Review Report:

"A climatology of the diurnal variations of stratospheric and mesospheric ozone over Bern, Switzerland" by Studer et al. (2013, ACPD)

Study of diurnal ozone variations is important not only to improve our understanding of their photochemical/dynamical processes, but also to improve the estimation of long-term trends. While there were some observed findings about diurnal ozone variations in the mesosphere, diurnal ozone variations in the stratosphere have not been well understood. Particularly, there were little observational evidences about seasonal to inter-annual dependence.

In this context, the present paper examined diurnal ozone variations in the stratosphere and mesosphere, using 17-yr continuous data from ground-based measurements at Bern. Measurement data are carefully analyzed. The present observational findings in the stratosphere are valuable; particularly, the results of seasonal and inter-annual dependence are new and intriguing. Therefore, I am sure these observed results are well worth publishing in ACP.

However, I have several concerns about the manuscript. First, the scientific background of this study is not well organized and written in this paper. Particularly, for Section 1, the paragraphs and their sentences introducing previous studies seem not ordered in an appropriate way (sometimes duplicated or contradicting); thus, I had difficulty finding the points. Also, in Section 4, the present results are not evaluated in the context of these previous studies. Just showing results is not sufficient as a scientific paper.

In addition, the authors need to have a more scientific and quantitative discussion on the observed findings. Particularly for "temperature tidal effect", just showing the qualitative "correlations" does not say any "cause-result relationship". I am keenly interested in the mechanism but the discussion lacks of scientific or quantitative viewpoints, and so not convincing.

I would recommend this paper be accepted after the above points considered and revised. Please see below for specific comments.

Major comments

1. 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. As the authors noticed, the controlling mechanisms of diurnal ozone variations are different between the mesosphere and the stratosphere, resulting in a smaller amplitude in the stratosphere that was difficult to detect in the previous studies. But in the present Section 1, this point seems not clear (all are mixed and confusing). Please consider structuring the Section 1, by separating mesospheric and stratospheric diurnal variations (including observed findings, mechanisms..).

Other specific comments about Section 1 are in the following items.

- i. (Line 14 in Page 22447) This sentence appears suddenly; this kind of conclusion should appear after introducing previous papers in more details. I would recommend this sentence be deleted here.
- ii. (Lines 4-18 in Page 2249) This is true only in the upper stratosphere and the mesosphere. Sakazaki et al. (2013) concluded that the stratospheric O3 variations are caused by the variations in total Ox. Since this paper discusses the stratosphere, the authors also need to introduce photochemistry that is important in the stratosphere.
- iii. (Line 9 in Page 22449) "The reactions" should be "The reactions determining the ratio"?
- iv. (Line 19- in Page 22449) I do not understand why this paragraph is located here. (1) As you already introduced earlier, the diurnal variations in the lower to middle stratosphere were studied by some previous studies (Haefele et al., 2008; Huang et al., 2008; Sakazaki et al., 2013). So the description: "no clear picture exists for diurnal variations of ozone in the middle and lower stratosphere" seems contradicting. Please clarify in more details what point do the authors think are no clear. (2) "Not only photochemistry, but dynamics.." was already introduced from Lines 28- in Page 22448 (Sakazaki et al., 2013). (3) Some comparisons with CCMs (CTMs) ("Model simulations..") were also introduced earlier in this paper.
- v. (Lines 16-20 in Page 22450) This part may be merged in the paragraph from Line 4 in Page 22449.
- vi. Parrish et al. (2012) should be first referred in Section 1, because the authors referenced it several times in Section 4.
- Most of the previous papers are not referred after Section 1. In Section 4, the authors did not refer any observed findings in previous studies (e.g., Haefele et al., 2008; Huang et al., 2010a; Sakazaki et al., 2013 for the stratosphere) except for Parrish et al. (2012). Thus, it is unclear how the present

results support/update/revise the previous knowledge, particularly for the stratospheric diurnal variations. I would recommend that the authors appropriately compare their results with the previous findings.

- 3. Related to comment#2 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?
- 4. Please note that qualitative "correlations" do not mean any "cause-result relationship". A more scientific and quantitative discussion would be needed if the authors really want to suggest that "temperature-dependence of ozone photochemistry" is important for the inter-annual variability. For example, Haefele et al (2008) derived a quantitative, theoretical relationship in their Equation (1). It might be also helpful that Hirota et al. (1991) also derived a simple temperature-ozone relationship at photochemical equilibrium (although I am not sure whether this condition is satisfied in the diurnal cycle). At the same time, I suspect what happens if the noon-night difference is drawn as % values (not as absolute values). Accordingly, how does the background (daily-mean) ozone change with year?

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).

Hirota, I., M. Shiotani, T. Sakurai, and J. Gille (1991), Kelvin waves near the equatorial stratopause as seen in SBUV ozone data, *J. Meteor. Soc. Japan*, 69(2), 179-186.

Minor comments

- 1. (Line 11—13 in Page 22447) should be "The result is,.. ozone time series are.."
- 2. (Line 24 in Page 22452) What the "climatologies" mean? F 2000 means year 2000?
- 3. (Line 1 in Page 22453) Pleasse add a reference for the description: "WACCM is capable of reproducing the tidal seasonality". Tides in WACCM are also evaluated by Chang et al. (2008).

Chang, L., S. Palo, M. Hagan, J. Richter, R. Garcia, D. Riggin, and D. Fritts (2008), Structure of

the migrating diurnal tide in the Whole Atmosphere Community Climate Model (WACCM), *Adv. Space Res.*, 41, 1398–1407.

- (Section 2.3 in Page 22453) For HAMMONIA, data are obtained from a free-running simulation as is WACCM (not a nudged run)? Also, please specify boundary conditions (SST, ice cover etc) as is the description for WACCM.
- 5. (Lines 24-25 in Page 22454) Does Figure 1 represent mesospheric results?
- 6. (Lines 3-4 in Page 22455) What data are used for making a priori profile ("*a monthly mean profile*")?
- 7. (Lines 8 in Page 22456) Why the nighttime is defined as "11:30 p.m. to 1:30 p.m."? It appears to be irregular (not symmetric with respect to 00:00 am).
- 8. (Line 14 in Page 22457) "6.6 ppm versus 7.5 ppmv": Please specify the month and altitude.
- 9. (Line 13-14 in Page 22458) Transport by tides are shown by Sakazaki et al. (2013). Also, what *"in a similar way"* means?
- 10. (Line 17 in Page 22458) Remove "a".
- (Line 15 in Page 22458) WACCM and HAMMONIA can be used to separate migrating and nonmigrating tides?.
- 12. (Lines 15-16 in Page 22458) "*At the end of the day...*" I do not understand what altitude region the authors are talking about (in the stratosphere, or mesosphere?). Please describe more carefully.
- (Lines 22-24 in Page 22458) I would suggest adding a brief description about the MLS data in Section 2. Please add information about the version of data used, vertical resolution, and coincidence criteria (how "overpass" is defined?).
- (Lines 2- in Page 22459) Parrish et al (2012) should be introduced in Section 1 (see also major comment 1). Please state the longitude and latitude of Mauna Loa.
- 15. (Line 37 in Page 22459) similar to what? (GROMOS or WACCM?) Also, how similar? (e.g., quantitatively similar?)
- (Lines 8-10 in Page 22460) This feature should be first described in Section 4.2 because this is seen throughout the year. Also, the dawn minimum has been also measured by SMILES (Sakazaki et al., 2013).
- 17. (Lines 10-11 in Page 22461) Gebhardt et al. (2013) reported an NOx anomaly in 2000?
- 18. (Lines 16-17 in Page 22461) Data from ECMWF means ECMWF operational analysis, or ECMWF ranalysis (ERA-Interim)? Temperature data are averaged for 2.5 to 5.5 hPa? How the "noon" and "midnight" defined for ECMWF data, while it contains only four data in a day (00, 06, 12, 18 UTC)?
- 19. (Fig. 10 red lines) Does this mean that the phase of temperature tides sometimes reverse? (Is it true??)