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# *Interactive comment on* "Daily ozone cycle in the stratosphere: global, regional and seasonal behaviour modelled with the Whole Atmosphere Community Climate Model" *by* A. Schanz et al.

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Dear Referee #2,

thank you for your interest in our study and your corrections which we are going to consider in a revised version of the article. In the following we answer your comments step by step.

Specific comments

5562/26 '..preserves the biosphere from...'. Perhaps better to say: . . . protects biosphere from...



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We agree and we are going to adopt 'protects the biosphere from'.

5563/12 ...mitigation...'. Probably not the correct word for this purpose?

'mitigation' is going to substituted by 'depletion'.

5563/14-15 More recent references about observed ozone recovery from the SI2N ACP special issue.

Thank you for reminding us of more recent studies. We are going to include the study of Kyrölä et al.(2013), Gebhardt et al.(2014) and Jonsson et al.(2009) which show trends in profiles from satellites observations.

5564/22 Satellite orbits are not necessarily drifted away. The local equator crossing time is fixed for heliosynchronous orbits.

We agree that this holds not for heliosynchronous orbits. We are going to soften the statement by 'potentially drift away' or particularise it for NOAA/SBUV.

5565/13 '. . . almost all effects...'. Please specify omitted effects.

We are going to change the sentence to: 'This model includes the physical and chemical processes which are relevant for the daily ozone cycle (e.g. detailed photochemistry, transport, vertical mixing, parametrized gravity wave fluxes)'

5567/4+11 Is the time step 15 min and the output frequency one hour? Is the one hour enough for sunrise/sunset periods?

We agree that a follow-on-study with high temporal resolution focused on the solar terminator region would be interesting for the study of medium-scale gravity wave generation by the solar terminator. We are going to improve the text on this point according to the remarks made for referee #1, 5567.

5567/Eq. 3+5 Characterising the diurnal variation by peak-to-valley difference is a considerable simplifying assumption. Your results seem to justify this approach, probably



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Interactive Comment

connected to your very smoothly varying results (see question D below). Often seeing the real variation would be a more useful result but, of course, this would require more space for results. Comments?

Indeed it is a simplified approach. From our knowledge it is a suitable approach for photochemistry dominated daily ozone cycles. From further analysis we know that the winter vortex and its wobbling can cause diurnal variation with different phases and characteristics where the peak-to-valley difference is not so easy to interpret. However, any fitting to eigenfunctions of the daily cycle is not feasible at all, even for pure photochemistry.

5568/Eq. 5 Eq.(5) in the zonal mean of X you should have latitude, not longitude as a variable. True. We are going to correct the definition by replacing longitude by latitude.

5570/17 and Fig.1

A) How did you infer the diurnal variation of a gas?

We established daily data series in local time (LT) for each grid point for every day of the simulated year starting from 0-24 LT. The transformation from universal to local time is straight forward if the global output with a one hourly temporal resolution is reduced to 20 minutes by interpolation (this applies to a 4° latitudinal resolution). For each latitudinal grid point westward or eastward from the prime meridian the daily data series is shifted by +/- 20 minutes in order to yield a local time data series. The temporal resolution of the actual output is one hour but the daily data series in local time have 20 minutes resolution which is due to the interpolation. From the described daily data series we can derive latitudinal means as well as regional effects. Both the 'snapshot' and the 'traveling with the earth' method are not suitable for studying the regional effects as we did.

B) How do you take into account possible latitudinal variation in gas distribution?

In fact, latitudinal variations in the trace gases are important. We intend to present



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basic characteristics of the ozone budget in order to show the main depletion and production processes in the stratosphere. Moreover, Fig. 1 shows the important interconnection of the solar zenith angle and the ozone budget which we argued is most important for the characteristic of diurnal variation. However, the latitudinal variation of gases may change (as discussed in Sect. 6) the budget and hence the daily ozone cycle. A detailed analysis of latitudinal distribution of trace gases is very interesting but also requires a lot more analysis. We showed also latitudinal changes in N2O5, NO2 and NO in Fig. 14. A more comprehensive analysis on this topic might be beyond the scope of our article.

C) How did you separate transport, dynamics and chemical pathways?

WACCM is arranged to give comprehensive chemical data. We made use of the chemical production rates directly given by the model output. For example the reaction rate b4 of reaction

(b4); NO + O3 $\rightarrow$ NO2 + O2

is provided by WACCM as a global 4D output field. The same transformation as for gases described in A) gives a comprehensive view on diurnal variability of the specific reaction. All other chemical branches which affect the ozone budget were treated similarly. The chemical data presented in the article is

D) Have you done some kind of smoothing?

We did not apply any direct smoothing to the data. Indeed, all the figures are made from data with 20 minutes resolution which is not real as explained in A) and therefore might look smoothed. During the analysis, we did a WACCM simulation with extremely high temporal resolution (one minute model step and output data). From these simulations we learned that WACCM mostly shows a smooth behaviour in stratospheric ozone over daytime and also at sunrise so that our figures are an adequate illustration of the WACCM model. Obviously, a concerted resolution for the problem transforming from



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universal to local time would be a 20 minutes temporal resolution with 4° longitudinal model resolution. However, we ran WACCM on a PC were computational resources and hard disk memory are limited and compromises are inevitable.

Fig. 1 When you specify the latitude, please provide the limits of the latitude belt. In Fig. 1 (also in Fig. 2, 3, 9-12) we specify latitude lines. In case of Fig. 1 the caption is going to be improved by 'Zonal mean ozone conversion rates [...]'

Conclusions: Please add discussion about dynamic effects. I am also missing discussion about about what happens at other altitudes. There is a need to put results in comparison with the results in Sakazaki et al.(2013) and in Huang et al.(2010). This last reference is not mentioned at all in the references of the present article. We are going to add the reference of Huang et al.(2008)

Huang, F. T., Mayr, H. G., Russell III, J. M., Mlynczak, M. G., Reber, C. A.: Ozone diurnal variations and mean profiles in the mesosphere, lower thermosphere, and stratosphere, based on measurements from SABER on TIMED, J. Geophys. Res., 113, A4307, doi:10.1029/2007JA012739, 2008.

and change the sentence in 5572/5: 'Satellite-based observations from SMILES (Kikuchi et al., 2013), SABER and MLS showed a morning minimum and a late afternoon maximum in the daily ozone cycle in the tropics and subtropics (Huang et al.,2008; Sakazaki et al., 2013)'

In addition we are going to change a sentence at 5564/15: Satellite-based observations from the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) (Kikuchi et al., 2013), Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) (Russell et al., 1999) and Microwave Limb Sounder (MLS) (Barth et al., 1983) showed the existence of a∼daily ozone cycle in the stratosphere in tropics and mid-latitudes (Huang et al., 2008; Sakazaki et al., 2013).'

with references:



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Russell III, J. M., Mlynczak, M. G., Gordley, L. L., Tansock Jr., J. J., and Esplin, R. W.: Overview of the SABER experiment and preliminary calibration results, Proc. SPIE 3756, Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research III, 277 (October 20, 1999); doi10.1117/12.366382, 1999.

Barth, C. A., Rusch, D. W., Thomas, R. J., Mount, G. H., Rottman, G. J., Thomas, G. E., Sanders, R. W., and Lawrence, G. M.: Solar mesosphere explorer: Scientific objectives and results, Geophys. Res. Lett., 10, 237-240, doi:10.1029/GL010i004p00237, 1983.

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Interactive comment on Atmos. Chem. Phys. Discuss., 14, 5561, 2014.