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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Validation of Ozone Monitoring Instrument (OMI) ozone profiles and stratospheric ozone columns with Microwave Limb Sounder (MLS) measurements" *by* X. Liu et al.

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Response to referee 4's comments

We would like to thank the referee for constructive comments on our paper. We have addressed them as follows and made changes in the revised manuscript.

General Comments

G.1 One important update for this paper is that comparisons to MLS should always

show the total error of OMI and MLS, and comparisons of OMI to convolved MLS should always show the combined measurement error of OMI and MLS. This will validate both the OMI product and the OMI predicted errors. Specifically, errors should be shown for Fig 1g-l, Fig 2f-j, Fig 3, Fig 8 (note smoothing error should be shown not as a bias but as +- dotted lines. Measurement error should also be shown as separate +- lines), Fig 10-11 (not sure what the "upper limit" of errors means. The mean error should be shown.). This will put all comparisons between MLS and OMI into context to determine if and when the estimated errors are accurate versus the suggestion of significant systematic errors either in OMI or MLS (which would also address the concern of reviewer #2).

Response: We added the total error (i.e., OMI random-noise and smoothing errors and MLS precision) in Fig. 3. We also added the statistical estimates of OMI retrieval errors in Figs. 10-11 for comparison with those upper limits. The upper limits in Figs 10-11 are the root square differences between standard deviations minus a MLS SOC precision of 2%, and they represent the upper limit of OMI random-noise and smoothing errors (standard deviations of the OMI/MLS differences due to systematic OMI/MLS errors, interpolation errors, different footprints, forward model errors are ignored). Correspondingly, we added some discussion in the text and modified the figure captions.

The purpose of Fig. 1 is trying to illustrate the concept of smoothing errors and the way of computing relative differences (relative differences are computed with MLS as denominators, so they could be much larger than the total errors due to small MLS values in the tropics), so I think that adding total errors is not necessary. We are trying to show examples of ozone profile comparison in Fig. 2. I just plotted the mean biases (not standard deviations), I also think that it is not necessary to add total errors and measurement errors (more useful for checking OMI error estimates than checking systematic errors). In Fig. 8, because smoothing errors in green triangles are derived by assuming MLS as the truth, an exact value with sign (i.e., similar to bias) can be derived for each OMI/MLS pair. Also we think that the error bars for OMI estimates of

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smoothing errors are better for comparison with these derived smoothing errors.

Although we use OMI estimates of solution errors and MLS precision as a reference to show the standard deviation of the differences relative to these errors, we think that it is still difficult to validate these predicted errors strictly due to the lack of quantitative information about systematic errors, forward model/parameter errors for both OMI and MLS data, and geophysical variability due to different footprints. As you can see that the standard deviations of the differences are generally much larger than those error estimates especially in regions/altitudes of great variability.

G.2 Comparisons to sondes should be added between 215 and 100 hPa where comparisons to MLS are significantly worse. This would validate OMI between 215 and 100 hPa. The only reason not to add these comparisons is if more comprehensive comparisons to sondes are planned in one of the two other validation papers mentioned below. If comparison to sondes is planned in a future validation paper, than I change the recommendation to "accepted subject to minor revisions".

Response: Yes. We plan to validate our retrievals against ozonesonde observations of ozone profiles and tropospheric ozone columns. On the other hand, the comparison between 215-100 hPa is not too bad for this altitude range. The standard deviations of OMI/MLS (convolved) differences are close to the combined precision for this altitude range, OMI shows mean negative biases of $<$10% relative to convolved MLS data. Furthermore, MLS data have been extensively validated against ozonesonde, lidar and other satellite measurements. These validations suggest that MLS data likely have positive biases of 10-15% between 215-100 hPa, as have been discussed in the paper.

G.3 The introduction mentions that this is the first of 3 validation papers. A brief summary of the next validation papers should be mentioned so that the scope of the current paper within the full validation of the OMI profile results is established.

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Response: We changed "the first of the validation sequels" to "the first validation sequel" to avoid confident predictions since the other validation papers have not been submitted yet (as suggested by one referee to our OMI algorithm paper). To briefly summarize the purpose of this paper and following papers, we added "It focuses on validation of OMI stratospheric ozone profiles and SOC with MLS data to demonstrate that stratospheric ozone profiles can be retrieved accurately from OMI, and SOC can be retrieved from OMI with retrieval errors comparable to or smaller than current limb measurements. In separate papers, we will validate our retrievals against ozonesonde observations and OMI/MLS tropospheric ozone columns as well as operational total ozone products."

Specific comments

S.1 The abstract and conclusion sections should mention the OMI predicted errors to place the comparisons to MLS into context. The authors can use their judgment about the amount of detail provided for the predicted errors.

Response: As explained in the response to G.1, due to the difficulty of strict validation of these predicted errors, we think that it is not important to mention these in the abstract and conclusion.

S.2 Introduction switch wording: minimize significantly to: significantly minimize

Response: We made this change.

S.3 Section 3: If there was a reason 347 days was used rather than a full year, can this be stated? It seems odd to use 347 days rather than a full year.

Response: We changed "(347 days)" to "(347 days of MLS data available at the time of comparison)"

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S.4 The text near Equation 1 describes it as degrading MLS resolution, but later text describes it as convolving MLS profiles. To be clear, specifically say: convolved MLS profiles using Eq. 1. Apparently this degradation does not impact the SOC?

Response: We made this change. Yes. The degradation of MLS resolution is not applied in the integration of MLS SOC when comparing SOC as stated in the text.

S.5 Figures 5 and 11 show issues with large solar zenith angles. However, the impact or mitigation of these errors this on the OMI SOC is not addressed. Is there a suggestion to screen off of SZA? What is the estimated effect of the SZA-dependent systematic errors on the SOC in DU or % error?

Response: We added some discussion by adding on page 24927, lines 5 "of up to 1.5% at SZA larger than ˜50" as shown from Fig. 11 after "show some latitude/SZA dependence." Despite the SZA dependent systematic errors, we are not suggesting to screen off SZA since these errors are systematic and are not significantly large (actually closer to MLS values).

S.6 In section 3, the last sentence should be worded a bit more carefully, as it seems to suggestion that limb ozone measurements' main purpose is to create a tropospheric ozone column. The MLS ozone product has been used for many other purposes, perhaps not for air quality other than calculations of transport from the stratosphere into the troposphere. Could this be worded: This has high cost significance in designing future air quality missions in that OMI alone can now be used to measure tropospheric ozone column values.

Response: We deleted this sentence in the revision.

S.7 In section 4: the word original in original MLS profiles seems redundant. Figure comments: Figure 3 Can the predicted errors be shown as dotted or dashed lines to

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more easily distinguish them from OMI-MLS differences?

Response: We removed "original" and changed the line style to dashed line for predicted errors.

S.8 Figure 6 The mirroring makes the figure more confusing. Is it like this because SZA has a correspondence to latitude?

Response: Yes. SZA generally has a correspondence to latitude for the AURA orbiting, but the correspondence changes quite a bit during a year (i.e., between winter and summer). Because higher SZAs generally occur at higher latitudes, we mirror the southern and northern hemisphere. Plotting northern and southern hemisphere separately can separate the SZA-dependent differences from spatial differences.

S.9 Figure 7 This figure is very impressive. The MLS dots overlayed on panel (b) are not showing up well. These should be updated for better comparison. Perhaps a black circle filled in with the MLS value.

Response: We have tested several different ways before. Due to the number of MLS points, you will see mainly black if plotting back circles filled in MLS values. Plotting solid circles only will block OMI values. When the differences are small, MLS values will not show up well, but when the differences are large, they will show up (for example, a few points in the tropics, and Northern high latitudes). In the revision, we increased the thickness of these circles.

S.10 Figure 9 I wonder what this looks like when high latitudes and high SZAs are screened out. Does the quality change significantly?

Response: Filtering high SZAs/latitudes will slightly improve the comparison. For example, filtering SZAs $>$ 80 reduces the standard deviation from 7.71 to 7.52 DU, and

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mean bias is reduced by 0.06 DU.

S.10 Figure 10 Symbols are mixed up as noted by reviewer #2

Response: We made this change.

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Interactive Comment