

## ***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 #1,

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

5564: Connor et al. Present the diurnal variation including sunrise and sunset features, not only the night/day ratio.

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True, Connor et al.(1994) did more. Text is going to be improved: 'Connor et al.(1994) presented diurnal variation in stratospheric and mesospheric ozone from 9 months of observations of a ground-based microwave radiometer at Oroville, California.'

5566: Which coupler (reference)? Alternatively skip sentence because this is not relevant for the stratosphere.

We skip the sentence with the coupler.

At the beginning of Sect. 2 it should be already mentioned that chemistry, radiation and dynamics are fully coupled (as stated on 5573/3 which is too late).

We agree that the 'fully coupled' should appear earlier in the text.

How many years are simulated in the time slice (or perpetual 2000)?

We simulated one year. Text is going to be improved(p5566/22):

[. . .] released in February 2012. 'The F 2000 WACCM scenario was utilised to simulate one year starting from 1 January. The model scenario fully couples chemistry, radiation and dynamics.' The computation capacity [. . .]

5567: What is the output interval?

The output interval is one hour as specified in Sect. 2.2, 5567/11. To be more clear we are going to replace 'with a time spacing of one hour' to 'with an output interval of one hour'.

A 15 min time step is also rather long for the chemistry at sunrise, please expand text slightly.

For sunrise a time step of a few minutes is much more desirable. However, we were limited in computing power so that it was not possible to realise higher resolutions. Text is going to be improved to explain the restriction (5567/4):

'Although it is desirable to have even shorter time steps for photochemistry during

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sunrise, the used computer power limits the resolution to 15 min.'

Eq.(1) is not relevant to the subject.

We agree that Eq. (1) is not important. We skip it and its related text.

5569/5: Give a reference to photochemical data (JPL)?

We are going to add the JPL reference 'Chemical Kinetics and Photochemical Data for use in Atmospheric Studies' No.17 at line 5.

5569/5570: The catalytic cycles and changes in odd oxygen are not relevant for diurnal variations at 5 hPa, this matters only higher up. Remove or add at least a sentence of no higher levels are included.

The diurnal variation at 5 hPa is only a few percent. Thus catalytic cycles and diurnal changes of odd oxygen (e.g. Muncaster et al., 2011) play a role. The catalytic NO cycle is important for diurnal variations at 5 hPa in general (Fig. 1) and for regional effects (Sect. 6.2).

Eq.(9): Eq.(9) ignores the catalytic cycles and their rate limiting step. The radicals and the photolysis of O<sub>3</sub> and NO<sub>2</sub> cause a diurnal variation of the partitioning between O and O<sub>3</sub>. Please improve text here and also in Sect. 4.

Indeed Eq.(9) ignores the rate-determining steps but it just shows the ozone budget. Of course the model simulates all species and their budget with respect to all the other species. We are going to add a sentence at 5570/1:

'The reactions involving NO, NO<sub>2</sub>, H, OH, HO<sub>2</sub>, Cl and Br are parts of catalytic ozone depletion cycles which are limited by the rates of intermediate steps (Johnson and Podolske, 1978).'

5563/24: Don't use 'depletion' and 'loss' if only temporary conversions to O-atoms is meant. 'Loss' or 'depletion' is going to be substituted by 'decrease' in 5563/24, 5571/11+21, 5574/9.

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5572: I don't see the reaction  $\text{NO} + \text{HO}_2 \rightarrow \text{NO}_2 + \text{OH}$  which is also important in the stratosphere, especially below 10 hPa.

In our simulation the reaction of NO with HO<sub>2</sub> converts much less than R9-11 and R16 at 5 hPa (less than 5 ppmv/h). In the text we focused on chemistry which is relevant for the problem.

5574/5575: The given numbers of zenith angles are for a flat atmosphere. Please give also information on the corrections for the spherical atmosphere in the model that should be present.

Solar ray bending angles due to refraction in the middle atmosphere is certainly less than 1 deg. So a straight line approximation can be applied for the solar rays within the middle atmosphere. However, we are going to correct the Earth's maximum tilt from 23.5° lat to 23.4° lat.

5577: 5 hPa is more the middle stratosphere than the upper stratosphere.

We are going to change 'In the upper stratosphere' by 'In the stratosphere at 5 hPa'

5581: Include some observations with Fig. 14, for example the nitrogen species seen by MIPAS on ENVISAT at 10 and 22 h local time.

We are going to evaluate options to include observational data in Fig.14 or including a reference for this topic.

5586: Usually the paper by Bates and Nicolet in JGR 55 is cited.

We are going to replace the reference of Bates and Nicolet(1950) by

Bates and Nicolet(1950), The photochemistry of atmospheric water vapor, J. Geophys. Res., 55, 3, 301–327, doi:10.1029/JZ055i003p00301, 1950.

Tides: Tides are mentioned several times but the effects are not quantified. Would that be possible for example by using a correlation of O<sub>3</sub> and N<sub>2</sub>O?

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We quantified diurnal variation in temperature in Fig. 7a-d with magenta contour. These diurnal variations are not necessarily tides only. There is a study of Sakazaki et al. (2012) which quantifies tides from TIMED/SABER and six global reanalysis data sets. Below 40km tides have amplitudes of about 2K. We are going to incorporate these results into the manuscript at 5578/12:

'[...] agreement to observations (e.g. Huang et al, 2010; Sakazaki et al.,2012). [...]'  
and correct 5578/3

'Thus diurnal temperature variations can affect the strength of the daily ozone cycle.'

Sakazaki, T., Fujiwara, M., Zhang, X., Hagan, M. E., and Forbes, J. M.: Diurnal tides from the troposphere to the lower mesosphere as deduced from TIMED/SABER satellite data and six global reanalysis data sets, *J. Geophys. Res.*, 117, D13108, doi:10.1029/2011JD017117, 2012.

Technical corrections

5566/14: CFCs of what? 'CFSs' is going to be replaced by 'CFCs'.

5567/22: 'place' or 'time'? 'given location' suits better.

5568/7: is 'regional' 'longitudinal'? 'longitudinal' is correct.

5568/10: definitions messed up. Indeed definition are messed up. Phi is replaced by lambda.

5571/24: 'than' missing 'than' inserted.

R9 and R14: A consistent notation for photolysis reactions should be used. Please correct R9 and R14. We are going to replace 'gamma' by 'hv' in R9 and R14.

5577/19: a word or a ':' is missing. Also at other equations. We are going to add a 'by' before Eq.(10). Also the ':' after Eq.(9) is going to be removed.

5582/5: typo. One of the two 'the' is going to be purged.

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5582/23: At point D in the figures are westerlies. 'a strong easterly winds' is going to be replaced by 'strong westerly winds'.

Table 1: Headline and numbers do not correspond. Inverse? Indeed they are inverse. We are going to invert them.

Fig.3: Wrong unit at y-axis. Units are going to be changed from 'ppm/h' to 'ppmv/h'.

Fig. 5: In Figure 5 the polar circles are at a wrong position (should be at the tangent point for solar rays), please correct this or remove the figure. We are going to correct the position of the polar circles.

Fig. 7: Please give a reference arrow in Figure 7, for example for 10 m/s. We are going to scale all arrows and give a reference for 100m/s in all four figures. 10m/s is a too small reference arrow. We are going to add in caption of Fig. 7A '['[...] overlaid and a reference for wind speed is given near the x-axis. [...]'

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