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Discussions

Interactive comment on "A climatology of the diurnal variations of stratospheric and mesospheric ozone over Bern, Switzerland" *by* S. Studer et al.

S. Studer et al.

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Firstly we like to apologize for the time delay with the revision of the article. The reason is that the first author left the university after getting the PhD degree. Though she always wanted to make the revision by herself, she told me on 4 February 2014 that she cannot manage the revision because of other duties and tasks.

She told me (Klemens Hocke) that I should take care on the revision of her paper and I agreed. The order of the authors of the manuscript will remain unchanged. Of course

it is a bit difficult for me to work with her text files, data files, and her programs. On the other hand I am optimistic to carry out the moderate revision in a few weeks.

We agree with both reviewers that the description of related works of other scientists should be improved. Further we are going to add intercomparisons between the findings of past studies and our study. The discussion and physical interpretation of the results of our study will be improved and extended.

Point-to-Point Response to Reviewer 2:

Thank you for your interest in our study, your positive comments and corrections.

Point 1 of your main comments: "1) I appreciate the reason for not applying the GROMOS averaging kernels to the AURA MLS and the model output in order to preserve the information from the higher resolution output/measurements. However, in several places it is speculated that differences in the derived diurnal cycle with GROMOS might be due to the varying resolutions. Even if it is not a major component of the paper, the authors should be able to repeat at least portions of the analysis using the convolved model output or AURA MLS data and answer the question as to whether and to what degree the vertical resolution is influencing the differences."

Your idea to apply kernel smoothing to the model or satellite data is good. We try to add an example figure for the daily ozone cycle of the WACCM model with and without kernel smoothing of the ozone profiles.

The comparison with Aura/MLS plays a minor role in the present study. In the revised version we will ommit Figure 8 (with Aura data) and possibly the article can be changed to a Aura/MLS-free article. The reason is that the daily ozone cycle observed by Aura is only based on 2 measurement points above Bern per day. This is not enough for a reliable discussion.

Point 2 of your main comments: 2) I am somewhat new to this research topic, so I appreciated the thorough list of past studies. However, it would be very helpful to the reader to summarize some of these results overall. As a community addressing the diurnal cycle in ozone, how much agreement or disagreement exists on the size of the variations/mechanisms in the mesosphere, and then in the stratosphere. I was a bit confused because the authors state for example that photochemical box models can reproduce the afternoon maximum in the middle stratosphere but the next paragraph says there is no clear picture to explain diurnal variations in the middle stratosphere. Such a summary picture would also help relate the current results to past studies.

We agree that the Introduction and the Discussion part of the paper are not optimal. We will clarify what we mean with "no clear picture of the daily ozone cycle" (please see our response to Point 1 of Reviewer 1).

Point 3: The authors seem to be grasping at straws in the discussion of the inter-annual variability in the last section. The authors speculate as to several causes to explain the largest variations, but these ideas should be explored further with more in depth discussion, or possibly removed altogether or put forth as part of a continuing effort. The authors could instead go into details about how their results either support or conflict with our current understanding of diurnal oscillations in the context of previous studies. Although the model

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results cannot be used to study the inter-annual variability, could the GROMOS data be added to Figure 8 to compare inter-annual variability with AURA/MLS?

We often hear the argument that a presentation of observational results alone is not sufficient for a paper. We like to reply: What would have happened to the Montreal Protocol if Chubachi and Farnham did not publish the detection of the ozone hole in the mid 80s,- though the correct explanation (heterogeneous catalytic depletion of polar ozone by PSCs) was found some years later? We are sure that observational papers are important since they foster other observational groups to look for the same effect or to contradict. Observational papers can be a motivation for performance of new simulations and development of theories by other experts. We think that "an observation with no explanation (or a clearly indicated speculation)" is better than reporting an "observation with a self-confidently presented explanation" which is found wrong later.

However we agree with you that the discussion part of our paper was written too hasty and we will optimize it by considering your suggestions. Figure 8 will be ommitted because Aura/MLS is in a sun-synchromous orbit. We think that the plots of interannual variability of the strength of the daily ozone cycle do not need a detailed explanation. We know that ozone depends on almost everything, thus it would be odd if the daily ozone cycle is constant from year to year. Hopefully other groups also present time series of the daily ozone cycle so that we get a better impression on the variability.

Minor comments

We are going to include your minor comments and suggestions in the revised version. At the moment it is difficult to find the high line numbers which you provide. However we are sure that it will improve the revised version. Thank you for your effort!

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Point-to-Point Response to Reviewer 1:

Thank you for your interest in our study which gives us a strong motivation. You mention several points for improvement which are a bit similar to some of the comments of reviewer 2 and which we agree too.

Point 1 of your main comments: In Section 1, the descriptions about previous studies are not well organized, with some descriptions seem contradicting. For example, the authors say "no comprehensive description of the diurnal ozone variation in the stratosphere is yet missing" but, just after it, they say "Various papers discussed the diurnal cycle in the stratosphere...". It seems that the authors just showed the "List" of previous studies on this paper. I would strongly recommend that the authors reorganize Section 1 more logically, in order to make it clear what is known and unknown. Also make it clear how the present results are scientifically important in the context of these previous studies. I guess that the authors want to suggest that stratospheric diurnal variations including their seasonality/inter-annual variability were not well known. The authors also may want to emphasize that satellites cannot cover high latitude regions. Accordingly, I recommend the descriptions about diurnal variations in the mesosphere and stratosphere be separated.

We agree that the introduction should be made clearer. Indeed there exist "no comprehensive picture" of the daily ozone cycle yet. How is the regional, latitudinal, longitudinal, seasonal and interannual behaviour of the daily ozone cycle? There was a global study about the daily ozone cycle in stratospheric ozone observed by TIMED/Saber. However this satellite was designed for the mesosphere and lower thermosphere. The stratospheric curves presented by Huang et al. look shaky and are not so much in agreement with other observations. The Huang papers are very good

but the results for the stratosphere seem to be not 100 percent reliable. It is similar to our paper and the Haefele paper which are also not "100 percent evidence" papers (maybe "70 percent evidence").

However you are right: we missed a detailed discussion/description of the past results. We are going to include this in the revised version.

Thank you, it is a good idea to separate stratospheric and mesospheric part of the daily ozone cycle.

Specific comments: Most of the previous papers are not referred after Section 1.

We agree that the discussion and intercomparisons are on a moderate or low level. The reason is that the article was shortly submitted before the PhD examination. In the revised version we will add a detailed discussion.

Related to comment2 above, in Section 4.2, please add some discussions about the mechanism of diurnal ozone variations in the stratosphere. As reference, the mechanism of afternoon maximum in the stratosphere is pointed out e.g., by Haefele et al. (2008), Huang et al. (2010) and Sakazaki et al. (2013). Also, do you have any explanation about the mechanism of seasonal cycle in Section 5?

The co-author A. Schanz will take care on this point. Possibly the generation of odd oxygen by photodissociation of molecular oxygen ($O_2 + h\nu$) plays the main role. He can provide an estimate obtained from the WACCM model.

Another related question: is the same mechanism also related to the seasonal cycle in Section 5? In other others, why do the authors focus only on the inter-annual variability for this mechanism? (I guess, for the temperature tidal variability, the seasonal cycle is more pronounced compared to inter-annual variability).

Meanwhile the co-author Ansgar Schanz analysed WACCM data in detail and we are going to sketch the main factors which have influence on the daily ozone cycle. So we will refer to his own publication which will be submitted in the end of the week. There are some other effects too like influence from zonal wind, NO and O3 abundances. This explains why it is a bit difficult to get a strong anti-correlation between temperature tide and daily ozone cycle.

With "temperature tides" we actually mean all kind of daily cycles in temperature which might be regionally quite different in the phase. We will screen the literature if we find more informations.

Thank you for the minor corrections which we are going to implement in the revised version.