Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-320-AC1, 2020

Atmospheric Measurement Techniques
Discussions

Interactive comment on "Model-based Climatology of Diurnal Variability in Stratospheric Ozone as a Data Analysis Tool" *by* Stacey M. Frith et al.

Stacey M. Frith et al.

stacey.m.frith@nasa.gov

Received and published: 20 February 2020

This manuscript presents a model-based climatology of diurnal ozone variations in the stratosphere (50-0.5 hPa) based on the NASA GEOS-GMI chemistry model. This climatology is of significant utility for observational data inter-comparisons and merging activities as it allows to correct for diurnal sampling biases in ozone records. This is a topic of high relevance for readers of AMT. The paper is well written and covers all the relevant details and citations. I recommend publication after addressing my comments below, most of them being minor.

** We thank the reviewer for their comments and address each point individually below, as indicated by the bold text. We note that during the review process a model error was

identified and a new simulation was run. We reanalyzed the new output, but found for ozone the differences were very small, and did not warrant producing a new climatology at this time. We will periodically update the climatology and include all model updates at that time.

Overall I'm missing a more quantitative discussion on uncertainties and limitations when using the diurnal climatology in different applications. I see three potential sources of uncertainty: (i) model errors, (ii) unresolved inter-annual variability, and (iii) climatology discretization. While (i) is very difficult to quantify, (ii) and (iii) could be assessed in a straight forward manner. The influence of inter annual variability is already discussed in a qualitative way (e.g. Fig S10, differences between 2017 and 2018 outputs) but could be extended to include quantitative estimates. Regarding (iii), a major source of uncertainty could be the relative broad temporal resolution of the climatology (monthly) which may introduce systematic deviations close to the terminator, particularly in the polar regions and at upper stratospheric levels (and above) where photochemistry is relatively fast (intra-month terminator variations are not resolved by the monthly climatology). These errors could be evaluated by e.g. applying the climatology-based diurnal correction to the 0.5-hourly resolved model output itself.

** We agree, and we have added a section in the summary with a more thorough discussion of the potential model errors. We have also made a good faith effort to include reasonable error bars for the climatology. In doing so we analyzed the variability of the high-resolution data going into the climatology (equivalent to re-sampling the model output from the climatology). The standard deviations are large, over 10% in high latitude winter. The climatology will smooth out sub-scale variability related to the diurnal cycle, but we weren't able to isolate that variability from the overall noise. We found very little difference in the standard deviations from hour to hour, suggesting that the longitudinal variability is dominating the variability due to day to day variations in the terminator time. We added a cautionary note in the summary with regard to using GDOC near the terminator. We have added the figure below showing the direct differences between the model simulation in 2017 and 2018 as a function of season and latitude at 4 pressure levels. The difference plotted is the max-min difference in local solar time.

Further, an upper vertical limit for a "safe use" of the climatology, would be helpful, particularly when considering that the climatology is provided up toâĹij80 km (0.01 hPa).

** We suggest a safe use range of 30 hPa to 0.3 hPa. This has been added to the text in the same conclusions section, and the actual data set will be truncated.

** Updated Summary Paragraph: In this work we do not focus on the chemical and dynamical mechanisms of the diurnal cycle but rather on the validity of the model-derived diurnal climatology as a tool for data analysis. We present a series of examples that highlights the usefulness of the climatology in data analysis as well as demonstrates the consistency between the observed and predicted ozone variations. These comparisons give us confidence in the climatology, but we also need to consider the potential sources of error. The first measure is the variability of the data going into the climatology. We use the standard error of the mean of the bin averages, assuming n=720 independent measurements in each bin, as the measure of this uncertainty. Uncertainty estimates based on this variability are 2% or less. However, care should be taken when reconstructing daily values using the monthly GDOC, especially near the terminator in the upper stratosphere, where the ozone gradient is sharp and varies in time over the month. True day-to-day or longitudinal variability in the diurnal cycle will be smoothed out in the averaging. Other potential sources of error are interannual variability and model error. In an effort to address both these issues, we consider several different simulations using iterative versions of the model and/or simulations of different years, and compare the diurnal cycle derived from each simulation. Figure S10 shows the December day-night ratios from diurnal climatologies constructed from four separate simulations. The overall patterns from all the simulations are very similar, suggesting that the representation of the diurnal cycle within the model is well estab-

lished. This does not preclude a model error (or more likely incomplete representation of relevant processes) that is present in all model versions. Ideally, as the model is used more in data analyses, such studies will also provide feedback to the modeling team. For more information on year-to-year variability, Figure S11 shows direct differences between GDOC derived from the 2017 and 2018 simulations from the same model. Below 5 hPa the differences are generally less than 1%. At higher levels there are sporadic instances of larger differences (3-5%) in the tropics (also seen in Figure S10) and at higher latitudes. As more years of model output become available, we will be able to better characterize interannual variability in the model. We recommend using GDOC primarily for monthly zonal mean analyses in the pressure range from 30 to 0.3 hPa, and expect the climatology to capture diurnal variations to well within 5% in most cases. For finer resolution studies, GDOC can be used in a first order effort to estimate the impact of the diurnal cycle, to be followed by analyses that are more refined. Users requiring more highly resolved information may contact the authors for access to the original model output.

Specific comments :p1 l21: "polar summer boundary" -> consider to rephrase to "polar day terminator"

** done

p4 l14-15: The reason for the vertical interpolation is not clear. Why switching to a different vertical grid if the climatology is provided on pressure levels and the interpolated levels have a similar vertical resolution as the original pressure levels? Further, Z* and pr are not defined.

** We have clarified this section, pr was meant to be Z* pressure levels. This was done for convenience; we often use Z* coordinates as a common vertical coordinate when comparing data sets. We noted this in the text: “ Interpolation to Z* levels is done largely for convenience; Z* pressure levels are often used as a common vertical coordinate when comparing ozone profiles from a variety of instruments reporting on different altitudes."

p4 l17-20: I guess that local solar time (LST) is meant with "time of day". Can you provide some more details on how the local time binning has been performed? Was the model output at different longitudes (but fixed UT) resampled to local time or was the local time (at fixed longitude) sampled from the output at different UT (and finally zonally averaged)? This question is relevant since the former option (while in principle allowing for better local time resolution) may introduce aliasing effects by e.g. stationary planetary waves while the latter option is much less sensitive to such aliasing effects.

** Yes, we mean local solar time, and that has been added to the text. The binning is done by sampling local time at a fixed longitude from output at different UTC. We have added the following details to the text to better explain how the local time binning is accomplished: We first average the model output in latitude to reduce the sampling from 1° to 5°. Then the binning in local solar time is accomplished by sampling from three consecutive days of half-hourly output. At each fixed longitude, latitude, pressure and day, we construct a 3-day time series (30 minute resolution, centered on the fixed day) of ozone values in UTC time, then integrate in time to convert from UTC to local solar time for that longitude. Thus, there is a diurnal cycle defined at each longitude. We then average the diurnal cycles at each longitude to get a daily zonal mean diurnal cycle, then we average over available days for each month. Finally, for each latitude, level and month, the half-hourly climatological values are normalized to the value at midnight (11:45-00:15 local time bin) and the final climatology is expressed in terms of variation from midnight. We note that GDOC can be re-normalized to any reference time as is most appropriate for a given analysis.

p4 l25-29: Can you quantify the agreement of the climatologies in Figure S10? The difference of the climatologies for different years could provide a good estimate of the uncertainty range caused by intra-annual variability.

** Yes, we have added Figure S11 to the Supplemental, and reference it in the text [see

above]. Figure is attached.

p9ff (Day Night Differences): Apart of Aura/MLS there are also other ozone-observing instruments on sun-synchronous platforms, some of them having different equator crossing LSTs compared to MLS. MIPAS on ENVISAT, for example, took sun-synchronous measurements at 10 am - 10 pm equator crossing LST, in principle allowing to extend the validation of the diurnal climatology by means of observed day-night differences to different LSTs.

** This is an excellent idea, unfortunately we did not have time to acquire and familiarize ourselves with the MIPAS data. However we will continue to work to evaluate the diurnal model using additional data sources, and hope to collaborate on efforts with other instrument teams.

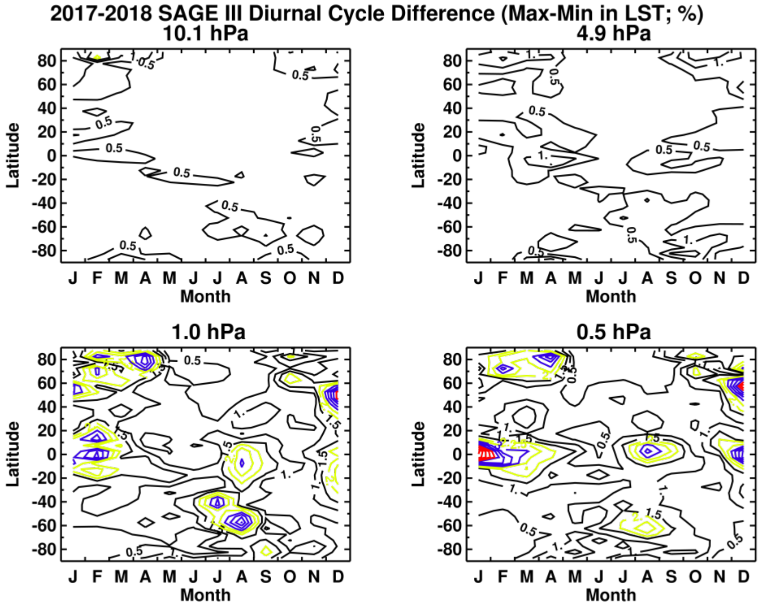
p11 l1-4: A possible reason for the divergence between GDOC and SAGE-III above 2hPa could also be related to the limitations of the monthly-resolved diurnal climatology: sunset (SS) and sunrise (SR) times are spread over a certain LST range in the monthly climatology, resulting in an artificial smearing of the diurnal gradient at SS and SR and hence in reduced SR/SS ratios.

** Yes, we now note this in the text: "At these levels, the SAGE III/ISS retrieval does not account for the sharp diurnal gradient in the ozone along the line of sight of the instrument. However, GDOC representations near the terminator may also be biased due to smearing of the diurnal ozone gradient in the monthly average as the terminator time shifts within the month."

p15 l4: the webpage is not accessible.

** The corrected web location has been added to the text.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-320, 2019.



2017-2018 SAGE III Diurnal Cycle Difference (Max-Min in LST; %)
10.1 hPa
4.9 hPa
1.0 hPa
0.5 hPa
Latitude
Month
J F M A M J J A S O N D

Fig. 1.