful information for the satellite retrieval community as well as fodder for the modelers to compare to. Also, a short discussion of instrument/measurement error bars would be extremely helpful.

Response1b):

As stated earlier, the variation with latitude can be seen in Figures 3(4ºlat), 5 (32º, 16º), 6(16º), and 7 (Equator).

Also as stated earlier, what we have done in response to the reviewer is to add an Appendix with 4 plots/2 figures corresponding to Figure 7 of the manuscript, for 32ºN and 44ºN latitude.

Also in response to the reviewer, we have added errors bars to Figures 6, 7, 8, and to the new Figures A1 and A2 in the Appendix of the manuscript. However, we did not add error bars to other figures, as they seem to only make the plots busier, and sometimes can make the details more difficult to discern. The errors are quite consistent from figure to figure because the SABER data are extremely stable, with few dropouts.

We have added a Section 2.2.2 (Statistical and error considerations) to the manuscript to describe our treatment of uncertainties, as follows:

"2.2.2 Statistical and error considerations

The analysis of uncertainties is the same for the current study as the previous study of the mean variations just described. It is only the input data that are different. Previously, the input consisted of zonal means that are averaged over both longitude and local time, as in 3D models. Here the zonal mean reflect measurements made at specific local times. Details of the statistical analysis are given in Huang et al.,[2106a, 2016b].

The studies use a least squares fit of the multiple regression of Equation (1). Uncertainties in the responses are found from the sample variance (Bevington and Robinson, 1992, Huang et al., 2016a) of the fit. The curvature matrix and its inversion are quite stable due to the excellent sampling of SABER, as there are essentially no significant data dropouts to speak of. So the standard errors are quite stable and reasonable, as can be seen in the error bars in Figures 6, 7, 8, and A1 and A2, in the Appendix. Although very stable in our case, the inversion of the curvature matrix does not explicitly or definitively address potential aliasing among the various terms of the multiple regression, unless the matrix is diagonal.

In Section 6 (Data length and aliasing) below, we show that the derived responses are essentially the same whether we use all the terms in Equation (1) or only the term containing the solar flux. So aliasing is not an issue here."

Specific comments:

2) Referee #1: Line 30: based on Line 39: The understanding of the response: : :.
Line 154: responses due to the solar: : :..

Response 2): Done. We thank the referee for noticing.

3) Referee #1: Figure 1 is extremely jumbled- please remove all trailing zeros (unless you know your altitude registration to 1 meter: : :.:ˆ) what does "data 2005001 2005365" mean on the plot when the caption says 2005085?

Response 3): We have revised the figure according to the reviewer.
The extra information was for 'bookkeeping" purposes only, and has been removed.

4) Referee #1: Figure 2: Please explain "znimn" in the figure caption or remove.

Response 4): "znlmn" denotes zonal mean

5) Referee #1: Line 250,258: change 20006 to 2006

Response 5): Done. We thank the referee for noticing.

6) Referee#1: Line 253-4. "The comparisons will indicate the quality of our results: : :" Does it? Either remove or expand.

Response 6): In relevant parts of the manuscript, we have given our opinion about the quality of results in comparisons with results by Beig et al., [2012] and Fadnavis and Beig [20006], based on HALOE data. Although we believe that the comparisons are good, they are by necessity subjective, because the HALOE results are given in 30º latitude composites. As discussed in the manuscript, according to the authors, the sampling of the HALOE data is routinely sparse, and responses are estimated using data over a 30º latitude bin. They do not describe exactly how the data are composited, but in any case, we cannot duplicate it. We get results at 4º degree latitude intervals, so quantitative comparisons should not be made.

7) Referee #1: Line264-5: As stated in the beginning of this review, if there are latitudinal changes in the diurnal cycle between solar min and max, please show us! This is very useful information. Or are you saying the responses change due to increased noise and shouldn't/can't be shown?? Either way, this reviewer feels that showing two latitude bands on the globe are not enough to make the point.

Response 7): We are perplexed. Nowhere (lines 264-265 or otherwise) do we even mention 'increased noise and shouldn't/can't be shown' concerning our data. Perhaps the reviewer is reading into what we state about the HALOE data, as opposed to our results.

As mentioned in response 6) above, for comparison with HALOE, we state that according to the authors, uncertainties in the HALOE data need to be considered, the main problem being routine sparse data. Consequently, HALOE responses are presented in composite 30º latitude bins. The authors do not describe exactly how they treat the data in order to derive responses, but they would not be averages over individual latitudes.

We get results at 4º latitude-intervals, and from everything that we have seen, there are no problems. In comparing with HALOE we would not be comparing exactly the same things, even if we averaged. So we are not sure what the reviewer means about 'noise and shouldn't be shown.'

Again, our comparisons with HALOE are necessary qualitative, but we believe are at least good.

We agree that showing our results at only two latitudes does not describe global variations as a function of latitude adequately.

But the fact that they are different at the two latitudes does show that there are variations with latitude.

In any case, we have added in the Appendix, 4 plots/Figures A1 and A2, depicting results at 32º and 44º. We have also added error bars to these plots, as well as to Figures, 6,7, and 8.

Again, in 11) below, Referee#1 states "… a more comprehensive paper showing different latitudes in 10, 20 or 30 degree bands would be useful and enlightening.

This is our point as well, and we could readily write a more comprehensive paper, concentrating on details and latitude. However, that should be for another day.

8) Referee#1: Line 274; should that be figure 3 (not 4)?

Response 8): We did mean Figure 4, and we realize that the sentence is confusing at that point. We have removed the sentence because Figure 4 is discussed in more details in the paragraph after the next.

9) Referee#1: Line 306: where are the uncertainties discussed? Line 307: please discuss your error bars [and/or reference]

Response 9): As stated in our response 1b), above, we have added errors bars to Figures 6,7, 8, A1, A2 of the manuscript. However, we do not think it useful to add error bars to other figures, as they seem to only make the plots busier. The errors are quite consistent from figure to figure because the SABER data are extremely stable, with few dropouts.

As stated earlier, we have added Section 2.2.2 **(**Statistical and error considerations) to the manuscript to describe our treatment of uncertainties.

It is given in quotes in the response to 1b). Also, aliasing among various terms in the regression are minimal. These are all supported by the discussion in Section 6 (Time span of measurements) of the manuscript, where it is found that the derived responses are essentially the same whether we use the all the terms in Equation (1) or only the term containing the solar flux.

10) Referee#1: Figures 3-8: explain LSTNRM in caption or remove.

Response 10): As noted in the manuscript, the ozone responses are presents in percent. The normalization depends on the situation. When comparing with HALOE, the normalization would be ozone values at sunrise/sunset. When comparing with zonal means that are averaged over local time, as in Figures 6 and 7, the normalization would also be average over local time.

11) Referee#1: Figures 6,7 and 8 contain the interesting results of this paper. Again, a more comprehensive paper showing different latitudes in 10, 20 or 30 degree bands would be useful and enlightening.

Response 11): As stated earlier, we have added in the Appendix Figures A1 and A2, depicting results at 32º and 44º. As noted in responses 1a), 1b), we are already covering the stratosphere, mesosphere, and lower thermosphere, for both ozone and temperature. We are not aware of any other study that has covered this much. We agree with the reviewer that a more comprehensive paper would be helpful.

12) Referee#1: Section 5.2 This reviewer can't help but feel that some numbers games are being played here. You compare SABER from 24s to 24n to Bieg 0-30 north and south separately. All the others are 25n to 25s (I believe- what latitudes are the red plusses??) so I recommend just removing the Beig data.

Response 12): We take exception to the reviewer's remarks about 'numbers games'. As a matter of principle, we avoid such games.

We included Figure 9 in the manuscript because readers might ask why, besides HALOE, we did not compare results with other previous studies. Figure 9 was taken intact from a previous paper by us [Huang et al. 2016b], to described previous results by others, based on a variety of data. As noted in the manuscript, these previous results did not describe how they address diurnal variations. The effects of diurnal variations on the responses were not a consideration for them. So comparisons would not be fruitful.

To answer the reviewer's question, in the current manuscript, in discussing Figure 9, we noted that "The red line (plusses) in Figure 9(a) show ozone responses from Soukharev and Hood [2006] (AUDTA, data from1979-2003), as reported by Austin et al. [2008], and from models (AUMDL, magenta lines and triangles), also reported by Austin et al. [2008], representing composite results from 25ºS to 25ºN latitude. The Soukharev and Hood [2006] results (red plusses) are a composite based on SBUV, HALOE, and SAGE data, …"

Note that the red plusses represent results in the latitude interval 25ºS to 25ºN. That's why our results are averaged over 24ºS to 24ºN (4-degree intervals).

Also note that their analysis used combined SBUV, SAGE, and HALOE data, which mixed measurements at different local times.

Austin et al.,[2012] discussed the differences among the results, and we would agree that they need to be explained. Because of the differences in the other results, we added Beig's results separately, to provide more information conveniently (so long as we made clear that the results were for 30º, we do not believe that it was confusing).

We also did not endeavor to explain the differences, as there are other data-related issues, as noted in the abstract and Summary and discussion section of the manuscript, where we state "We do not believe that diurnal variations are the major reason for the discrepancies, as there are likely other data-related issues. Other reasons for differences may be the conditions and constraints under which the various measurements were made (see Austin et al., 2008, Crooks and Gray [2005], Gray et al. [2005], Huang et al. [2016b])."

We have added a paragraph to the beginning of Section 5.2, as follows:

"Unlike the above comparisons with results by Beig et al.,[2012] based on HALOE data, other studies, such as those based on operational satellites, generally did not describe how the approached the issue of diurnal variations in detail. We will not then attempt to make comparisons, but only present some previous findings. In addition to issues related to local times, there are been reports based on data-related issues in general. Details can be found in Austin et al., [2008], Crooks and Gray [2005], Gray et al. [2005], and Huang et al. [2016b]."

13) Referee#1: Line 518 Previous studies based on: : :.

Response 13): We thank the reviewer for noticing.

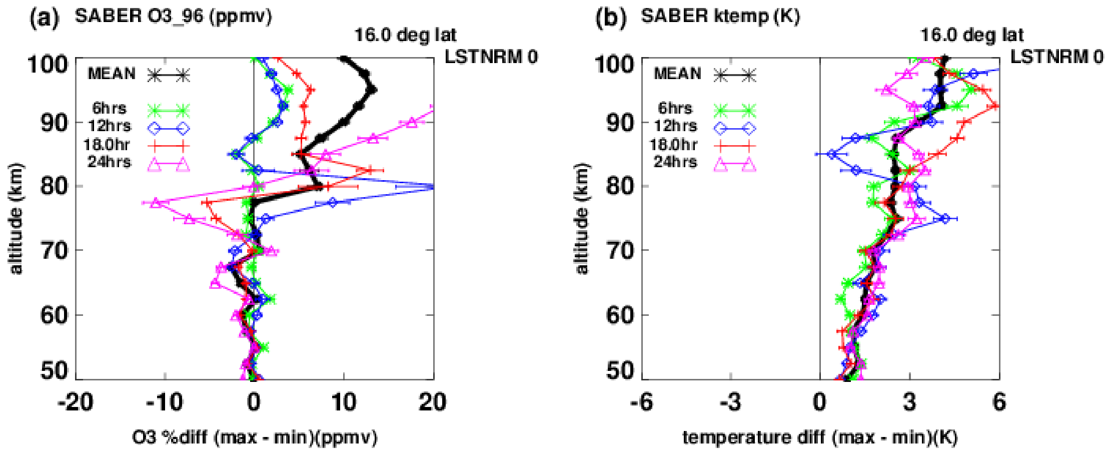

Figure 6. Ozone (left panel) and temperature (right) responses from 50 to 100 km at 16ºN. Values are responses at solar max minus responses at solar min (% /100sfu) for ozone and ºK/100sfu for temperature. Black asterisks denote responses based on zonal means that are averages over both longitude and local time. Green asterisks denote our responses based on zonal means fixed at 6hrs, blue diamonds fixed at 12hrs, red plusses at 18 hrs, and magenta triangles at 24hr, based on SABER data.

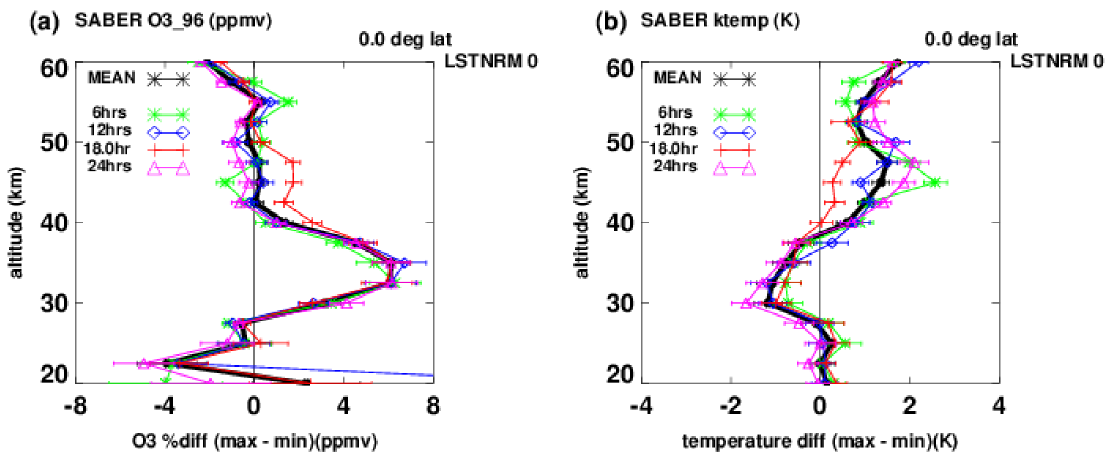

Figure 7. As in Figure 6, but from 20 to 60 km. Ozone (left panel) and temperature (right) responses at 0º. Values are responses at solar max minus responses at solar min (% /100sfu) for ozone and ºK/100sfu for temperature. Black asterisks denote our responses based on zonal means that are averages over both longitude and local time. Green asterisks denote our responses of zonal means at 6hrs, blue diamonds at 12hrs, red plusses at 18 hrs, and magenta triangles at 24hrs, based on SABER data.

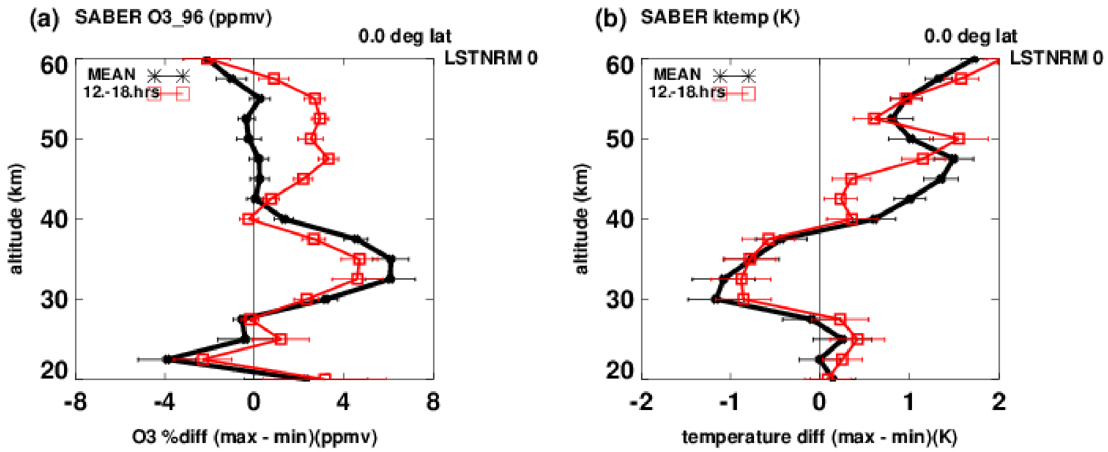

Figure 8. Ozone (left panel) and temperature (right panel) responses to solar activity versus altitude, at the Equator, from 20 to 60 km. Values are responses at solar max minus responses at solar min in % per 100 sfu for ozone, and K/100 sfu for temperature. Black asterisks denote responses based on zonal means that are averages over both longitude and local time. Red squares denote corresponding results, but with local times increasing linearly from 12 to 18 hrs from 2002 to 2014.

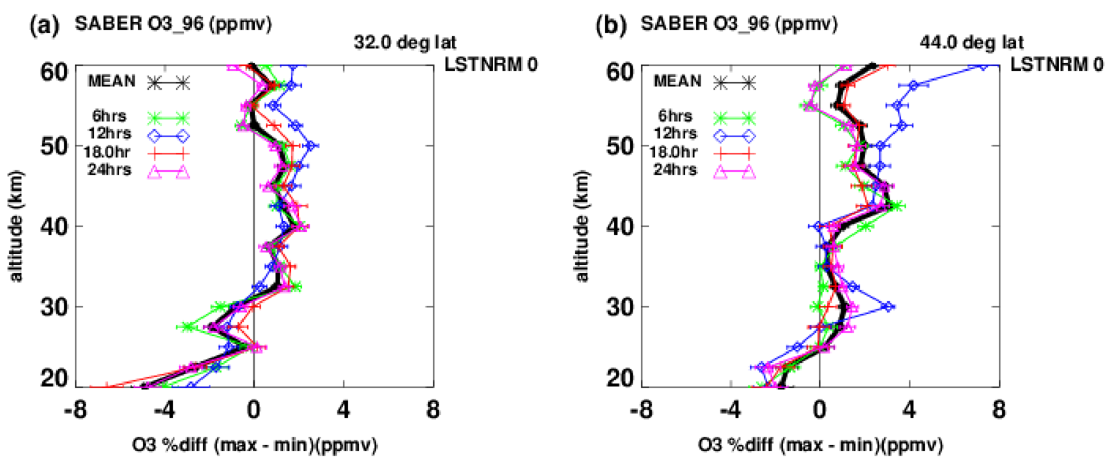

Figure A1. As in Figure 7, Ozone responses at 32º (left panel) and 44º from 20 to 60 km. Values are responses at solar max minus responses at solar min (% /100sfu) . Black asterisks denote our responses based on zonal means that are averages over both longitude and local time. Green asterisks denote our responses of zonal means at 6hrs, blue diamonds at 12hrs, red plusses at 18 hrs, and magenta triangles at 24hrs, based on SABER data.

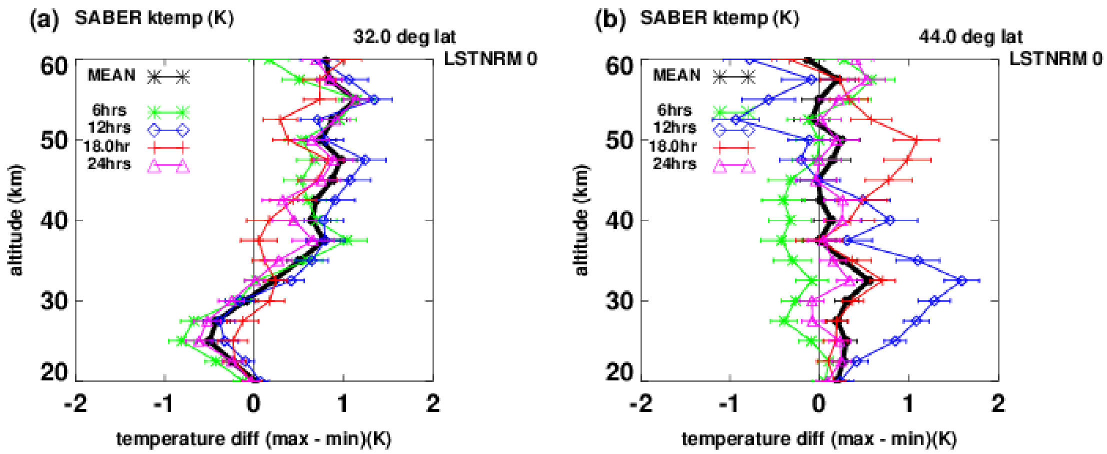

Figure A2. As in Figure A1. temperature responses at 32º (left panel) and 44º, from 20 to 60 km. Values are responses at solar max minus responses at solar min (ºK/100sfu). Black asterisks denote our responses based on zonal means that are averages over both longitude and local time. Green asterisks denote our responses of zonal means at 6hrs, blue diamonds at 12hrs, red plusses at 18 hrs, and magenta triangles at 24hrs, based on SABER data.

References:

Bevington, P. R. and Robinson, D. K.,: Data reduction and error analysis for the physical sciences, McGraw-Hill, New York, USA, 1992.

Huang, F. T., Mayr, H. G., Russell III, J. M., and Mlynczak, M.G.: Ozone and temperature decadal responses to solar variability in the mesosphere and lower thermosphere, based on measurements from SABER on TIMED, Ann. Geophys., 34, 29–40, doi:10.5194/angeo-34-29-2016, 2016a.

Huang, F. T., H. G. Mayr, J. M. Russell III, and M. G. Mlynczak, Ozone and temperature 601 decadal responses to solar variability in the stratosphere and lower mesosphere, based on 602 measurements from SABER on TIMED, Ann. Geophys., 34, 801–813, doi:10.5194/angeo-34-603 801-2016, 2016b.

Soukharev, B. E., and L. L. Hood (2006), The solar cycle variation of stratospheric ozone: Multiple regression analysis of long-term satellite data sets and comparisons with models, J. Geophys. Res., 111, D20314, doi:10.1029/2006JD007107.

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2019-38, 2019.