**Atmospheric
Chemistry
and Physics
Discussions**

# *Interactive comment on* "Development of a climate record of tropospheric and stratospheric ozone from satellite remote sensing: evidence of an early recovery of global stratospheric ozone" *by* J. R. Ziemke and S. Chandra

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COMMENTS BY ANONYMOUS REFEREE#1:

Comments to "Development of a climate record of tropospheric and stratospheric ozone from satellite remote sensing: evidence of an early recovery of global stratospheric ozone" by Ziemke et al.

This study carefully uses six years of higher-fidelity OMI/MLS residuals to evaluate the 32-year long record CCD results of stratospheric and tropospheric column ozone

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(1979-2010). The evaluation shows that CCD results in the Pacific and the zonal means from the tropics to high latitudes are consistent with OMI/MLS results and thus can be used to study the inter-annual variability and long-term trends of ozone. Then it mainly analyzes the QBO signals and ozone trends from the long-term data record. It shows that QBO is the main source of inter-annual variability of stratospheric ozone especially in the Southern Hemisphere and also shows QBO signal of 2-7 DU in the troposphere. The trend analysis interestingly shows steady stratospheric ozone recovery at middle latitudes since the middle 1990's and current level is comparable to 1980s. It is generally well organized and written and is suitable for publication on ACP. However, some sections (e.g., the section that discuss cloud ozone) could be improved. I recommend this paper to be published after addressing the following minor specific comments:

1. Title, I suggest adding "column" before ozone from satellite" since the dataset does not include vertical profile, but stratospheric and tropospheric column ozone.

Done - good point since we are evaluating column amounts and not ozone profiles.

2. P3176 line 21, since these studies are limited to the tropical Pacific, it is better to be more specific: "tropical Pacific" instead of "tropical latitudes".

Done.

3. P3177 line 11, again to be more specific: add "tropical" before "Pacific"

Done.

4. Section 3.2.1, CCD results are compared with OMI/MLS residual results only in the tropics (Figures 2 and 3). According to section 3.2 and the results presented later, the CCD method is extended to daily retrievals over the globe, although the original CCD method only derives monthly mean tropospheric ozone column in the tropics using deep convective clouds in the Pacific. Therefore, I suggest that the authors compare both retrievals between 60S-60N.

Our intention was that Figures 1-3 with discussion should be included to provide a

short beginning overview of the CCD method which was developed originally for deriving gridded tropospheric ozone measurements in the tropical low latitudes. In latter figures/discussions we compare the two retrievals (i.e., CCD versus OMI/MLS) for 60S-60N in monthly means. All of the analysis in our paper pertains to monthly means although the OMI CCD measurements were first derived daily and then averaged monthly.

5. P3178 line 21, the differences also include retrieval errors associated with clouds, which sometimes can be significant. For example, high ozone inside the clouds can cause significant positive errors in the retrieved ozone above clouds due to multiple scattering [Liu et al., 2004].

It is possible that column differences in Figure 4 could in part involve ozone measurement errors over thick clouds from OMI. Liu et al. [2004] discusses ozone retrieval errors (positive offset errors) in column ozone measurements over thick clouds caused by the assumption of opaque Lambertian cloud surfaces in the TOMS algorithm. Liu et al. [2004] invoked a radiative transfer model (PPGSRAD) to investigate an older version 7 TOMS algorithm which used infrared cloud pressure climatology (i.e., ISCCP climatology). In comparison, OMI ozone measurements in Figure 4 use in situ OCCPs derived from UV which vary with each footprint measurement and generally lie several hundred hPa lower in altitude than IR cloud pressures. It is difficult to assess OMI cloud ozone errors with the Liu et al. [2004] TOMS version 7 results. However, Ziemke et al. [2009] showed that the OMI ozone measurements over thick clouds in the tropics with the OMTO3 algorithm seemed to yield well-calibrated and consistent ozone concentrations and column amounts. In the revision we discuss these points and include the Liu et al. [2004] reference. 6. P3178 line 25, it should be noted that the CCD method is a statistical method (subtracting 2-sigma from the mean value): the negative differences could be partly caused by subtracting too much ozone. This should be mentioned here.

The negative values in Figure 4 in the higher latitudes of about -5 to -10 DU during winter are associated with $2\sigma$ numbers which are actually smaller than the $2\sigma$ values

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during summer when there are no negative column differences. We mention in the paper that the negative differences in Figure 4 indicate a yet unresolved offset existing between CCD and MLS column ozone in winter associated with thick clouds and high solar zenith angles; we cannot resolve the exact (OMI and/or MLS) problems which are causing negative values in Figure 4.

7. P3179, I suggest changing "is correctly deriving" in present continuous tense to "correctly derives"

Done.

8. P3179-3180, since the derivation of "cloud ozone" does not involve OCCP, I suggest also plotting the difference between average OCCP (with reflectivity larger than 0.8) and tropopause (even though the average OCCP is probably larger than the tropopause) in another figure, which helps determine whether positive biases are mainly caused by low clouds or not and thus helps identify other sources of "cloud ozone". I noticed that there are two paragraphs of discussion about the difference between climatologies of OCCP and THIR in p3179 lines 5-24. I think that it is much better to show the difference between average OCCP with reflectivity greater than 0.8 and tropopause since it is consistent with the CCD method. Adding a figure makes it easier to understand and follow the discussion.

At the time of acceptance of our paper for ACPD in January 2012 we had already done an analysis as you have prescribed above in effort to possibly find correlation between the positive tropospheric ozone differences in Figure 4 and low clouds. In one case we calculated OCCP minus tropopause pressure seasonal climatology for R>0.8 scenes. It turns out that there is no significant positive (or even negative) correlation between the pressure differences and the column ozone differences in Figure 4. The ozone and cloud pressure results we found do not contribute to understanding the ozone differences in Figure 4 for deep convective clouds. One would need to know the amount of surface/boundary layer ozone injected into optically thick clouds from below

relative to other sources of ozone in and above the clouds. To understand the sources and magnitude of cloud ozone in Figure 4 would require extensive cloud/convection modeling which is beyond the scope of our study. In our revision we discuss these points noted here but we did not include new figures.

9. P3179 line 19, it is not clear about the meaning of "low-to-high ozone concentrations", please clarify it.

Done.

10. P3179 line 23, I suggest also adding "positive retrieval errors associated with clouds", i.e., "lightning, biomass burning, and positive retrieval errors associated with clouds"

Done.

11. P3181 line 24, I suggest removing the words in parenthesis as it is not clear whether these ozone are inside/above deep convective clouds/high reflectivity low clouds.

Done – this has been deleted from the sentence.

12. P3183 line 14, this sentence does not read well, add a "there are " before "clean signals"?

Sentences are re-worded in the revised paragraph.

13. P3183 line 24, change "yr" to "years"

Done.

14. P3185 line 12, it is not clear about what "Pacific mean CCD measurements" means here: CCD results only in the Pacific (but then Figure 14 shows Atlantic means) or CCD results derived from high reflectivity clouds in the Pacific. Please clarify this.

Clarified now in the revision.

15. P3188, it may be worthwhile to add another panel in Figure 15 to also show the relative trends in percent since we normally think ozone depletion is much severer in the southern hemisphere (at least relatively). This will help readers better understand the ozone depletion/recovery in both hemispheres.

This is a good point to show trends in both Dobson Units per decade and percent per decade. From your suggestion we have modified Figure 15 to now include units of percent per decade.

References

Liu, X., M. J. Newchurch, R. Loughman, and P. K. Bhartia (2004), Errors resulting from assuming opaque Lambertian clouds in TOMS ozone retrieval, J. Quant. Spectrosc. Radiat. Transfer, 85, 337-365. Interactive comment on Atmos. Chem. Phys. Discuss., 12, 3169, 2012.

We have added this reference to the paper including related discussion.

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Interactive comment on Atmos. Chem. Phys. Discuss., 12, 3169, 2012.